Progressive Rehabilitation and Closure Plan (PRC Plan)

Anglo American Dawson South
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1 Cover Page

As required by the DETSI Application form 'Submission of a Progressive rehabilitation and closure plan' (ESR/2019/4964, Version 3.01, dated 16th September 2024), the following information is provided as a cover page to this PRC plan.

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Acronyms and Abbreviations

Header	Header
AHD	Australian Height Datum
AMD	Acid Mine Drainage
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZGV	Australian and New Zealand Guidelines for Fresh Water and Marine Water Quality
AQP	Appropriately Qualified Person
ARI	Average Recurrence Interval
ASL	Above sea level
AWSA	Alternative Water Supply Agreement
bgs	Below ground surface
CCPR	Community Consultation Plan and Register
CHPP	Coal Handling Preparation Plant
CMLR	Centre of Mined Land Rehabilitation
DCN	Dawson Central / North Mine
DCRF	Dawson Community Reference Forum
DEM	Digital Elevation Model
DETSI	Department of Environment, Tourism, Science & Innovation (formerly DES and DESI)
DGV	Default Guideline Values
DNRM	Department of Natural Resources and Mining
DS	Dawson South
EA	Environmental Authority
EIS	Environmental Impact Statement
EP Act	*Environment Protection Act 1994*
ERA	Environmentally Relevant Activities
ERC	Estimated Rehabilitation Cost
ESA	Environmentally sensitive areas
ESCP	Erosion and Sediment Control Plan
GIS	Geographic Information System
IA	Improvement Area
LEM	Landform Evolution Modelling
LOD	Land Outcome Document
LOM	Life of Mine
LRA	Land Resource Area
MERFP Act	*Minerals and Energy Resources (Financial Provisioning) Act 2018*
MSES	*Matters of State Environmental Significance*
MIA	Mine Industrial Area
mg/L	milligrams per litre
ML	Mining Lease
NC Act	*Nature Conservation Act 1992*
NEPC	National Environment Protection Council
NUMA	Non-Use Management Area
PMLU	Post Mining Land Use
PRCP	Progressive Rehabilitation and Closure Plan

Header	Header
QA/QC	Quality Assurance / Quality Control
QNP	Queensland Nitrate Plant
RA	Rehabilitation Area
RAP	Remediation Action Plan
RE	Regional Ecosystem
REDD	Regional Ecosystem Description Database
REMP	Receiving Environment Monitoring Program
RL	Reduced Level
ROM	Run of Mine
SEP	Stakeholder Engagement Plan
SEVT	Semi-evergreen vine thicket
SIA	Social Impact Assessment
SPP	State Planning Policy
t	Tonnes
TSF	Tailing Storage Facilities
VMA	*Vegetation Management Act 1999*
WMP	Water Management Plan
WRD	Waste Rock Dump
yr	Year
°C	Degrees Celsius
µS/cm	Micro siemens per centimetres

2 Introduction

2.1 Purpose

The *Mineral and Energy Resources (Financial Provisioning) Act 2018* (Qld) (MERFP Act) includes provisions to introduce new requirements under the *Environmental Protection Act 1994 (Qld)* (EP Act) for the progressive rehabilitation and closure of mined land. These requirements include the development of a Progressive Rehabilitation and Closure Plan (PRCP), to plan how and where activities will be carried out, in a way that maximises the progressive rehabilitation of the land to a stable condition. The PRCP is comprised of two parts:

1. A rehabilitation planning part; and

2. The PRCP schedule.

This document fulfils the requirements for the rehabilitation planning part for Dawson South (DS) (also referred to as the 'site'). The purpose of the rehabilitation planning part is to support and justify the development of the PRCP schedule (Appendix 4.1), and detail how progressive rehabilitation and closure will be carried out over the entire site and on a rehabilitation and improvement basis (DETSI, 2023).

The rehabilitation planning part is not approved by the administering authority, but must be submitted to support the PRCP schedule, which is approved by the administering authority and operates separately to the Environmental Authority (EA).

As stated in the PRCP statutory guideline (DETSI, 2023, "*the EA authorises the carrying out of an environmentally relevant activity (ERA) and includes conditions to avoid, mitigate, or manage environmental harm that could occur during an activity. The PRC Plan schedule contains milestones and conditions that relate to the completion of progressive rehabilitation and mine closure. Both the EA and the PRC Plan schedule apply to the entire life of the mining activities, irrespective of when the underlying tenure expires. As per section 202E of the EP Act, where there is an inconsistency between an EA and a PRC Plan schedule the EA prevails to the extent of the inconsistency*".

The PRCP schedule (number 2 above) is provided separately to this document in the spreadsheet template provided by DETSI. Key elements of this schedule are included as Appendix 4.1 to this document.

2.2 Scope

This PRCP applies to DS. DS is an existing mine which operates under EA EPML00657413, the latest version of which came into effect 3 December 2025. This is a transitional PRCP submitted in response to the transition notice issued by DETSI, and transitional provisions under the *EP Act* apply. As a transitional site, existing rehabilitation and closure outcomes in the EA and other land outcome documents (LODs), as defined under section 750 of the EP Act, can be transitioned into the PRCP. DS relies on several LODs under the *EP Act* as part of the transitionary process; these are listed below in hierarchical order, such that where there is an inconsistency between these documents the first document in the list prevails to the extent of the inconsistency (DETSI, 2023):

1. EA. Meets LOD definition under s750 of the EP Act: a) an EA.

2. The Plan of Operations 2018-2020 is the latest Plan of Operations for DS. Although no longer current, it is briefly described herein, as the “Plan of Operations” as noted in Condition E2 of the current EA, and hence the Plan of Operations is regarded as a Land Outcome Document.

3. The Water Management Plan (WMP) is mentioned in Conditions F3, F24, F26, F27, and F32 of the current EA. It includes technical aspects related to the transfer and storage of mine water as well as environmental issues. The plan describes how specific management and technical issues are dealt with in the most effective manner at the date of preparation..

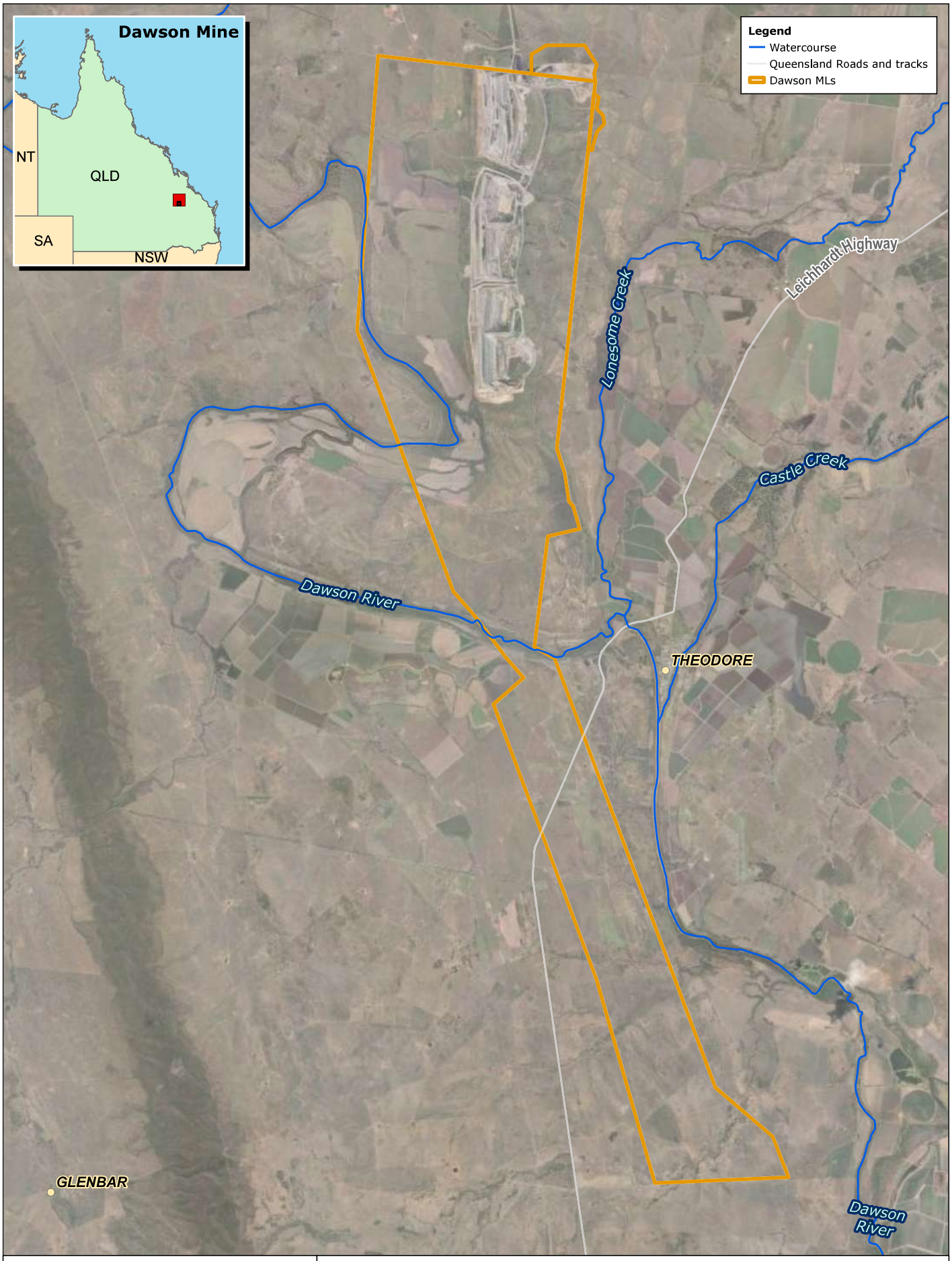
4. The Erosion and Sediment Control Plan (ESCP) is mentioned in Condition F31 and F32 of the current EA. It covers the management of erosion and sediment in areas that are not or only partly rehabilitated within DS.

2.3 Site Description

DS is located in the Dawson Valley in the Banana Shire, at the southern end of the Bowen Basin in Central Queensland. The site lies immediately south of the Dawson Central North (DCN) mine. Combined with DCN, the two mines are collectively known and form a single operating unit referred to as the Dawson Mine. The DCN mine is subject to a separate EA and PRCP. The Dawson Mine is approximately 180 - 200 kilometres (km) west of Gladstone.

The operating area of DS is approximately 3 km to 15 km northwest of the town of Theodore. The DS MLs extend to 15 km south-west of this town (Figure 2-1). The mining leases comprising DS MLs are located in the Counties of Dawson (Parish of Woolthorpe), Bauhinia (Gibber Gunyah), and Labouchere (Highworth).Authorised disturbance areas for DS and protected areas associated with Willawa Nature Refuge are included within the boundaries of the DS MLs (Figure 2-2).

DS produces between 3-5 Mtpa of primarily thermal coal. Coal is processed at Dawson Central, from which it is railed to Gladstone for export. All administration buildings, workshops and associated infrastructure are located within the ML for DCN and are not covered within this PRCP.The operating life expectancy of DS, based on current rates of production, known reserves, commodity prices and numerous other factors, is estimated at approximately 2049.



Coordinate System:
AGD 1966 AMG Zone 56

Date: 20/04/2026
Created By: CB/IY/IS
Drawing Size: A4

0 1 2 3km

Figure 2-1 Site Location

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

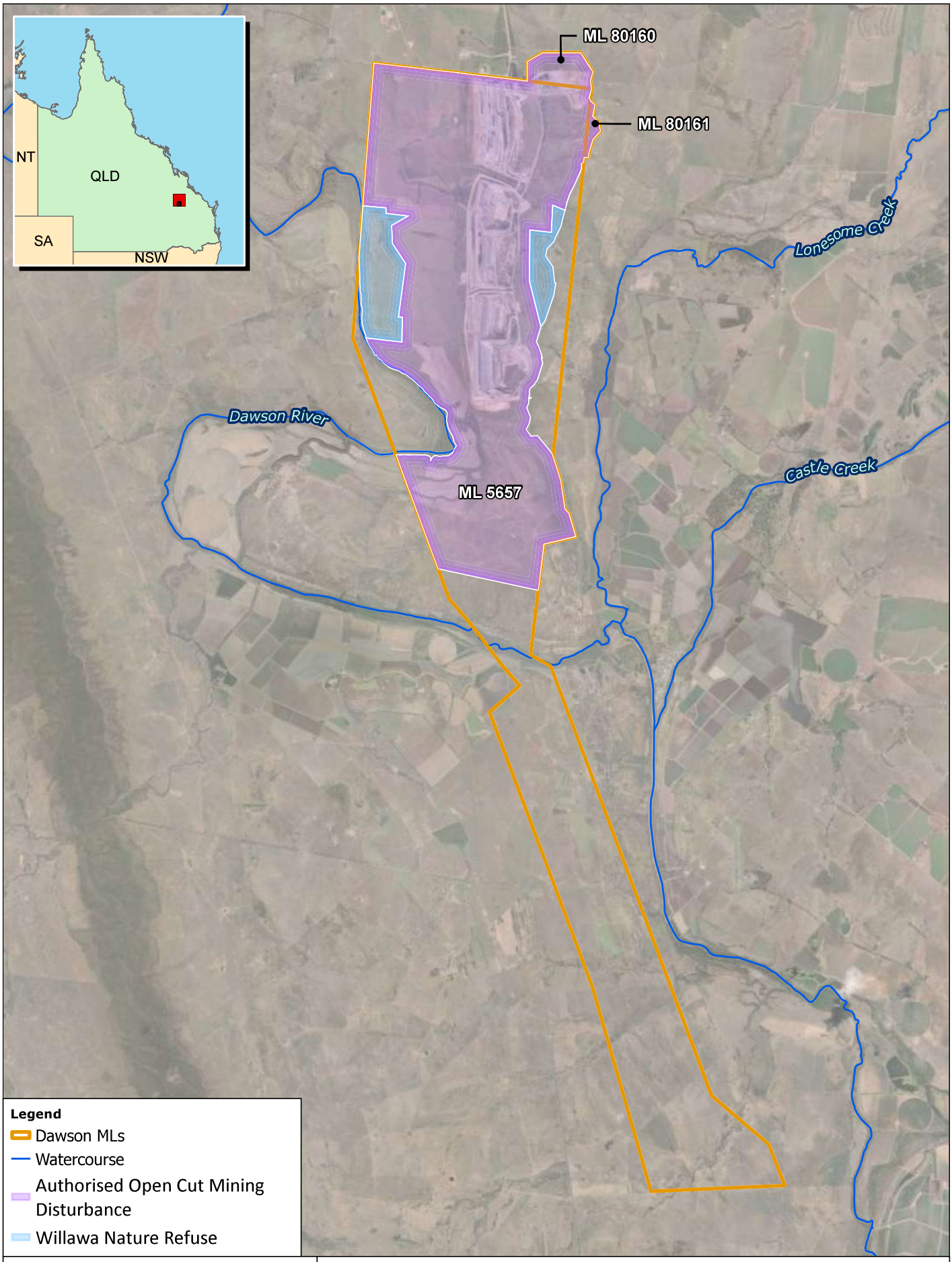


Figure 2-2 Authorised Disturbance Areas as per EA EPML00657413

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

PRCP Guideline Requirements	Section in Report
3.1 PROJECT PLANNING	
Legislative Requirements In accordance with section 126C(1)(b) and (c)(ii) of the EP Act, the rehabilitation planning part of the PRCP must include a description of:	
• each resource tenure, including area of each tenure	3.1.2.1
• relevant activities to which the application relates	3.1.4.1
• duration of relevant activities	3.1.4.2
• how and where the relevant activities were carried out, including maps	3.1.2.2
Baseline Information The following information about the site, where relevant, is considered necessary by the administering authority (as per section 126C(1)(j) of the *EP Act*) to decide whether to approve the PRCP schedule:	3.1.1
• site topography (locally and regionally)	3.1.1.1
• climate (general and specific (rain, evaporation, temperatures)) including long term projections	3.1.1.2
• geological setting	3.1.1.3
• site hydrology and fluvial networks	3.1.1.5
• groundwater levels and properties	3.1.1.4
• soil types, properties and productivity	3.1.1.6
• land stability (pre-existing land degradation/erosion and predisposition to ongoing stability issues)	3.1.1.7
• vegetation communities and ecological data (including existing regional ecosystem mapping)	3.1.1.8
• fauna presence and populations	3.1.1.9
• pre-mining land use	3.1.1.10
• identification of underlying landholders	3.1.1.12
Project Description The project description must include the following details:	3.1.2
• mining tenements	3.1.2.1
• primary mine features/infrastructure on site (e.g. TSF, waste rock dump, etc.)	3.1.2.2
• type of mining operation	3.1.2.3
• proposed duration of operation as a whole	3.1.2.3
Design for Closure The rehabilitation planning part of the PRCP for new or expanding sites must include a description of how the certain aspects have been designed for closure. Note transitional PRCPs are not required to demonstrate design for closure for existing or approved disturbance, and as such this section is not applicable to NOC.	3.1.3
Rehabilitation/Improvement Planning In order to meet the legislative requirements in sections 126C(1)(b) and (c)(ii) of the *EP Act*, the rehabilitation planning part must include:	3.1.4
• identification of all relevant activities on the mine site	3.1.4.1
• the predicted duration of each of the relevant activities proposed for the mine site	3.1.4.2
• the size/extent of the relevant activities	3.1.2
• whether the different relevant activities can be progressively rehabilitated	3.1.4.2

PRCP Guideline Requirements	Section in Report
Applicability to Transitional PRCPs Under section 126C(1)(j) of the *EP Act*, transitional PRCPs must also include the following details about any existing rehabilitation already completed at the time of submission of the proposed PRCP:	
• a description of the rehabilitation works previously carried out	3.1.4.3
• when the rehabilitation works commenced and were completed	3.1.4.3
• whether the rehabilitation has been applied for or approved as progressively certified under the *EP Act*	3.1.4
Spatial Information The following spatial information must be submitted as part of the PRCP:	
• location and maximum extent of disturbance footprint for the mine life	3.9.2
• the PMLUs and NUMAs for the area within the resource tenures	3.9.2
• any sensitive receptors	3.9.2
• Spatial Information outlining the rehabilitation and improvement areas that correspond with the proposed PRCP schedule, for a 10-year period (minimum)	3.9.2
3.2 POST-MINING LAND USE	3.3
Legislative Requirements *In accordance with section 126C(1)(d) of the EP Act, the rehabilitation planning part of the PRCP must state the extent to which each post-mining land use for land identified in the PRCP schedule for the plan is consistent with:*	
a. *the outcome of consultation with the community in developing the plan, and*	3.3.4
b. *any strategies or plans for the land of a local government, the State or the Commonwealth.*	3.3.7
An applicant must propose a PMLU for all land within the relevant resource tenures of the EA (this includes land that will be undisturbed). Where a PMLU has been previously addressed in a land outcome document and is able to be transitioned into the PRCP schedule, the applicant is not required to complete the information requirements under section 126C(1)(j) of the *EP Act* in this section for those PMLUs.	
The description of proposed PMLUs must include (where relevant), but is not limited to:	
• a description of the use of the land	3.3.5
• if applicable, the specific vegetation types (e.g. RE 13.2.9) or land suitability classification (e.g. Class 4)	3.3.3
• identification of any permanent or essential management infrastructure to be included as part of the PMLU	3.3.5
• success criteria for measuring whether the PMLU has been achieved successfully.	3.3.6 / Appendix 4.1
3.3 NON-USE MANAGEMENT AREAS Cross reference what has been addressed	3.4
Legislative Requirements *In accordance with sections 126C(1)(d), (g) and (h) of the EP Act, for each proposed non-use management area, the rehabilitation planning part of the PRCP must:*	
• *state the reasons the applicant considers the area cannot be rehabilitated to a stable condition (g)*	3.4.1
• *include copies of reports or other evidence relied on by the applicant for each proposed non-use management area (h)*	3.4.1
• *state the extent to which the proposed non-use management area is consistent with the outcome of consultation with the community in developing the plan (d)*	3.4.3
• *state the extent to which the non-use management area is consistent with any strategies or plans for the land of a local government, the State or the Commonwealth (d)*	3.4.4

PRCP Guideline Requirements	Section in Report
Where a NUMA has already been identified in a land outcome document and is able to be transitioned into the PRCP schedule, the applicant is not required to comply with sections 126C(1)(g) or (h) or 126D(2) or (3) of the EP Act, nor complete the information requirements under section 126C(1)(j) of the EP Act, for those NUMAs. Requirements under section 126C(1)(d) still apply.	
The proposed PRCP must include a detailed description of the nominated NUMA(s) for the site. The description must include, but is not limited to:	
• description of the land at surrender	3.4.2
• any relevant safety features	3.4.2.3
• success criteria for measuring whether the NUMA has achieved sufficient improvement (in which each of the following is minimised: a. the risk of the area collapsing, eroding or subsiding; b. the need to actively manage the area; and c. access to the area by an animal or person by, for example, fencing the boundary of the area)	Appendix 4.1
3.4 VOIDS IN FLOOD PLAINS	3.5
Legislative requirement *In accordance with section 126D (3) of the EP Act, if land the subject of the proposed PRCP schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition.*	
Note where a land outcome document has a pre-approved land outcome for a void with a location specified, flood plain modelling is not required.	
3.5 COMMUNITY CONSULTATION	3.2
Legislative Requirement *In accordance with section 126C(1)(c)(iii) and (iv) of the EP Act, the rehabilitation planning part of the PRCP must include:*	
• *details of the consultation undertaken by the applicant in developing the proposed PRCP, and*	3.2/Appendix 4.4
• *details of how the applicant will undertake ongoing consultation in relation to the rehabilitation to be carried out under the plan.*	3.2/Appendix 4.4
Where there are land outcomes has been identified in a land outcome document, the applicant must include details of any previous community consultation undertaken or advise if previous consultation has not been recorded or is unknown. To comply with section 126C(1)(c)(iii) of the EP Act, the rehabilitation planning part must include a community consultation register identifying the consultation carried out in developing the PRCP. The community consultation register must include:	
• previous consultation (history of community engagement)	3.2/Appendix 4.4
• consultation date(s)	3.2/Appendix 4.4
• identification of each community member	3.2/Appendix 4.4
• description of consultation type (workshop, quarterly meetings, etc.)	3.2/Appendix 4.4
• information provided to the community	3.2/Appendix 4.4
• issues raised/discussed by the community	3.2/Appendix 4.4
• how issues have been considered	3.2/Appendix 4.4
• decisions/outcomes of engagement	3.2/Appendix 4.4
• commitments made by the applicant	3.2/Appendix 4.4
To comply with section 126C(1)(c)(iv) of the EP Act, the rehabilitation planning part must include a community consultation plan detailing how ongoing consultation will be carried out in relation to the rehabilitation to be carried out under the PRCP. The community consultation plan must include details of:	
• the objectives for community consultation	3.2/Appendix 4.4

PRCP Guideline Requirements	Section in Report
• how the community will be engaged	3.2/Appendix 4.4
• proposed consultation frequency	3.2/Appendix 4.4
• what information will be released for community consultation	3.2/Appendix 4.4
• how feedback/comments will be considered	3.2/Appendix 4.4
3.6 REHABILITATION AND MANAGEMENT METHODOLOGY	3.6
Legislative requirement *In accordance with section 126C(1)(e) and (i), the rehabilitation planning part of the PRCP must*	
• *For each proposed post-mining land use for land, state the proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones under the proposed PRCP schedule.*	3.6
• *For each proposed non-use management area, state the proposed methodology for achieving best practice management of the area to support the management milestones under the proposed PRCP schedule for the area.*	3.6
Hydrogeology Assess the hydrogeology of the site and all connected strata and develop a conceptual model of the mine site's groundwater systems. This information must be integrated into the design of rehabilitation strategies and choice of PMLU or NUMA. The hydrogeological assessment should include the following steps:	
• determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards	3.6.1, Appendix 4.6
• locating groundwater recharge and discharge locations locally and regionally	3.6.1, Appendix 4.6
• groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs)	3.6.1, Appendix 4.6
• current and potential future uses of groundwater including existing groundwater extraction bores	3.6.1, Appendix 4.6
• groundwater flow direction and velocity, including field tests to determine hydraulic conductivity	3.6.1, Appendix 4.6
• the development of potentiometric mapping and hydro stratigraphic cross sections	3.6.1, Appendix 4.6
• groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage	3.6.1, Appendix 4.6
Flooding In addition to floodplain modelling, the applicant must also assess the flooding susceptibility and influence across the site	3.6.2, Appendix 4.5
If flooding is a consideration, develop a hydrologic model of the catchment and a hydraulic model of the proposed mining area.	3.6.2.3
When assessing flooding, you must at least:	
• consider the location of domains in relation to potential flood levels	3.6.2.1
• consider alteration of flow upstream and downstream	3.6.2.2
• model flood levels (including probable maximum flood levels) for a range of design storm events	3.6.2.3
• develop a flooding risk profile	3.6.2.4
Soil and Capping Material Assessment A soil assessment must be carried out that, at a minimum, identifies and characterises the following:	3.6.3
• the quality and quantity of available resources (such as topsoil, clay material and competent rock) required to complete the target rehabilitation methodology	3.6.3.1, 3.6.3.2
• the location (i.e. with respect to haul distance) and accessibility of cover material (i.e. is the material located on the tenure or are other approvals required?)	3.6.3.3

PRCP Guideline Requirements	Section in Report
• an assessment to determine the need for ameliorants and fertilisers	3.6.3.4
• the relationship between soils and vegetation ecosystems for the PMLU and rehabilitation methodology	3.6.3.5
Waste Characterisation	3.6.4
• Describe contaminants that can pose a risk to the environment, such as contaminants associated with AMD, neutral mine drainage and saline mine drainage	3.6.4.1, 3.6.7.2
• Demonstrate that the sampling regime meets best practice standards, is spatially representative of all material being mined (i.e. the ore body, exposed pit walls and overburden etc.) and representative of all lithologies	3.6.4.2
• Describe how mine waste streams can be classified confidently based on environmental risk and managements requirements	3.6.4.3
• Describe the generation of block models and estimation of the volume of mine waste based on waste type (i.e. level of environmental risk)	3.6.4.4
• Provide recommendations for the management and mitigation of waste streams to manage environmental risk and achieve proposed rehabilitation methods and objectives.	3.6.4.4
• Maintain a database to store the characteristics of each rock type	3.6.4.2
• Characterise materials based on both static tests and kinetic tests	3.6.4.2
• Conceptual site model for waste rock dumps, stockpiles, and TSFs must identify site-specific factors that may result in geochemical risks, including consideration of natural and anthropogenic processes that influence management controls	3.6.4.5
Landform Design The final landform design must include:	3.6.5
• 3D design plans of the final landform	3.6.5.5
• method of determining landform design	3.6.5.1, 3.6.5.2
• modelling predicting the long-term stability of the final landform design	3.6.5.5
• method of construction	3.6.5.7
• Quality Assurance / Quality Control (QA/QC) requirements	3.6.5.7
• trial methodology to verify the predicted success of the final landform design	3.6.5.2
• limitations and assumptions of the landform design	3.6.5.1
Key considerations of the landform design report must also include:	
• structure location, footprint and height (including proposed lift heights) – these factors may be influenced by location of environmental values, local topography, location of sensitive receptors or visual impact	3.6.5.5
• whether the structure requires a lining to prevent water or air ingress and minimise the potential for seepage release and/or a seepage collection system	3.6.5
• whether the landform is 'water-retaining' or 'water-shedding', considering rainfall patterns, and intensity, and the composition and texture of the waste	3.6.5.3
• the identification of materials available for landform rehabilitation including their ability to achieve the required landform design outcomes	3.6.5.2
• erosion assessments to determine landform heights, gradients, profiles, and material placement	3.6.5.6
• slope profile design considering the interactions between soil erodibility, rainfall erosivity, landform height, gradient and vegetation cover to identify acceptable erosion rates over a long-term average	3.6.5.6
• settling and subsidence over time, which may impact the availability of areas for rehabilitation	3.6.5.6
• hydrological and hydrogeological assessments	3.6.5.2

PRCP Guideline Requirements	Section in Report
• a waste placement strategy developed to mitigate environmental and rehabilitation risks during the construction and decommissioning phase	3.6.5.2
• specific landform requirements committed to in stakeholder consultation, mine planning or other sources, which could include rock incorporation, designed flow paths, aesthetic considerations, non-linear batter slopes and targeted placement of materials	3.6.5.2
• monitoring to determine performance of control measures (i.e. liners or seepage collection systems)	3.6.7.2
Provide an analysis of future stability based on the factors described above (e.g. landform evolution modelling).	3.6.5.4
Cover Design Where waste has the potential for AMD, neutral mine drainage or saline mine drainage, an appropriate cover system must be designed taking into consideration:	3.6.6
• results from geochemical characterisation	3.6.6.1
• type and physical characteristics of the material being covered (from the material balance developed for the site	3.6.6.1
• site conditions	3.6.6.1
• availability of suitable cover materials (both quality and quantity)	3.6.6.1
• criteria for discharge (i.e. to protect environmental values)	3.6.6.1
• suitable vegetation	3.6.8
The cover design should include:	
• identification and specification of the objectives of the cover system	3.6.6
• a detailed description of the design including the thickness of each layer	3.6.6.1
• a detailed description of construction methodology including any proposed staging of the cover system	3.6.6.1
• a quantitative assessment that identifies the location and quantity of proposed capping material available on site	3.6.6.1
• proposed QA/QC for the construction of the cover system including the timely implementation of corrective actions where deviations from the design are identified	3.6.5.7
Water Management The rehabilitation planning part must include a description of the following:	
• a description of the contaminants that pose a risk to environmental values of the receiving environment	3.6.7.2
• source, pathway and fate of contaminants that have the potential to impact environmental values	3.6.7.2
• infiltration and seepage intervention and collection controls	3.6.7.2
• surface water diversions and long-term management requirements	3.6.7.1
• dewatering requirements	3.6.7.3
• on-going water management and reduction requirements (i.e. treatment)	3.6.7.3
Revegetation Revegetation Plan must propose activities to establish self-sustaining vegetation communities appropriate for the intended PMLU	
Revegetation Plan must:	3.6.8
• articulate revegetation objectives	3.6.8.1
• identify key flora species appropriate for the PMLU	3.6.8.3, Appendix 4.1
• identify species of conservation significance	3.6.8.4
• identify fauna habitat or use requirements, including monitoring and management plan	3.6.8.5

PRCP Guideline Requirements	Section in Report
• include evidence and justification for analogue sites of the monitoring plan	3.6.8.2
• describe works for establishing and managing revegetation	3.6.8.6, 3.6.8.7
• identify appropriate plant/seed mixes and their source	3.6.8.3, 3.6.8.6, Appendix 4.1
• identify seed density application rate and timing of seeding	3.6.8.6
• identify proposed locations of any infrastructure required to protect revegetation	3.6.8.7
• identify the growth media suitable to sustain the PMLU and its availability	3.6.8.6
• identify topsoil depth requirements	3.6.8.6
The following elements must be included in the site preparation strategies:	
• the application and incorporation of ameliorants (if required for chemical balance) and bulk ameliorants such as gypsum, lime and other organic materials	3.6.8.6
• spreading of growth medium layer (topsoil, topsoil / rock mix, or suitable waste if appropriate) to a depth suitable for the target vegetation	3.6.8.6
• the application of seed, fertiliser and, where applicable, irrigation.	3.6.8.6
Tailings Storage Facilities The tailings require characterisation to determine the geochemistry, rheology and geotechnical parameters that influence the rehabilitation or management strategies and the capacity of the site to support revegetation.	
The geotechnical characterisation of tailings must also include:	
• Particle size distribution analysis based on conditions in the TSF. Particle size distribution of tailings affects their hydraulic sorting down the tailings beach, and their settling, consolidation and desiccation on atmospheric exposure	3.6.9.1
• Specific gravity testing. The specific gravity of tailings affects their hydraulic sorting down the tailings beach, and their settling and consolidation	3.6.9.1
• Atterberg limit testing to determine the plasticity of the tailings, which affects their settling, consolidation and desiccation on atmospheric exposure	3.6.9.1
• The moisture content and dry density profiles with depth of the indicative tailings. The dry density profile indicates the efficiency to which the available storage volume for tailings is utilised. Rheological testing to determine the pumpability of the tailings	3.6.9.1
• Settling testing of the tailings used as an indicator of the settling density of the tailings	3.6.9.1
• Shear strength testing of the indicative tailings, both peak and remoulded shear strengths. The shear strength profile of deposited tailings affect their bearing capacity on rehabilitation	3.6.9.1
• Consolidation testing of the tailings to estimate their consolidated density and saturated hydraulic conductivity	3.6.9.1
• Soil water characteristic curve testing to assess the unsaturated behaviour of the tailings on desiccation and calculate the unsaturated hydraulic conductivity function	3.6.9.1
• Instrumented column testing of the tailings to assess their settling, self-weight consolidation and desiccation	3.6.9.1
The design for a TSF must include relevant elements:	
• lining of TSF (i.e. embankments and base of structure)	3.6.9.2
• leak detection systems	3.6.9.2
• cellular design of TSF	3.6.9.2
• seepage collection systems	3.6.9.2
• design storage allowance	3.6.9.2
• spillway location	3.6.9.2

PRCP Guideline Requirements	Section in Report
• designing TSF for progressive rehabilitation	3.6.9.2
Voids For mine sites with voids, the rehabilitation planning part must include a void closure plan that includes, but is not limited to, the following:	3.6.10, Appendix 4.12
• options available for minimising final void area and volume (where a final void is proposed)	3.6.10.1
• proposed final dimensions of the void (i.e. depth, length and width)	3.6.10.2
• pit wall geotechnical and geochemical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events	3.6.10.3, Appendix 4.12
• proposed final slope angles of high wall, low wall and end walls of each final void	3.6.10.2, 3.6.10.3
• void hydrology, addressing the long-term water balance and water level in the voids, stratification connections to groundwater resources and potential for overflow	3.6.10.4
• groundwater modelling to determine whether the void is acting as a sink or a source for groundwater	3.6.10.5
• a water balance study including an assessment of void surface and groundwater interactions such as:	3.6.10.6
• groundwater lowering/reduction in hydraulic head (from new voids e.g. caves/karst systems)	3.6.10.5, 3.6.10.6
• cones of depression and associated impacts	3.6.10.6
• the drainage and flooding behaviours of surface waters in the vicinity of the void	3.6.10.6
• the potential extent of flooding and implications of interactions with the void	3.6.10.6
• a conceptual model that incorporates all projected inflows, outflows, and recharge rates	3.6.10.6, 3.6.10.7
• water storage and long-term water balance	3.6.10.6
• each of the major water fluxes into and out of the void	3.6.10.6
• the sources of surface water within the mine catchment that are likely to influence the water quality in the void	3.6.10.6
• predicted water quality in the long-term including potential stratification	3.6.10.8, 3.6.10.9
• a 3D void design plan	3.6.10 Figures 2.2 to 2.4
• rehabilitation strategies	3.6.10.10
Underground mining For underground mining operations, the rehabilitation planning part must include:	
• a geotechnical study	Appendix 4.3
• an assessment of groundwater interactions and potential lowering of groundwater levels that includes: • consideration of the potential exposure of previously saturated geological formations to air - leading to AMD generation • consideration of measures to avoid or minimise groundwater discharges to the surface through appropriate mine access planning, including post mining sealing off of tunnels, shafts, adits, boreholes, and other openings	3.6.11.2
• the development of a hydrogeological conceptual model	3.6.11.2
• subsidence analysis and modelling and a subsidence vegetation/habitat impact assessment	3.6.11.3
• consideration of how potential entries to underground workings will be sealed (i.e. through some form of capping or back filling)	3.6.11.3
• how surface ponding and cracking will be mitigated	3.6.11.3

PRCP Guideline Requirements	Section in Report
• identification of post-closure stabilisation of underground workings in order to manage the potential for unplanned surface subsidence and unplanned ground collapse such as sinkholes and pot holing	3.6.11.3
Rehabilitation trials Provide details of any rehabilitation trials that have occurred.	3.7.5
Built Infrastructure The rehabilitation planning part must include:	3.6.12
• Identification of infrastructure that will be decommissioned and the methods for decommissioning	3.6.12.1
• A description of infrastructure that will remain post rehabilitation and the identification of ongoing maintenance requirements	3.6.12.2, 3.6.12.3
• Evidence of agreement for any infrastructure that will have ownership transferred	3.6.12.2
3.7 RISK ASSESSMENT	3.7
Legislative requirement *In accordance with section 126C(1)(f) of the EP Act, the rehabilitation planning part of the PRCP must identify the risks of a stable condition for land described as a post-mining land use not being achieved, and how the applicant intends to manage or minimise the risks.*	
Identify sources of risk, areas of impacts, events and their causes and their potential consequences	3.7.1
Determine causes and sources of risk, their positive and negative consequences, and the likelihood that those consequences can occur. The level of confidence in the analysis and any assumptions made should be clearly identified in the risk assessment	3.7.2
Determine what risks need to be managed and prioritised.	3.7.2
Risk treatment must detail:	3.7.2
• the reasons for selecting the treatment option	3.7.2
• those responsible for the approval and implementation of the plan	3.7.2
• proposed actions	3.7.2
• resource requirements	3.7.2
• performance measures and constraints	3.7.2
• reporting and monitoring requirements	3.7.2
• timing and scheduling	3.7.2
3.8 MONITORING AND MAINTENANCE	3..8
• The rehabilitation planning part must contain a monitoring and maintenance program that identifies and describes the monitoring systems that will be carried out in order to demonstrate a milestone and milestone criteria have been achieved.	3.8
• The program must include, where relevant to the milestone and milestone criteria (but is not limited to):	3.8.5
• schedule of monitoring, reporting and review for each milestone	3.8.5
• description of methodologies and standards, which could include field-based assessments and the application of new remote sensing, GIS and other relevant emerging technologies	3.8.1
• monitoring that enables the repeatable collection of relevant statistically valid data	3.8.1
• monitoring using appropriate quality assurance and data management processes and systems	3.8.3
• regular analysis of site data including multi-year comparison trends and bench-marking against analogue/reference sites	3.8.4

PRCP Guideline Requirements	Section in Report
• contingency strategies if monitoring data indicates milestone criteria are not being met	3.8.5
• post-closure monitoring to ensure milestone criteria has been demonstrated	3.8.2
• intent of monitoring reports, such as provision of results and key findings	3.8.5
• Describe the processes and activities that will be used to determine the biophysical state of rehabilitation and closure	3.8.1
• Standardised and repeatable approach to the measurement of certain biophysical attributes and processes must be identified that can be compared against the PRCP schedule	3.8.1
• If there has/is any monitoring or maintenance of areas already rehabilitated, details must be included in the PRCP	Appendix 4.11

3 Rehabilitation Planning Part

3.1 Project Planning

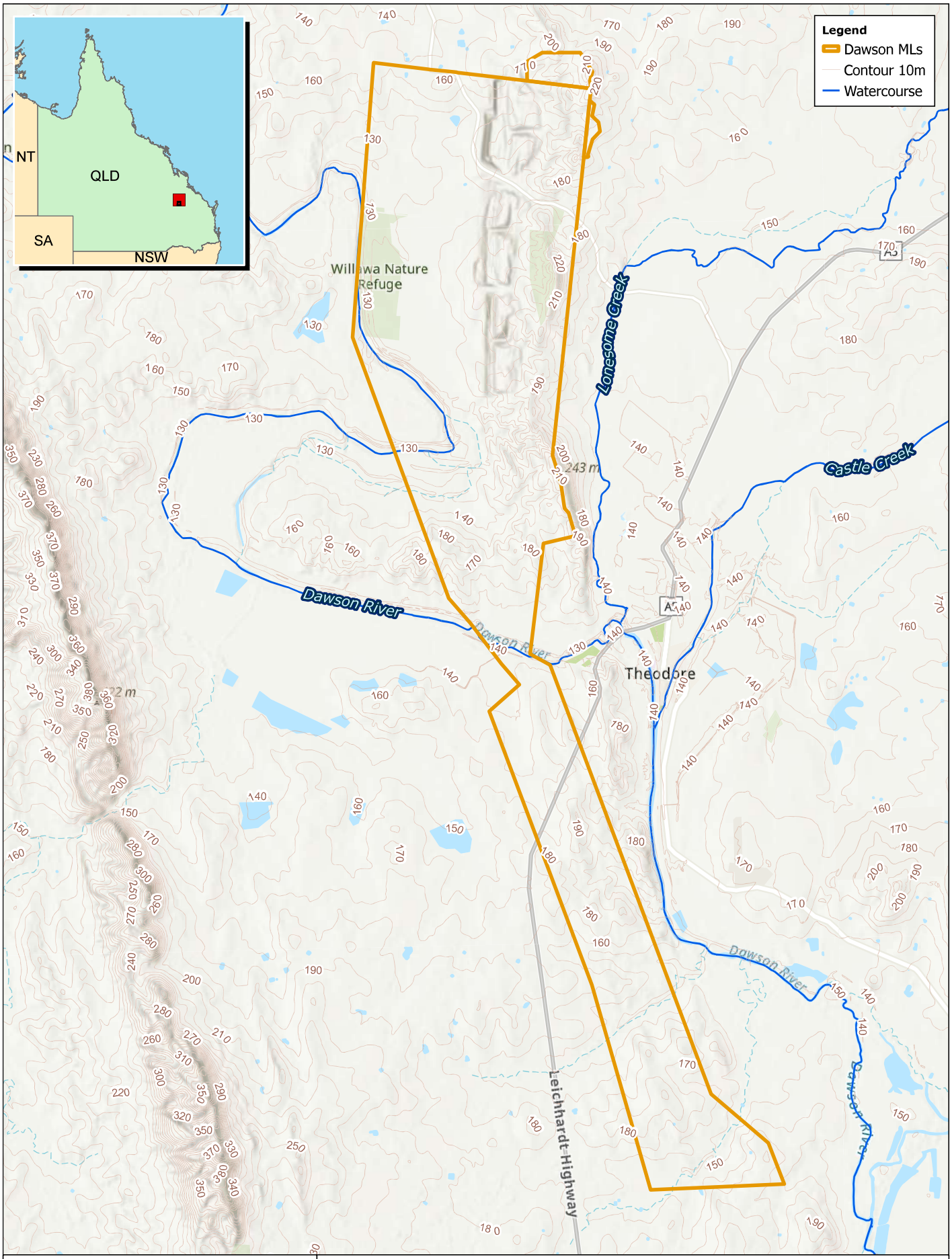
3.1.1 Baseline Information

3.1.1.1 Site Topography

The DS MLs are oriented in a north-south direction, along the coal deposit strike. The Dawson River passes through the MLs meandering generally in a northerly direction, entering the DS MLs from the south-east before exiting to the west, before reentering in the central west area of the ML and exiting in the north west boundary of the ML.

Current opertations of the DS mine is confined to the northern part of the DS MLs, north of the town of Theodore consistent with the area of authorised disturbance limited to north of the Dawson River. The operational area is located between the Dawson River and Malakoff Range on topography ranging from approximately 120m Australian Height Datum (AHD) at the low-lying alluvial flood plains adjacent to the Dawson River in the western section of the ML to approximately 220m AHD on the undulating hills of the Malakoff Range in the eastern sections of the ML (Figure 3-1).

Surface disturbance is dominated by open cut excavations and overburden emplacements. Ongoing progressive rehabilitation activities have returned some areas to grazing and other vegetated land (Section 3.1.4.3).



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Figure 3-1 Topography and Drainage

Dawson Mine Complex

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3.1.1.2 Climate

The climate in the region is characterised by hot wet summer seasons and warm dry winters. The mean maximum temperature ranges from around 34°C in January to 21°C in July. Annual rainfall in the region ranges from a monthly mean of around 94mm in February to around 21mm in August.

Rainfall data for the Dawson mine area is available from Bureau of Meteorology (BOM) stations located at Moura (Site No 039071), approximately 35km away, and Theodore (Site No 39158), approximately 28km away. Other weather data is available from Thangool (Site Number 039089), located approximately 55 km away, and Taroom (Site Number 035070) approximately 110 km away (Table 3-1).

Evaporation data from Thangool Airport indicate that the mean yearly pan evaporation is more than three times the annual rainfall (Table 3-1). No evaporation data is available from the Taroom site. Evaporation data shows mean monthly evaporation ranges between 87.0 mm to 229.4 mm. The highest evaporation occurs during the summer months (November to January; 204 mm to 229.4 mm), while the lowest evaporation occurs during the winter months (May to August; 87.0 mm to 124.0 mm).

Table 3-1 Climate Data (BOM, 2025)

Month	Mean Rainfall (mm)		Mean daily evaporation (mm)		Mean maximum temperature (°C)	
	Moura (1941 to current)	Theodore (1967 to current)	Thangool (1992 to present)	Taroom not available	Thangool (1992 to present)	Taroom
January	91.8	81.4	229.4	-	33.8	34.0
February	93.0	92.7	191.4	-	33.2	33.1
March	66.2	49.9	198.4	-	32.1	31.8
April	37.6	37.7	153.0	-	29.6	28.9
May	36.4	35.9	124.0	-	26.2	24.7
June	26.8	28.7	87.0	-	23.5	21.7
July	25.4	29.4	96.1	-	23.2	21.2
August	22.2	26.6	124.0	-	25.1	23.4
September	27.7	27.9	165.0	-	28.2	27.1
October	56.6	63.2	207.7	-	30.6	30.1
November	75	78.3	204.0	-	31.9	32.1
December	99.9	90.7	229.4	-	33.2	33.6
Annual	665.9	669.4	2007.5	-	29.2	28.5

3.1.1.3 Geology

DS is located in the southern portion of the Bowen Basin sedimentary basin comprising Permian to Triassic age rocks with numerous coal seams. The bedrock in the project area comprises sedimentary rocks dipping between 5° and 16° towards the west, with two distinct stratigraphic units:

- Triassic Rewan Formation, a monotonous sequence of barren claystones, siltstones and sandstone overlying the Permian units; and
- Permian sequence which contains the coal seams targeted at DS.

A thin layer of irregular unconsolidated Tertiary sediments overlies the Permian and Triassic formations, and thin linear deposits of Quaternary alluvium are associated with creeks and drainage lines, notably along the Dawson River.

Regionally, the DS MLs sit in the southeastern limb of the Mimosa Syncline in the Taroom Trough and abut the Gogango Overfolded Zone. The implication for the mine is that the main structural features are fold and thrust belts established by a compressive event in the late Tertiary. Mine geology and structure are dominated by a series of northwest trending thrust faults, with the western blocks downthrown. Reverse faulting occurs throughout the Dawson Mine area, but is more common towards the north, at DCN. Reverse faulting generally strikes in a north-west direction and dips to the north-east at angles of 30° to 70°.

Displacement of the faults varies considerably along strike, and it is likely that all coal seams have been disrupted by the larger faults, thereby affecting groundwater flow, for which the coal seams are the main conduits. Structural movement along faults will follow weaker zones in strata, which may be within the seam or the immediate roof and floor. Some faults represent relatively clean breaks that are less than 1m wide, but some consist of fractured zones that are 20-30m wide. The dominant trend of joint sets is north-south to north-west/south-east, with joint spacing between 2-4m wide. Iron staining is present in some joints, indicating water movement along joints.Figure 3-2 and Figure 3-3 presents the surface geology and the solid geology of the DS MLs.

Table 3-2 Stratigraphy of the Dawson Mining Complex (JBT Consulting 2019)

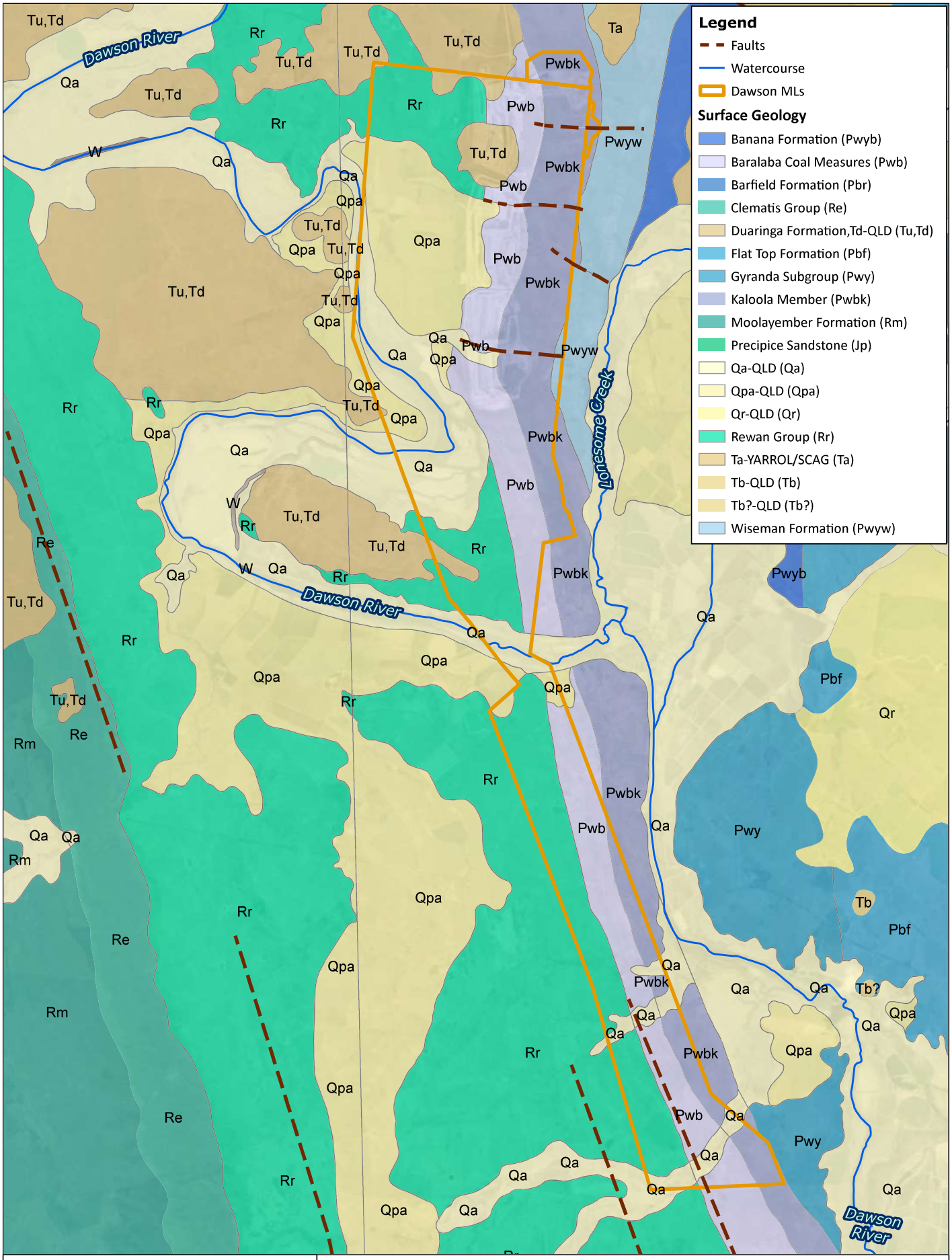
Geological Age	Formation	Description
Quaternary (Holocene)		Mine spoil
Quaternary	Recent Alluvium	Clay, slit, sand, gravel; flood plain alluvium associated current surface drainage features such as Kianga Creek
Tertiary	Unnamed Tertiary	Clay with minor sand and gravel
Permian	Baralaba Coal Measures	Feldspathic and lithic sandstone, interbedded siltstone, mudstone, shale and coal seams. Coal seams mined at Dawson, including approximate thickness, include (from shallowest to deepest): • A Seam (2.7 - 4.0m) • B Seam (1.8 - 3.2m) • BL Seam (2.6 - 4.0m) • C Seam (1.7 - 3.4m) • DU Seam (1.2 - 3.0m) • D Seam (1.7 - 1.9m) • E Seam (2.4 - 3.0m)
	Kaloola Member	Mudstone, siltstone, feldspathic and lithic sandstone, tuff and conglomerate; minor coal.
	Wiseman Formation	Calcareous lithic sandstone, mudstone, siltstone and rare coal.
	Banana Formation	Siltstone and shale with minor tuff and volcanic sandstone and rare coal.

Quaternary alluvia – sand, silt and gravel – are associated with the floodplains. The thickness of these deposits is variable but rarely exceeds 6m. Tertiary silts, sands and clays that are 5m to 15m deep in DCN thicken in DS to as much as 30m. Increases in thickness are generally related to the presence of an erosion resistant silcrete and ferricrete caprock, 2m to 6m thick, which occasionally forms dominant topographic ridges in the area. Areas of black soil, 1m to 2m thick, have been interpreted as the weathered remnants of a Tertiary basalt flow.

The Triassic Rewan Formation overlies the Baralaba Coal Measures at the western side of the area. Sedimentary rock of the Rewan Formation were deposited in lakes and swamps and consist of interbedded claystones, mudstones and siltstones with only rare sandstones.

The rocks that make up the Baralaba Coal Measures in DS are predominantly sandstones and siltstones. Organic matter partings are common and plant debris occurs frequently but is most prevalent immediately below the coal seams. In this area the sequence averages about 250m (150-350m) and can be divided into two units, of which the upper unit contains all known economic seams, with individual coal measures within this layer ranging from 0.8-6.5m in thickness. The lower unit is relatively barren and attains a maximum thickness of 50m. Seam splitting is common in all seams, and the resultant splits can be laterally continuous over tens of kilometres.

The six key mined coal measures are Seams A-E. Stratigraphy outcrop on the MLs in the east and dip westwards. At DS, seam dips are mainly in the range 10° to 13° to the west but may be locally as steep as 20° in the vicinity of faults. The A Seam occurs at a depth of some 300m at the western boundary of the ML. Much of the overlying formations consists of Triassic siltstones, shale, and minor sandstone which overly the Baralaba Coal Measures.



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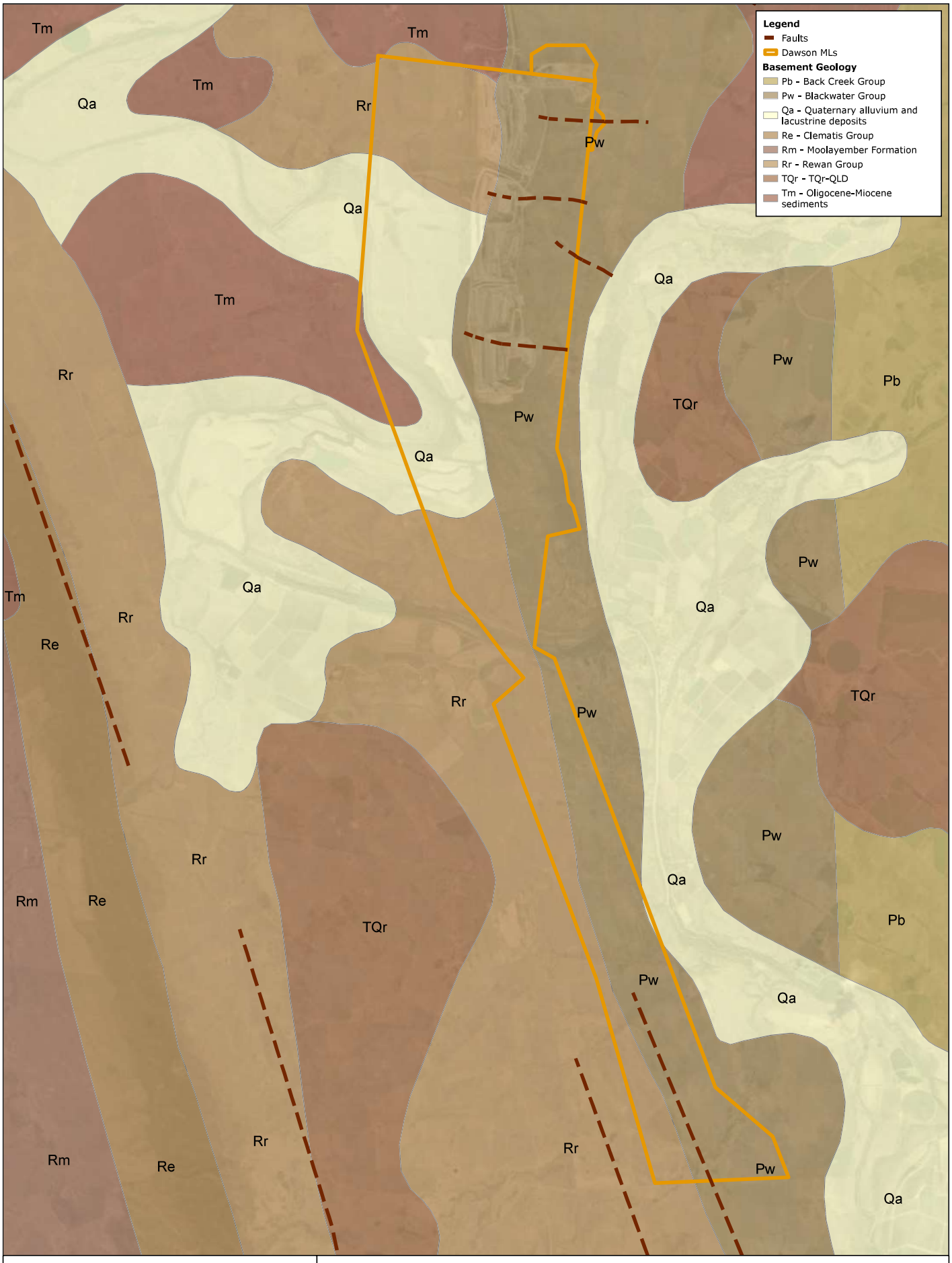
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Figure 3-2 Outcropping Geology

Dawson Mine Complex

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Figure 3-3 Basement Geology

Dawson Mine Complex

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3.1.1.4 Hydrogeology

3.1.1.4.1 Groundwater Systems

The regional hydrogeology of DS includes two minor aquifer units in the project area. These aquifers are associated with alluvium and the Baralaba Coal Measures. Other formations are low yeilding and are classified as aquitards.

In the alluvium, groundwater flow occurs laterally along sand and gravel lenses. Recharge occurs from rainfall infiltration into the alluvium from the nearby Malakoff Range, with flow east to west through the site with some discharge occuring into the Dawson River.

The Baralaba Coal Measures are recharged at outcrop in the western area of the ML, with groundwater flow towards the west becoming confined at depth beneath the Rewan Formation. Groundwater occurrence within the Permian coal measures is discussed in AGE (2004) and AGE (2007) and is summarised below:

- The interburden (sandstone/siltstone that occurs between coal seams) is described as being hydraulically “tight”, i.e. the interburden is extremely low-yielding and generally dry when drilled;
- The coal seams are confined aquifers that are the main regional-scale conduits for groundwater flow within the Permian sediments; and
- While the coal seams are described as being the main conduits for groundwater flow, the permeability (hydraulic conductivity) is generally low.

The underlying hydrogeology and description of key hydro-lithological units at DS are summarised below:

- Quaternary Alluvium

A quaternary alluvium unit is restricted to isolated areas associated with surface water drainage systems such as the Dawson River and further north of the DS operations at Kianga Creek.

Review of long-term trend analysis indicates that the fluctuation in shallow aquifers are the result of rainfall recharge conditions and are not impacted by coal seam gas operations that were historically undertaken in the vicinity of the project area.

- Tertiary Duringa Formation

Limited hydrogeological data are available for this geological unit with no registered groundwater bores screened in this formation. The Environmental Impact Statement (EIS) for DS describes these Tertiary sediments as silts, sands and clays between 5 m to 15 m deep in Dawson Central thickening in DS to as much as 30 m (EH & S Systems, 2006). Groundwater flows in Tertiary strata have not been commonly encountered during exploration. As such, it is inferred that there are no significant aquifers in this unit (AGE, 2004).

- Triassic Rewan Formation

The Rewan Formation is characterised by siltstone, claystones and lithic sandstones and is regarded as a regional aquitard. It is an important hydrostratigraphic unit in the groundwater regime as the formation inhibits the vertical and horizontal propagation of depressurisation that would likely occur in the underlying Baralaba Coal Measures during mining (hydrogeologist.com.au, 2023).

- Permian Coal Measures

Groundwater occurs within the Baralaba Coal Measures (AGE, 2004 and 2007). The coal seams are confined aquifers which generally exhibit relatively low permeability (hydraulic conductivity) and recharge rates. Groundwater storage and movement occurs within the coal seam cleats and fissures, and within fractures associated with faults intersecting the seams.

The sediments of the interburden and overburden sequence are usually relatively impermeable and form aquitards (JBT, 2019). However, iron staining on joints in sandstones indicate some groundwater storage and movement occurs. Hydraulic properties and hydrogeological conditions of the coal seams and interbeds can be summarised as:

- The interburden (sandstone/siltstone that occurs between coal seams) is described as being hydraulically "tight", i.e. the interburden is extremely low-yielding and dry when drilled;
- The coal seams are confined aquifers that are the main regional-scale conduits for groundwater flow within the Permian sediments;
- While the coal seams are described as being the main conduits for groundwater flow, the permeability (hydraulic conductivity) is generally low. The average permeability of the coal seams (C seam down to E Seam) range from 2.0 x 10^{-3} m/day (2.31 x 10^{-8} m/s) to 9.35 x 10^{-3} m/day (1.08 x 10^{-7} m/s), with permeability decreasing with depth (AGE, 2004);
- Air-lift yield tests on exploration bores within the Permian coal measures indicates that yields are generally low (<0.3 L/s), though higher yields may be encountered where the borehole intersects fractures or joints (AGE, 2004);
- Based on these observations it could be concluded that the permeability of the coal measures is similar to that encountered at other Bowen Basin mines and that pits and underground workings could be expected to have relatively low rates of groundwater inflow; and
- Based on information obtained from various drilling studies (AGE 2004 in discussion of ACIRL (1983) and Graham (1979)) it is concluded that relatively high groundwater yields (~6 L/s reported to exploration boreholes) are associated with joints as well as cavernous zones within faults and shear zones.

The potential for faults to impact on groundwater occurrence and movement is summarised as follows:

- Faults and fractures act as conduits for groundwater flow. Available data indicates that initially high yields decrease over relatively short periods of time (weeks or months), indicating that the faults represent a high yielding but low storage aquifer system.
- It is likely that faults and fractures will continue to act as conduits for groundwater flow once the initial yield is reduced by inflows to mining operations. However, the water is likely to be sourced from adjacent areas of groundwater storage, such as spoil, or from areas where surface water recharges the localised dilated zones close to the mined voids, with the faults/fractures acting as conduits for recharged water.

3.1.1.4.2 Groundwater Monitoring Bore Network

The DS monitoring bore network comprises 21 available and potential bores, screened in numerous geological horizons (Table 3-4). Groundwater monitoring commenced in 2004 but ceased in 2014 when a groundwater report was submitted to support an EA amendment in 2014. Additional monitoring bores have since been installed, with the latest drilling completed in 2023

(Hydrogeologist.com.au, 2023). Groundwater monitoring data is discussed in more detail in Appendix 4.5.

The location of all existing monitoring bores and nearby registered bores is provided in Figure 3-4.

Table 3-3 Groundwater monitoring bores

Bore ID	Easting (m)	Northing (m)	Bore Depth (mbGL)	Top of Standpipe Elevation (mAHD)	Screen Interval (mbGL)	Geological horizon targeted and/or screened
BH1	199362.1	7249744	288	134.82		Permian Coal Measures
BH2	199188.6	7249613	31	130.49		Permian Coal Measures
BH3	199666.2	7246718	181	150.57		Permian Coal Measures
GW1	200118	7252308	26	174.44		Permian Coal Measures
GW1A	200120.7	7252326	183.6	174.28		Permian Coal Measures
GW2	199819	7259768	10	141.11		Permian Coal Measures
GW2A	199933	7251406	177	143.38		Permian Coal Measures
GW3	200817.2	7249737				Unknown
GW4	199909	7249574	174	144.05		Permian Coal Measures
GW4A	199919	7249690	199	147.86		Fault
DSMB03#	201408	7238271	22	138.78	17 - 20	Alluvium
DSMB04#	200755	7238489	23	138.21	17 - 20	Alluvium
DSMB05#	199958.2	7242428	18.1	127.52	14 - 17	Alluvium
DSMB06#	199742.8	7243192	19.5	131.9	16 – 19	Alluvium
DSMB07#	199158.1	7244361	19.5	129.84	16.5 – 19.5	Alluvium
DSMB08	200776.5	7241911	92	163.4	69 - 78	Permian Coal Measures
DSMB10	201663.4	7241544	56	189.8	50 - 56	Permian Underburden
DSMB13#	197537.9	7246445	24.6	132.06	17 - 20	Alluvium
DSMB14#	197362.9	7248966	16	129.57	13 - 16	Alluvium
DSMB15	199710.3	7245593	20	139.67	6-Oct	Permian Coal Measures
DSMB16	198609.2	7247568	19	132.13	10.5 - 13.5	Alluvium

Notes: Easting and northing coordinates are in AGD66, Zone 56
mAHD – metres above Australian Height Datum,
mbGL - metres below ground level
 # Existing bores identified to be transitioned to align with I19 of the EA

The current condition/status of bores with ID's starting with "GW and BH" is unknown. An ongoing bore census is being undertaken to determine the status of older monitoring bores and potential for future monitoring purposes. Groundwater bores GW2, GW3 and GW4 were to be decommissioned as bore construction details are not available, and the screened intervals are unknown (EGC, 2012).

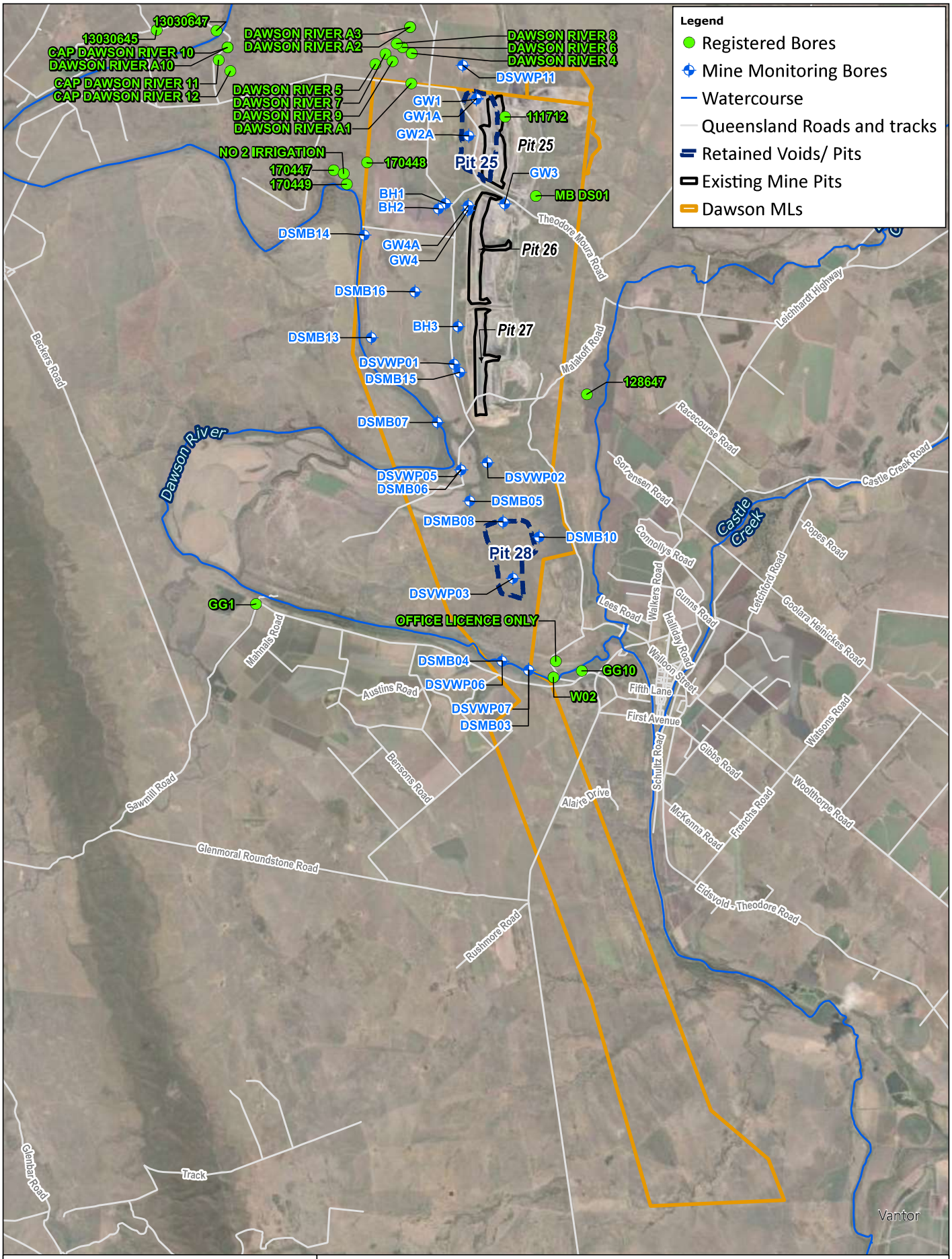
Five (5) Vibrating Wire Piezometers (VWP) arrays and two single VWP gauges were installed between February 2021 and February 2023. VWP construction details, targeted horizons and locations are provided in Table 3-5 (Hydrogeologist.com.au, 2023).

The VWP loggers are set to record every hour and datalogger and telemetry equipment are installed on each of the VWPs.

Table 3-4 Vibrating Wire Piezometers

Bore ID	Easting	Northing	Collar elevation (mAHD)	Hole depth (mbGL)	Sensor #	Sensor depth (mbGL)	Sensor depth (mAHD)	Target unit
DSVWP01	199568.6	7245792	136.594	267	1	257.5	-120.906	DU seam
					2	243	-106.406	C seam
					3	187	-50.406	B seam
DSVWP02	200388.5	7243371	130.015	147	1	138	-7.985	DL seam
					2	110	20.015	DU seam
					3	76	54.015	C seam
DSVWP03	201019.5	7240526	179.697	249	1	150	29.697	C seam
					2	190	-10.303	DU seam
					3	230	-50.303	DL seam
DSVWP05	199739.8	7243193	131.24	150	1	140	-8.76	Rewan
					2	87	44.24	Rewan
					3	45	86.24	Rewan
DSVWP06	200750	7238490	139.86	39.4	1	36.7	103.15	Rewan
DSVWP07	201406	7238266	139.39	50	1	36.5	102.89	Permian overburden
DSVWP11	199785.1	7253142	153.312	240	1	103	50.312	A seam
					2	165.5	-12.188	B seam
					3	225	-71.688	C seam

.



Coordinate System:
AGD 1966 AMG Zone 56

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Figure 3-4 Groundwater Monitoring Bore Locations

Dawson Mine Complex

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There are a number of existing registered bores in the project area and the current use and status is unknown. Several bores are located more than 3km west of the site, along the Dawson River, typically 20m to 30m below ground level and likely screened in alluvium along the Dawson River itself.

Existing groundwater bores identified in Table 3-3 listed in I19 of the EA will be subject to a groundwater monitoring event which will include groundwater quality and gauging in accordance with characteristics specified in the EA. New groundwater monitoring bores listed in attachment 1 of the accompanying PRCP schedule will also be subject to this investigation. Subsequent reports detailing the results from this investigation will inform future groundwater trigger levels. The transitional arrangements are listed in condition I19 of the EA.

3.1.1.4.3 Groundwater Levels

Groundwater level data over the period February 2005 to January 2014 is shown in Figure 3-5 below. The data shows decreasing groundwater elevations in bores in close proximity to the mining areas apart from monitoring bore DSGW2. The groundwater level of this bore showed an initial rise, up from 13.8 mbGL to 4.8 mbGL (April 2006), and ongoing fluctuation between 2.6 mbGL to 7.3 mbGL, up to last readings in July 2010. Measurements are no longer available after this date, suggesting this bore has subsequently been buried.

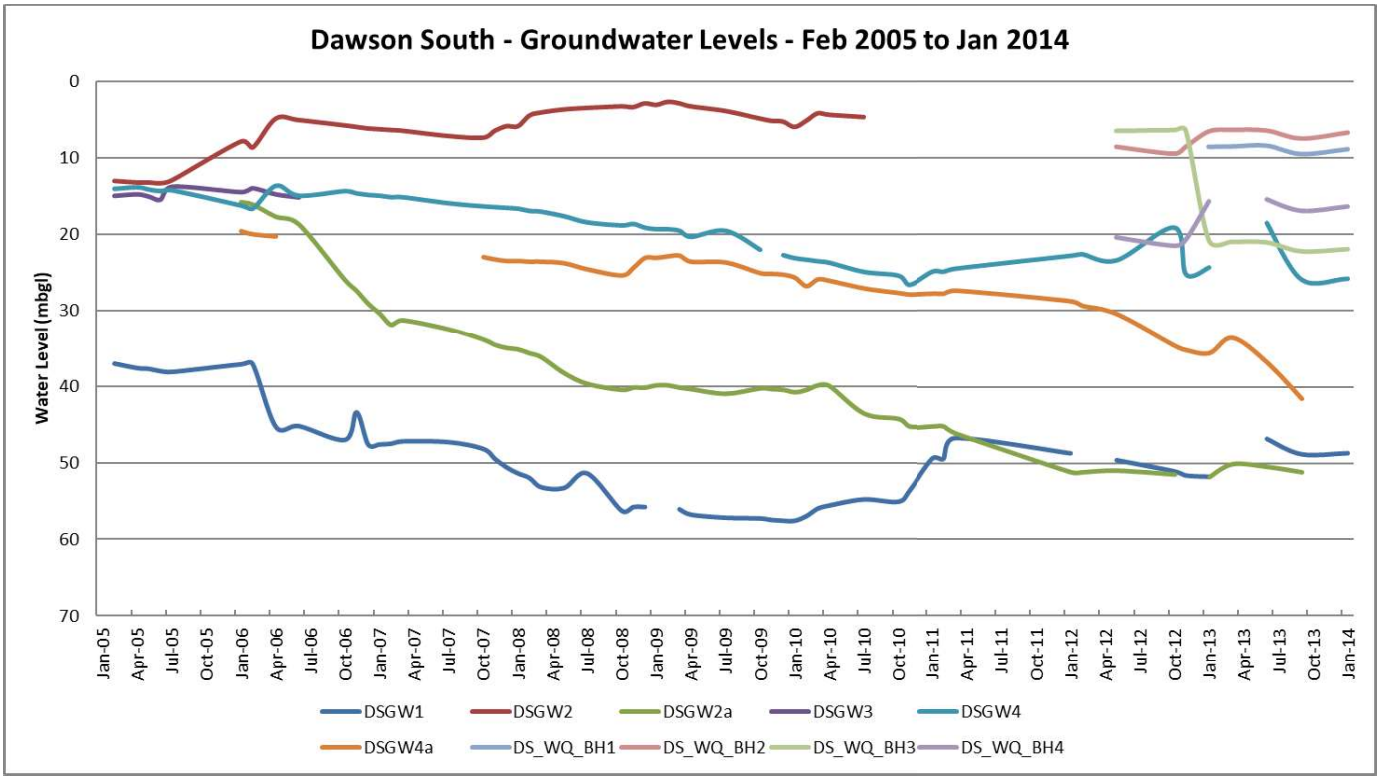


Figure 3-5 Groundwater levels February 2005 to January 2014

No groundwater monitoring data for DS is available between January 2014 and 2022. Recent groundwater monitoring data is available from newly installed monitoring bores in 2023 (Hydrogeologist.com.au, 2023). The initial groundwater level measurements were recorded at each monitoring bore following construction and after airlift development, and are summarised in Table 3-6 below. Additional data collected from 2024 show no significant change in groundwater levels in the Permian Coal Measures or Alluvium.

Table 3-5 Groundwater levels in newly constructed bores

Bore ID	Target Unit	SWL + (mbTOC)	SWL (mAHD)
DSMB03	Alluvium	12.26	126.52
DSMB04	Alluvium	12.85	125.36
DSMB05	Alluvium	8.87	118.65
DSMB06	Alluvium	13.88	118.02
DSMB07	Alluvium	14.76	115.72
DSMB08	Permian Coal Measures – A Seam	27.58	135.80
DSMB10	Permian underburden	49.96	140.71
DSMB13	Alluvium	17.90	115.66
DSMB14	Alluvium	Dry	Dry
DSMB15	Permian coal measures	Dry	Dry
DSMB16	Alluvium	Dry	Dry

Notes: mAHD – metres above Australian Height Datum, mbTOC – metres below top of casing

3.1.1.4.4 Groundwater Quality

Groundwater quality measurements collected from existing bores between 2003 to 2012 are provided in Table 3-6 (JBT, 2019). EC ranged from <1,000 in GW2 to approx. 9,710 µS/cm in GW2A with a median range from 2,870 to 6,870 µS/cm in other bores.

Table 3-6 Electrical Conductivity (EC) Data – 2003 to 2012 (JBT, 2019)

Statistic	GW1	GW2	GW2A	GW3	GW4A	GW4
Minimum (µS/cm)	3020	210	2090	6860	2690	3000
Maximum (µS/cm)	3880	9630	9710	6880	3260	5350
Mean. (µS/cm)	3351	4707	3009	6870	2986	4492
Median. (µS/cm)	3300	3140	2870	6870	2980	4575
Sample Count	21	17	23	2	19	22

Additional groundwater quality data was obtained from field measurements carried out during the drilling and monitoring bore installations between March 2021 and April 2023 (hydrogeologist.com.au, 2023). Results indicated relatively low EC in the Alluvium aquifer from 1,491 µS/cm to 3,750 µS/cm (with the exception of DSMB05, which has an EC of 7,250 µS/cm). Bores screened in the lower formations, including the coal seams, had elevated EC from 4,840 µS/cm to 5,120 µS/cm (Table 3-8).

Table 3-7 Groundwater quality field measurements (hydrogeologist.com.au, 2023)

Bore ID	Date sampled	Target Unit	SWL + (mbTOC)	pH	EC (µS/cm)	Temp (°C)
DSMB03	19 February 2023	Alluvium	12.26	8.76	1491	19.6
DSMB04	4 April 2023	Alluvium	12.85	7.91	2420	20.1
DSMB05	9 March 2022	Alluvium	8.87	7.71	7250	19.8
DSMB06	6 March 2022	Alluvium	13.88	8.71	3330	23.8
DSMB07	14 March 2022	Alluvium	14.76	8.14	3750	21.1
DSMB08	6 March 2021	Permian Coal Measures – A Seam	27.58	8.16	5120	27.9
DSMB10	23 February 2023	Permian underburden	49.96	6.93	4840	20.2
DSMB13	14 March 2022	Alluvium	17.90	8.30	3750	22.1

Notes: SWL (mbTOC) – Standing Water Level (metres below Top of Cover)

EC (µS/cm) – Electrical Conductivity (micro-Siemens per centimeter)

3.1.1.5 Hydrology and fluvial networks

Surface water from the site flows off the Malakoff Range into the Dawson River (catchment 50,800km^2). The river bisects the ML at Theodore and flows partly inside the western margins of the ML in a northerly direction until it drains into the Fitzroy River (catchment 156,286km^2) north-east of Duaringa, some 230km downstream of the northern DCN ML boundary. The Fitzroy River ultimately drains into the Coral Sea near Rockhampton, some 370km downstream of the Dawson-Fitzroy confluence.

The Dawson River has highly variable flow regimes, both seasonally and annually. It is used by the agricultural sector for crop irrigation and feedlots, by large industry for the production of Coal Seam Gas (CSG), and by adjacent townships as a source of water. The main surface water usage in the area is associated with agriculture, mining, urban development and CSG water management. Flow in the Dawson River is controlled upstream of the mine by the Theodore Weir (at Theodore) and downstream of the mine by the Moura Weir (just north of the Dawson Highway). The weirs facilitate irrigation for primary industry adjacent to the river. As such, the Dawson River water quality and quantity is important for the district's long-term productivity.

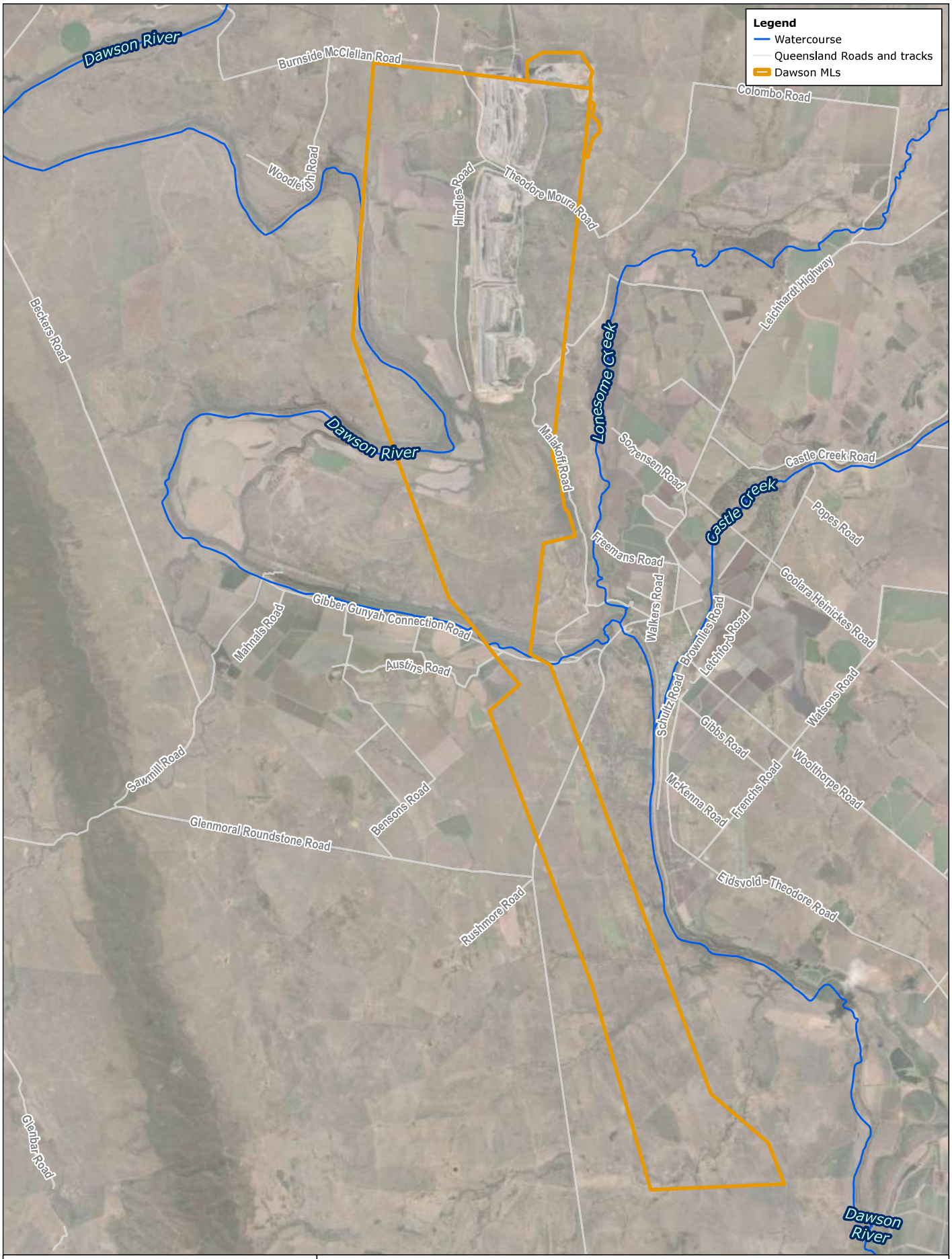
The Dawson River is deeply incised adjacent to the mine site with a river bank on average 10m high and stands approximately 1m to 2m above the alluvial floodplain. The banks are subject to severe erosion in places. A number of westerly flowing ephemeral creeks cross the Dawson Mine MLs towards the Dawson River, including Kianga Ck, Mt. Wiseman Ck, Borehole Ck, Four Mile Ck, Silverton Ck, Huon Ck, and, in the northern non-mined extremity of Dawson North, Banana Ck.

Water management on site aims to separate clean water from mine affected water (MAW) sources and, through water recycling, aims to maximise the reuse of water to limit the demand on external sources and the need to discharge from the mine. Surface water quality downstream of the operation has been recorded since 1957 (Table 3-9), while upstream data was collected as early as 1924, with records ceasing in 2002 (Neilly Group Engineering 2024)

Table 3-8 Streamflow gauging stations on Dawson River near DS

Streamflow gauging stations on Dawson River	Name	Location	Duration of records
130317	Dawson River at Woodleigh	~10km downstream DS	1957 - current
130305	Dawson River at Theodore	~5km upstream DS	1924 - 2002
130358	Dawson River at Isla-Delusion Crossing	>30 km upstream DS	1993 - 2002

DS has implemented policies and procedures to mitigate the risk that the quality of water leaving site is impacted by site activities. Dams and rivers are regularly monitored for algae, pH levels, conductivity, suspended solids, and sulphate. The Fitzroy Regional Receiving Environmental Monitoring Program (FRREMP) is a basin-wide water quality monitoring program DS participates in. Water quality monitoring is, implemented across the site in accordance with FRREMP to ensure derived water quality objectives are maintained, and water releases, if they occur, do not impact the environment (Hydrobiology, 2023).



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Figure 3-6 Major Watercourses

Dawson Mine Complex

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3.1.1.6 Soil types, properties, and productivity

Soils at DS have developed in a climate of low rainfall and high temperatures. While the low rainfall at the site has prevented leaching of the soils, seasonal drought, dry conditions, and high temperatures have also restricted the generation of organic matter, resulting in relatively low (top) soil fertility, consistent with soils of the wider region.

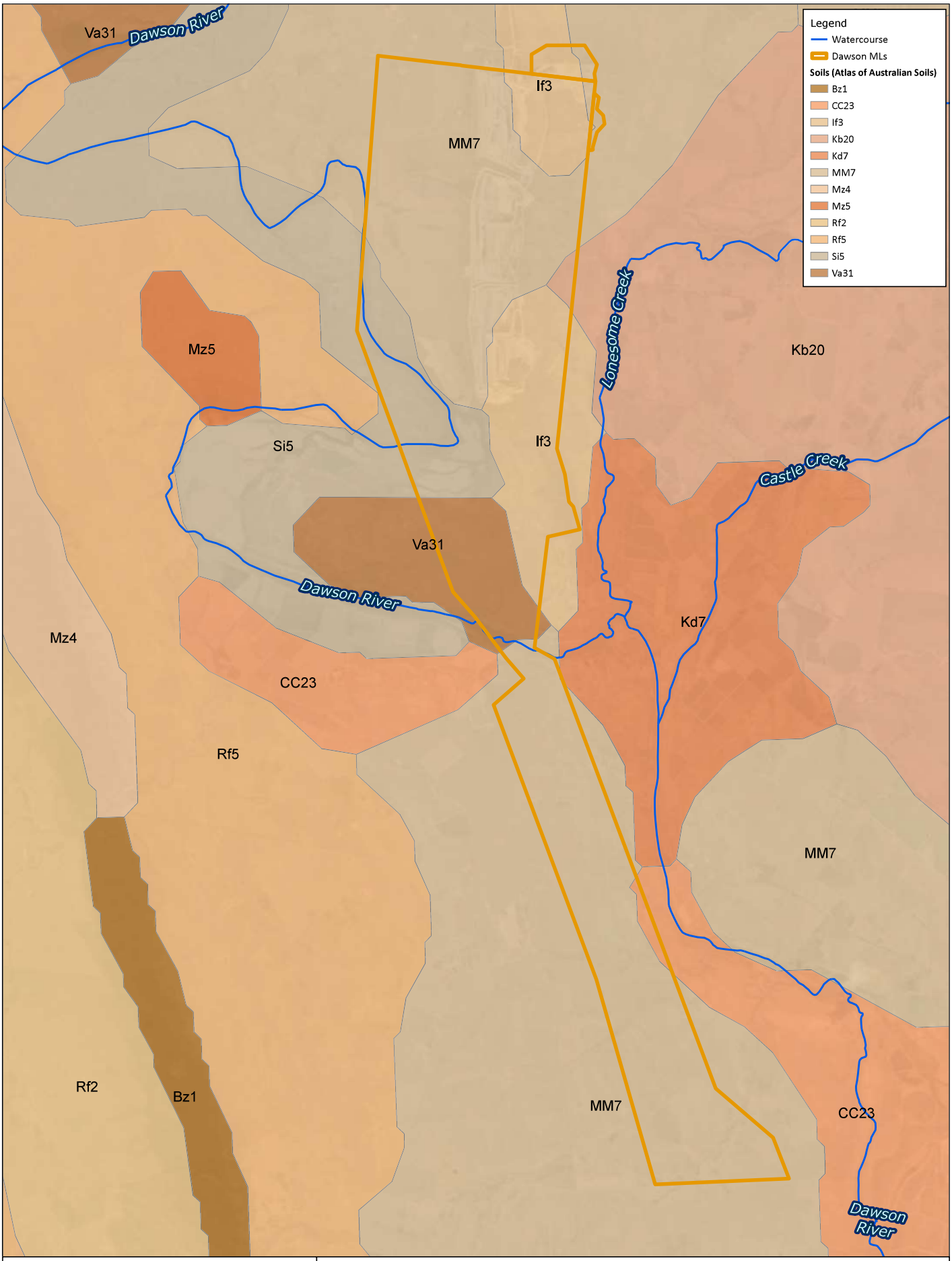
The main soil types present on site are self-mulching cracking clays, particularly brown and red clays, equivalent to vertosols, as per the Australian Soil Classification (Isbell *et al*. 2021). Smaller areas of duplex soils, including the alluvial soils of the Dawson River (sodosols) and non-cracking crumbly clays (ferrosols) occur in the area north-west of Theodore (Table 3-10 and Figure 3-7).

The cracking clays (vertolsols) in large parts of the MLs have shrink - swell properties, and thin, surface crusty horizons 30 mm or less thick. When dry, open cracks occur at some times during most years. These soils are typical of Brigalow and Semi Evergreen Vine Thicket (SEVT) vegetation, though often cleared for agricultural purposes, such as at DS.

The duplex soils (sodosols) occur on undulating plains with some stony ridges and rock outcrops. They have a texture contrast between the A and B horizons. They are typically sodic and highly erosive when the surface is disturbed. At DS, these soils are exclusively used for agricultural purposes, except for very narrow corridors of regenerating and remnant native vegetation along the major drainage lines, including the western part of the Willawa Nature Refuge.

The non-cracking clays (ferrosols) on Malakoff Range slopes on the eastern edge of DS MLs are variable in their nature depending on slope, slope position and parent material (Emmerton, 2004). The soil surface is firm or more commonly hard-set and all soils are shallow. At DS, this soil unit contains some areas of regenerating remnant Eucalypt and Brigalow communities.

Detailed pre-mining soil investigations have been undertaken by Emmerton (2004) in part of DS MLs. Details of these investigations are provided in Appendix 4.2.



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Figure 3-7 Soils (Atlas of Australian Soils)

Dawson Mine Complex

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Table 3-9 Description of Soil Types

Mapping Unit [and Australian Soil Classification equivalent]	Description
Brown and red self-mulching cracking clays (MM7) [Vertosols]	Moderate to gently undulating lowlands and plains: dominant soils are moderately deep to deep clays, which in some areas have a moderate gilgai microrelief (1-2 ft). In some areas the soil surface may be strewn with silcrete (billy) gravel to 4 in. diameter. Brown clays (Ug5.34, Ug5.38, Ug5.32, and Ug5.37) are dominant but grey forms (Ug5.25, Ug5.24, and Ug5.22) are also common; dark clays (Ug5.13, Ug5.15, and Ug5.16) also occur. Closely associated are thin-surfaced loamy duplex soils, chiefly (Dr2.13 and Dr2.33), (Db1.13 and Db1.33), and (Dy2.33 and Dy2.43), which occur particularly on floodplains of small streams. Small areas of friable earths (Gn3.13 and Gn3.12) also occur, particularly where the unit borders the high mountains of unit Bz1
Hard pedal mottled-yellow duplex soils (Va31) [Sodosols]	Gentle or moderately undulating lands with some more strongly dissected marginal slopes: dominant soils are loamy surfaced (6-8 in.) (Dy3.43) and (Dy3.33). Also occurring, more particularly on the marginal slopes, are duplex soils with deeper sandy A horizons (1-20 in.) which are often gravelly. Common forms are (Dy3.43 and Dy3 .42). Other duplex soils also occur, particularly along drainage lines; these are chiefly (Db1.13), (Dy2.43), (Dy2.33), (Dd1.13), (Dd1.33), and (Dy4.32). Included in the unit are small areas of moderately to strongly gilgaied cracking clays (Ug5.24) and occasional small areas of sandy red earths (Gn2. 11)
Non-cracking crumbly clays (If3) [Ferrosols]	Steep high ridges of dissected plateaux, with steep scarps and some small plains: chief soils seem to be shallow dark pedal clays (Uf6.22) and (Uf6.11) with shallow loams (Um6.21), (Um4), and (Um1.43). Other soils include (Ug5.12), (Uf6.31), (Gn3.12), (Dr2.12), and (Dy2.43)
Alluvial floodplains mostly associated with major streams (SI5) [Sodosols]	Alluvial floodplains mostly associated with major streams; the area is sometimes dissected by broad shallow drainage lines and there are occasional old low levees: most common are loamy duplex soils of moderate A horizon depth (6-12 in.) and grey-brown clay subsoils (Dy2.33), much less commonly (Dy2.13) and (Dy2.43). The slightly higher areas have deeper sandier A horizons (12-15 in.) and brown or reddish-brown clay subsoils (Db1.33), (Db1.13), and (Dr2.13 and Dr2.12). Marginal to the alluvial plains and particularly fringing depressed areas are thin-surfaced loamy duplex soils (Dd1.33) and (Dd1.43). In the associated broad drainage lines and depressions cracking clays occur, chiefly (Ug5.24), (Ug5.14), and (Ug5.15) and occasionally (Ug5.5 and Ug5.4). Adjacent to major stream banks a range of uniform-textured soils often occurs, chiefly (Uf6.32), (Um5.4), and (Uc5.11)

3.1.1.7 Land Stability

Most of the soil types inherently have negligible to minor limitations except in drainage lines where the combined effects of overland flows and water velocity will increase erosion risks. Similarly, steeper slopes such as those on the riverbank itself increase the risks of erosion.

The stability of land surfaces created since mining is primarily related to the nature of the underlying spoil. Types of spoil and their characteristics are described in Section 3.6.4. Gullying, piping, and rilling is absent on the coarse sandstone spoils (Types 1 and 2 spoil), but more common on the finer textured spoils (Types 3 and 4 spoil). Spoil management procedures are in place to ensure that spoil is used appropriately and managed to ensure a stable surface, as further described in Section 3.6.4.

An Erosion and Sediment Control Plan (ESCP) is required by the EA and forms a LOD. It provides procedures to manage erosion and the release of sediment to receiving water and contamination of stormwater. Procedures include identifying erosion and sediment transport risk, use of various structures and techniques to control erosion, maintenance of measures put in place, and monitoring and measurement.

3.1.1.8 Vegetation communities and ecological data

Queensland Herbarium pre-clearing Broad Vegetation Group mapping indicates that, prior to European arrival, the land on which DS is located would have been covered with open forests and woodlands dominated by:

- Brigalow (*Acacia harpophylla*) (Dawson North, Dawson South, and the adjacent parts of Dawson Central);
- Poplar Box (*Eucalyptus populnea*) and Silver-leaved Ironbark (*E. melanophloia*), particularly in south-west of Theodore;
- Blue Gum (*E. tereticornis*), Coolibah (*E. coolabah*), Brigalow, and Poplar Box along creek lines and on floodplains;
- Mixed species Eucalypt (*Eucalyptus* spp.) woodland and open woodland, on the upper slopes of low hills towards the west;
- Semi-evergreen Vine Thicket (SEVT) (southern end of the Malakoff Range); and
- Mitchell Grass - Bluegrass (*Astrebla* spp., *Dichanthium* spp.) tussock grassland, in small scattered patches.

Historical aerial photography from 1953 (QI Imagery, 2023) indicates that much of the surrounding areas were cleared for agriculture. Further clearing since then has resulted in a landscape surrounding the mine that is almost completely cleared of native vegetation, except for very small and scattered stands of Brigalow, narrow fringes of riparian vegetation along the main creeks and the Dawson River, and east of the DS mine Pit 26/27 (Brigalow). By the time surveys were conducted for the Dawson South EIS (EH&S, 2006), all of the Dawson South mine footprint therefore had already been cleared of native vegetation. Table 3-11 lists extant Regional Ecosystems (RE) within the DS MLs mapped as remnant or high value regrowth native vegetation by the Queensland Herbarium.

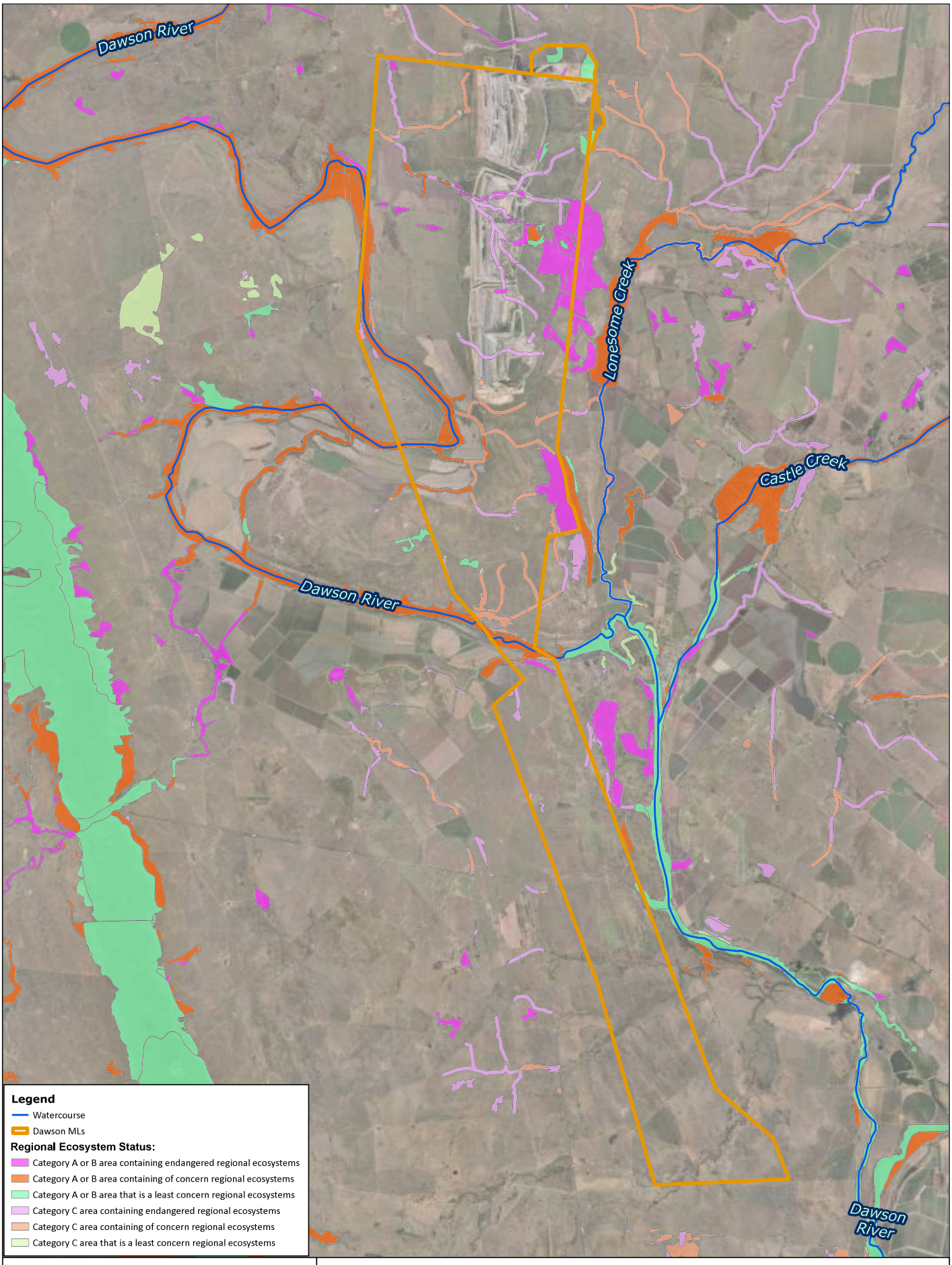
Most polygons of remnant or high value regrowth vegetation consist of combinations of two or more REs, as shown in the distribution map in Figure 3-8. Many of the stands of remnant vegetation have an elevated conservation status, including Of Concern or Endangered (VM Act). Those REs listed as having an Endangered biodiversity status under the *VM Act* (as shown under the Regional Ecosystem Description Database - REDD) constitute Category B environmentally sensitive areas (ESAs), as defined under Schedule 19 of the *Environmental Protection Regulation 2019*. Queensland Herbarium Regional Ecosystem maps have been prepared at a scale of 1:100,000, and may therefore not always be accurate at the local level. Additional field work would be required to verify the RE and precise boundaries of mapped polygons.

Given the lack of baseline information prior to clearing of the land for agricultural purposes, the types and areas of RE's displaced are unknown for the DS area as a whole.

Table 3-10 Regional Ecosystem Descriptions, their Status, and Area with in the MLs

Regional Ecosystem	Description	VM Act*^	Area (ha)
11.3.1	*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains	E	10.3
11.3.2	*Eucalyptus populnea* woodland on alluvial plains	OC	67.0
11.3.3	*Eucalyptus coolabah* woodland on alluvial plains	OC	19.5
11.3.4	*Eucalyptus tereticornis* and/or *Eucalyptus* spp. woodland on alluvial plains	OC	270.7
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	OC	43.7
11.4.3	*Acacia harpophylla* and/or *Casuarina cristata* shrubby open forest on Cainozoic clay plains	E	30.1
11.4.7	*Eucalyptus populnea* with *Acacia harpophylla* and/*or Casuarina cristata* open forest to woodland on Cainozoic clay plains	E	31.9
11.4.9	Brigalow (*Acacia harpophylla*) and yellowwood (*Terminalia oblongata*) woodland	E	18.3
11.5.2	*Eucalyptus crebra*, *Corymbia* spp., with *E. moluccana* woodland on lower slopes of Cainozoic sand plains and/or remnant surfaces	NC	11.6
11.9.1	*Acacia harpophylla- Eucalyptus cambageana* woodland to open forest on fine-grained sedimentary rocks	E	4.6
11.9.2	*Eucalyptus melanophloia* +/- *E. orgadophila* woodland to open woodland on fine-grained sedimentary rocks	NC	162.0
11.9.4	Semi-evergreen vine thicket or *Acacia harpophylla* with a semi-evergreen vine thicket understorey on fine-grained sedimentary rocks	E	39.8
11.9.5	*Acacia harpophylla* and/or *Casuarina cristata* open forest to woodland on fine-grained sedimentary rocks	E	211.2
11.9.7	*Eucalyptus populnea, Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks	OC	87.6
11.9.9	*Eucalyptus crebra* woodland on fine-grained sedimentary rocks	NC	64.3
11.9.12	*Dichanthium sericeum* grassland with clumps of *Acacia harpophylla* on fine-grained sedimentary rocks	E	16.9

* E = Endangered, OC = Of Concern, NC = No Concern. ^ Biodiversity Status



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Figure 3-8 Regional Ecosystems

Dawson Mine Complex

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3.1.1.8.1 Vegetated Corridors and Reserves

There are currently no continuous vegetated corridors within the vicinity of DS. The riparian vegetation along creeks and drainage lines is typically discontinuous or consists of regenerating vegetation. The nearest corridor with continuous vegetation is located some 20km west of DS, at the Roundstone State Forest.

The two-part Willawa Nature Refuge contains an eastern section and a western section either side of Pit 26/27, totalling 428.25 ha. The Western section is adjacent to the Dawson River, within the ML but separated from the mine site by 1.5km of cleared grazing land and contains largely regenerating floodplain forest. The eastern section, 200m east of the mine site, contains both regenerating and remnant Brigalow and Eucalypt forest.

The Willawa Nature Refuge Conservation Agreement allows for several activities including but not limited to grazing and disturbance associated vehicle tracks, road easements, powerlines, fencing, underground operations and surface works (gas drainage and crack amelioration). These activities will continue to be undertaken as per the agreement conditions, however they do not form disturbance areas and rehabilitation areas under this PRCP. The intended post mine land use of the Willawa Nature Refuge is bushland, however this does not exclude grazing activities which will continue to be undertaken in these areas in accordance with the agreement

3.1.1.8.2 Threatened Plant Species

While a number of plant species listed as threatened on the *NC Act* have been recorded in the region of DS, only two have been recorded within the MLs to date. These include Carnarvon Gorge Fan Palm *(Livistona nitida)* (listed as Near Threatened under the NC Act), found on the Dawson River ephemeral water bodies in the north west of the ML (WBM Oceanics Australia 2003). Both of these locations are outside the mining envelope and are not affected by mining or mine closure.

The extensive disturbance caused by previous clearing for grazing and mining, indicates that the potential for additional species to occur within the MLs is restricted.

3.1.1.8.3 Weeds of Management Concern

Key weed species of management concern within the DS area include Rubber Vine *(Cryptostegia grandiflora),* Yellow bells (*Tecoma* stans), Mimosa bush (*Vachellia farnesiana)* and Parthenium Weed *(Parthenium hysterophorous)* listed under the *Biosecurity Act 2014* as restricted invasive plants. Other weeds species such as Leucaena *(Leucaena leucocephala)* are also present at the site. These species and other exotic plant species can interfere with revegetation goals by outcompeting desirable species. Leucaena is an agricultural species grown in nearby plantations as cattle fodder crop. Seeds from such plantations were likely the original source of the spread of Leucaena into the DCN, and from there into DS. Ongoing cultivation of this species at nearby properties will likely also hinder control of this species at DS. Weeds of concern across the DS mine lease are also of concern for the wider region.

Control of restricted invasive plants such as Rubber Vine and Parthenium Weed is required under the *Biosecurity Act 2014* (Qld). Priority weed management at DS focuses on well-defined areas of known invasive plant infestations that offer the opportunity for eradication within the immediate to short term. Weed management priorities also focus on areas of low density weed infestations that have the potential to spread through vehicle movement (e.g. traffic areas such as perimeter firebreaks and main access tracks through natural areas) or via overland flow (e.g. watercourses and floodplain). Active weed control is ongoing.

3.1.1.9 Fauna presence and populations

Fauna surveys have been undertaken at DS for the EIS (WBM Oceanics Australia, 2003), and during flora and fauna monitoring in 2014 and 2018 (Ecological Survey and Management, 2014; 2018). The EIS field program recorded 188 terrestrial fauna species, including 22 mammals, 28 reptiles, 16 frog and 122 birds (EH&S, 2006). Overall, the area is not particularly species rich, and a number of fauna groups were poorly represented or absent, including arboreal mammals, small dasyurid ground mammals, macropods, small passerine birds, skinks and geckos. This is consistent with the high level of disturbance of the area and the resultant absence of suitable habitat, e.g. lack of suitable tree hollows, ground cover conditions, shrubby understorey, canopy tree cover and presence of exotic plants.

Fauna assemblages are generally richer in non-mined and remnant habitats compared to rehabilitated habitats, likely to be related to the greater habitat complexity encountered in those environments. Species encountered within the rehabilitated monitoring sites tended to be hardy generalists that were typically adaptive, highly mobile or disturbance tolerant. They included highly mobile species (birds, bats and larger mammals) able to forage across large areas and retreat to suitable habitat for refuge and potentially breeding outside of the disturbed areas.

Similar to flora, while a range of fauna species listed as threatened on the *NC Act* have been recorded in the region of DS, only one has been recorded on the MLs to date. The Squatter Pigeon *(Geophaps scripta scripta)* (listed as Vulnerable under the *NC Act*) was recorded on an unsealed vehicle track on the Malakoff Range during the EIS surveys (WBM Oceanics Australia, 2003).

Several species of introduced fauna have been recorded at the Dawson Mine area (including DS). These include Dog *(Canis familiaris)*, Dingo *(Canis lupus dingo)*, European Red Fox *(Vulpes vulpes)*, Feral Cat *(Felis catus)*, European Rabbit *(Oryctolagus cuniculus)*, and Feral Pig *(Sus scrofa)*, listed as restricted invasive animals under the *Biosecurity Act 2014*. Other introduced species recorded include Cane Toad *(Rhinella marinus)*, House Sparrow *(Passer domesticus)*, and House Mouse *(Mus musculus)* (Ecological Survey and Management, 2018).

Aquatic fauna is essentially restricted to the Dawson River and permanent water holes and adjacent areas. Most native fish species recorded during the EIS studies have relatively widespread geographic distributions (WBM Oceanics Australia, 2003).

3.1.1.10 Pre-mining land use

Pre-mining land use was predominantly cattle grazing on improved Buffel Grass pastures, with some areas of dryland cropping on the flood plains.

Current land use in the area surrounding DS is largely a continuation of pre-mining land use (Figure 3-9). Thus, the dominant land use is grazing on cleared land, some of which contain improved pasture. There are also areas of dryland cropping on the MLs, but outside the active mining envelope.

The major western part of the Willawa Nature Refuge is located along the Dawson River banks extending to approximately 1.5km west of Pit 26/27, while the smaller eastern part is located approximately 300-900m to the east of these pits along the Malakoff range.



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Figure 3-9 Current Land Use

Dawson Mine Complex

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3.1.1.11 Land suitability and capability

The Agricultural Land Evaluation Guidelines for Queensland outline methods for defining and deriving land suitability and capability classes (DSITI and DNRM, 2015). Land Classes describe the suitability of land for particular agricultural land uses (Table 3-11).

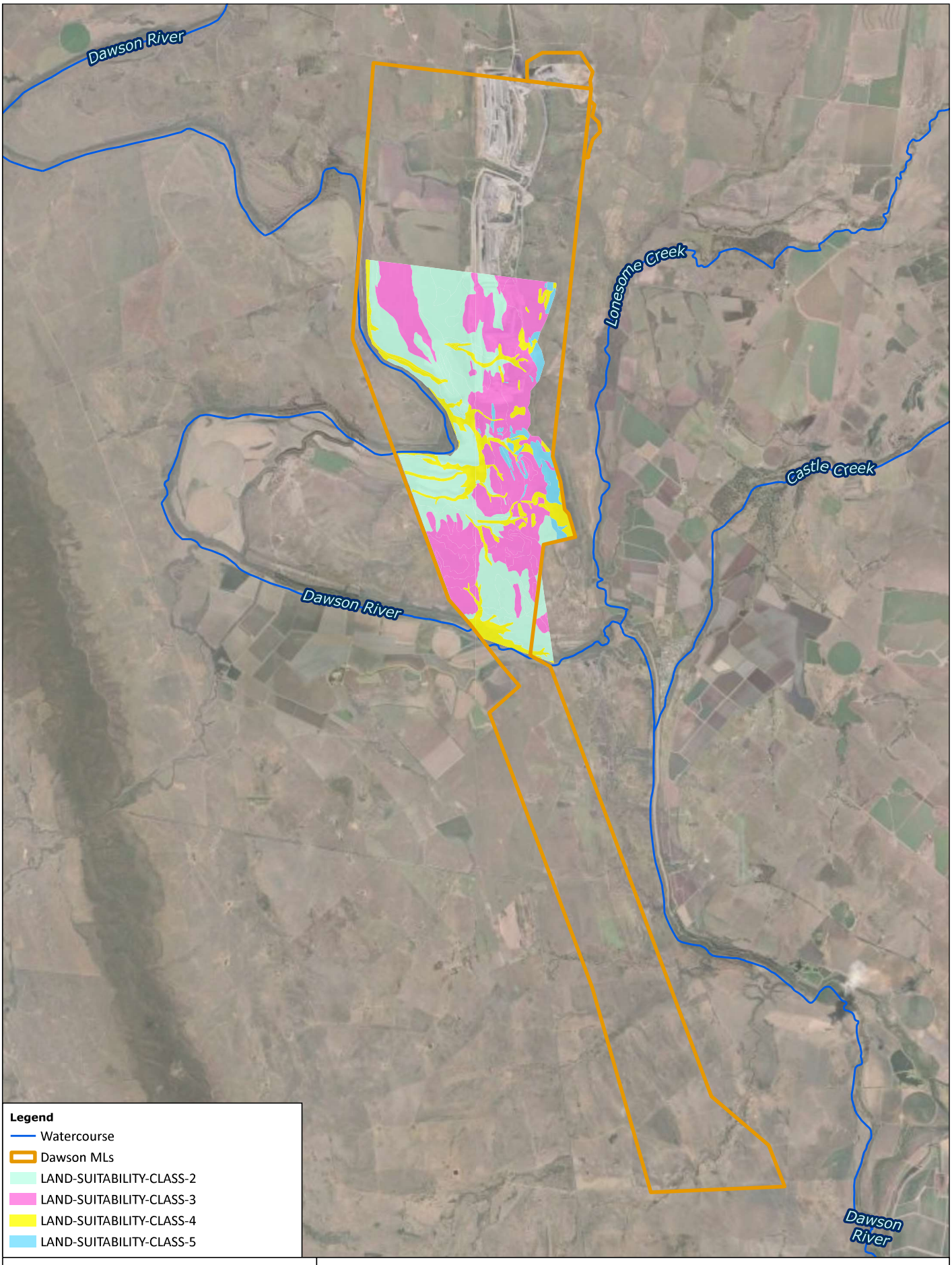
Areas within DS (pre-mining) are mapped as Class A Agricultural Land in the area of Pits 25 to 27 and on the Dawson River floodplain, with Class C Agricultural Land mainly on higher ground such as the Malakoff Range and in the area of the MLs south of Theodore. Class A land represents crop land that is suitable for a wide range of current and potential crops with nil to moderate limitations to production. Class C land represents land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment.

Class A land outside of the mine footprint is also marked under the Strategic Cropping Land (SCL) trigger (the mine footprint is excluded) (Figure 3-11). However, despite these nominations, most land on and surrounding the DS MLs is used for grazing, not for cropping. Further, it is not feasible to return areas of Class A or SCL disturbed by mining to a cropping land use, due to the changed landforms and changed site conditions in the post-mining landscape resulting in relatively steep slopes. It is also not contemplated in the LODs.

Table 3-11 Agricultural Land Classes

Class	Description
A (cropland)	A1 – land suitable for a wide range of broadacre crops A2 – land suitable a wide range of horticultural crops only. This allows better discrimination of crop land at both local and state-wide levels
B (limited cropland)	Land that is not suitable for a wide range of crops (broadacre and/or horticultural) but is suitable for a narrow range of crops or crops with specialised requirements e.g. tea, pineapples, plantation forestry. Class B land may be suitable for a wider range of crops with changes to knowledge, economics or technology. It is also suitable for sown pastures and pasture phases may be an integral part of a cropping system on this type of land. The original definition of class B land (Land Resources Branch, 1990) resulted in inconsistent allocations of crop land because of the presence of a major 'and/or' statement in it. In some areas this resulted in the creation of subclasses B1 and B2, but this distinction is no longer required.
C (pasture land)	C1 land is the higher fertility grazing land typically used for beef cattle fattening and includes the brigalow and gidgee lands that are not suitable for cropping. C2 land is more typically suited to sheep and cattle breeding C3 is restricted to grazing with low stocking rates.
D (not suitable for agriculture)	Not suitable for agricultural purposes generally due to the presence of extreme limitations such as very steep slopes, rock outcrop, salinity, acidic drainage or severe degradation. Class D land also includes land alienated from agricultural use (e.g. urban areas) and land with high order conservation tenure (e.g. national parks).

A figure of the pre-mining land suitability class is provided in Figure 3-10.



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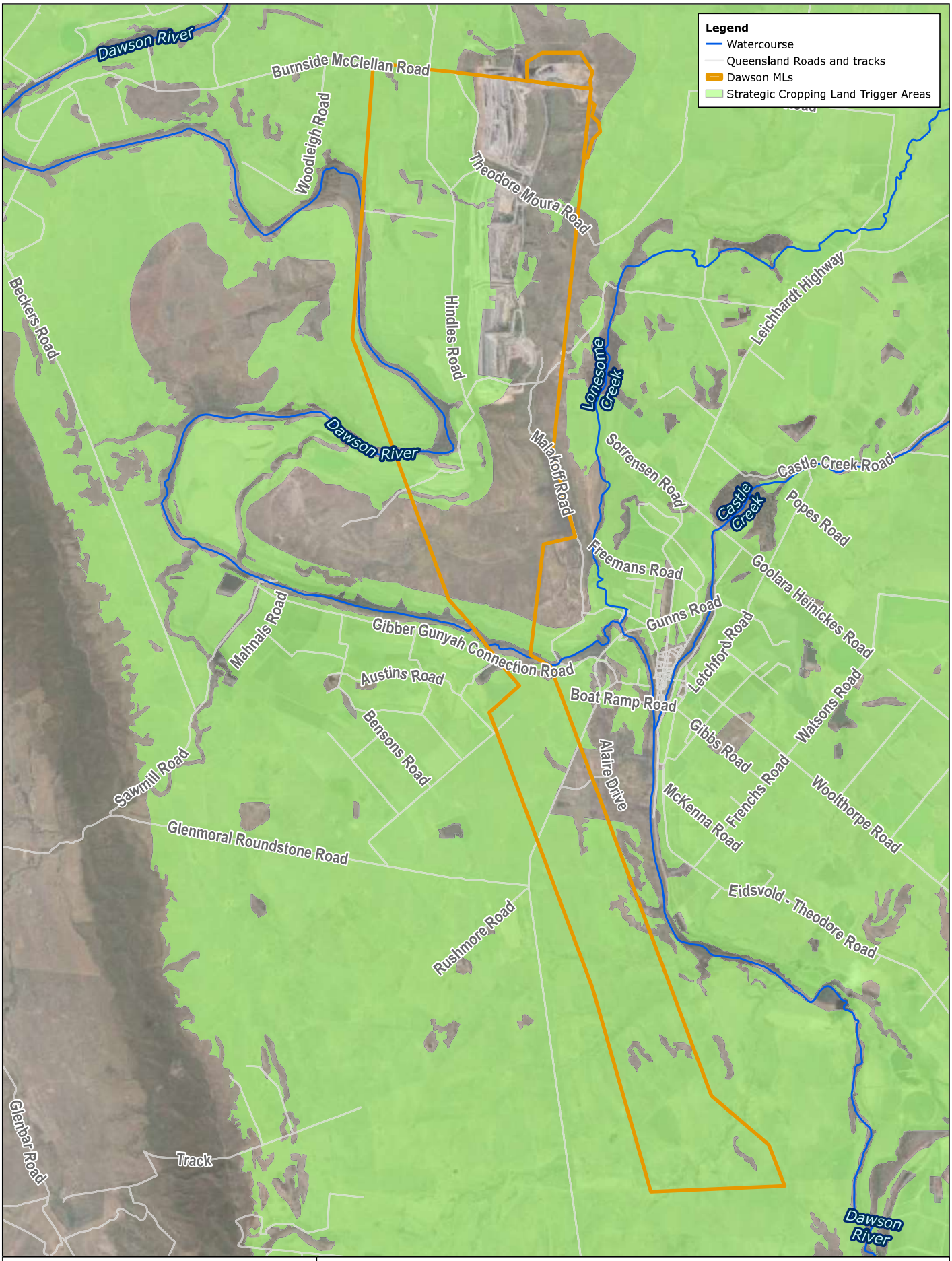
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Figure 3-10 Pre-mining Land Suitability Class

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Figure 3-11 Strategic Cropping Land Trigger Areas

Dawson Mine Complex

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3.1.1.12 Landholders

The DS Mine is located on a number of land parcels, held by different landholders. These are identified in Table 3-12 and Figure 3-12 below.

Table 3-12 Land Ownership

Lot and Plan	Tenure
ML5656	
1 on SP241815	Freehold
1 on RP185801	Freehold
2 on RP185801	Freehold
2 on RP2042063	Freehold
2 on RP616429	Freehold
2 on LE262	Freehold
3 on RP185801	Freehold
4 on SP185801	Freehold
5 on SP185801	Freehold
6 on SP185802	Freehold
7 on SP185802	Freehold
12 on BH69	Freehold
13 on LE253	Freehold
15 on RP185801	Freehold
16 on RP185801	Freehold
17 on RP185801	Freehold
18 on RP185801	Freehold
26 on LE262	Freehold
29 on DW137	Freehold
30 on DW138	Freehold
38 on DW108	Freehold
42 on LE172	Term Lease
44 on LE105	Term Lease
82 on LE147	Term Lease
1 on RL8003	Term Lease
2 on DW65	Term Lease
2 on DW71	Term Lease
13 on CP849905	Term Lease
16 on DW529	Term Lease
74 on LE105	Term Lease
75 on SP104408	Term Lease
10 on DW73	Reserve
4 on CP904436	Reserve
12 on DW77	Reserve
86 on LE171	Reserve
97 on USL14584	Unallocated State Land
A on RP179583	Easement
Unnamed Road (ASA 2)	
Hindles Road (SA1)	
Theodore & Baralaba Road (SA1)	

Lot and Plan	Tenure
Unnamed Road within Surface Area (SA1)	
Leichardt Highway	
Leichardt Road	
Gibber Gunyah Connection Road	
Unnamed Road	
Closed Road	
ML80160	
24 on DW91	Freehold
ML80161	
16 on DW529	Term Lease



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Date: 20/04/2026

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Figure 3-12 Mining Leases and Land Holders

Dawson Mine Complex

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3.1.2 Project description

3.1.2.1 Mining tenements

The DS EA (EMPL00657413) encompasses three mining leases, covering approximately 8,935ha (Table 3-14).

Table 3-13 Mining Leases

Tenure Number	Tenure Name	Tenure Type	Expiry Date	Total Area (ha)
ML 5657	Anglo Coal (Dawson South) Pty Ltd	Mining Lease	31 Mar 2026	8,796.00
ML 80160	Anglo Coal (Dawson South) Pty Ltd	Mining Lease	30 June 2031	115.50
ML 80161	Anglo Coal (Dawson South) Pty Ltd	Mining Lease	30 June 2031	23.73
ML Area Subtotal				**8,935.23**

3.1.2.2 Primary mine features / infrastructure

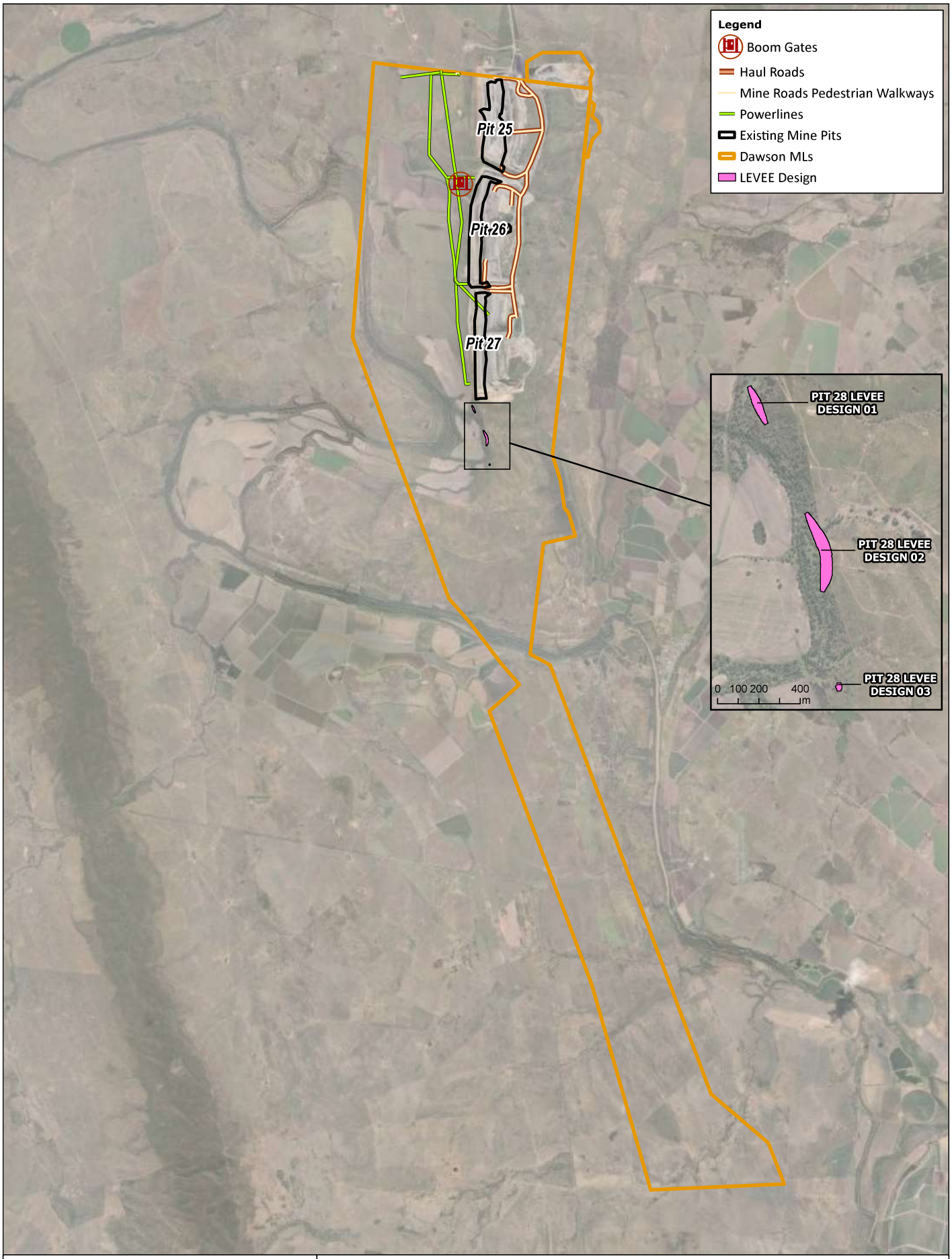
Open cut coal mining is the primary type of mining for DS. No underground mining has occurred in DS. Highwall mining has occurred in some places.

The current extent of the operations at DS includes the following key features:

- Four open cut pits (Pits 25 – 28);
- Overburden landforms;
- Mine infrastructure (clean water diversions, culverts, industrial dam western backbone pipeline used to transfer mine affected water between pits, minor infrastructure such as sediment control structures, drains, coal stockpile areas);
- Levees to the west to protect operational areas from a 1:1,000 AEP flood in the Dawson River; and
- Roads and tracks.

The key existing mine features of DS are shown in Figure 3-13.

At cessation, mining and related activities will have disturbed approximately 2,162ha of land. With a current rehabilitation completion area of 159ha, a total of 2,003ha remains to be rehabilitated before relinquishment. Any areas of land not rehabilitated at cessation of mining operations will be rehabilitated between then and relinquishment.



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Date: 28/04/2026
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Figure 3-13 Key Mine Features

Dawson Mine Complex

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3.1.2.3 Type of mining operation and duration

DS is primarily operated as an open cut coal mine, commencing operations in the northern part of ML5657 in 2003, and extending towards the south since then. Open cut operations use either a dragline or a truck and shovel combination to excavate overburden from a high wall, typically after blasting, with waste rock dumped initially on an ex-pit waste rock dump, followed by in-pit dumping on the low wall once mining has progressed to accommodate the waste rock in-pit. Run of Mine (ROM) coal is produced from the underlying seams by shovel, which is then transported by dump trucks to a dump station via haul roads, and from the dump stations by conveyor system to the CHPP at Dawson Central (north of DS). No rejects storage facility or tailings dams are established at DS.

Small areas of highwall mining within C Seam and E Seam have also been undertaken at DS. This mining method involves entering the coal seam from the toe of a highwall by excavating coal resources using specialised tunnelling/mining equipment creating rectangular drives of approximately 3.5m width set between 2-6.5m apart from one another. The method leaves the overburden in place. All highwall mining entries have been sealed over by dumping excavated overburden material over the entries.

Production at DS is approximately 5 Mtpa and the estimated life of mine is 2049.

3.1.3 Design for closure

Transitional PRC Plans are not required to demonstrate how aspects of the mine site have been designed for closure for existing or approved disturbance, however, any expansion to an existing site must demonstrate how it has been designed for closure.

Dawson is under a transitional PRC Plan and has no planned expansions to the existing site.

3.1.4 Rehabilitation/ improvement planning

3.1.4.1 Identification of Environmentally Relevant Activities (ERAs)

Table 3-15 identifies the ERA, as defined under Schedule 2A of the Environmental Protection Regulation 2008, which is mining of black coal.

Table 3-14 Environmentally Relevant Activities

Environmentally Relevant Activity/Activities	Location(s)
Mining – ML black coal – 13, Site Specific	ML5657
	ML80160
	ML80161

3.1.4.2 Predicted duration of ERAs and progressive rehabilitation

Mining across all the DS MLs is currently planned to be completed by 2049. Progressive rehabilitation works are underway in the northern part of DS and are expected to continue until cessation of mining. The mid/long-term planning department for the site have developed an indicative LOM rehabilitation schedule, based on the long-term mining schedule (Appendix 4.1).

LOM rehabilitation planning is an iterative ongoing process which is updated at least annually following the overarching LOM planning process. Rehabilitation of infrastructure areas will occur as soon as practical following decommissioning of infrastructure. Progressive rehabilitation will involve regrading, topsoiling, ripping and seeding activities. Rehabilitation will be completed through use of

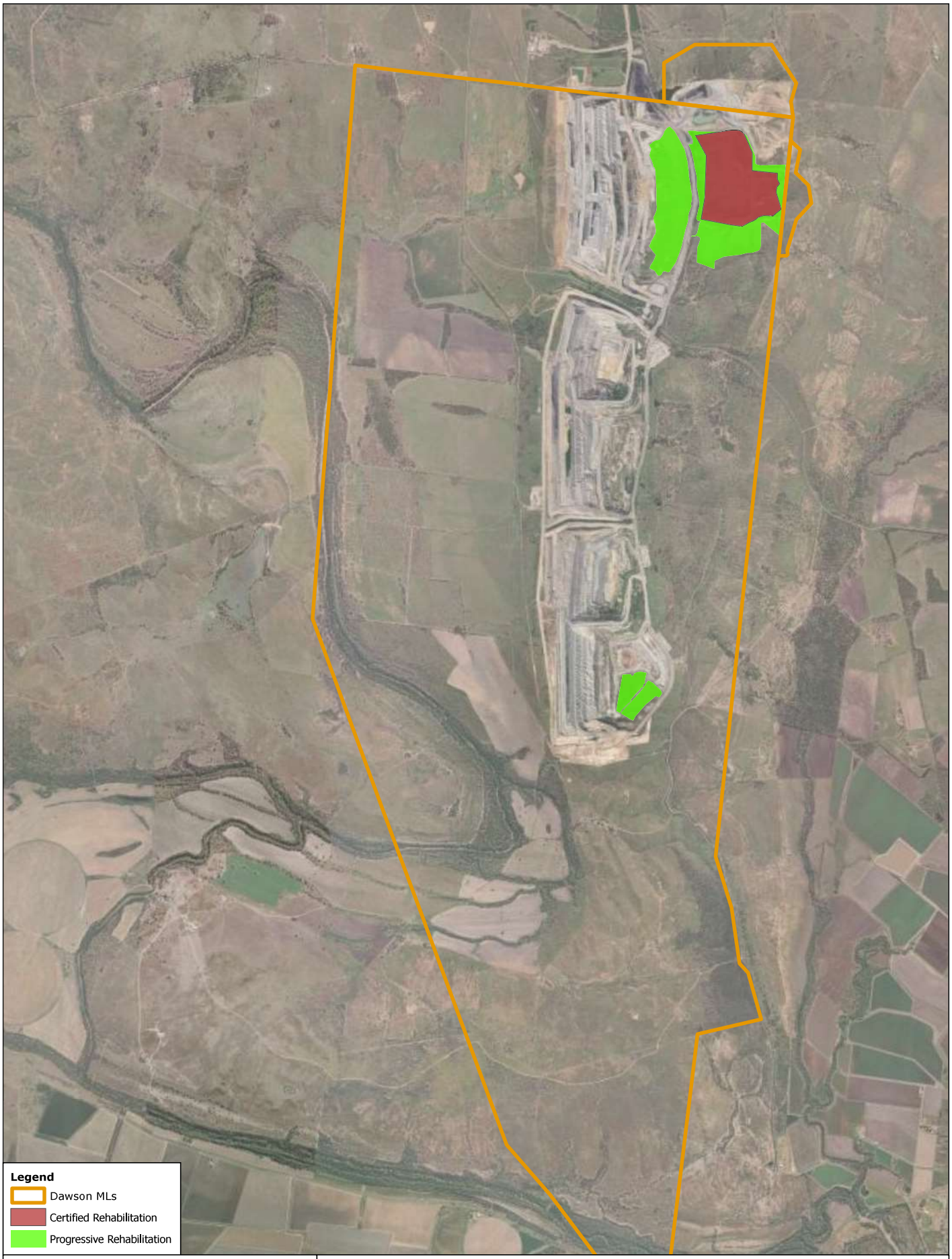
onsite equipment and resources and a contracted third-party rehabilitation and earthmoving company.

3.1.4.3 Existing rehabilitation and certification

Rehabilitation was undertaken in 2012 east of Pit 25, in the northern part of Figure 3-14. Here, a 165ha area of spoil was graded to 1:6 slope, topsoiled, and seeded with a range of native pasture species as well as native shrub and tree species with the objective to providefor cattle grazing. The banks of a clean freshwater dam was stabilised and revegetated near this area in 2016 to provide for stock water. Trials undertaken in this area have shown weight gain measurements of weaners over multiple years which were higher than those in an adjacent control (unmined and un-rehabilitated) paddock.

The location of existing rehabilitaiton and certification areas is provided in Figure 3-15. The southern area of DS MLs is excluded as no disturbance has occurred in this area.

A total of 81.8ha of this rehabilitated area was certified as achieving completion criteria in January 2025 (DETSI, 2025b). Monitoring has demonstrated grass coverage has achieved 40-60% cover and 1000kg/ha biomass has been achieved.



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Figure 3-14 Existing and Certified Rehabilitation

Dawson Mine Complex

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3.1.4.4 Rehabilitation Methods

Rehabilitation methodology at DS consists of the following:

- 1st Stage – Bulk push works to create a safe, structurally stable final landform that does not cause environmental harm, comprising:
  - Rehabilitation area design;
  - Landform re-shaping; and
- 2nd Stage – Detailed works to establish revegetation of shaped and disturbed areas, including area features such as water management and habitat structures, comprising:
  - Landform trim;
  - Detailed feature design and construction;
  - Installation of water management structures (contour banks, spine drains/rock chutes)
  - Growth medium application and amelioration;
  - Fertilising, seeding and mulching; and
  - Final rehabilitation survey.

Further details are provided in the Revegetation Plan in Section 3.6.8.

3.1.4.5 Rehabilitation monitoring program and performance

A rehabilitation monitoring program has been developed by DS. The monitoring process involves four key steps, as provided below:

- Pre- field monitoring works;
- Field monitoring;
- Data analysis; and
- Results and remedial actions.

Further detail is provided in Section 3.8.

3.2 Community consultation

The PRCP has been informed by the consultation undertaken with our stakeholders on mine closure and rehabilitation.

Anglo American has been undertaking community consultation with its stakeholders since acquiring the Dawson Mine (formally known as the Moura Mine) in 2002. Community consultation is integrated into the Social Performance Management System and guided by the Anglo American Social Way 3.0 Policy, Toolkit, and Assurance Framework (AASW)[1] and other relevant Anglo American Standards such as the Mine Closure Standard and Toolbox[2].

The AASW is aligned with internal standards, including:

- International Finance Corporation's Environmental and Social Performance Standards
- UN Guiding Principles on Business and Human Rights
- Voluntary Principles on Security and Human Rights
- International Council on Mining and Metal's Position Statement and Good Practice Guide on Indigenous Peoples and Mining
- Initiative for Responsible Mining Assurance
- OECD Guidelines for Multinational Enterprises.

As part of the meeting the requirements of Social Way 3.0 the Dawson Mine has integrated mine closure into the site Social Management Plan (SMP)[3] and Stakeholder Engagement Plan (SEP). The purpose of the Stakeholder Engagement Plan is to improve dialogue, enhance partnerships and promote wider engagement at the local and regional level, while continuing to responsibly meet the needs of the business. The SEP identifies the Dawson Mine's:

- Approach to stakeholder engagement;
- Implementation tools and action plan;
- Monitoring and evaluation (including recording and tracking stakeholder engagements); and
- Reporting.

Under Social Way, the Dawson Mine is required to maintain a Commitment Procedure and Register[4].-

It is within this context that the Community Consultation Plan and Register for DS (refer to (Appendix 4.3) has been developed. It includes:

- Engagements for the 2012 Preliminary Mine Completion Plan

[1] https://socialway.angloamerican.com/en/about updated from the system formally known as SEAT and SEAT2

[2] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/sustainability/mine-closure-toolbox-version-3-2019.pdf updated from the 2007 version

[3] https://socialway.angloamerican.com/en/toolkit/review-and-planning/review-and-planning/introduction/about-social-performance

[4] https://socialway.angloamerican.com/en/toolkit/review-and-planning/review-and-planning/guidance/do/task-7-update-the-social-management-plan

- Engagements that informed the current PCRP and Register
- Community Consultation Plan to guide future engagements.

Table 3-15 sets out the Community Consultation Register for engagements undertaken since the 2012 Dawson Mine Preliminary Completion Plan.

Table 3-15 Community Consultation Register

Stakeholder	Year/ Frequency	Method	What did the site present/what was discussed	Issues/ concerns or opportunities raised	How issues have been considered and the decisions and outcomes of engagement	Commitments made by Anglo American or existing commitment[5]
Moura, Banana and Theodore	2020, 2021 and 2022	Community Impact/ Perception Survey	Preferred options for post mining land use and considerations for planning post mining land use	Preference for grazing and agricultural land use. Need to undertake ongoing rehabilitation and social impacts of mine closure	Rehabilitation, final land form and final land use Concerns (e.g. sustainability of Moura post mining) considered in Dawson Mine Social Management Plan	n/a
Gangulu	2020 and 2021	Coordination Committee Meeting	Mine rehabilitation	The need for ongoing rehabilitation	Rehabilitation	Gangulu to be continued to be involved in the mine closure process
Neighbours	2018, 2019, 2021, 2022 and 2023	Neighbours Dinner	Mine closure and rehabilitation	The need for ongoing rehabilitation	Rehabilitation, final land form and final land use	As per agreements with neighbours
DCRF	2022	Meeting	Mine closure, final land use and rehabilitation	Need to undertake ongoing rehabilitation and social impacts of mine closure	Rehabilitation, final land form and final land use Concerns (e.g. sustainability of Moura post mining) considered in Dawson Mine Social Management Plan	To maintain the DCRF meetings

The CCP aligns with the existing Dawson SEP, however, has a specific focus on the implement of the engaging and collaborating with stakeholders in relation to the Dawson Mine's Progressive Rehabilitation and Closure Plan (PRCP).

[5] From the Dawson Mine Commitments Register

The objectives of this CCP for the Dawson Mine are to continue to:

- Identify, notify, and engage the community in relation to the rehabilitation and closure of Dawson Mine;
- Provide mechanisms to allow ongoing community consultation throughout the remaining stages of the Dawson Mine to communicate progressive rehabilitation, socio-economic and environmental impacts related to mine closure;
- Collaborate with the community to identify rehabilitation and closure opportunities and constraints that could influence effectiveness of final land outcomes; and
- Continue to provide an appropriate platform for comments and feedback.

The community will continue to be proactively engaged through existing systems and processes established under the Dawson Mine Stakeholder Engagement Plan:

- One on one meetings
- Gangulu CHIMA Coordination Committee Meetings
- Meetings with Wullli Wulli
- Quarterly DCRF meetings
- Annual Neighbours Dinners
- Issue/topic focus groups/workshops or one on one meetings as required/requested.

Anglo American will continue to maintain established other systems and processes where the stakeholders, including traditional owners, neighbours and other community members can raise, issues, concerns, grievances or opportunities with Dawson Mine:

- Walk into the Anglo American town office based in Moura
- Call/e-mail the Moura town office; and
- Grievance procedure.

Table 3-16 sets out the PRCP Community Consultation Action Plan within the context of the Anglo American Mine Closure Standard. The PRCP Community Consultation Action Plan will be delivered in the broader context of the Dawson Mine Social Management Plan, of which the Stakeholder Engagement Plan is a main component.

Table 3-16 Community Consultation Action Plan

Stakeholder Group	Purpose of Engagement (IAP² Spectrum) [6]	Engagement Method	Engagement Frequency	Information released for community consultation	How feedback/ comments will be considered
Draft Closure Plan (15 -10 years from closure)					
Gangulu	Provide updates on rehabilitation and mine closure (consult)	Meeting	As part of CHIMA scheduling	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Wulli Wulli	Provide updates on rehabilitation and mine closure (consult)	Meeting	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Neighbours	Provide updates on rehabilitation and mine closure (consult)	One on one meetings and annual Neighbours Dinner	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Banana Shire Council	Provide updates on rehabilitation and mine closure (consult)	Meeting	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Moura, Banana and Theodore	Respond to any questions or concerns (inform)	One on one meetings	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Detailed Closure Plan (10 -5 years from closure)					
Gangulu	Management of cultural heritage as part of rehabilitation and closure (collaborate)	Meetings and site visits	As required	Information as relevant to the management of cultural heritage	Development and implementation of management plan/s
Wullli Wulli	Management of cultural heritage as part of rehabilitation and closure (collaborate)	Meetings and site visits	As required	Information as relevant to the management of cultural heritage	Development and implementation of management plan/s
Neighbours	Management of impacts on neighbours (involve)	Meetings and site visits Neighbours dinner	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s
Banana Shire Council	Management of impacts on infrastructure and services provided in and between Moura, Theodore and Banana (involve)	Meetings	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s

[6] IAP² International Association for Public Participation Engagement Spectrum

Stakeholder Group	Purpose of Engagement (IAP[2] Spectrum) [6]	Engagement Method	Engagement Frequency	Information released for community consultation	How feedback/ comments will be considered
Moura, Theodore and Banana	Management of social and economic impacts (involve)	Meetings/focus groups/workshops	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s
State Government	Management of impacts on infrastructure and services provided in and between Moura, Theodore and Banana (involve)	Meetings	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s

3.3 Post-mining land use

3.3.1 Regulatory context

A PMLU is defined under section 112 of the *EP Act* as "the purpose for which the land will be used after all relevant activities for the PRCP carried out on the land have ended". Determining the appropriate PMLUs is a critical first step in mine rehabilitation planning. It supports and informs the remainder of the proposed PRCP, including rehabilitation and management strategies, and the PRCP schedule.

Mining is a temporary land use, and therefore it is important to consider a future land use that aligns with social, economic, environmental expectations for the site, as per Section 126C(1)(d) of the *EP Act*. Criteria for all PMLUs to be adopted for DS will align to the requirements of the *EP Act* as described. The *EP Act* and Regulation contain several additional Sections that need to be complied with, as further described below.

3.3.1.1 Section 111A of Environmental Protection (EP) Act

For a proposed PMLU to be accepted, the PRCP must demonstrate that the land can be rehabilitated to a stable condition in accordance with the following definition from Section 111A of the EP Act:

Land is in a stable condition if -

a) The land is safe and structurally stable, and

b) There is no environmental harm being caused by anything on or in the land, and

c) The land can sustain a PMLU.

This PRCP provides the pathway through which the above conditions can be achieved for the nominated PMLUs.

3.3.1.2 EP Regulation

The EP Regulation requires that each PMLU -

a) Is viable, having regard to the use of land in the surrounding region, and

b) Satisfies at least one of the following-

i) The use is consistent with how the land was used before a mining activity was carried out on the land;

ii) The use is consistent with a development approval relating to the land;

iii) The use is consistent with a use of the land, other than a use that is mining, permitted under a State or Commonwealth Act, including, for example, a planning instrument under the Planning Act; and/or

iv) The use will deliver, or is aimed at delivering, a beneficial environmental outcome.

3.3.2 Transitional PRC Plan context

PMLUs which have been previously addressed or referred to in LODs can potentially be transitioned into the PRCP. The LODs of particular relevance to PMLU include the:

- EA (EPML00657413 – 3 December 2025);
- Plan of Operations (1 October 2018 – 31 December 2020) (Anglo American 2018); and
- EIS (EH&S Systems Pty Ltd 2006).

The EA amendment refers to two PMLU relevant 'Rehabilitation Objectives' in Table E1 of the EA (Table 3-17), including:

- Bushland; and
- Grazing.

There are no maps associated with the PMLU Rehabilitation Objectives in the EA, but the Plan of Operation's interpretation of EA Rehabilitation Objectives is that these are PMLUs, and notes that much of the mine is being rehabilitated for grazing land use. A trial to test this land use is described in the DS Plan of Operations (and summarized in Section 3.7.3). The resulting information attained through this trial would then be used to develop further rehabilitation targets and outcomes for DS.

Infrastructure that could be adapted to grazing could remain post-mining, and mine-affected water, including some water stored in voids, may be suitable as stock water (at least initially), as demonstrated by beneficial re-use agreements for water and communications infrastructure that are already in place with neighbouring graziers. According to the Plan of Operations, water infrastructure for this purpose would be designated as "grazing" PMLU, while the bushland PMLUs typified by the Rehabilitation Objectives in the EA would be more suitable on steeper areas unsuitable for grazing pasture (Anglo American, 2018).

Notwithstanding the intention to maximise the re-use of the voids, two voids will remain in DS as Non-Use Management Areas (NUMAs). Rehabilitation objectives associated with NUMAs, as detailed in Table E1 of the EA (Table 3-17):

- Safe for humans and livestock; and
- Voids are groundwater sinks and do not overlap.

Undisturbed areas of the MLs will continue to be used for grazing pasture or cropping by third parties. Post-mining, it is proposed that these areas will remain under these land uses.

Table 3-17 EA EMPL00657413 (3 December 2025) DS – Rehabilitation Requirements

Mine Domain	Mine Feature Name	Rehabilitation Goal	Rehabilitation objectives	Indicators	Completion Criteria
All Domains, with the exception of the Final Void	All	Safe, stable, self-sustaining and non-polluting	Bushland	Native plant species richness (total no. in RE)	15
				Non-eucalypt trees (stems per ha)	200
				Tree canopy cover (%)	30
				Native shrub cover (%)	20
				Native perennial grass cover (%)	20
				Organic litter cover (%)	60
			Grazing	Grass cover (%)	40-60
				Biomass (kg/ha)	1000
Final Void Non-use management area (NUMA)	Residual Void	Safe and stable	Safe for humans and livestock	Geotechnically and erosionally stable	a) Maximum NUMA extent of Pit 25 of no greater than 76.7ha projected surface area; and b) maximum NUMA extent of Pit 28 of no greater than 91.7ha projected surface area; and c) exposed coal seam is capped; d) fencing; and e) warning signage posted at 50m intervals above the final voids; f) landform design in accordance with Table E2 of EA EPML00657413; and g) erosionally and geotechnically stable.
		Non-polluting	Voids are groundwater sinks and do not overlap	Void modelling and monitoring	a) The voids will not cause environmental harm outside of the relevant tenure boundary; b) The void water quality and quantity in the voids will not cause harm to the surrounding environment; and c) Water levels within the residual voids are not predicted to reach ≥121mRL
		Self-sustaining	Not applicable	Not Applicable	Not Applicable

3.3.3 Land use context

Previous clearing has resulted in a landscape surrounding the mine that is almost completely cleared of native vegetation, except for very small and scattered stands of Brigalow, narrow fringes of riparian vegetation along the main creeks and the Dawson River, and stands of Eucalypt, Brigalow and SEVT on the Malakoff Range on the eastern fringes of Pit 26 - 28.

Cleared land within the area surrounding DS is largely used for cattle grazing, both on unimproved and improved pastures. Areas towards the Dawson River contain cropping, including some irrigated cropping. The Willawa Nature Refuge occurs on either side of Pit 26/27. This Refuge consists of two parts, including a smaller area east of Pit 26/27, and a larger area adjacent to the Dawson River, along the western boundary of the ML. Most of the Willawa Nature Refuge consists of regenerating native vegetation, except for a narrow fringe of riparian vegetation along the Dawson River and the small stand of remnant Eucalypt and SEVT east of Pit 26/27.

The PMLUs developed for this PRCP aim to emulate general characteristics consistent with this wider landscape, within the constraints posed by historical and current mining related activities and consequent changes in land suitability resulting from changed physical, chemical and biological properties of soil, changes in slope and slope length, and changes in soil depth.

Rehabilitation and revegetation has also been designed to provide wildlife habitat through the establishment of native trees and shrubs of species, similar to the unmined areas within the general locale of DS. Similarly, hills and slopes on the waste rock dumps and low walls sloping into voids, will provide additional microclimates and heterogeneous microhabitat areas. The establishment of wildlife habitat will connect to remnant or regenerating native habitat east of the mine.

3.3.4 Community consultation

As outlined in Section 3.2, proposed PMLUs for DS have been presented to the local community and stakeholders, and feedback on final land use requested in annual perception surveys. More specific details on mine closure and the proposed PMLUs have also been presented to the DCRF members during community reference forum presentations. Details and justifications for proposed PMLUs, further updates to PMLU areas as the mine plan is refined, and outcomes of ongoing rehabilitation and trials feeding back into the final the rehabilitation plan, will continue be communicated through to relevant stakeholders as outlined in the CCPR (Appendix 4.3).

Specific details on PMLUs for EPML00657413 were included in an Anglo American slideshow briefing stakeholders on mine closure planning for DS.

Consultation with government departments has enabled PMLUs to be refined in this PRCP, taking existing legislated requirements associated with salinity concentrations in the voids, and the definitions of native or rehabilitated vegetation into consideration.

Feedback from forums and local community meetings continues to confirm that Anglo American's commitment to a mine completion plan is a priority for them, and that progressive rehabilitation of the mine site is preferred. Community concerns associated with mine closure related more to social impacts, with a focus on sustainable employment in communities, and minimising the impact on communities post closure. Stakeholders also wondered how ownership of the land post-closure will transition from Anglo American ownership post-closure.

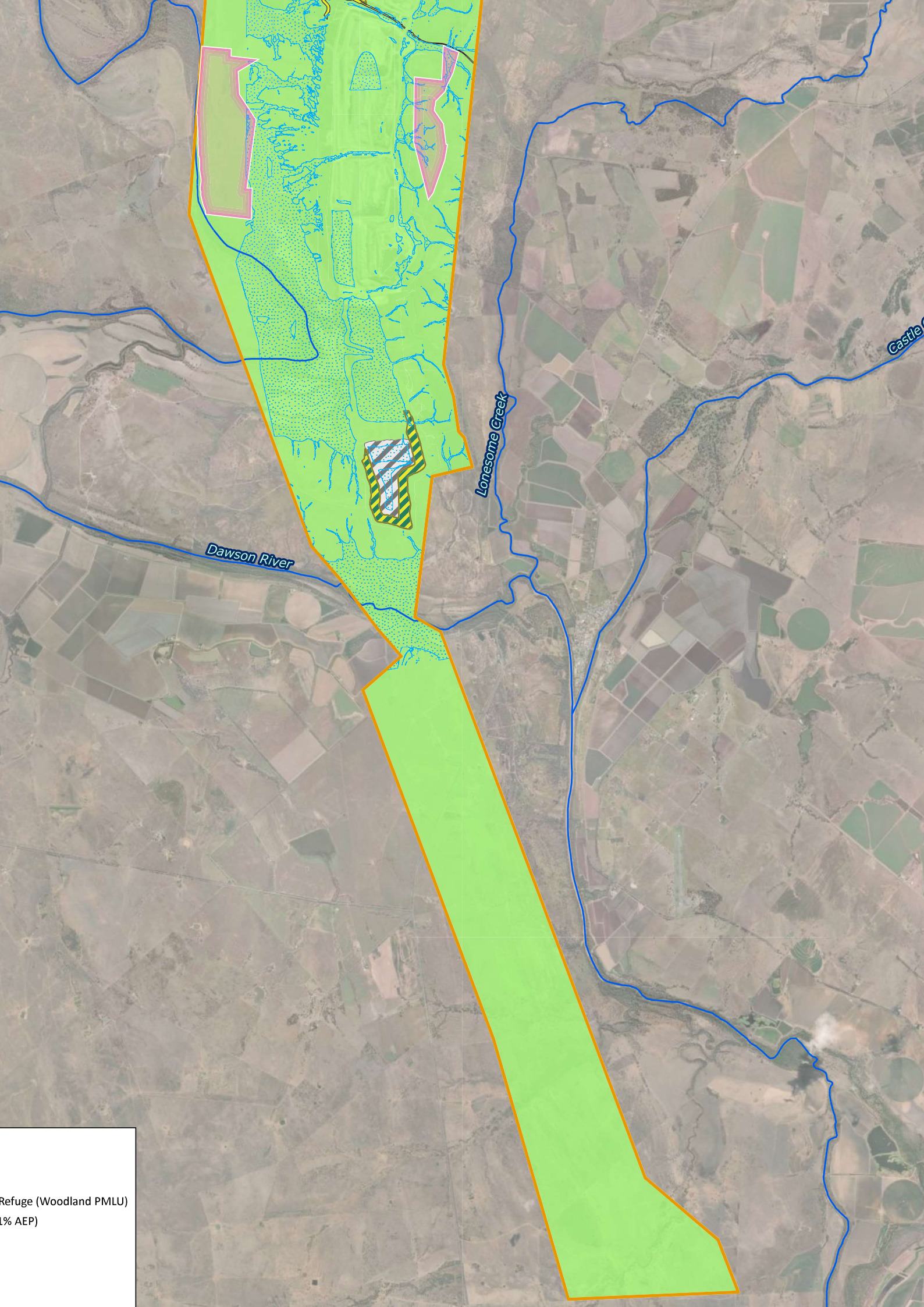
3.3.5 Description of each nominated PMLU

The two PMLUs implied by the rehabilitation Objectives of the EA (ie Bushland and Grazing) are described in detail in this Section.

DS has continued to trial new methods of rehabilitation throughout its operating life. These trials are often informed by ACARP research projects and may be used in future PMLUs if appropriate uses are identified during the trials. DS notes that the rehabilitation trials themselves are not considered milestones, and they are not used to populate the rehabilitation schedule.

A third PMLU, permanent infrastructure, has been added to capture Theodore-Moura road which passes through the MLs.

Figure 3-15 shows a map of the PMLUs for DS.


Lonesome Creek
Dawson River
Refuge (Woodland PMLU)
1% AEP)

3.3.5.1 Grazing

The Rehabilitation Objectives in the EA termed “Grazing” is consistent with the dominant land use of the surrounding region. While there are small occurrences of cropping land on the DS MLs, this land is not significantly implicated in any DS rehabilitation or closure process, and is therefore not further referred to in this PRCP.

The Grazing PMLU aims to contain a diversity of self-sustaining grasses and native vegetation targeted for areas with favourable grazing attributes and a potential for the land to become adequately productive. This reflects condition of existing rehabilitation, which typically contains grass as well as shrubs and trees. Therefore, the Grazing PMLU is regarded as a proven concept at Dawson. When targeting vegetation communities for this PMLU, consideration is given to the regulatory constraints of the approvals, the surrounding land uses, and the quantity and quality of growth medium resources.

Haul roads are part of this PMLU, to be used as fire breaks and for stock mustering. Ancillary infrastructure expected to remain, such as stock fencing, safety fencing, roads and any power infrastructure consistent with this PMLU will only be retained with a formal agreement with landholders, and where it does not have a material impact on the PMLU. Ongoing management of fencing, access roads and weed populations is likely to be required.

Where grazing is not feasible, such as on steeper slopes adjacent to NUMAs, the Bushland PMLU will be applied. While the objective of these areas is to emulate native ecosystems, they are established on reconstructed landforms or highly disturbed ground, and cannot be expected to achieve the floristic assemblages and diversity that existed prior to disturbance due to changes in aspect, slope, growth media, moisture retention capacity. Restoration of a specific regional ecosystem, such as can be encountered at the analogue sites, is therefore not a realistic outcome.

The preferred objective is to achieve a diverse species mix comprising native vegetation species which are predisposed to establishment and survival on highly modified landforms. This PMLU is also intended to support transit of fauna across of the landscape, as a wildlife corridor, and also connect remnant habitat adjoining DS. However, although the DS PMLUs will likely go some way to restoring wildlife corridors, and providing refugia in the wider landscape, the site is largely surrounded by cleared agricultural land with limited connectivity to other areas of remnant bushland.

Except on steep slopes, stock grazing may be used as a management tool of weeds and ground fuel loads.

3.3.5.1.1 Managed Resource Protection

The Managed Resource Protection area will be retained as Bushland, however this does not exclude grazing activities in accordance with the Willawa Nature Refuge Agreement conditions. There are rehabilitation and management requirements included in the Willawa Nature Refuge Agreement (State of Queensland, 2005).

3.3.6 PMLU Suitability

A summary review of the proposed PMLU suitability across a broad range of considerations as per section 126C(1) of the EP Act is provided in Table 3-19. Milestones associated with the PMLUs are listed in Table 3-19.

Table 3-18 PMLU Suitability

	Grazing	Bushland
Regulatory/ statutory constraints (contaminated land, local/regional LUP, conservation and/or heritage values, ILUAs)	POSITIVE No regulatory constraints	POSITIVE No regulatory constraints
Physical constraints (slopes, voids, geology)	POSITIVE No physical constraints	POSITIVE No physical constraints
Chemical constraints (i.e., mineral waste, other waste disposal)	POSITIVE No chemical constraints	POSITIVE No chemical constraints
Compatibility with best practice (i.e. backfill, re-profiling, capping)	POSITIVE Compatible with best practice	POSITIVE Compatible with best practice
Compatibility with surrounding land use	POSITIVE Compatible with surrounding land use	POSITIVE Compatible with surrounding land use
Economic benefits (tourism, public use, productive land use – i.e., grazing)	POSITIVE Provides economic benefit	NEUTRAL Partially provides economic benefit
Environmental benefits (retained clean water, create wildlife corridors, revegetation)	POSITIVE Provides environmental benefits	POSITIVE Provides environmental benefits
Social benefits (recreational use, amenity, employment)	POSITIVE Provides social benefits	POSITIVE Provides social benefits
Relative cost	POSITIVE Cost effective	POSITIVE Cost effective
Potential to retain or transition infrastructure	NEUTRAL Select infrastructure can be retained/transitioned	NEUTRAL Select infrastructure can be retained/transitioned

Table 3-19 PMLUs and their Milestones

PMLU	Rehabilitation Area (RA)	Milestones	Progressively rehabilitated
Grazing	RA 1 – Infrastructure (cleared areas, access tracks, topsoil stockpile, exploration pads, laydown yards, pipelines, powerlines	RM1 - Infrastructure decommissioning and removal RM2 - Identification, remediation and removal of contaminated landRM3- Landform development, reshaping and reprofiling RM4- Surface preparation RM5- Revegetation RM6- Achievement of surface requirements RM7- Achievement of PMLU to a stable landform RM8 - Achievement of post-mining land use water quality	No, rehabilitation completed upon closure once infrastructure no longer required
	RA 2 - Overburden Dumps (ramps, haul roads, spoil DRE, spoil TS, back filled mining pits)	RM1 - Infrastructure decommissioning and removal RM2 - Identification, remediation and removal of contaminated land RM3- Landform development, reshaping and reprofiling RM4- Surface preparation RM5- Revegetation RM6- Achievement of surface requirements RM7- Achievement of PMLU to a stable landform RM8 - Achievement of post-mining land use water quality	Yes- where possible
	RA 4 - Existing Rehabilitation	RM6- Achievement of surface requirements RM7- Achievement of PMLU to a stable landform RM8 - Achievement of post-mining land use water quality	Yes
	RA 6 - Ancillary and Exploration activities	RM1 - Infrastructure decommissioning and removal RM6- Achievement of surface requirements RM7- Achievement of PMLU to a stable landform RM8 - Achievement of post-mining land use water quality	No
Bushland	RA 3 – Overburden Dumps (ramps, haul roads, spoil DRE, spoil TS, back filled mining pits)	RM1 - Infrastructure decommissioning and removal RM2 - Identification, remediation and removal of contaminated land RM3- Landform development, reshaping and reprofiling RM4- Surface preparation RM5- Revegetation RM6- Achievement of surface requirements RM7- Achievement of PMLU to a stable landform RM8 - Achievement of post-mining land use water quality	Yes- where possible
Permenent Infrastructure	RA 5 – Permenent Infrastructure	RM8 - Achievement of post-mining land use water quality	No

3.3.7 Alignment with relevant strategies and plans

All of DS is located within the Banana Shire Council Local Government Area, which forms part of the Central Queensland Region. Both these areas are subject to strategies and plans as described below.

3.3.7.1 Central Queensland Regional Plan

The Central Queensland Regional Plan (Department of State Development, Infrastructure and Planning, 2013) is a statutory regional plan, providing strategic direction and policies to deliver outcomes for the Central Queensland regions which align with the state's interests in planning and development. The key drivers for preparing the plan are the Queensland Government's intention to:

- Enable opportunities for economic growth to ensure our regions are resilient and prosperous
- Protect areas of regionally significant agricultural production from incompatible resource activities while maximising opportunities for co-existence of resource and agricultural land uses
- Safeguard the areas required for the growth of towns
- Drive the region's economic diversity and opportunity
- Identify infrastructure outcomes that will support economic growth
- Facilitate tourism pursuits across the region
- Avoid the introduction of additional, unnecessary regulation
- Recognise and respect the role of local government to plan for their local area.

This PRC Plan is in line with the environmental aims of the Central Queensland Regional Plan. The PRC Plan also aims to enable continued economic growth. It does so by facilitating a productive PMLU for DS with opportunities for both farming and tourism through rehabilitation with both grazing and bushland outcomes.

3.3.7.2 Banana Shire Planning Scheme

The Banana Shire Planning Scheme has been prepared in accordance with the *Planning Act 2016* (Qld), and came into effect on 23 June 2021. The planning scheme applies over the entire Banana Shire Council area, and sets out the intent for development for a twenty year horizon. The strategic intent of the planning scheme that it will deliver (abridged from the planning scheme):

- A fair, orderly and sustainable pattern of development – The settlement pattern of the Shire facilitates greater self-sufficiency by reinforcing the roles and functions of Biloela, Moura, Taroom and Theodore which will experience the majority of growth activity, reflecting the increased investment in infrastructure and services. The smaller towns retain local character and will continue to service local needs with growth limited by the availability of infrastructure and vulnerability to natural hazards. Development creates attractive, affordable, healthy and safe places to live, work, visit and play that integrate with the sequenced provision of infrastructure.
- Preservation of the economic and environmental values of rural areas – The rural character of agricultural land, mining resources and natural areas is protected and maintained for their production, landscape and environmental values.
- A strong sense of community identity – The individuality and diversity of the communities of the Shire is retained by preserving place character and the unique culture and heritage.

- Protection of natural environment and hazard mitigation – Natural areas and features of significance including National Parks, conservation parks, water resources, wetlands, springs, rivers and other major watercourses and their catchments are managed and protected to conserve their ecological values and biodiversity.

- A viable, complex and diverse economy – The Shire continues to be a shire of opportunity, with a complex and diverse economy. Existing major industries such as the Teys Abattoir, Callide Power Station, Moura Queensland Nitrate Plant and Moura Cotton Gin continue to contribute to the local and regional economy. The traditional sectors of construction, mining, agriculture, tourism, manufacturing, retail, energy production, transport and logistics, government and education continue to grow and support local employment. Opportunities for new industries are driven by the Shire's strategic location, planned and established infrastructure, existing and potential supply chains and the availability of a skilled labour force.

- Suitable standards of infrastructure – The Shire's infrastructure and services meet the needs of individual communities and industry, protect public health, support economic development and improve accessibility.

This PRC Plan is aligned with these intents, by rehabilitating the environment and maximising the potential for use of the land for rural pursuits and ecosystem support, while providing a safe, stable, and non-polluting environment, and retaining infrastructure that has future use for the community and for the economic use of the land.

3.4 Non-use management areas

3.4.1 Site context

DS will contain two NUMAs, Pit 25 and Pit 28. Both of these NUMAs have been transitioned into the PRCP schedule and critical properties summarised below in Table 3-20.

Due to the nature of the mining method employed, a bulk material deficiency across the landforms, and collected water in voids becoming hypersaline over time (Table 3-20), final residual voids were considered unable to support a productive PMLU, resulting in the allocation of a post-mine Land Suitability Class 5 (not suitable for grazing). Investigations into potential aquaculture in the final void waters was found to be limited by the modelled long-term water quality of the void lake waters (ERM, 2024).

Closure planning has aimed to minimise NUMA areas through partial infilling the pits at the low walls. The defined NUMA extents are limited to a 'buffer' zone 14 metres above the maximum predicted water level on the regraded low walls and high walls. Where slopes allow, these void walls will have PMLUs of Grazing. As a result, the NUMAs represents a portion of the total void area (Table 3-20),

Table 3-20 Summary of NUMAs in the DS final landform

NUMA	Location	Approx size (ha)*	Predicted water quality (TDS after 100 years) (mg/L)	Maximum predicted water level (mAHD)	Approximate void crest level (mAHD)
Pit 25	Dawson South	76.7	32,000	81	140
Pit 28	Dawson South	91.7	12,000	83	140

3.4.2 Description of NUMA at surrender

The NUMA is a subset of the final void and includes the pit lake, and part of the walls at the predicted maximum pit lake level plus a buffer. The walls will be reshaped to a slope that is safe and stable, growth medium applied, and seeded with a grass and tree mix.

A pit lake will develop within the void, with a water quality that is expected to become more saline over time. Various landform design scenarios were considered to assess how they may affect the future water level and quality. The selected design minimises the interaction between pit water and the environment, including aquifers, by minimising the catchment inflows and lowering the pit lake water surface elevation by:

- Contouring of the final landform to maximise external drainage to the surface water system;
- Providing at least 0.1% Annual Exceedance Probability (AEP) flood immunity of the final residual void from a major Dawson River flood event by locating the void outside of the floodplain.

Conceptual cross sections of each of the NUMAs are provided in Figure 3-16 and Figure 3-17.

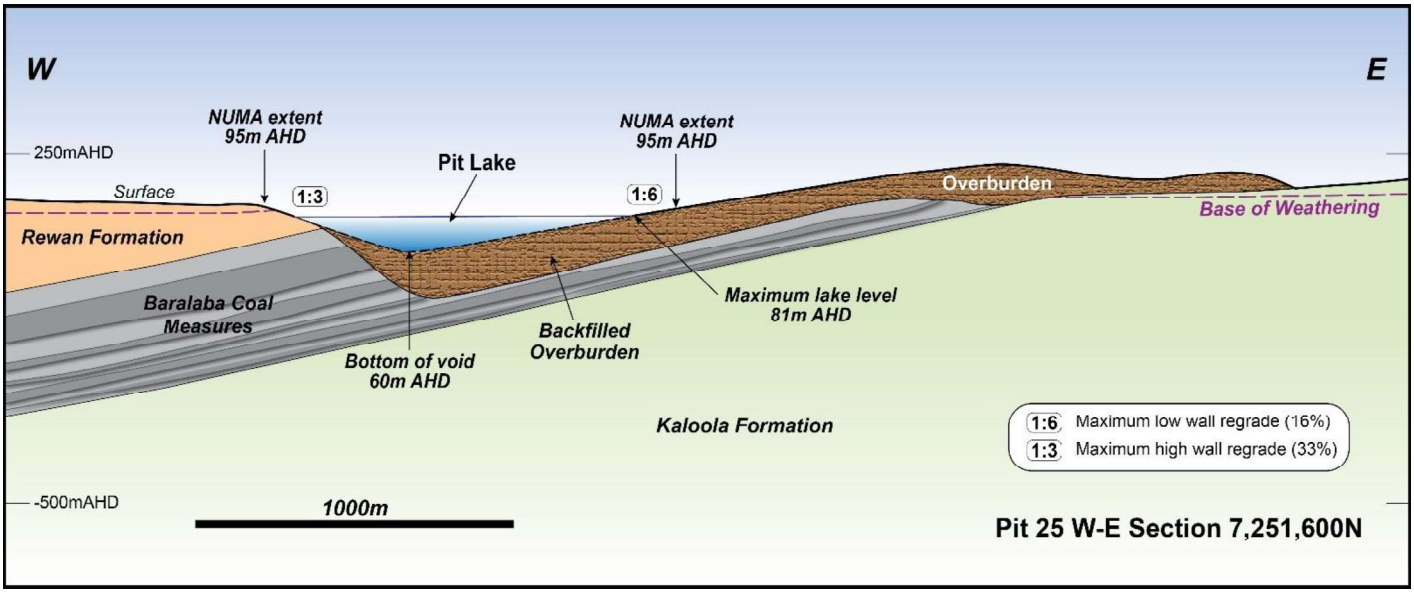


Figure 3-16 NUMA conceptual cross section A- A'- Pit 25

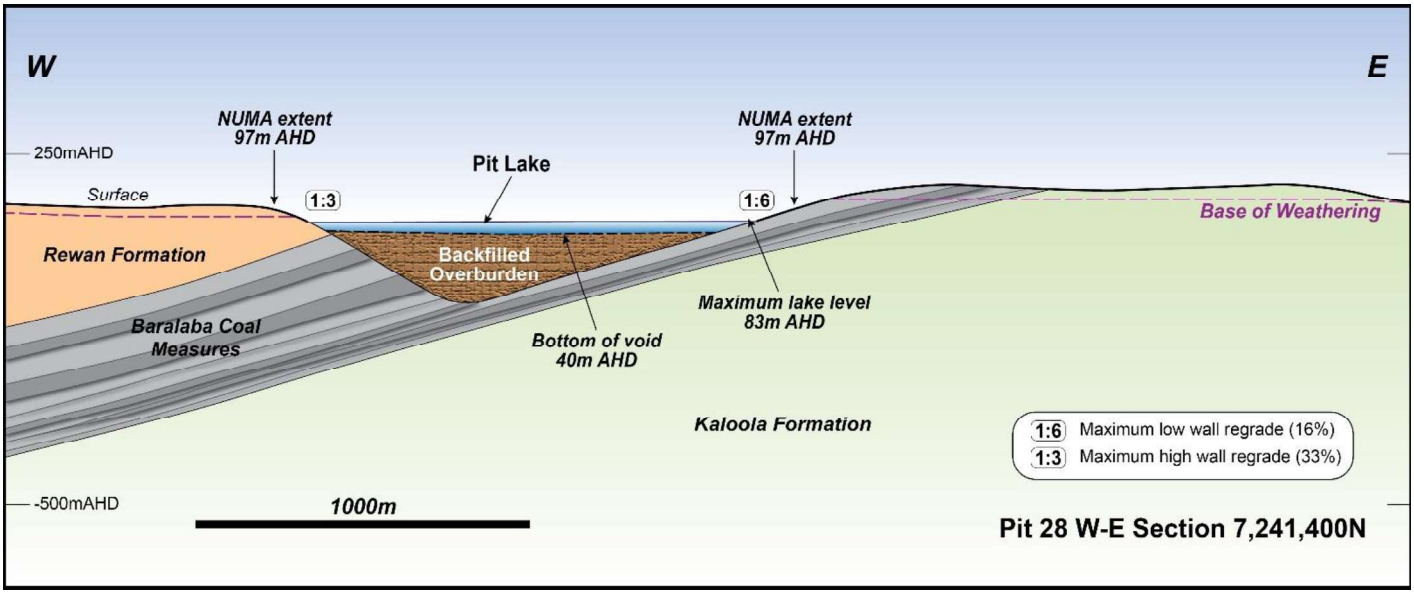
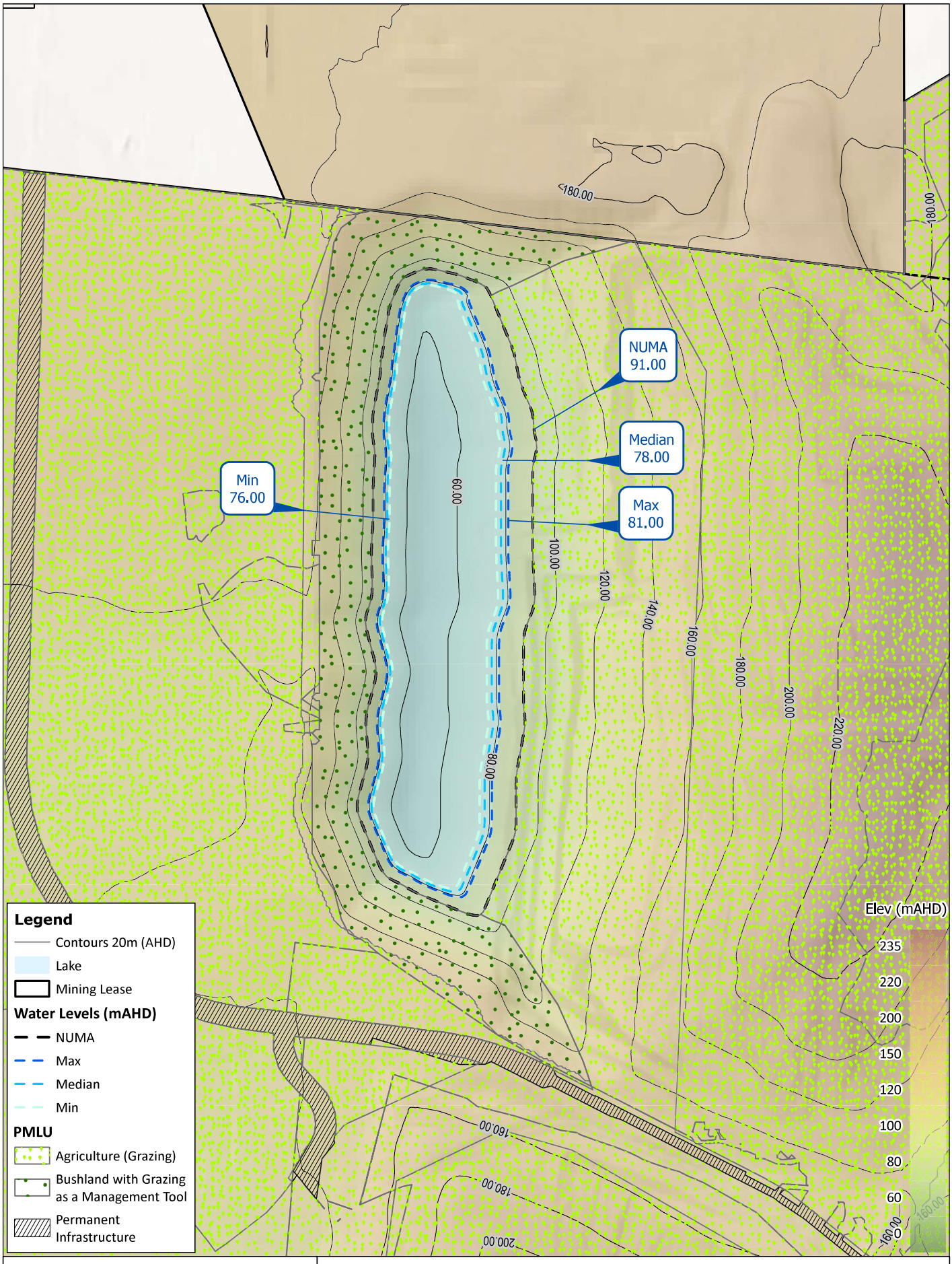


Figure 3-17 NUMA conceptual cross section B- B'- Pit 28

Both Pit 25 and Pit 28 will be backfilled with large volumes of overburden (Figure 3-16 and Figure 3-17). This minimises the water column depth in both voids. Optimal resource extraction and progressive rehabilitation and backfilling at Pit 28 results in a deeper void in the southern section than the northern section.

3.4.2.1 Footprint

The footprints for each of the NUMAs listed in Table 3-20 are provided in Figure 3-18 and Figure 3-19. The size of the NUMAs has been minimised as much as possible by reshaping the low wall and stabilising it in a way that can support a PMLU over a large portion of the void.



Coordinate System:
AGD 1966 AMG Zone 56

Date: 20/04/2026
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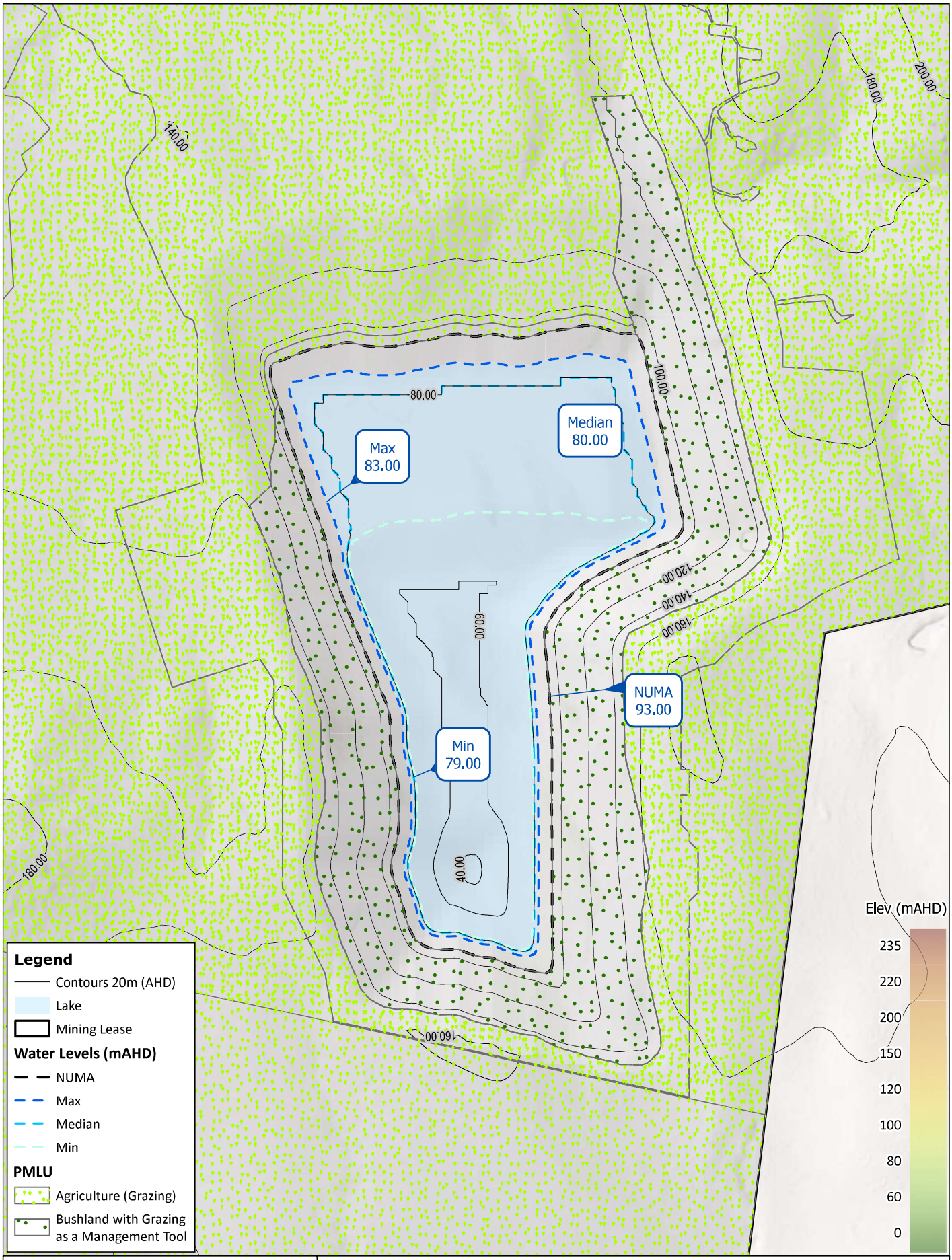
0 0.25 0.5km

Figure 3-18 Final Landform Water Levels - Pit 25

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican



Coordinate System:
AGD 1966 AMG Zone 56

Date: 20/04/2026
Created By: DC
Drawing Size: A4

0 0.25 0.5km

Figure 3-19 Final Landform Water Levels - Pit 28

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

3.4.2.2 Location of void in relation to floodplain

The location of the final void NUMAs are constrained, due to the mining activities associated with the extraction of the coal resource. The location of the NUMAs will be outside the Dawson River floodplain and isolated from surface water catchment areas, with permanent flood immunity of 0.1%AEP.

Further discussion of this flooding assessment in included in Appendix 4.4.

3.4.2.3 Safety features

The following features will be present in relation to the proposed NUMA:

- Signage – Warning signage at 50 m intervals around the final void rim will be placed to warn of the void related risks and deter public access to the water body.
- Fencing– a fence will be installed at the NUMA to prevent water access.

3.4.3 Community Consultation

As previously discussed in Section 3.3.4, consultation has occurred with relevant stakeholders. The EIS highlighted that there would be areas not suitable for grazing. Consultation with government departments has enabled PMLUs to be refined for this PRCP, and the identification of the NUMA taking existing requirements associated with salinity levels in voids into consideration.

3.4.4 Alignment with Relevant Strategy and Plans

DS NUMAs are located within the Central Queensland Banana Shire Council area. The retention of the voids as NUMAs is neither inconsistent with the Banana Shire Planning Scheme 2021 planning scheme nor the Central Queensland Regional Plan (both described in Section 3.3.7) and should be viewed as a subset of the site which will be rehabilitated. Sufficient improvements to the land will be carried out on the NUMAs prior to relinquishment.

3.4.5 Milestones for NUMA

Milestones for the NUMAs are outlined in Table 3-21.

Table 3-21 Milestones for NUMAs

PMLU	Improvement Area (IA)	Milestone
NUMA (Non-Use Management Area)	IA1 – Void NUMAs	MM1 – Achievement of final landform design MM2 – Achievement of safetyrequirements MM3 – Achievement of sufficient improvement

3.5 Voids in flood plains

A whole-of-site two-dimensional flooding study has been undertaken for the Dawson Complex (inclusive of DCN and DS) as part of this PRCP (Appendix 4.4). The model extents include:

- Hydrologic: Catchment watershed for Kianga, Lonesome, Borehole and Dawson catchments to the downstream (western) side of the Dawson Mine Complex.
- Hydraulic: Dawson Mining Complex (approximately 5km wide and 58 km long).

Critical aspects addressed by the flood assessment include:

- Ensuring voids have at least 0.1% AEP flood immunity from mainstream flooding.
- Ensuring diversions remain stable under a range of flow conditions.

The hydraulic modelling software used for the assessment was TUFLOW Single Precision 2023-03-AC (latest release at time of modelling) heavily parallelised compute solution scheme. Climate change has been considered using a climate scenario of SSP3-7.0 (2.7-5.0), with factors to extreme rainfall depth, initial and continuing losses applied as per the draft update to the Climate Change Considerations chapter in Australian Rainfall and Runoff" A guide to flood estimation (DCCEEW, 2023).

3.5.1.1 Location of flood interaction areas

Flood interactions with the final landform are common for most parts of DS project area and are particularly relevant to areas where voids or permanent water management structures will be retained in the vicinity of the Dawson River. Flood modelling has been conducted to ensure all both voids are isolated from flood waters.

A Probable Maximum Preciptation (PMP) event, simulating a 1:10,000 AEP, shows the Dawson River does flood into Pit 28 during a rainfall event this size. This is presented in Figure 3-20. The cross section at the top of the figure demonstrates flood immunity in a 1:1,000 event, however the 1:10,000 event shows a water depth elevation of up to 64 metres (the void fills with water).

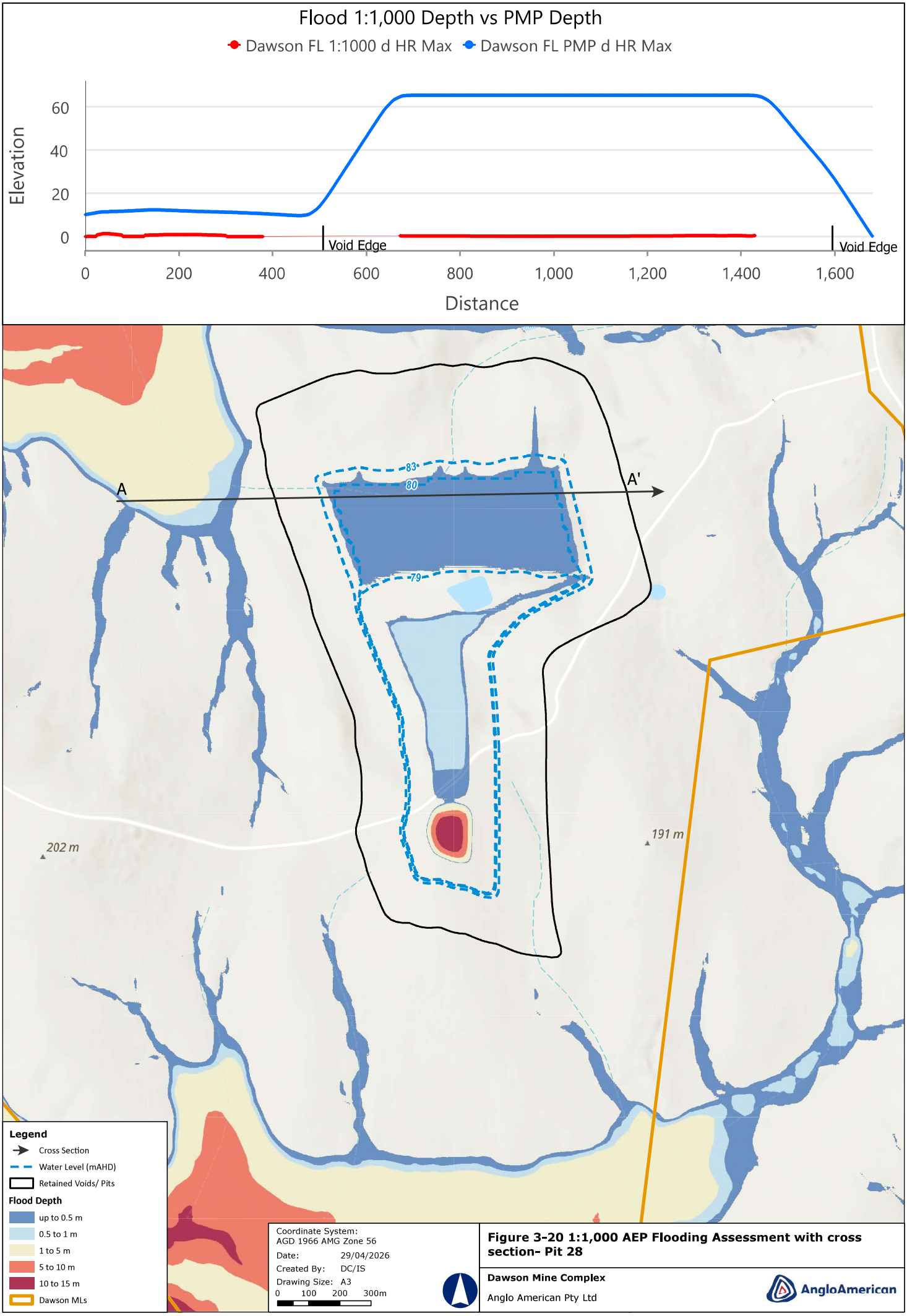


Figure 3-20 1:1,000 AEP Flooding Assessment with cross section- Pit 28

Dawson Mine Complex

Anglo American Pty Ltd

3.5.1.2 Alteration of catchment flows

A baseline flood assessment report was completed in March 2024 for DS (Neilly Group Engineering 2024). Hydrologic modelling for the 0.1% AEP design flood event for pre-development conditions was completed. The range of adopted baseline design peak flow estimates for AEP events at DS at the Woodleigh gauging station downstream of DS on the Dawson River is shown in Table 3-22.

Table 3-22 Dawson River at Woodleigh Flood Peak Flow Estimates (m^3/s)

	Flood Peak Flow Estimate (m3/s)				
	10% AEP	5% AEP	2% AEP	1% AEP	0.1% AEP
Dawson River at Woodleigh	1,266	1,774	2.987	3,713	10,598

In baseline flood modelling, water surface elevation ranged from 144 m AHD immediately upstream of DS to 133 m AHD downstream, with maximum depths in excess of 19 m occurring in the centre of the Dawson River, and flood waters extending across large expanses of flood plains, often in excess of 3 km from the riverbed (Neilly Group Engineering, 2024).

Hydrologic model configurations for the PRCP and the baseline model, obtained after the initial model run are detailed inTable 3-23.

Table 3-23 Hydrologic model configuration parameters

Hydrologic Model	Estimated catchment (km2)	Kc value	m value	Initial loss (mm)	Continuing loss (mm/hr)
Baseline	29,185	202.2	0.8	8.3	1.8
PRCP	26,477	194.4	0.8	59.0	2.1

3.5.1.3 Modelled flood levels

Development of hydrologic modelling for the PRCP has occurred for all relevant catchments of DS (Appendix 4.4).Modelling considered likely flood extents for a range of design storm events, up to and including probable maximum flood levels, including climate change considerations. The 0.1% AEP modelling, (including climate change considerations), was adopted as the appropriate flood extent to apply for development of management outcomes.

The results of modelling indicate that all final voids at DS have 0.1% AEP flood immunity with sufficient freeboard. However, there are a number of key areas across DS site where landform interactions with flood events are expected to occur under a 0.1% AEP flooding event. A summary of the flood outcomes for each of the mining areas are detailed as follows:

Pit 25:

- Pit 25 maintains flood immunity. Flood waters of depths less than 1 m extend to within 500 m of the pit boundary, but do not reach the void.
- Minor ponding occurs up against the waste landforms to the south of Pit 25. Ponded waters are predominantly less than 1 m in depth and are not prevalent through the final landform.

Pit 28:

- Pit 28 maintains flood immunity. Flood waters of depth up 4 m occur within 500 m of pit boundaries on the western and southern sides, but flood waters do not extend to the pit.

- Flood waters of the Dawson River extend to the toe of the waste landforms associated with Pit 28, on the eastern side and western sides, and to some extent to the south.

3.5.1.4 Modelled Maximum Flood velocities

Modelling of flood velocities show erosional and stability risks remain low in the final landform during 0.1% AEP events. Predicted flood velocities against the levees proposed for flood protection at Pit 28 are minimal is comparison to the velocities of flood waters in the Dawson River. Velocities are generally 0.5-1 cubic metres per second, with maximum velocities of up to 1-3 cubic metres per second close to Flood Levee 01 (Figure 3-21).

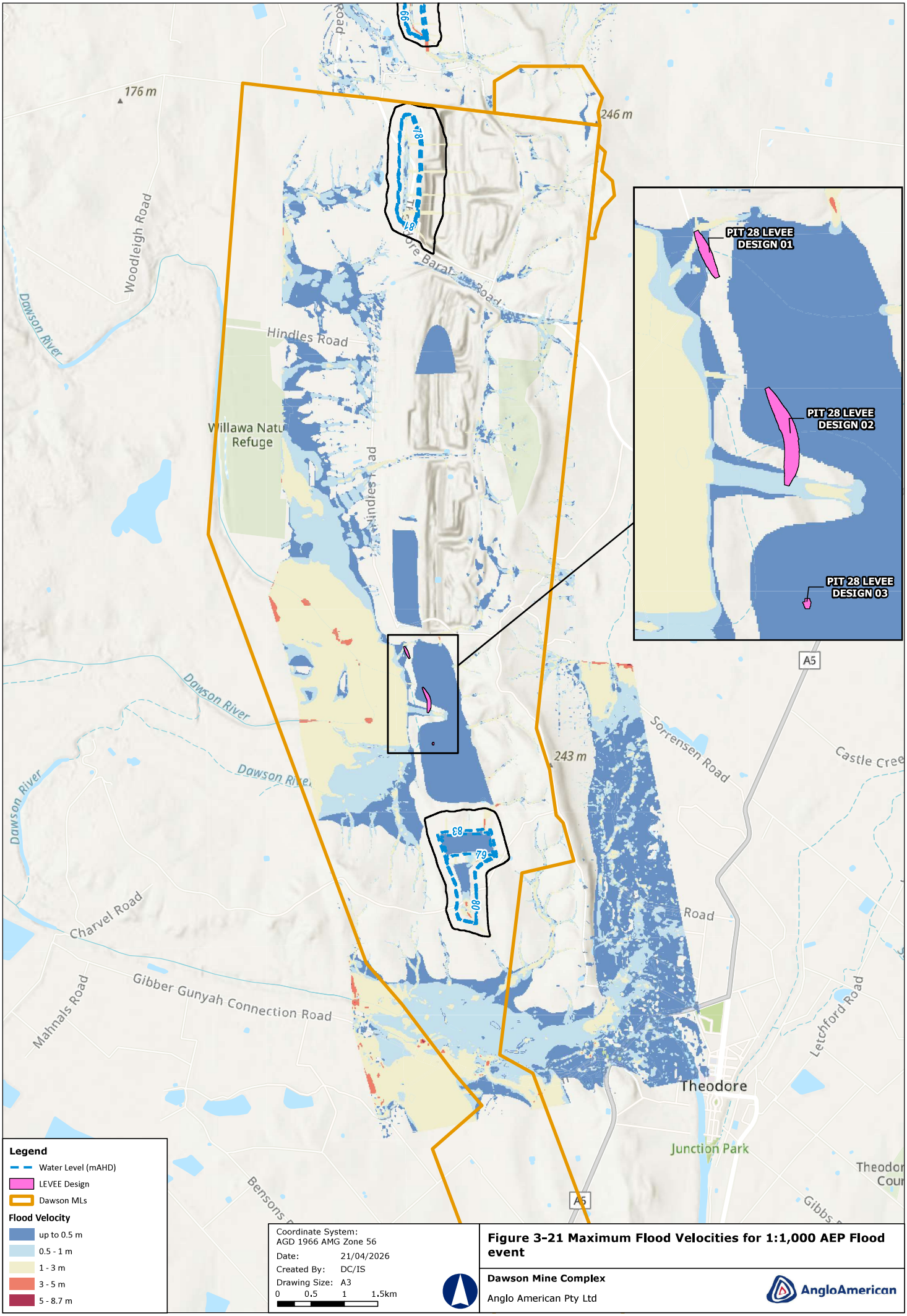


Figure 3-21 Maximum Flood Velocities for 1:1,000 AEP Flood event

Dawson Mine Complex

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3.5.1.5 Flooding risk profile

A flood risk profile has been developed to identify and rank the risk of the key features and areas of concern at DS. This has been completed to consider the susceptibility and likely influence of flooding on the areas and features of concern. Mitigation measures to address any elevated level of flood risk are also detailed. Based on the Queensland Emergency Risk Management Framework Risk Matrix (State of Queensland 2018), which takes into consideration the Likelihood, Vulnerability and Consequence the flood risk profile across DS has been classified as low. The flood risks for DS are shown below in Table 3-24.

Table 3-24 Flood risk profile for DS features

Feature	Risk Rating	Comment
Pit voids	Low	All pit voids achieve 0.1% AEP immunity.
Waste Landforms	Low	The landform will be designed to incorporate measures to minimise the risk of landform slumping and erosion in areas of anticipated ponding flood waters.
Dawson River	Low	Closure design of landforms adjacent to the flood water flows for the Dawson River will incorporate measures to minimise the risk of landform erosion or slumping.

3.5.1.5.1 Pit 28 Levee Design

Three flood levee's have been designed to provide the planned pit 28 1:1000 year flood immunity during the operational period. The designed flood levees have been designed with appropriate materials consistent with structures constructed elsewhere at Dawson Site. Trenches underlying the embankments will be keyed into the underlying formations to provide additional flooding protection. Batters on the embankments will be consistent with slope angles on overburden dumps at DS, at 1:3 gradient, and will be topsoiled and revegetated to provide erosional protection. 3m high safety berms will also be constructed on each side of the levees.

Geotechnical design drawings including heights, cross sections, crest elevations, construction material and erosion protection are provided in Appendix 4.12.

3.6 Rehabilitation and management methodology

3.6.1 Hydrogeology

The following activities were completed in order to appropriately assess groundwater management and methodologies at DS:

- A review of geological, groundwater, and environment reports from DS and the mining activities;
- A review of the site groundwater monitoring bore network and associated data;
- A review of water supply bores in proximity to the mining areas and associated monitoring data;
- A review of the conceptual model developed of the groundwater regime at each of the mine areas and its surrounds, based on all available data;
- The development and construction of a numerical model for the predictive simulation at the mining areas and the extent of the mining impacts on groundwater levels during mining operations and post closure; and
- The development of feasible mitigation and management strategies, if and where necessary.

3.6.1.1 Conceptual Model

A summary of the conceptual groundwater model built for DS is discussed briefly below. A report summarising key components of the model and graphic presentations for the mining areas are provided in Appendix 4.5.

3.6.1.2 Numerical Model

3.6.1.2.1 Model Layers

A numerical model representing the key hydrostratigraphic units present at DS has been built (KCB, 2025). The hydrostratigraphy of the study area was represented using 11 model layers, each representing different formations that are mainly discontinuous across the model domain. Multiple layers represent the Baralaba Coal Measures, including additional interburden layering to assist with the representation of the A, B, C, D and E coal seams.

3.6.1.2.2 Calibrated Groundwater Levels

The calibration approach to the model was aimed to fix parameter estimation on the prevailing groundwater conditions over the period of October 1990 to March 2023. This period was selected as this is the most reliable sequence of observation data available in the vicinity of the project site. Recordings after 2014 are limited, due to a small number of bores and one record for each year. Historical groundwater level data extracted from 95 monitoring bores located in the project area were used in the calibration.

The transient model simulation successfully matched observed groundwater level trends identified in the groundwater level monitoring records. The model calibration was considered robust and adequate for undertaking subsequent predictive simulations. Calibration in the shallow deposits (alluvium and tertiary sediments) was considered important, as this formation is most likely to represent/reflect potential groundwater-related impacts.

3.6.1.2.3 Predictive Modelling of Groundwater Flow

The predictive scenarios considered groundwater response to existing mining (life of mine to closure) and proposed mining (life of mine to closure) conditions. The duration of predictive simulations was

from 2023 to 2052, as specified by the life of mine plan for DS. The duration of stress periods was refined to assess wet and dry seasonal groundwater changes. For the mining periods, drain cells were activated to coincide with the mine plan (location and depth of mining) and turned off to allow recovery, corresponding with the pit backfill and rehabilitation plan.

The post-closure groundwater inflow flux was estimated for a range of void lake elevations, from the maximum inflow rate when groundwater levels are at the base of the pit (lowest), to the pre-mining groundwater level elevation where no groundwater inflow is observed (representing steady-state or equilibrium conditions).

3.6.1.2.4 Residual Drawdown Impacts at Identified Receptors

3.6.1.2.4.1 Potential Impact on Groundwater Users

Potential impact on groundwater users was completed using a desktop assessment, aimed at identifying water supply bores surrounding the project site that could potentially be impacted by the Project. This bore census drew upon information gathered from a search of the DNRME groundwater database and targeted bores and properties that could potentially be impacted by the project due to their proximity to proposed mining activities.

Desktop assessment conclusions were as follows :

- Groundwater use is primarily supply for agricultural purposes, within 5 km of the Project boundaries.
- No impacts to third-party users of existing water supply bores were predicted based on the maximum amount of groundwater drawdown which occurs at the end of operations.

3.6.1.2.4.2 Potential Impact of Drawdown on Surface Water Users

The site is located adjacent to Dawson River. The Dawson River and its tributary drainage lines are ephemeral and are characterised by short duration, surface water flows that are typically restricted to periods immediately after rainfall events.

Located adjacent to the Dawson River, two groundwater monitoring bores (DSMB05 and DSMB13) monitor the groundwater elevations in the underlying alluvial aquifer. The groundwater elevation in the alluvium did not show any significant response to rainfall recharge (KCB, 2025). This suggests that there is no direct interconnection between runoff and the alluvial aquifer close to the Dawson River.

Groundwater monitoring bore DSBM05 is also adjacent to Pit 27. There appears to be no response (drawdown) to the groundwater level in the alluvium from the current mining activities in Pit 27. This suggests minimal hydrualic connectivity between the alluvium and Permian Coal Seam aquifers. These observations further suggest that the Project is unlikely to have any cumulative impact on the surface water environment.

3.6.1.2.4.3 Potential Impacts to GDE's

Within 5 km of the Project low potential terrestrial GDEs (identified from GDE mapping datasets) are located along the Dawson River, Lonesome Creek and a vegetation managed wetland near the town of Theodore (KCB, 2025). The GDEs along the Dawson River and Lonesome Creek are within the predicted 0.2m drawdown extent, modelled at the end of operations.

The maximum predicted groundwater drawdown at the end of operations is predicted to be 30 metres. This is less than the current drawdown of 40 metres. This suggests any impact to the currently mapped low potential GDEs will be neglible in the post closure landform.

3.6.1.2.5 Particle Tracking

Particle tracking has been simulated to provide an understanding of the potential for migration of more saline water out of the pit voids/spoils areas to the receiving environment. Particle seeds were placed at the perimeter of the voids from start of the closure period and particle tracking was undertaken using forward particle tracks through to the 1,000-year period (to assess the potential flow from the areas).

The assessment confirmed Pit 25 and Pit 28 will act as long-term sinks in the final landform. The forward projections (indications of flow paths from all final voids, including backfilled) for DS show that some inter-void flow will occur initially as the voids fill from Pit 25 through to Pit 27, however Pit 28 remains an isolated sink in the post closure landform.

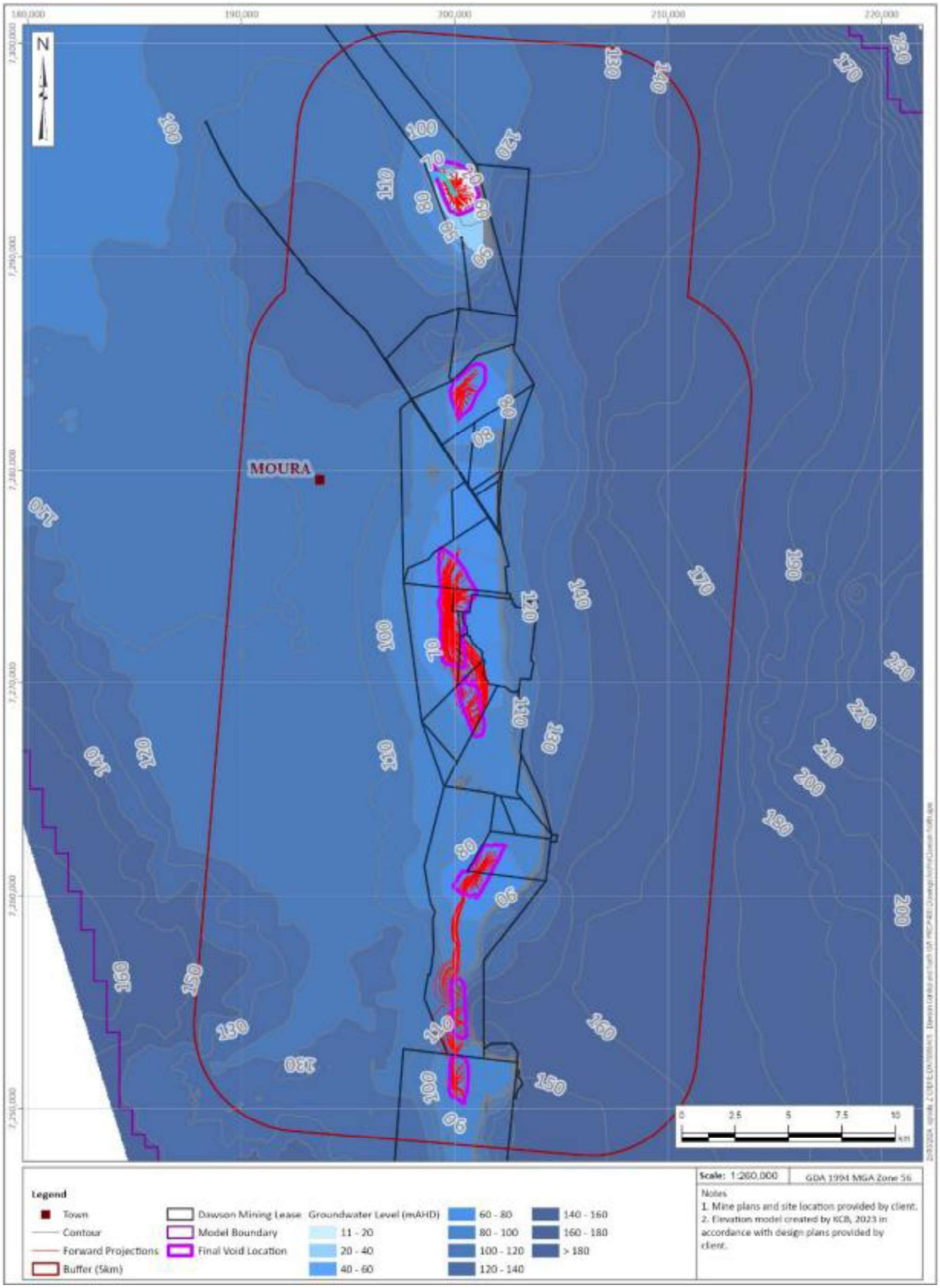


Figure 3-22 Particle tracking for Dawson Central North and Dawson South (Pit 28 not shown)

3.6.1.3 Ongoing and Post Mining

3.6.1.3.1 Borehole Decommissioning

Groundwater monitoring wells will be decommissioned in accordance with the latest Minimum Construction Requirements for Water Bores in Australia, unless a groundwater well is a usable asset, and an arrangement has been agreed in writing for handover of that asset, through consultation with relevant stakeholders during detailed closure planning.

As per the guideline, to decommission a water bore, several requirements must be met and include the following:

- eliminating any physical hazard (e.g. filling in open holes);
- preventing groundwater contamination;
- conserving yield and maintaining hydrostatic head of aquifers; and
- preventing waters intermixing.

3.6.1.3.2 Contaminated Land and Groundwater

Once all infrastructure and demolition materials have been removed, a contaminated site assessment will be completed by an Appropriately Qualified Person (AQP). If required, Remediation Action Plans (RAPs) will be developed, and remediation works completed in-line with relevant legislative requirements and good industry practice.

Information regarding the findings from the contaminated site assessment, and the activities completed as per the Remediation Action Plan, will be presented in the Final Rehabilitation Report to DETSI.

3.6.1.3.3 Post Closure Monitoring Program

A post closure monitoring program will be developed to continue to evaluate the success of all rehabilitation and review its trajectory towards completion criteria and meeting statutory requirements for closure.

A response plan based in the adaptive management methods aligned to the relevant completion criteria will be used to respond to any inadequate rehabilitation performance. This post closure monitoring program will be enhanced to cover other indicators including but not limited to community sustainability (if required), cultural heritage protection, and groundwater quality.

3.6.1.4 Impact Assessment

3.6.1.4.1 Post-Closure Groundwater Levels

The post-closure predicted void rebounding water levels estimated for Pit 25 and Pit 28, were re-applied to the groundwater model, using a time-variable General Head Boundary (GHB) to assess the post-closure groundwater conditions. The model considered 1,000-year post-closure period, where all drain cells in Dawson South voids were deactivated/removed and recharge applied, in accordance with the long-term historical average.

Generally groundwater elevations rebound after the extraction of all coal resources has concluded and all dewatering operations have ceased (in 2052). The largest groundwater drawdown is associated with the southern most section of the lease, with groundwater levels 150 to 170 metres below pre mining levels (nominally 1963). An estimated 50 years after closure, groundwater levels will be 80 metres below pre-mining levels in the north and 140 metres below pre-mining levels in the south.

Groundwater levels will slowly recover after each pit is backfilled and spoil stockpiles are progressively rehabilitated. Eventually, cones of depression form around the two remaining voids, Pit 25 and Pit 28, which both act as hydrualic sinks in the post closure landform.

3.6.1.4.2 Post-Closure Groundwater Quality

No additional impacts to groundwater quality are anticipated as a result of operations. The mining process will result in drawdown effects directing groundwater toward the voids, which limits migration of potential saline groundwater away from the mining area.

Groundwater quality assessment data indicate that although the water quality in the void would progressively deteriorate due to the effects of evapo-concentration (more evaporation than freshwater dilution), the water quality risks to surrounding water resources remains extremely low..

3.6.1.4.3 Potential Impacts to Environmental Values

The operational and post-closure impacts have been discussed in prior sections for the following EV's:

- Groundwater users;
- Surface water features; and
- Groundwater quality.

3.6.1.4.4 Summary of Impact Assessment

The assessment updated an existing numerical groundwater model that included both DCN as well as DS and refined this model to account for the potential predicted cumulative changes associated with the proposed Project. The groundwater continues to locally flow towards the mining complex. With the pit void water levels being lower than the surrounding groundwater system, the Dawson Mine complex and associated pit lakes continue to act as groundwater 'sinks' 1,000 years post-closure.

3.6.2 Soil and capping material assessment

Baseline soil and land suitability descriptions are presented in Section 3.1.1.6, with further detail provided in a Soil and Land Suitability assessment in Appendix 4.2. The following sections summarise the quality and quantity of available resources for the DS site. Growth media assessments indicate that limited material of suitable quantity and quality is available to support the rehabilitation requirements for the operation.

3.6.2.1 Quality of available resources

Initial investigations of in-situ soil resources were completed by Emmerton (2004) for the DS EIS, and by Baker (2004a), both across a similar area.

Soil stripping depths for topsoil in areas to be disturbed by mining were generally considered to be in the 200-300mm range, with less for some small areas of duplex soils (Emmerton 2004), and up to 500mm or more in deep, cracking clay medium clay soils developed from weathered non-quartzose permian sedimentary rocks and deep, well structured grey-brown clays on lower sloping plains (Baker 2004a).

Suitability assessments were carried out for dryland cropping and grazing on improved pasture, the two most prevalent land uses at that time. Dryland cropping is not considered to be a suitable PMLU for DS, hence only the grazing on improved pasture suitability assessment is described here.

In summary, while there are some lands where there are severe to extreme limitations to grazing, most of the lands directly affected by the mine can be productively grazed with negligible or minor

limitations, particularly in relation to nutrient deficiency, though some soils appear to have lost nutrients with lower than desirable concentrations of organic carbon and total nitrogen and some soils have lower than desirable concentrations of zinc and sulphate. These limitations can be effectively managed and corrected. Salinity increases with depth, but salinity of the upper soil levels poses negligible to minor limitations for most soils. Soil erosion through water is also not considered as representing a significant limitation, except of steeper slopes, particularly where slopes exceed 20%.

Overall, most growth media used in rehabilitation do have quality limitations but can be made suitable for use with targeted amelioration (Table 3-25). The principal ameliorants are fertiliser and gypsum, but alternative soil stabilising improvers other than gypsum will be explored at the time of implementation. The application of gypsum decreases the exchangeable sodium percentage and increases the Ca:Mg ratio of the soils. These two parameters together are expected to increase the stability of the soil. The fertiliser is required to increase the total N and P (Colwell) of the soil.

Table 3-25 Growth media fertility assessment

Soil Management Unit (Baker, 2004)	Growth media	Quality Limitation	Suitable with amelioration
-	Topsoil A Horizon	Medium clay content Low sodicity Neutral to alkaline	Not required
-	Topsoil B Horizon	None Medium clay content Low sodicity Neutral to alkaline	Not required
-	Tertiary material	Surficial soils and clays Alkaline Sodic Prone to severe erosion and instability	Yes. Fertilisers can be used and dispersibility improved through use of gypsum if slope gradients are appropriate.
3 and 4	Weathered Coal Measures	Siltstone, clays and fine-grained mudstones Alkaline Sodic Prone to erosion and instability	Yes. Fertilisers can be used and dispersibility improved through use of gypsum if slope gradients are appropriate.
1 and 2	Fresh Coal Measures	Sandstone and interbedded sandstone, siltstone and mudstone Low clay content Medium sodicity Alkaline	Yes. Fertilisers can be used and dispersibility improved through use of gypsum if slope gradients are appropriate.
-	Coal	Spontaneous combustion	Not required. Coal is not expected on the surface of the closure landform

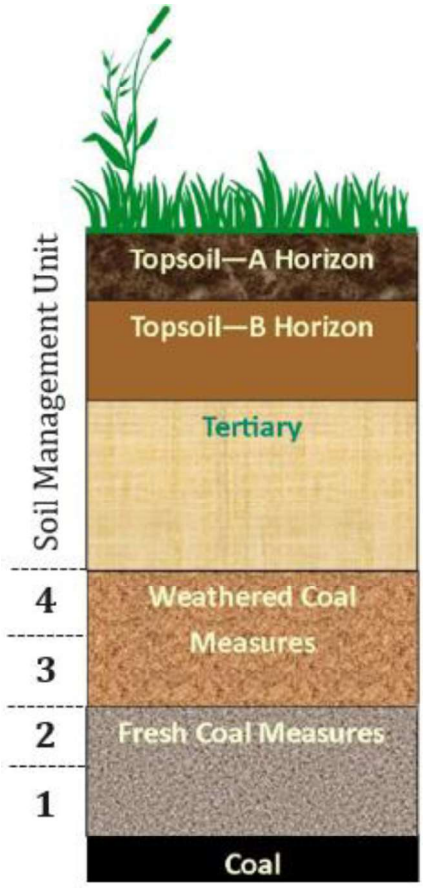


Figure 3-23 Schematic of soil management units across DS (adapted from Baker, 2004a).

3.6.2.2 Quantity of available resources

Baker (2004b) introduced a concept for final landform treatment, aiming for a final land use of Bushland, achieved using less topsoil. A spoil classification into four Spoil Management Types (SMT) formed the basis of this concept, as described in Section 3.6.4. Type 1 and Type 2 spoil without topsoil has proved to support good revegetation, particularly woody vegetation but also ground cover. Preferential placement is therefore based on placing topsoil in areas of greatest need to achieve final rehabilitation requirements. This includes areas of finer spoil particularly on the western margins of the mine (Type 3 and Type 4 spoil) to support pasture establishment and limit erosion potential, but also on long outward facing slopes on Type 2 spoil that are to be vegetated with grass. Topsoil has also been placed in strips across the contour, alternating with bare spoil, to extend the use of topsoil. Experience at Pit 18 (DCN) indicates that revegetation on the topsoiled strips and that on the direct seeding strips merge with one another to the extent that the strips can no longer be perceived on aerial imagery after 4 – 5 years. Details on trials are described in Section 3.7.3.

The spoil classifications mapped by Baker (2004c) were assigned to the DS area and a topsoil balance calculated, assuming topsoiling only where necessary according to the revised rehabilitation strategy (Figure 3-23).

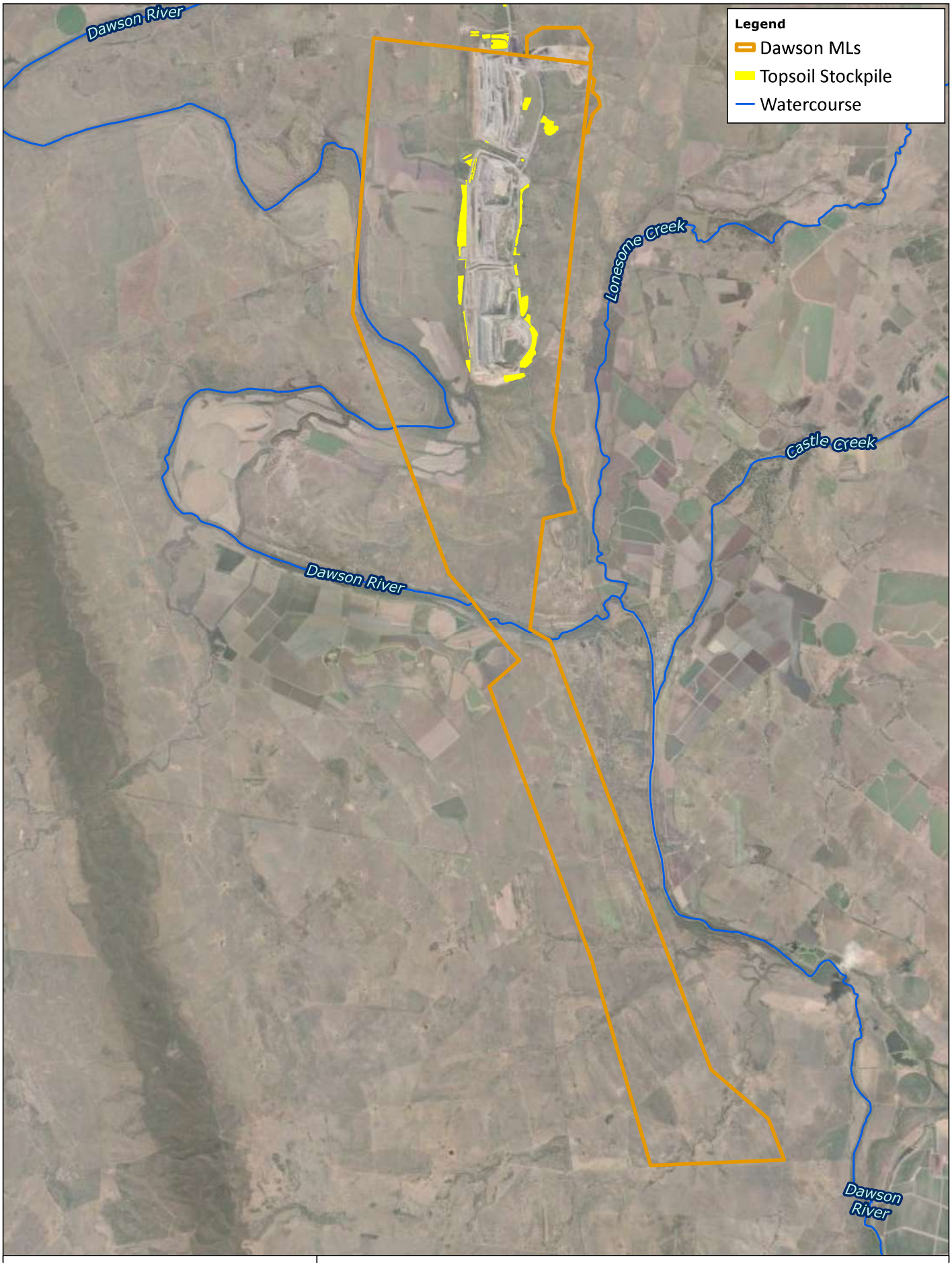
Table 3-26 shows the latest topsoil balance for both DCN and DS available from the 2024 ERC topsoil calculations. For DS, it includes 1256 ha to be 100% covered with topsoil plus 378 ha in which topsoil will cover 50% of the area, with the remainder seeded with predominantly trees and shrubs directly into spoil, as described above. The surplus of 1,612,543 m^3 of topsoil at DS (managed as a single unit with DCN as the Dawson Mine) will be used to cover the shortfall of topsoil at DCN, resulting in an overall surplus of 595,191 m^3 in the overall operation.

Table 3-26 Topsoil Balance DS Location

	DCN	DS	Total
Topsoil Volume Available (m^3)	3,957,166	3,779,764	7,736,929
Full Cover Topsoil as 100% coverage at 0.15m			
- Area (m^2)	1013	1256	2269
- Depth (m)	0.15	0.15	
- Volume (m^3)	1,519,886	1,883,682	3,403,567
Strategic Topsoil as allowance 50% coverage at 0.15m			
- Area (m2)	4606	378	4984
- Depth (m)	0.15	0.15	
- Volume (m^3)	3,454,631	283,539	3,738,170
Topsoil Volume required (m^3)	4,974,517	2,167,220	7,141,737
Topsoil Balance (m^3)	-1,017,351	1,612,543	595,191

3.6.2.3 Location and accessibility of resources

If direct placement of topsoil for rehabilitation is not available, topsoil is stockpiled. As part of ongoing detailed planning and schedule for rehabilitation, optimisation of the best source, haulage routes and locations for stockpiling of growth media materials will be completed, to ensure efficiency of transport and storage requirements. Current topsoil stockpile locations are outlined in Figure 3-24.



Coordinate System:
AGD 1966 AMG Zone 56

Date: 20/04/2026
Created By: DC/IS
Drawing Size: A4

0 1 2 3km

Figure 3-24 Topsoil Stockpile Locations

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

3.6.2.4 Requirement for ameliorants and fertilisers

As a shown by the work of Emmerton (2004) and Baker (2004a, b, c), where available, there are generally no significant contraints in the use of the topsoils at Dawson Mine. Nevertheless, topsoils are tested prior to application to verify whether soil physical and chemical composition may require amelioration to provide a suitable growth medium. Where revegetation is to be undertaken without application of topsoil (only on Type 1 or 2 spoil), the growth medium is also tested.

Topsoil will be amended or blended to relieve all key chemical, physical and biological limitations to growth (pH, EC, cations, cation balance, macro-nutrients, organic matter), based on recognised soil nutrient adequacy thresholds.

Dispersive spoils and soils are ameliorated to prevent erosion by incorporation of gypsum throughout the upper 35 cm to 50 cm of the final landform profile at a rate sufficient to achieve a target residual ESP below the generic soil stability threshold (nominally of 5% for topsoil and 14% for spoil, or higher values where supported by site-specific spoil analysis). Ongoing soil testing is undertaken to determine the long-term benefits of gypsum application.

3.6.2.5 Suitability of soils to support PMLU outcomes

As described above, there are no major constraints in the use of the soils and spoils at Dawson Mine for the Grazing or Bushland PMLUs assigned to rehabilitated areas. Topsoils will be applied to enable a Grazing PMLU on Type 3 and 4 (and some Type 2) spoils, while direct seeding into Type 1 and 2 spoils will favour a Bushland PMLU primarily consisting of native woody species. Growth medium amelioration is undertaken as required prior to revegetation.

3.6.3 Mine waste characterisation

DS and DCN have been (and still are) operated as a single Dawson Mine, despite operating under separate EAs, and as such, geochemical characterisation studies have been conducted across Dawson Mine as a whole.

3.6.3.1 Description of mine waste materials

Land stability is determined to a large extent by the characteristics of the spoil that underlies the landform surfaces at DS. Key factors include chemical characteristics and grain size of the spoil. Spoil at Dawson can be characterised as follows (Anglo American, 2012):

- Spoil is generally alkaline, with a pH of around 8.
- EC is highly variable, ranging from 43.5 µS/cm to 1,244µS/cm, with a median of 169µS/cm, indicating that most spoils are non-saline. High salinities up to 1,244 µS/cm are atypical and localised
- Exchangeable sodium percentages (ESP) are also highly variable, ranging from 0.23% to 24.8% with a median of 9.5%, indicating that spoils are generally not sodic to moderately sodic. Sodium levels are accompanied by high Calcium levels
- Gullying, piping, and rilling is absent on the coarse sandstone spoils, but more common on the finer textured spoils, yet not to the extent as is common further north in the Bowen Basin.

Based on an extensive survey program undertaken by PW Baker and Associates (2004), spoil at Dawson Mine has been classified into four Spoil Management Units (SMU). These include:

- Type 1 – Dawson coarse sandstone spoil: include the coarse sandstone spoils which form almost all of the eastern spoils through to most of the central inner spoil areas at Dawson Mine. This material offers the greatest capability to resist erosion.
- Type 2 – Gibihi intergrade spoil: This is a quality intergrade spoil (a mixture of Type 1 and Type 3 – due to blasting and excavating) with higher fines content than the coarser Type 1 sandstone spoils.
- Type 3 – Fine Kianga spoil with few significant chemical /physical limitations: mostly from B Seam origins, generally predominates in most areas.
- Type 4 – Fine Kianga spoil with increased chemical/physical limitations: mostly A Seam origins and is generally of much poorer quality than the lower B Seam with increased extent of limiting factors in terms of spoil quality and erosional stability.

SMUs 1 and 2 listed above are present in the 'fresh coal measures' stratigraphic unit in Figure 3-23. It is easily recognisable and is resistant to erosion. SMUs 3 and 4 are related to coal seams A and B and contain a larger portion of tertiary and weathered coal material than types 1 and 2. A seam material is readily recognised by its lighter brown and yellow hues. B seam material is darker, with grey, black and deep chocolate colours (Anglo American, 2019a). Both these materials are more prone to erosion than SMUs 1 and 2.

Pit 25 has previously experienced spontaneous combustion. The propensity of coal to combust spontaneously was assessed by B3 Mining Services (2023). Material tested included bulk grab samples from the A, CL, B, and AU seams at Dawson mine. Methods used include measurement of the self-heating rate index (R70), as well as derivation of minimum self-heating temperature and crossing point temperature indices from coal sample quality data. These derived indices were also used to obtain a relative indication of the intrinsic propensity of the coal for spontaneous combustion.

The R70 self-heating rate values ranged from 0.81 °C/h to 4.00 °C/h, which rates the samples as having a Low-Medium to Very High intrinsic spontaneous combustion propensity, based on Queensland conditions. These values are consistent with the rank and type of coal. It should be noted that the R70 test is performed on a dry basis and as such it does not provide any indication of the time taken to reach thermal runaway. Calculated spontaneous combustion index values for crossing point temperature indicate the samples had a Low to Medium spontaneous combustion propensity rating. The measured relative ignition temperatures for the samples confirm the intrinsic spontaneous combustion propensity rating obtained from the R70 values.

A technical report assessing spontaneous combustion potential is provided in Appendix 4.7.

3.6.3.2 Review of sampling regime

Sampling of the spoil and waste rock dumps was completed by Baker in 2004 and described above in 3.1.1.6. Additional opportunistic samples of overburden or interseam material is collected during exploration drilling and when mining advances into new areas. ROM coal processed into product (saleable coal) are routinely sampled prior to shipping. Additional sampling of waste rock material was completed in November 2025 to assist in the characterisation of soil materials.

The two waste streams, coarse rejects and fine rejects (tailings) are also routinely sampled. Neither of these products are produced (or sampled) at DS.

Sampling of active tailings facilities occurs on an annual basis (Anglo American, 2012a) to ensure changes in composition of trends in geochemistry are detected early. The sampling of the tailings includes those listed in Table 3-27.

No tailings or rejects are deposited or sampled in the DS area.

Table 3-27 Tailings Sampling Analytical Suite

Net Acid Producing Potential (NAPP)	Net Acid Generation (NAG)	Net Acid Neutralising Capacity (ANC)
Total Sulphate	Total Sulphur	Aluminium
Arsenic	Copper	Iron
Manganese	Nickel	Selenium
Silver	Sulphide	pH
Conductivity (EC)	Total Soluble Salts	Moisture Content

Surface water sampling is completed across the site on a regular basis. The numerous dams and pits across the sites are monitored for algae, pH, EC, suspended solids and sulphate. During release of mine affected water, daily monitoring of water quality (EC, pH and turbidity) at the release points is conducted, with the first sample must be taken without 2 hours of commencement of release. Measurements of sulphate must be taken weekly during the release period, with the first sample taken within 2 hours of commencement of the release. Additional potential contaminants are monitored weekly during the release period (DETSI, 2025a).

All exploration drilling is geologically logged at the time of drilling and geological characteristics described, with particular focus on the intersection of coal seam, and interseam material. Lithological thicknesses are logged to the centimetre, with coal textures noted in detail such as vitrinite and ash content. Roof and floor strata are also logged in detail, with overburden logged as either siltstone, claystone, sandstone or shale. These are further defined into SMUs dependent on the physical characteristics, placement in the strata (age) and colour.

The coal seams identified in exploration logging are then imported into a 3D package for further modelling and definition. Wireframes are then produced, linking each of the seams across the DS area. Interseams are defined to optimise coal recovery and scheduling during operations. Volume calculations of coal resources and overburden is produced so a mine plan can be implemented. The volumes are then split into a cut and fill schedule, and the recovery of coal and placement of overburden can be determined across the mine.

An example of the coal seam splits and continuity of the seams across the DCN and DS area is presented in Figure 3-25.

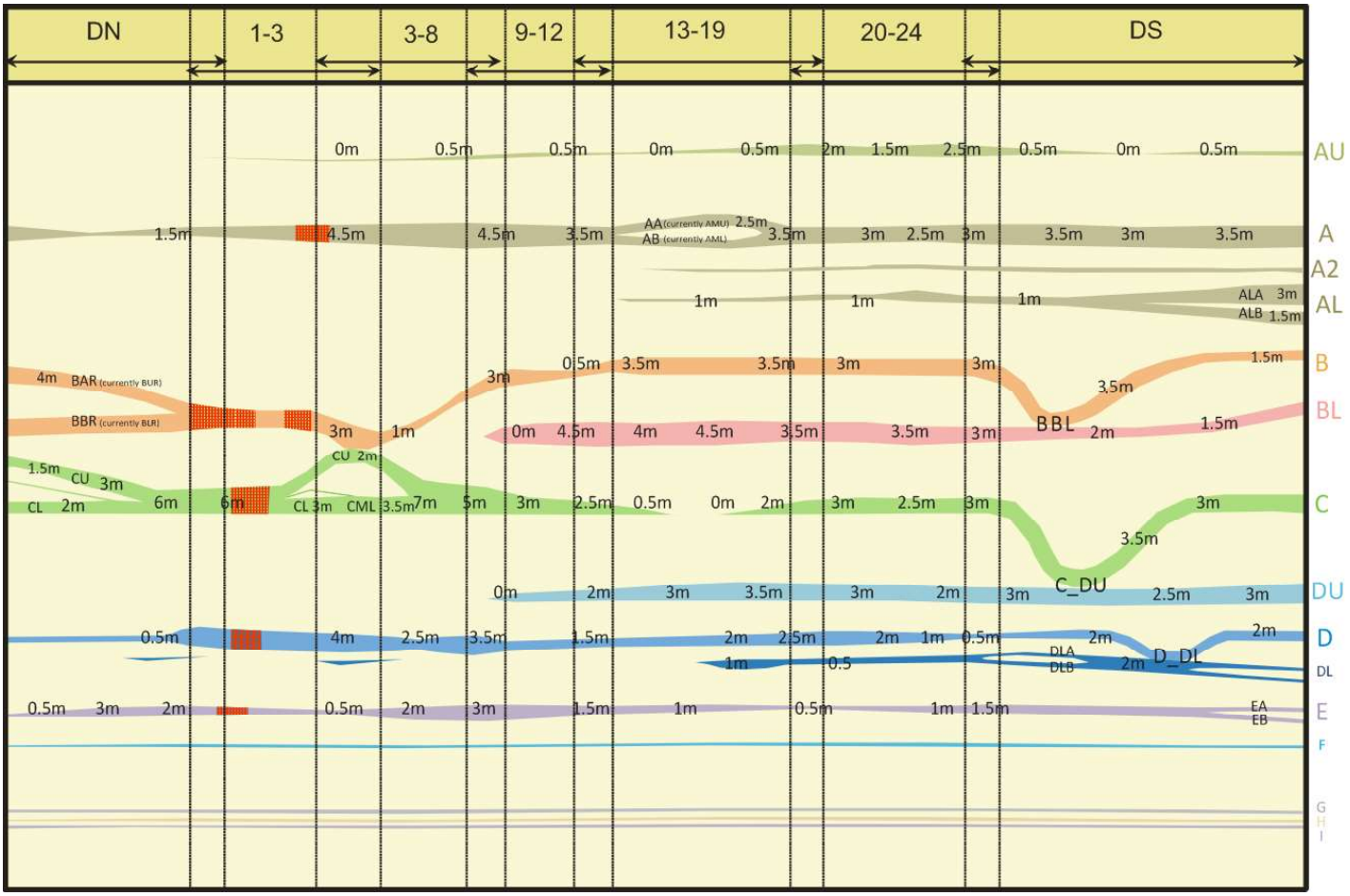


Figure 3-25 Schematic of coal seam splits across DCN and DS (Anglo American, 2022)

All data collected from geological logging, in addition to surface water, groundwater or spoil characterisation is stored in a secure database on site. AcQuire is the database used onsite to store geological data.

3.6.3.3 Classification of mine waste streams

All material mined at DS can be characterised into

- Coal (saleable coal); and
- Overburden or spoil:
  - The overburden and spoil are further characterised into 4 spoil management units (SMUs) as described in Section 3.6.3.1.

Coal is processed and shipped for sale. Fine coal rejects are deposited in tailings dams located at DCN. No tailings dams are located at DS. Coarse rejects are also produced as part of the processing of coal and are deposited in storage areas. There are no coarse rejects stockpiles or dumps located at DS. Overburden is stored in mined out pits or stockpiled close by. Due to the amount of overburden removed during the extraction of the coal resource, the DS landscape is defined by these large overburden stockpiles.

Coal partings extracted during the mining process are selectively handled and disposed of in pit, or deep in waste dumps to avoid oxygen ingress and proactively managepotential spontaneous combustion risks.

3.6.3.4 Management and mitigation of mine waste streams

Risk based management is embedded in site practices. During mining operations, spoil is characterised into SMUs 1-4 (Section 3.6.4.1). The erodible SMUs, 3 and 4, are preferentially placed at the bottom of the stockpile where possible and SMUs 1 and 2 used on the surface. Accurate mine planning around the extraction of coal seams A and B mean the placement of SMUs 3 and 4 can be accurately scheduled and planned in the resultant landform. The SMUs are easily distinguishable in the field due to colour and friability. An appropriate layer of inert spoil is placed on top of the landform regardless, to ensure there is no self-heating capacity possible in any remnant coal. Highwall and auger mining areas are covered with spoil to create the final landform, thus also sealing these areas.

No tailings or rejects will be stored at DS, avoiding the potential spontaneous combustion from these materials.

3.6.3.5 Conceptual site model for mine waste storage facilities

There are no mine waste storage facilities planned for DS.

3.6.4 Landform design

All landform designs have been guided by an objective to achieve long-term stability, and the performance of the design concept was tested using appropriate analyses of long-term stability. As DS is a transitional site, with existing progressive rehabilitation areas that have been designed and reviewed for actual performance, the design concept has not only been informed by theoretical modelling and analysis, but also reflects observation of on-ground practices. As such, formal rehabilitation trials are not proposed to test the overall landform design concept and instead the historical record has been used to guide rehabilitation practices. However, small scale modifications of rehabilitation practices may be applied from year-to-year, and consequential site practices adjusted, as the actual performance of areas with different prescriptions continue to inform the overarching design concept.

3.6.4.1 Key Inputs and Assumptions

The key inputs and assumptions for rehabilitation and landform design are listed in Table 3-28.

Table 3-28 Landform design key assumptions

Design	Slope Angle (%)
Max. low wall regrade	<16.7
Max. high wall regrade	<33.3

3.6.4.2 Key Design Methods and Considerations

3.6.4.2.1 Landform Areas to be Rehabilitated

The location of each of the key landform structures that have already been rehabilitated, and are still planned to be rehabilitated, is as shown in Figure 3-13.

3.6.4.2.2 Environmental Factors

Key environmental factors of relevance and considered in the landform design include:

- The waste material used is suitable for its position within the landform. A small proportion of materials require specific handling and placement strategies;

- The potential for floodplain interaction has required mitigation and protection through design;
- There are no hydrogeological factors of concern; and
- Community and stakeholder consultation has helped to inform the landform design.

3.6.4.2.3 Water Management

Landform design will primarily adopt a water-shedding arrangement. It is expected that the primary contaminant from newly rehabilitated landforms will be sediment, and therefore all runoff from rehabilitation areas will have sediment controls in place for the initial period whilst vegetation is establishing.

3.6.4.2.4 Earthworks Design, Slope Gradient, and Erosion Risk

A key consideration of the landform design at DS is the overall slope gradient, and significant focus has been put towards understanding the maximum potential slope that will support stable landforms. Another consideration is the space available to deposit mine waste (overburden). As a result, linear landform slopes are adopted as standard, as these are the most efficient in containing the volume of overburden generated.

As described in Section 3.1.1.6, four types of spoil are recognised at Dawson Mine, including DS. Landform design and construction have to be cognisant of the different properties of these spoil types. Site experience extending well over 50 years, as well as landform modelling and laboratory erosion modelling (Landloch, 2018a, b), have resulted in the application and use of rules of thumb for the different types of spoil in the creation of stable landforms. Due to the greater prevalence of Type 3 and 4 (fine grained) spoil, slopes at DS are less than at DCN, with a rule of thumb maximum of 17%. Additional landform evolution modelling was commissioned in preparation of this PRCP (Hancock 2024), which shows that these rules have been conservative (Section 3.6.5.6).

Voids are backfilled with spoil/pre-strip where possible, and/or used for tailings and rejects disposal. Two final voids will remain as NUMAs in DS. All walls will be laid back as per Table 3-29.

Infrastructure areas will be re-shaped, except where infrastructure will remain post-closure, as per written agreement with the landowner.

3.6.4.3 Development of design concept

Rehabilitation activities have been refined over time since early rehabilitation activities at Dawson Mine pre-1978. The contemporary approach follows a more scientific basis to rehabilitation techniques and material placement then in the past. The current design concept is for free-draining landforms that provide flexibility in design to suit the surrounding landform, enabling rolling slopes which can be blended into the natural topography. The current approach ensures that the primary drivers for the landform method are related to final landform and land use, material characteristics, climatic conditions, pit lake water quality, and desired rehabilitation outcomes.

3.6.4.4 Key landform design principles

The following considerations have been taken into account during option selection and landform design:

- Safety and security
- Physical, chemical and ecological stability
- Risk limitation

- Minimising socio-economic impact
- Cost effectiveness; and
- Management of all residual risks.

Selective placement of mine waste has assisted in management of dispersive materials, and landform designs have aimed to maximise in-pit dumping.

3.6.4.5 Final rehabilitation design concept

The DS design concept incorporates linear slope batters with surface drainage features. This involves optimising landform height, slope gradient and vegetation cover to achieve acceptable erosion rates. The final landform proposed for DS has been produced in 3D, optimising the bulk material movement of coal and overburden material to determine balanced cut and fill volumes across the area. Deswik modelling software has been used to optimise material movement to avoid unneccessary double handling of material. These are then fed into a mine schedule to be implemented through the life of the asset.

Geomorphic design has been considered in the generation of the final landforms at DS to understand and limit the amount of overland surface water flow. This design framework mimics natural systems of water flow, and in combination with Landform Evolution Modelling (LEM) can be used to highlight areas that may warrant additional protection or focus for vegetation in early years of rehabilition. LEM has been completed for DS and in combination with geomorphic design will provide additional insight into areas of potential erosion in the final landform (Appendix 4.8).

Combined geomorphic and linear landform designs have been assessed at DCN in the past (Golder, 2020). The findings of these studies, in combination of the extensive site knowledge of progressive rehabilitation over the life of mine, have informed the design of the proposed final landform at DS. Community desires were also considered as the design was further developed.

Rehabilitation and landform design have been completed for all disturbance areas and are detailed in Appendix 4.8.

3.6.4.6 Landform performance assessment

Landform evolution modelling of spoil located within the highwalls of Pit 2 (northern end of Central Dawson) and Pit 20 (southern end of Central Dawson) was undertaken by Landloch (2018a). Due to the similarity of the material across the northern and southern parts of the Dawson Mine, the results of this modelling is also relevant to DS.

For both Pits, the spoil material consisted of “Type 4 – A Seam” material in the sense of Baker (2004c), with a relatively high fraction of clays and fines, and increased chemical/physical limitations for rehabilitation. However, whereas the approximate clay content in the sample for Pit 2 was 35-40%, the sample from Pit 20 contained over 50% clay.

SIBERIA software was used to test long term stability of spoil emplacements without reprofiling, and with reprofiling to 50% (1:2 or 26.6 degrees) and 33% (1:3 or 18.4 degrees) slopes (i.e. three scenarios) for 200 years duration.

Subsequently, Landloch (2018b) undertook erosion modelling based on simulation plots set up in a laboratory, with ten climatic variables such as differing rates of precipitation, solar radiation, and wind applied. The impact of grass cover was also determined. It was concluded that the establishment of high levels of surface vegetative cover is critical for erosional stability. In particular, vegetation should be dominated by stoloniferous grass species that are in direct contact with the soil surface. Gypsum

should be applied to mitigate the dispersive nature of the spoil, and concentrated overland flow and ponding should be minimised by installing crest bunds and ripping across the slope.

3.6.4.6.1 Landform Evolution Modelling

Additional landform evolution modelling was undertaken in SIBERIA software to further inform landform design for the proposed closure landform at DS (Hancock, 2024 provided as Appendix 4.8). Parameters were determined from sites outlined in Sheridan et al (2000) and flume and rainfall simulator studies which developed the Queensland Coal Association Version 1.0 erosion database (Gyasi-Agyei and Willgoose, 1997) from the Dawson (then Moura) site. These were site specific parameters.

Erodibilities for a range of different mine wastes and different surface materials from an extensive field campaign with a rainfall simulator over a three-year period were used. Data was available for plots with slope of 20% and different discharges using rainfall applied for 30 minutes. This rainfall, runoff, infiltration characteristics and sediment transport data were scaled using local pluviograph records to extend the plot data and generate a long runoff and erosion series from which the input parameters were derived. SIBERIA parameters used for this modelling is provided in Table 3-29.

Table 3-29 SIBERIA parameters- DS closure landform

Parameter	Value
b_1	0.0003
m_1	1.5
n_1	2
b_3	1
m_3	1

Details of the parameters used can be found in Gyasi-Agyei and Willgoose (1997), Sheridan *et al.* (2000) and Willgoose (2005). The parameters derived from this process are for Dawson (Moura) topsoil which is assumed as the cover for the landscape with no vegetation. There are no parameters available for the highwall materials. Therefore, the erosion patterns, particularly for the highwall, are conservative and likely to be an overestimate.

For hillslopes with significant planned vegetation cover such as Dawson, there will be a significant reduction in both erosion rate and gullying. To accommodate this reduction, the RUSLE vegetation cover C-factor can be used to estimate the likely reduction in erosion (Wischmeier and Smith, 1978; Rosewell, 1993). C-factors are available from a range of sources (Wischmeier and Smith, 1978; Blanco and Lal, 2008). Assuming the vegetation cover is moderate, a C-factor of 0.1 has been selected based on the table for vegetation in Blanco and Lal (2008) and refined from the C-factor map of Australia in Teng et al. (2016). The SIBERIA β_1 value is then approximated by multiplying the K-factor and C-factor values.

3.6.4.6.2 Modelling and model set up

Five Digital Elevation Models (DEMs) were provided for modelling as outlined in Table 3-30.

Table 3-30 DEMs provided for SIBERIA modelling

DEM title	Applicable voids/area	Area (ha)	Elevation (m)
Dawson North	North Pit	2,480	381
Dawson South	Pits 25 and 28	6,196	198
PIT02	Pit 2	1,487	281
PIT0312	Pit 3-12	5,180	398
PIT0319	Pit 13 and 19	7,145	263

All modelling was performed using the SIBERIA landscape evolution model (Willgoose, 2005a,b). The SIBERIA model was run for 300 years with outputs at 10, 100 and 300 years. The model assessed each DEM listed in Table 3-30 using the parameters described above in Table 3-29. Final results are provided in Table 3-31.

In each simulation, landforms with vegetation cover produced better results, with significantly lower erosion rates in landforms with vegetation cover. As expected, erosion rates are highest during the first ten years, with reducing rates over time. An output from a non-vegetated landform (i.e. worst-case scenario) is provided in Figure 3-26.

Table 3-31 Erosion Rates- DS Closure Landform

	Vegetation			Non-Vegetated		
Time (years)	10	100	300	10	100	300
Erosion Rate (t/ha/yr)	6.63	5.51	4.10	31.9	24.2	21.1
Max Erosion (gully depth – m)	0.51	2.60	13.42	5.91	28.62	35.44
Max deposition (m)	0.95	3.77	6.91	4.23	15.5	24.67

Pit 24 is included in the erosion rates above despite being located on DCN MLs. See Dawson Central/North PRCP for more details

The landform design described in Section 3.6.5.5 conforms to these findings. Bench or drop structures will be installed downslope to assist with diverting surface water flows in the void and minimise the development of erosion features such as piping or rilling. Minor changes in proposed closure landforms will not result in significant changes in the modelling outcomes provided the same design criteria including slope length and angle are met.

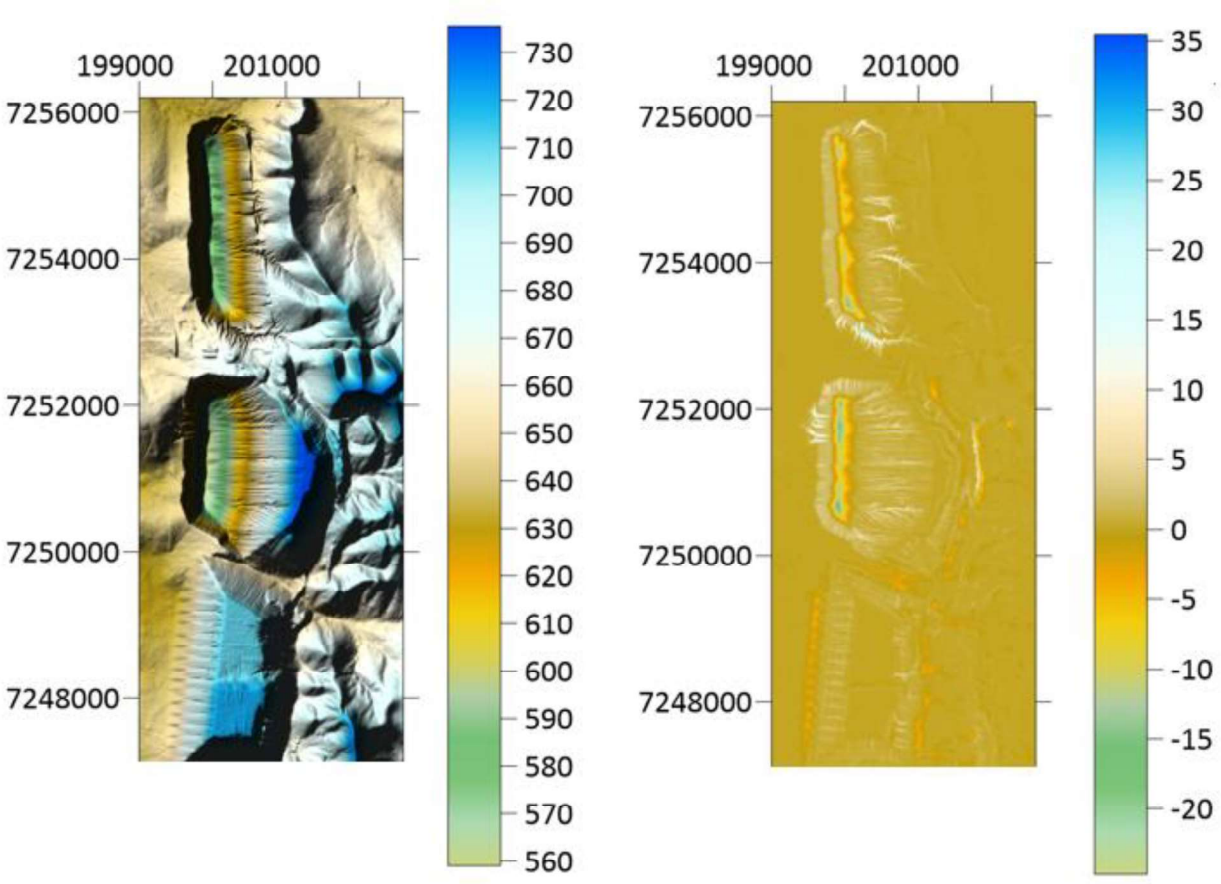


Figure 3-26 Erosion of the closure landform- 300 year simulation no vegetation. Total erosion (left - elevation in metres) and deposition plot (right - erosion depth in metres)

3.6.4.6.3 Linkages to Rehabilitation Milestones

The creation of rehabilitation milestones in the PRCP schedule has considered the outputs from the updated SIBERIA modelling, combined with previous outputs from erosion modelling at Dawson and other analogous sites in Queensland. The importance of establishing vegetation quickly, in suitably treated substrate or topsoil, will be critical to the stabilty of the slope angles proposed for the final landform at DS. The average slope angle, depth of growth media and ripping and seeding in the rehabilitation milestones have taken the results of SIBERIA modelling into consideration.

The deposition plots provided as outputs of the SIBERIA modelling, highlight areas of potential elevated erosion in the post closure landform (Figure 3-25). These areas can be a focus of post closure monitoring and maintenance if rehabilitation milestones are at risk of not being achieved and early intervention executed.

3.6.4.7 Landform rehabilitation process

Construction Methodology

Construction of the rehabilitated landforms includes the following key aspects:

- Completion of earthworks to achieve the required slope arrangement, with time allowance for settlement of waste rock prior to completion of rehabilitation activities;
- Installation of drainage structures to ensure the landforms will effectively shed surface water;

- Minor earthworks with smaller machinery to improve tolerance to design and to complete works which cannot be established with larger equipment;
- Placement of growth media with deep ripping to incorporate into the underlying landform materials; and
- Revegetation activities.

QA/QC Requirements

DS has a number of quality assurance and quality control processes in place so that the landforms are constructed in accordance with the design concept and adhere to detailed design specifications established for each area. A proposed 3D landform design is provided to a third-party earth moving contractor to complete the required earthworks. Once these construction activities are completed, internal survey teams complete high resolution data capture, using drones or satellite information, to record elevation in the landform. Once completed, these data are reviewed internally, and by third parties, to verify that the design criteria have been met. Any aftercare and maintenance requirements are captured at this time, and remediation efforts are completed.

3.6.5 Cover design

3.6.5.1 Mine Waste

To protect the receiving environment and ensure rehabilitation is successful, a cover system may be required to manage the exposure of mine waste materials or other wastes that are known to, or may have the potential to, interact with oxygen and water resulting in acidic, neutral or alkaline drainage with elevated metal or salt concentrations.

3.6.5.1.1 Summary of mine waste geochemical and physical characteristics

Mined material at DS consists of saleable coal, coal processing wastes consisting of fine rejects or tailings and coarse tailings, and mine waste or spoil. Spoil has been further classified into four SMU at DS, based on the mine waste properties. SMU 1 and 2 useful competent coarse spoil, while SMU 3 and 4 contain finer material with some limitations for constructing landforms (Baker, 2004; Anglo American, 2019a).

The specific geochemical and physical characterisation of mine waste is discussed in Section 3.6.4, however traits relevant to cover design can be summarised as follows (Anglo American, 2012):

- Material is generally alkaline, with a pH of around 8;
- EC is highly variable; most spoils are non-saline;
- ESP is highly variable; and
- Coarse sandstone spoils are not prone to gullying, piping and rilling; erosion levels increase in finer textured spoils.

Pit 25 has previously experienced spontaneous combustion; propensity to spontaneously combust was rated Low-Medium to Very High propensity, on a dry basis.

Generally, SMU 1 and 2 provide reduced risk of erosion, while SMU 3 and 4 have physical and chemical limitations, resulting in a higher susceptibility to erosion.

Broadly speaking, the coal processing wastes (coarse rejects and tailings) represent a higher geochemical risk for the site, as processing generally concentrates any impurities (including metals

and total soluble salts) in the waste streams. However, tested coarse rejects and tailings material were generally considered to be non-polluting and NAF and there were no specific enrichments of metals or any other contaminants at concerning levels found.

3.6.5.1.2 Placement and capping

Landform evolution modelling for DS was undertaken to evaluate the potential erodibility of the landform slopes and to assist with developing placement and capping requirements for the proposed closure landforms (Appendix 4.8). Modelling confirmed that spoil management will need to involve classification and segregation during mining, based on the geochemical and geophysical traits of each spoil unit. Spoil (SMU 1 and 2 units) will be preferentially placed or mixed via reshaping works to ensure reduction of risk of erosion from dispersive spoils (SMU 3 and 4 units) within areas of landform. Where deemed necessary, a minimum depth of 1m of competent, non-dispersive SMU 1 or 2 spoil will be placed on the outer surface of the landform to minimise the risk of gullies, rilling or erosion occurring, prior to spreading topsoil or growth medium.

Slopes will be constructed to grades of 16.7% (externally draining slopes, internally draining slopes, top of dumps, roads and infrastructure and 33% for highwalls, with bench spacing placed at maximum intervals while still achieving an acceptable erosion rate. The landforms and capping have been designed to be free-draining and to shed water (Red Earth Engineering, 2020).

Ore processing is not undertaken at DS, and as a result, no tailings storage occurs at the site. All tailings generated from DS ore will be directed to Dawson North Cell 3 in DCN after processing.

Further information on the capping and closure of tailings facilities is covered in the PRCP for DCN.

3.6.5.1.3 Quality and quantity of capping resources

Section 3.6.3 discusses the availability and quality of capping resources at DS. In summary, harvested topsoil and subsoil materials were found to be suitable for use in rehabilitation works with an end land use of dryland cropping or grazing on improved pastures (Emmerton, 2004). Harvesting topsoil and subsoil to a depth of 150 – 300 mm, and in some areas as deep as 1,000 mm (pending salinity and sodicity levels), was recommended. Current inventory indicates a topsoil surplus at DS. However, studies have shown SMU 1 and 2 spoil types have the capacity to support good revegetation outcomes (Baker 2004a; Emmerton 2004); preferential placement of available topsoil to areas of greatest need will be employed to achieve desired closure and rehabilitation outcomes. These outcomes are suitable for the proposed Bushland PMLU at DS.

DS will use dynamic capping material reconciliations and optimisations to identify the best source, haulage routes and locations of capping materials for rehabilitation works, to improve both the understanding and efficiency of capping. Where there are quality limitations for stockpiled growth media or capping materials, targeted amelioration will be undertaken to improve vegetation growth potential. Generally, ameliorants are not anticipated to be required for use with topsoil or SMU1 and 2. Where required, fertiliser and gypsum are key ameliorants that could be added to the soil, to decrease the high ESP and increase the calcium:magnesium ratio of the soils. These two parameters together would increase the stability of any dispersive topsoil and therefore improve rehabilitation success.

3.6.5.2 Landfill

There are no active landfill facilities at DS. Landfill facilities at DCN are used for disposal of DS general waste in accordance with Anglo American Waste Management Mine Operating Procedure and managed in accordance with Anglo American MOP 0017 Landfill Management Mine Operating Procedure (2019). Information on the capping and closure of landfill facilities is covered under the PRCP for DCN.

3.6.6 Water management

3.6.6.1 Water inventory management

The Dawson Water Management Plan informs water decisions on site to ensure adequate storage provisions are made for the collection and controlled discharge of water from the mine area during operations; to ensure that the quality and quantity of water entering the environment is maintained at acceptable levels (Anglo American, 2017).

Water is required on site dust suppression, ore-processing, and potable requirements. Water inputs for DS are sourced from the following:

- Potable water: obtained from the Moura town standpipe and used for drinking water;
- Groundwater: poor quality water generated by the intersection of aquifers during mining; and
- Surface water run-off flows: overland flow of variable quality.

Drainage at DS runs from east to south-west, across operational areas, with active and disused mining voids often disrupting natural water flows. Taking advantage of the natural drainage, mine-affected surface water is directed towards storage dams or disused voids, with the latter offering large storage volumes with very low risk of discharge. Water not impacted by mining is diverted into natural watercourses, unless it is likely to be carrying a high sediment load, in which case it is be diverted to erosion and sediment control structures.

Intersected groundwater and mine-affected surface water that accumulates in voids is pumped via an extensive piping and water containment network from void to void, south to north, into adjacent DCN operations for storage and eventual evaporation in the Dawson North Satellite Pit. There is also a licensed release point (RP-DS03T) from Pit 26/27 into the receiving waters of Dawson River (WRM, 2019). Any mine-affected water releases must comply with release limits stipulated in the EA for DS (Table 3-32).

Table 3-32 Mine-affected water release limits (WRM, 2019).

Quality Characteristic	Units	Minimum	Maximum
Electrical Conductivity	µS/cm	n/a	Variable[1]
pH	pH units	6.5	9.0
Turbidity	NTU	n/a	560
Sulphate (SO_4^{2-})	mg/L	n/a	Variable[1]

Note: [1]Release limits for EC and SO_4 are dependent on receiving water flow

Specific individual capacities, regulations and requirements are outlined in Section 3.6.7.1.2. The total operational storage capacity of water containment structures at DS is approximately 43GL (Red Earth Engineering, 2022).

3.6.6.1.1 Regulated water containment structures

There are no regulated water containment structures at DS.

3.6.6.1.2 Non-regulated water containment structures

Details regarding non-regulated water containment structures and their storage capacity are outlined in Table 3-33. It is likely that some structures will be retained post closure for use in stock water and general water supply, subject to agreements being put in place with relevant stakeholders and

associated water allocations (where required and available). Sediment basins located onsite will be removed and incorporated into the final closure landform.

Table 3-33 DS water containment structures (Red Earth Engineering, 2022; WRM, 2019)

Name	Area (ha)	Storage capacity (ML)	Water type	Drains offsite#	Function
DS Industrial Dam	128.6	600	Non-mine	Yes	Mine-affected water storage
DS MIA Dam (location is on DCN EA)	53.0	47	Mine	Yes	Mine-affected water storage
Pit 25	100.7	39,700	Mine	No	Mine-affected water storage
Sediment Dam C3	97.0	93	Mine	No	Sediment dam
Sediment Dam C4	93.8	182	Mine	No	Sediment dam

All water drainage areas leave site at authorised release points

3.6.6.2 Contaminants of concern

The primary contaminant of concern for water at DS relevant to the execution of closure activities is sediment. Erosion risk is a key consideration when developing rehabilitation and closure plans on site. Contour banks and drop structures are commonly incorporated into rehabilitated slopes. The mobilisation of sediment indicates active erosion processes on the rehabilitated surface, including the removal of topsoil containing the majority of macro and micronutrients needed for revegetation. Deposition of sediment in low energy environments may alter the functioning of the landform design intention.

Average monthly rainfall from Moura and Theodore can be translated to a monthly erosion risk rating which is based on guidance from the IECA Best Practice Erosion and Sediment Control Guideline (IECA, 2008). Refer to Table 3-34for the DS monthly erosion risk.

Table 3-34 DS Monthly Erosion Risk

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Risk Level	Moderate			Low		Very Low				Moderate		

To reduce the impacts of sediment being mobilised, DS follows the DCN Erosion and Sediment Control Plan. The document provides guidance to DS staff and contractors in minimising erosion and the release of sediments to receiving waters. It outlines the principles of management and prevention of erosion impacts as well as a process for development of project specific erosion and sediment controls. It also documents the inspections and monitoring requirements DS use to provide early detection of potential issues and to ensure the controls are working efficiently and effectively.

The other major consideration for aquatic and land receptors is if there is excessive leaching of salinity from the rehabilitated landform. Considerable focus has gone into assessment of the salinity risk, and design of the landform and water regime to mitigate that risk. Details of those studies and associated management strategies, where required, are summarised in Section 3.6.5.

Other contaminant sources of concern have also been explored (see Mine Waste Characterisation Section 3.6.4) such as metals, metalloids, hydrocarbons, ammonia, nitrate and sodium. A list of their trigger investigation levels from the EA detailed in Table 3-35 (DETSI, 2025).

Table 3-35 Release contaminant trigger investigation levels, potential contaminants (DETSI, 2025a)

Quality Characteristic	Trigger Levels (ug/L)
Aluminium	55
Arsenic	13
Cadmium	0.2
Chromium	1
Copper	2
Iron	300
Lead	4
Mercury	0.2
Nickel	11
Zinc	8
Boron	370
Cobalt	90
Manganese	1900
Molybdenum	34
Selenium	10
Silver	1
Uranium	1
Vanadium	10
Ammonia	900
Nitrate	1100
Petroleum hydrocarbons (C6-C9)	20
Petroleum hydrocarbons (C6-C9)	100
Fluoride (total)	2000

3.6.6.2.1 Source, pathway, and fate of contaminants

Potential sources, pathways and receptor or fate of the contaminants are summarised below in Table 3-36.

3.6.6.2.2 Infiltration and seepage intervention and collection controls

There are no infiltration and seepage intervention and collection controls proposed or required at DS.

Table 3-36 Overarching contaminants of concern by source-pathway-receptor

SPR	Issue	Potential for environmental harm	Key interventions and management strategies	Contaminants of concern	Rehabilitation areas / Improvement areas
Source	Saline and or dispersive waste material encapsulated in final landform	Interaction of saline or dispersive material with water resulting in mobilisation of saline or dispersive material and other contaminants	Placement and encapsulation strategy for final landforms	Sediment Salinity Spontaneous combustion Other contaminants	RA2 RA3 IA1
	Point source contaminants from all areas	Mobilisation of sediment, salinity, or other contaminants	Records of contaminants placement on site		RA1 RA2 RA3 IA1
	Airborne dust and odour from the final landform surface	Mobilisation of other contaminants and particulates	Application of a dust suppression agent if a delay between cessation of production and rehabilitation occurs Rehabilitate as soon as available to stabilise surface		RA1 RA2 RA3 IA1
Pathway	Runoff into surface water drainage features	Mobilisation of sediment, salinity, or other contaminants	Monitor water quality of receiving environmental and manage if required	Sediment Salinity Spontaneous combustion Other contaminants	RA1 RA2 RA3
	Seepage daylighting at final landform surface – natural surface interfaces	Interactions between daylighting locations and surrounding surface environment	Monitor for seepage locations and manage if required Monitor water quality of receiving environment		RA1 RA2 RA3
	Runoff into surface water drainage into retention and sediment dams	Mobilisation of sediment, salinity, or other contaminants	Monitor water quality of receiving environmental and manage if required		RA2 RA3
	Airborne particulates that are then deposited	Transport as airborne particulates	Rehabilitate as soon as available to stabilise surface		RA1 RA2 RA3 IA1
Receptor	NUMA voids	N/A	N/A	Sediment Salinity Spontaneous combustion Other contaminants	IA1
	Receiving surface water environment	Impact to sensitive receptors – human or animal, or aquatic ecosystems	Monitor receiving environment and apply EA water quality criteria		

SPR	Issue	Potential for environmental harm	Key interventions and management strategies	Contaminants of concern	Rehabilitation areas / Improvement areas
	Surrounding groundwater system	Pit lake may be permanent sinks or sources, or with interactions with surrounding surface systems No impacts to surrounding or regional groundwater systems or users will occur	Monitor groundwater levels		IA1
	Surrounding surface areas and dwellings	Impact to sensitive receptors – human or animal Undesirable modification to surface systems such as vegetation	Monitor sensitive receptors and dust deposition levels		RA1 RA2 RA3 RA4 RA5 RA6

3.6.6.3 Long term water management requirements

Water management closure plans will focus on containing any mine affected water on site and avoid off-site migration of potential contaminants by managing the mine water inventory and designing voids as sinks. Detailed modelling of the water balance within each void has been completed to predict the long-term water quality and stabilised water levels, and the potential for discharge of water from site (see Section 3.6.10 for further details). Modelling indicates that an uncontrolled release of water is not expected to occur during rehabilitation or closure.

There will be two voids at closure which will retain water and become NUMAs. The details of each retained void and potential storage capacity are outlined in Table 3-37. Long term water quality and water balance modelling has been completed, and outcomes of the modelling are detailed in Appendix 4.6.

Table 3-37 NUMA void catchment and storage

NUMA void	Catchment area (ha)	Maximum surface area (ha)	Storage Capacity (GL)
Pit 25	184	162	62.5*
Pit 28	170	152	56.2*
* Storage calculated from a pit crest of 134m AHD for Pit 25 and 129m for Pit 28			

Any authorised discharge points at the time of closure will be retained during the closure period to cater for unforeseen circumstances or necessary releases during the execution of rehabilitation and closure works program. It is intended that any remaining water licenses will be surrendered following closure, in a yet to be formalised process.

3.6.7 Revegetation Plan

A Revegetation Plan outlining the activities that will occur to establish self-sustaining vegetation that is aligned with the intended PMLUs is summarised below. Revegetation and rehabilitation activities are limited to those areas disturbed by DS activities.

3.6.7.1 Revegetation objectives

The overall objective of revegetation at DS is to return previously disturbed land to their intended PMLU. Intended PMLU and revegetation activities allocated to each Rehabilitation Area are listed in Table 3-17. Additional general revegetation objectives include:

- Rehabilitated areas are geotechnically safe and stable, and are non-polluting;
- Rehabilitated areas are reshaped to support revegetation of plant species known to occur on similar landforms and on similar soils;
- Vegetation is sustained after rehabilitation and closure activities are completed.

Specific revegetation objectives for particular PMLUs are as follows:

- Grazing PMLU - to enhance the grazing capacity through the use of suitable productive and self-sustaining grass species that are adapted to the conditions likely to be experienced within the nominated rehabilitation domains over the long term, thus allowing for productive uses for future landowners;
- Bushland PMLU - to maximise the self-sustaining capacity of the vegetation through the use of plant species native to the region, occurring on similar landforms, and on similar soils, and that are thus adapted to the conditions likely to be experienced within the nominated rehabilitation domains

over the long term. The contribution of revegetation to the safe, stable, and sustainable objectives of slope and surface rehabilitation along waterways is maximised.

3.6.7.2 Reference/Analogue Sites

PMLU for most of DS is intended to be primarily grazing with only small areas intended as Bushland. Re-creation of the original vegetation communities on the newly created land surfaces due to mining would be impossible because of the transformations to hydrology, topography and geology resulting from the mining process. For example, stripping, storage and respreading of topsoil, often on slopes steeper than the original, negatively alters a range of soil properties (e.g. soil structure, nutrients, organic matter, permeability), impacting on the establishment of species and vegetation communities over time.

Revegetation efforts can be guided by the vegetation that has established elsewhere in the region under conditions as similar as possible to those that are anticipated to be experienced within the rehabilitation areas post-mining. That is, vegetation growing on similar landforms, soils and drainage conditions. Such sites are termed reference or analogue sites.

Due to the disturbance experienced at the rehabilitated sites, vegetation and habitat at any natural reference sites will only ever be an approximation to what can be achieved with revegetation at the rehabilitated sites. Hence, reference sites in remnant vegetation can be used for guidance only for the aims of rehabilitation and condition monitoring.

While monitoring sites at the Pit 25 certified grazing area would represent suitable reference sites for the Grazing PMLU (see Section 3.1.4.3), at this stage, no reference sites have been nominated for the Bushland PMLU. However, as noted in Table 3-17, the existing EA of 3 December 2025 contains completion criteria for both Bushland and Grazing PMLUs which are adopted by this PRCP, obviating the need for comparison against reference sites.

3.6.7.3 Plant species selection

It is unlikely that the vegetation communities occurring prior to mining can be re-created on mined land due to the changes in substrate and landforms that have occurred during the mining process. There is therefore no expectation that a specific, recognised regional ecosystem (RE) could be re-created on any previously disturbed surface. However, the Queensland Herbarium Technical Descriptions (Pollock 2018) of REs common to the region and typical of hills and slopes (similar to the waste rock emplacements) have been used to guide the selection of species for revegetation. The relevant REs include:

- RE 11.3.25: *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines. Occurring along the Dawson River and major tributaries;
- RE 11.9.9: *Eucalyptus crebra* woodland on fine-grained sedimentary rocks. Occuring on the ranges east of Dawson Mine;
- RE 11.10.1: *Corymbia citriodora* woodland on coarse-grained sedimentary rocks. Occurring on ranges 15km west of Dawson Mine; and
- RE 11.10.3*: Acacia shirleyi* or *A. catenulata* open forest on coarse-grained sedimentary rocks. Crests and scarps. Occurring on ranges 15km west of Dawson Mine.

The Technical Descriptions provide species lists based on a limited number of sites assessed by the Queensland Herbarium. For example, the technical description for RE 11.9.9 is based on five assessment sites (covering <5ha), while the remnant extent is over 100,000ha. Therefore, many more species can be expected to be common to the REs than are provided in the Technical Descriptions. Species used for future rehabilitation listed in Appendix 4.1 are therefore indicative and other species native to the region may also be used within revegetated sites. The use of native species for both

Bushland and Grazing PMLUs will minimise the risk of exotic species spreading into areas where they are not wanted. Species to be used for revegetation are further determined based on:

- Lists of native species used to date for rehabilitation at Dawson Mine, taking survival rates into account;
- Records of native species listed in the Atlas of Living Australia for a search area surrounding the Dawson Mine, taking in Callide Timber Reserve, Overdeen State Forest, Belmont State Forest, Camboon State Forest, the Shankeen Nature Refuge, Isla Gorge National Park, and Mimosa Park Nature Refuge. Species selected for inclusion are those that occur widely, with multiple records, that are expected to be adaptable to a relatively wide range of habitats;
- A suitability assessment of native species for the types of habitat presented in the rehabilitated landscape, that is, habitat with thin soils, rock armouring and steep slopes as well as habitat on flat or topsoiled land (including ridge tops and valleys);
- The selection of suitable native flora species will considered regulatory constraints relevant to Dawson Mine, the surrounding and post-mining land use concept, and the capacity of the available growth media resources at the time of revegetation to support the selected species. It will allow for a resilient vegetation adapted to the conditions, while providing habitat and grazing values; and
- When selecting species appropriate for use, consideration is given to the original vegetation communities that occurred prior to development, whilst recognising that re-creation of pre-mining vegetation on a newly created land surface would be impossible because of the transformations to hydrology, topography and geology due to the mining and rehabilitation process.

3.6.7.4 Species of conservation significance

No species of conservation significance have been found within the mine's footprint during monitoring to date (Ecological Survey & Management 2014, 2018).

3.6.7.5 Fauna habitat or use requirements

Past and current land use within and surrounding the DS MLs consists primarily of grazing (apart from mining), due to a relatively limited land capability, with some irrigated cropping near the Dawson River water source. However, the MLs, including both undisturbed and disturbed parts, contain definite habitat values. This includes existing habitat, such as the remnant regional ecosystems scattered around the undisturbed parts of the MLs. That habitat will remain post mining. It also includes additional habitat that can and is being created as Bushland PMLU on the post-mining landforms. Rehabilitation and revegetation within these areas can be expected to provide native fauna habitat through the long-term establishment of native trees and shrubs. Habitat for native fauna within the Bushland PMLU is therefore expected to be more complex and diverse, providing habitat opportunities to more fauna species, than that provided by the cleared grasslands occupying the area prior to mining.

Monitoring indicates a total of 326 native fauna species have been identified across the whole Dawson Mine site, including 18 amphibians, 54 reptiles, 196 birds, and 58 mammals (Ecological Survey and Management, 2018). During monitoring in 2005, 2008, 2011, 2014, and 2018, the average proportion of species recorded in rehabilitated monitoring sites was 47% and 53% in remnant sites.

The results of monitoring indicate that the creation of habitat is progressing, through the establishment of native trees and shrubs of species similar to those occurring in nearby undisturbed areas. Slopes on the ex-pit waste rock dumps and low walls into retained voids will provide additional microclimates, adding variation in ground solar exposure, drainage patterns, and, in the long-term, soil formation patterns, providing opportunities particularly for ground dwelling fauna. Ground dwelling reptiles and amphibians can be sensitive to this and likely to benefit from this habitat.

3.6.7.6 Revegetation process and site preparation strategies

3.6.7.6.1 Growth Medium

All topsoil (A horizon) located in areas to be mined is stripped in a one pass operation by scrapers. Where scrapers are not available, topsoil may also be pushed up in rills by dozers. Rills are removed by truck and loader and placed directly on land to be rehabilitated or stored on stockpiles with a minimum of handling to preserve the soil structure. Stockpile dimensions will be dictated by the topsoil material – biologically active topsoil material (stripped to 0.2 m) will be restricted to 2-3 m in height. The volume of growth medium and the number of stockpiles is dynamic, as growth medium is placed on progressively rehabilitated land. A growth medium inventory is maintained based on survey pick-up. To avoid contamination with B horizon material, which renders the A horizon material unusable, stripping will occur on dry days only, and when visibility is good. Stripping at night is only undertaken when this is unavoidable and when the risk of contamination is acceptable.

Typical topsoil depth is 150mm (stripping and placement).Topsoil is allocated to the most critical areas as determined during spoil characterisation, including primarily Type 3 and 4 spoils, but also long outward facing slopes on Type 2 spoil that are to be vegetated with grass to be amenable to other surrounding land practices. Topsoil has also been placed in strips across the contour, alternating with bare spoil, to extend the use of topsoil.

Before placement, topsoil is analysed for nutrient deficiencies and other defects. Treatments include application of fertiliser and gypsum.

After placement, soils are ripped by dozer along the contour or, if engineered drainage lines are included, on a shallow grade. Ripping depths are at least 300mm, depending on the type of spoil, depth of topsoil, and type of equipment available. Where dozers are unavailable, tractors may be used for shallow scarifying.

3.6.7.6.2 Seeding and Fertilising

A vegetative cover is established to stabilise the substrate and to generate a productive PMLU. Stabilisation is the prime concern directly after placement of topsoil, which is best achieved with stoloniferous grasses. Annual seeding mixtures are developed from the target flora species. Application rates range from around 6-10kg/ha or more for Bushland PMLUs and 20-30kg/ha for Grazing PMLU, depending on site requirements, with drainage lines and berms receiving a heavier application of seed and fertiliser compared to broadacre slopes.

In addition, a suite of shrub and tree species native to the region have been selected to complete a self-sustaining vegetative cover (Attachment 3 and 4 in Appendix 4.1). This list of species consists of species selected from REs common to the region. Species selected for inclusion are those that occur widely, with multiple records, that are expected to be adaptable to a relatively wide range of habitats. Several of these species are already growing successfully at DS. The actual seed mix used will depend on requirements of the target area, PMLU, sowing season, and seed availability.

Seed is procured from commercial suppliers together with certification of germination and purity to acceptable standard. Seed is ordered ideally 4-6 months in advance to maximise the availability of desired seed when required for sowing. As many native species seed irregularly, longer term orders (up to five years in advance) are considered to ensure that desired seed can be collected by the suppliers when target species are seeding in abundance. Seed is stored for as short a period as possible before use, and for a maximum of two years, at low humidity and temperatures.

Seed treatment varies depending on the nature of the seed and application. Seed may need to be treated with smoke or hot water, although seeds sown by a dozer will need to be dry for handling. Aerially applied seed that are light in weight (e.g. Eucalypt) are best coated to avoid drifting from the target area by air flow. Seeds may be coated with fertiliser, rhizobium inoculation (legumes), or insecticides to prevent predation by ants.

Seeding is typically delivered by dozer mounted seeder, with fertiliser via spreader. Fertiliser application depends on site and substrate characteristics, choice of plant species, and PMLU. In some instances alternate seeding and amelioration methods may be used, for example, aerial/drone application, hand seeding etc.

Where possible, seeding is scheduled to coincide with the onset of the coming wet season from November to March, preferably after at least one rainfall event, as this ensures antecedent soil moisture and minimises growth medium loss (through wind erosion). Due to climatic conditions this may not be achievable, however the intent is usually to have seed spread pre-December each year.

3.6.7.6.3 Seed sourcing

Seed is sourced from reliable suppliers with evidence of appropriate seed analysis quality control reports detailing particular species seed count / purity and viability / germination levels. Ongoing investigations and analysis may be undertaken of acceptance levels of species required, species identification verification and pre-treatment and pelleting options.

Native plant seed will be sourced locally where practicable to optimise results as local provenance will be more suited to establishment and survival under local climatic and soil conditions. Locally sourced propagules will also prevent genetic pollution of local or regional species.

3.6.7.7 Revegetation maintenance

3.6.7.7.1 Weed and pest management

DS conducts weed management consistent with the local shire (Banana Shire) weed strategy for management of any identified and controlled weed species recorded on the site. Management of animal pests is also undertaken in accordance with the local shire pest strategy, and in accordance with feral animal control priorities of relevance to the local community.

At closure, the noxious weed eradication program will continue across the DS areas to ensure identification and eradication of noxious weeds at each stage of growth, as required to meet proposed completion criteria. DS will also continue pest management activities at closure with an objective to keep pest animals at low density, to protect landscape values.

3.6.7.7.2 Fencing

Grazing paddocks may be established where suitable, such as on gentle sloping surfaces. Fences will be required to manage livestock, in particular to exclude livestock from areas incompatible with grazing (such as Bushland PMLU, or newly establishing revegetation) and to facilitate stock rotation management practices. Fencing will consist of standard stock fence or no-climb stock fence.

3.6.8 Tailings Storage Facilities

3.6.8.1 Characterisation of tailings

Ore processing is not undertaken at DS, and as a result, no tailings are generated. All tailings generated from DS ore will be directed to Dawson North Cell 3 in DCN after processing.

Characterisation of tailings is discussed in the PRCP for DCN.

3.6.8.2 Design of tailings storage facilities

Ore processing is not undertaken at DS, and as a result, no tailings storage occurs at the site. All tailings generated from DS ore will be directed to Dawson North Cell 3 in DCN after processing.

The design of those TSFs is discussed in the PRCP for DCN.

3.6.9 Voids

A void closure plan has been developed for DS and the key considerations provided in the sections following.

3.6.9.1 Design philosophy

The guiding best practice principles of void rehabilitation are (Klohn Crippen Berger, 2024):

- minimise residual void size and depth by backfilling and/or maximise any potential future use of the area, where this can be done in a manner that ensures public safety;
- render the void safe and stable, such that it does not cause environmental harm and is able to sustain the post-mining land use approved in the PRCP, i.e. posing no environmental, safety or health risks; and
- develop a solution that is sustainable and does not require intensive ongoing management, such as ongoing water treatment.

At DS there are two final voids, Pit 25 and Pit 28, that require consideration. These voids vary in depth, shape, groundwater interaction, and surrounding land use interaction. These guiding principles have been used, in conjunction with the site-specific conditions for each void, to determine rehabilitation scenarios.

In general, the following is proposed:

- Voids will be isolated from floodplains by constructing permanent landforms between the void and floodplain. All voids at DS have at least 0.1%AEP flood immunity;
- Low walls will be reshaped to achieve a gradient that is erosionally stable. The gradient is calculated based on the spoil properties within the void and the drainage network density;
- No highwalls will be retained on the mine site;
- Coal seams in the void will be managed in a way that minimises spontaneous combustion. Generally, coal seams with a low propensity to combust do not require any treatment, and coal seams with a medium or high propensity to combust will be covered by spoil. The proposed highwall reshaping will generally provide this cover; and
- Void dimensions will be minimised as far as practical. This is achieved through a combination of in-pit placement during mining, and then extensive reshaping during rehabilitation.

The two final void designs will be influenced by the behaviour of water within the voids. The void design is a function of the reshape activities proposed during rehabilitation, and its setting in the landscape.

This reshape allows for the formation of a pit lake within the voids and designed in such a way that it is safe and stable but due to site constraints, cannot support a post mining land use, making it a NUMA. Both Pit 25 and Pit 28 will be NUMA voids at DS.

3.6.9.2 Void size

The final void dimensions have been minimised as far as practical. This is achieved during mining through in-pit placement of backfill and spoil. The final landform of the two final voids has been achieved by optimising the location of final spoil stockpiles, and backfilling the voids with spoil where the mining method and schedule has allowed.

The remaining NUMA sizes have been tabulated below.

Table 3-38 NUMA Pit Sizes

Pit Name	Mine Section	Max Surface Area (ha)	NUMA area (ha)*
Pit 25	Dawson South	162	76.7
Pit 28		152	91.7

Reshaping activities of existing stockpiles are already underway at DS, with the objective of making them safe and stable and maximising land use potential.

3.6.9.3 Void stability

Where a void is to remain during or after rehabilitation, human and animal safety is a concern. Voids can present a physical hazard because of relatively steep walls and potentially unstable horizontal benches and inclined ramps. Other hazards may result from coal left in the walls, mine waste disposed of in the void and water in the void or seeping from the void. Slopes within voids need to be left stable, which may require the flattening of unstable lithological units, most commonly the upper weathered zone. No highwalls will remain in the DS final landform.

To confirm void stability, a stability analysis was completed on Pit 25, the largest of the two proposed voids (Table 3-39). Given the similarities between the two pit voids, Pit 28 is also anticipated to also have adequate geotechnical stability. Similarities between the two pits relevant to the FoS assessment included:

- Pit 25's final void depth of 88 bgl compared with Pit 28's final void depth of 94 bgl.
- A minimal difference in medium equilibrium levels of pit lakes only ranging in depth from 2 – 6 mAHD for all modelled scenarios.
- The lack of identified major geological structures in both pit voids, suggesting that weathering on highwalls and endwalls was unlikely to penetrate deeply enough to cause geotechnically significant surface fretting.
- Any physical weathering such as slaking has the potential to occur (to some depth) in dumped spoil is considered to be accommodated by the reduction in strength parameters used the geotechnical stability assessment for Pit 25.

The designed minimum factor of safety >1.5 was achieved across all closure scenarios (full pit lake, intermediately full pit lake and dry void). The factors of safety calculated for each section and void are outlined in Table 3-39. A geotechnical cross section used for the analysis of each of the voids is provided in Figure 3-27.

Table 3-39 Factors of Safety for pit 25

Location and Scenario	Minimum Factor of Safety
Pit 25 South Low wall	
Dry Void	3.62
Intermediate pit lake	2.99
Long-term pit lake	2.93
Pit 25 South high wall	
Dry Void	3.12
Intermediate pit lake	2.12
Long-term pit lake	2.42

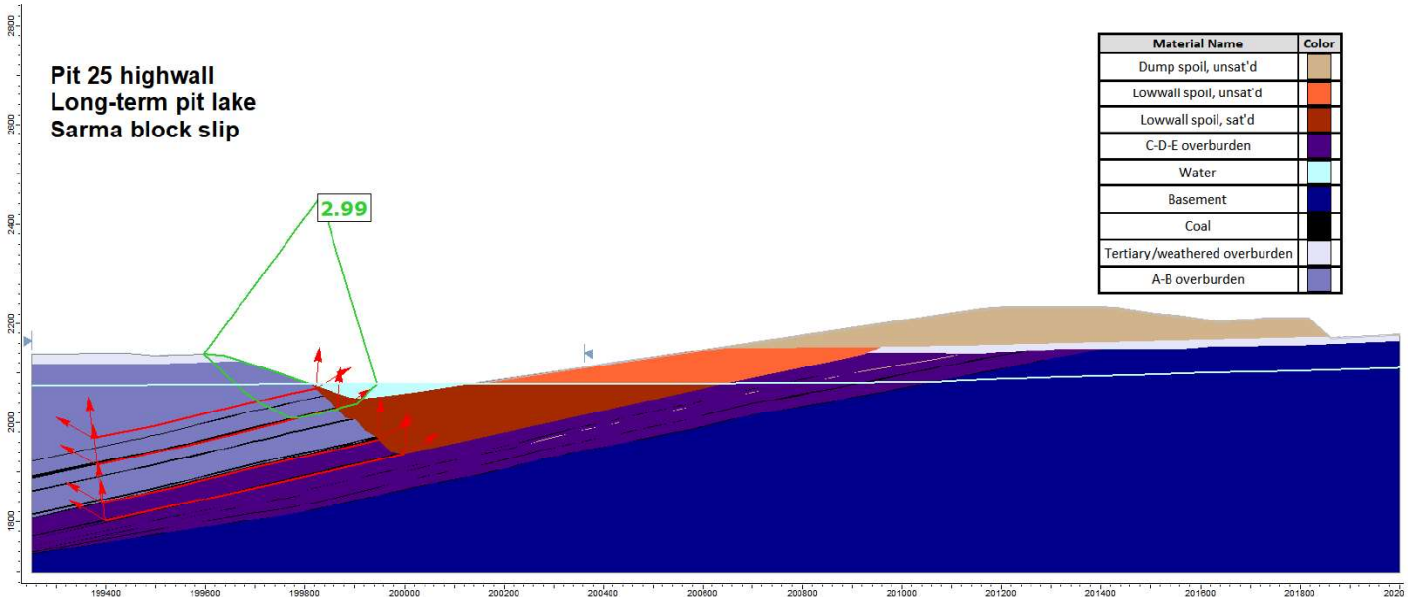


Figure 3-27 Stability analysis of a cross section across Pit 25

Low walls will be reshaped to achieve a gradient that is erosionally stable. The gradient is calculated based on the spoil properties within the void and the drainage network density and acceptable erosion rates.

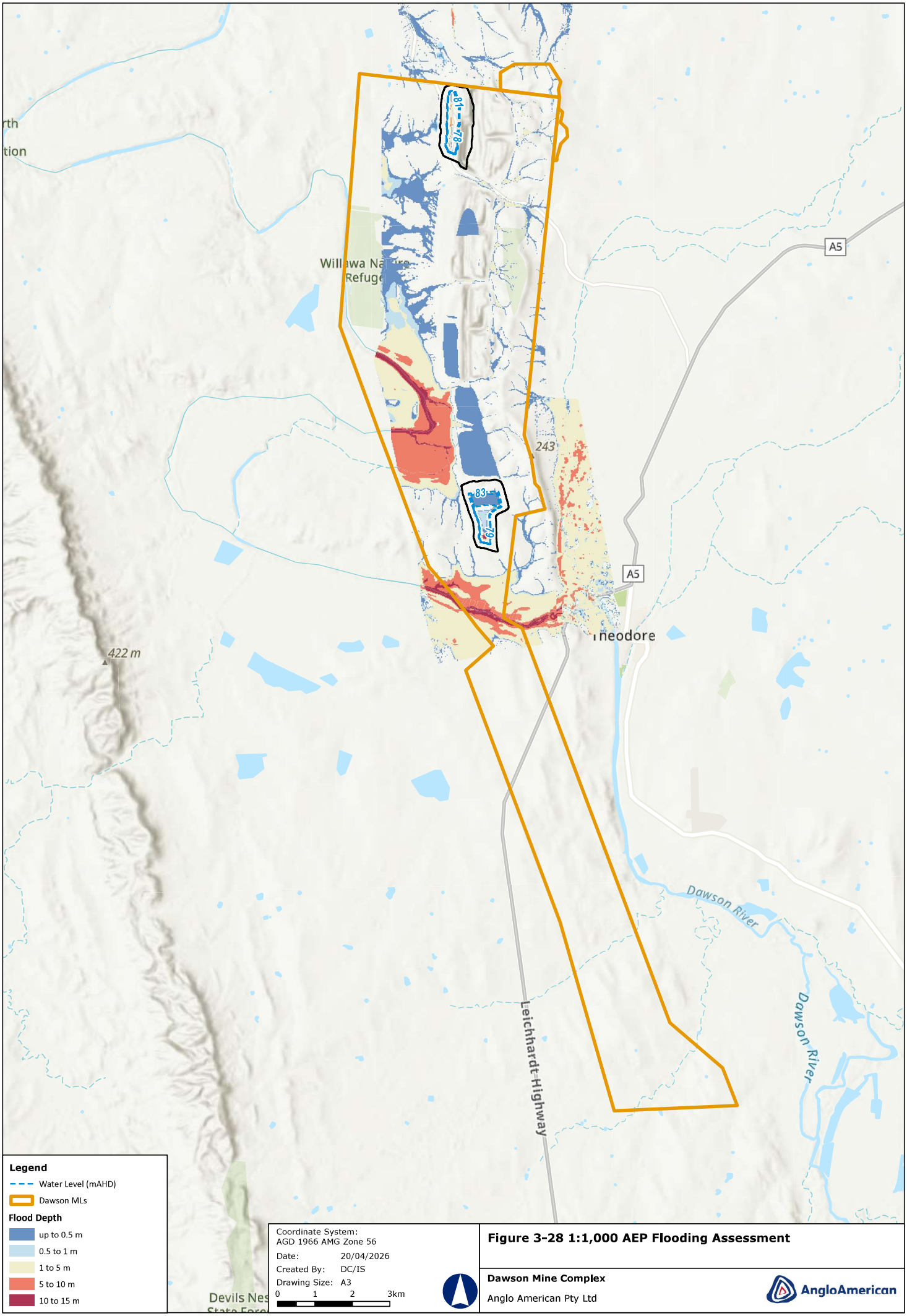
3.6.9.4 Surface water interaction

The final voids are isolated from floodplains by constructing permanent landforms between the void and floodplain. A two-dimensional flood model has been developed for the whole site and used to assess and design permanent landforms around voids (Appendix 4.4).

The flood model was used to assess the volume of water which falls during precipitation events for both current and climate change scenarios over a range of Annual Exceedance Probability (AEP) scenarios. For both voids at DS there is no interaction between flooded watercourses and the voids for events up to and including the 0.1% AEP flood event under both current and climate change scenarios (Figure 3-28; Appendix 4.4).

Most voids have a small local catchment with minor contributions from local drainage features. The final landforms have been shaped to divert surface water flow away from the voids. This is principally to reduce erosion of the final landform to ensure the voids remain safe and stable into perpetuity (Appendix 4.4).

None of the voids at DS interact with defined “watercourses” under the *Water Act 2000* (Qld).


A5
A5
243
422 m
Dawson River
Dawson River
Leichhardt Highway
Legend
Water Level (mAHD)
Dawson MLs
Flood Depth
up to 0.5 m
0.5 to 1 m
1 to 5 m
5 to 10 m
10 to 15 m
Coordinate System:
AGD 1966 AMG Zone 56
Date: 20/04/2026
Created By: DC/IS
Drawing Size: A3
0 1 2 3km
Figure 3-28 1:1,000 AEP Flooding Assessment
Dawson Mine Complex
Anglo American Pty Ltd
AngloAmerican

3.6.9.5 Groundwater interaction

The outcome of the groundwater model indicates the final pit voids will maintain a lower water level than the surrounding groundwater system, therefore remaining to be groundwater sinks.

An assessment has been undertaken of the potential for water within the final voids to impact on the adjacent groundwater system (Appendix 4.5). The most likely conduit for the flow of water from the final voids to the adjacent groundwater system is the base of Tertiary/Quaternary sediments. This is due to the relatively highly hydraulic conductivity of this formation in comparison to the surrounding siltstone, sandstone and mudstones of the Permian Formation. The coal seams present in voids may also act as conduits for groundwater flow. However, any exposed coal seams will be backfilled/blocked with spoil prior to submergence, which will reduce potential groundwater flows through these formations.

Relatively high groundwater inflow rates have been reported during mining, associated with the intersection of joints and/or faults and shear zones. However, the storage within the fracture systems is relatively low and initially high rates of inflow tend to be short-lived. As mining progresses, it is conceptualised that ongoing inflow from faults and fractures will tend to be related to localised recharge to the dilated zone that surrounds each pit (due to relaxation of the strata towards the void and subsequent opening of faults/fractures that act as conduits for localised recharge at the pit crest or from water contained within spoil). The voids will be geotechnically mapped at the conclusion of mining and any faults of geotechnical structures of significance noted. If any fractures of faults are present in the final void walls, it is not expected these will provide extensive low-conductivity conduits for flow post closure.

3.6.9.6 Pit groundwater inflows

The post-closure groundwater inflow flux was estimated for a range of void lake elevations, from the maximum inflow rate when groundwater levels are at the base of the pit (lowest), to the pre-mining groundwater level elevation where no groundwater inflow is observed (representing steady-state or equilibrium conditions).

Final void elevations were simulated using the current Dawson water balance model (in GoldSIM), as part of the surface water assessment and presented in the figures below. This water balance incorporated all contributing fluxes to the voids, including the estimated groundwater inflow from this numerical model assessment.

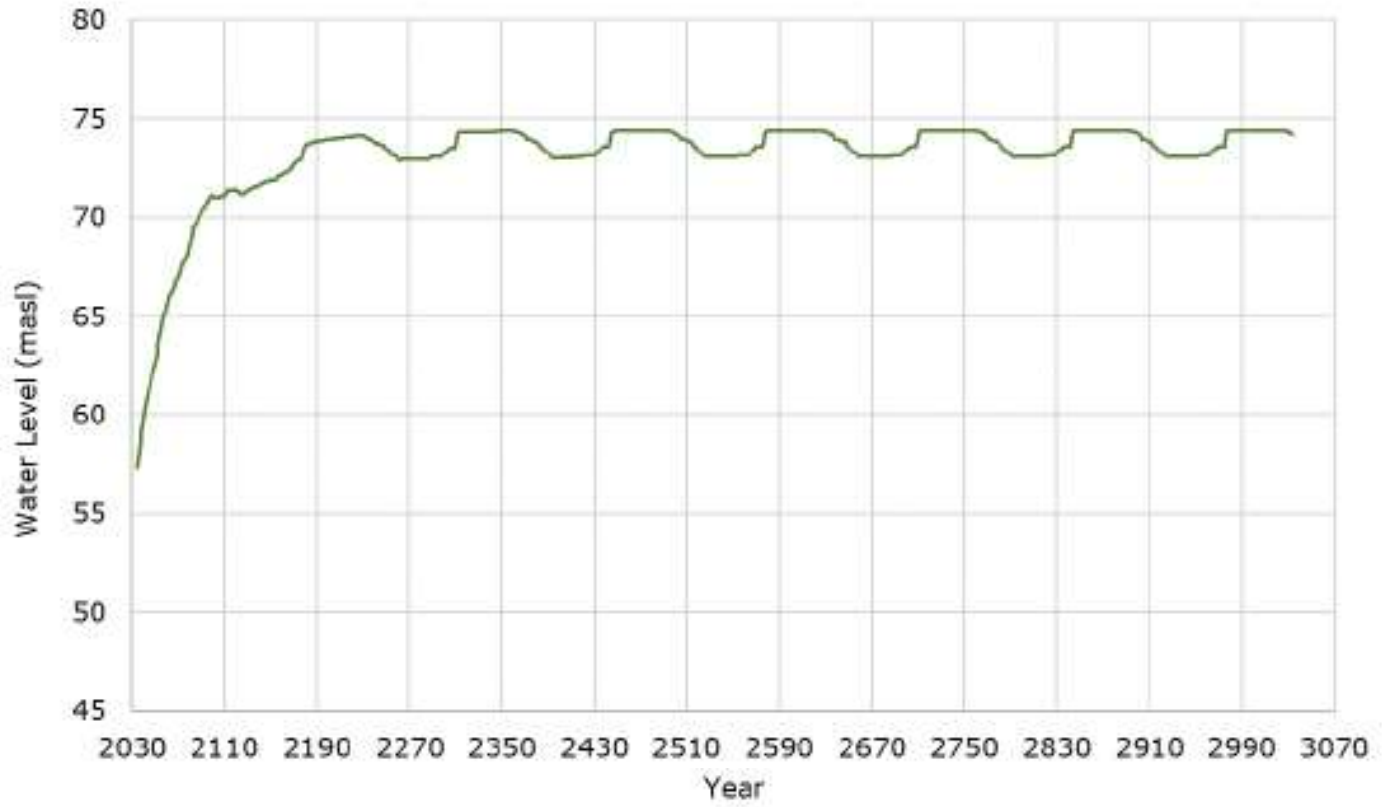


Figure 3-29 Pit 25 Predicted Void Water Levels

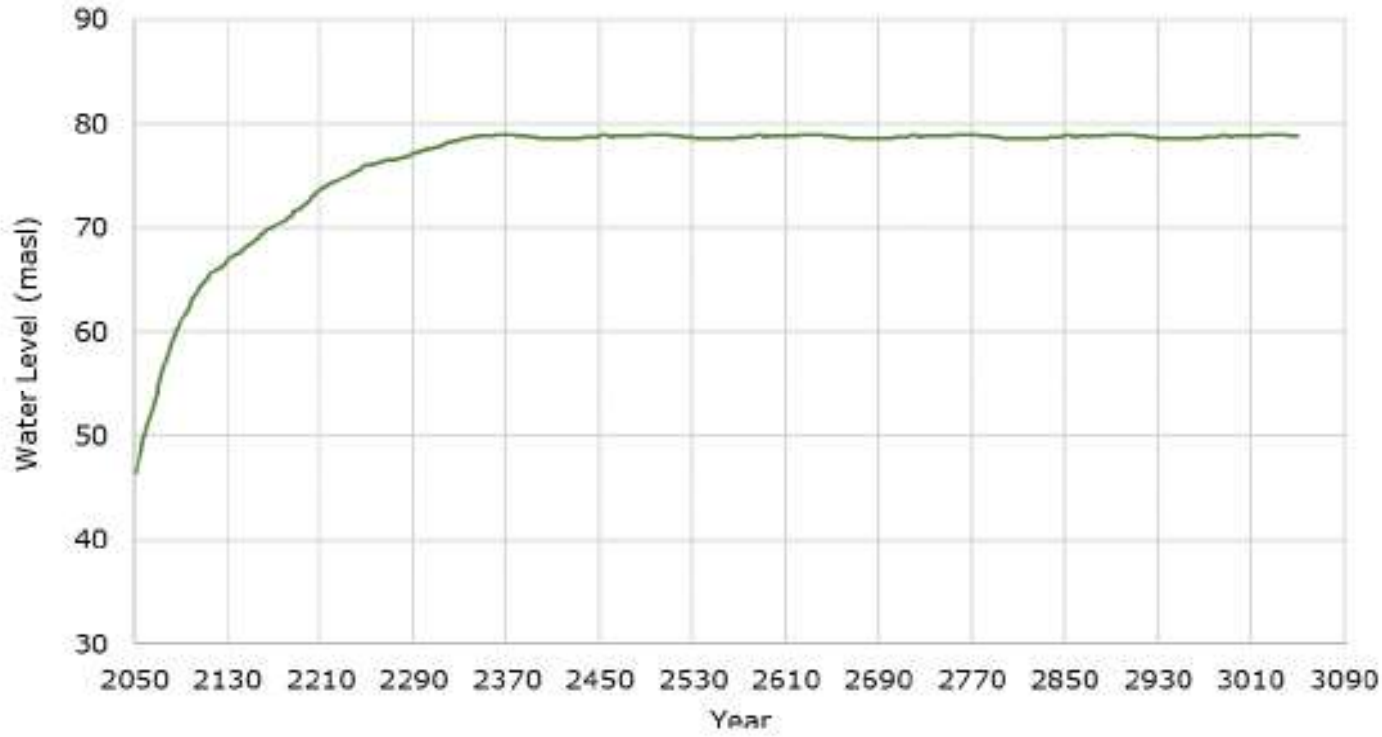


Figure 3-30 Pit 28 Predicted Void Water Levels

3.6.9.7 Pit lake formation

The two voids at DS will be backfilled with variable volumes of spoil. However, the amount of spoil available is not sufficient to return the landform to its original elevation. As such, pit lakes will form in the depressions, and become a permanent feature of the landform. The backfilled spoil in the voids will have an impact on the water level recovery following mining, as water will initially accumulate in the spoil rather than the open void. The spoil/storage relationship has been estimated based on the total pit shell area (mine floor levels and completion of mining) and the final landform level. A porosity of 0.4 was adapted for the spoil which is consistent with measurements taken at Dawson and other mines in the Bowen Basin (ACARP, 2021). The porosity and spoil/storage relationship have been included in the water quality; water balance modelling used to inform long term conditions of the pit lakes (Appendix 4.6).

There is considerable scope for the mine and rehabilitation design to influence the water quality and level that forms in the two pit voids to achieve the best outcome in terms of extent and quality. Reshaping the spoil within the void can alter the water balance.

The formation and behaviour of pit lakes with voids at DS was assessed using several tools and have been considered in the following technical studies; all of which have informed the conditions of the permanent pit lake.

- Flooding Assessment - Appendix 4.4;
- Groundwater Assessment – Appendix 4.5; and
- Water balance and water quality model – Appendix 4.6.

The main contributions to these pit lakes include surface water runoff from the reshaped ramps and dump lowwalls, direct rainfall and groundwater inflows. The main losses are from evaporation and some minor groundwater seepage. A water balance model was used to predict the formation of pit lakes, including the time to achieve a steady state water level and its quality over time. These pit lakes may be a groundwater source, a groundwater sink, or may alternate between the two depending on climatic influences.

The final predicted steady state pit water level for Pit 25 is 78m AHD, which is approximately 62 metres below the crest of the void. The final predicted steady state pit lake level for Pit 28 is 80 m AHD, approximately 60 metres below the crest of the void (Table 3-40). The water level in each void is well below the crest, showing there is no interaction with the receiving environment. Flood modelling of extreme flooding events (1:10,000 AEP events) show the Dawson river flow could interact with Pit 28 (Appendix 4.4). Given the water volumes and flow rates expected to the present in the Dawson River during an event of this size, no contaminant transport or other modelling is warranted.

The variability of fill times between the voids are a function of the interaction between key variables such as the catchment area (and subsequent runoff contribution) relative to final void storage capacity. Active dewatering of the groundwater table to allow for mining operations is likely to affect the timing and recovery of the regional groundwater table, and subsequent filling of the voids with water. Additionally, the reshaping of stockpiles and local catchment areas will also affect the timing of the pit lake formation. The scheduling and mining of each of the voids has been considered in hydrogeological modelling (Appendix 4.5).

Table 3-40 Final Equilibrium Level Results Summary for each void

Void ID	Equilibrium Level (m AHD)			Min Freeboard to Surface Overflow RL (m)	Overflows to Receiving Environment (Y/N)	Estimated Time to Reach Equilibrium (Years)
	Min	Median	Max			
Pit 25	76	78	81	62	No	320
Pit 28	79	80	83	60	No	120

3.6.9.8 Pit lake salinity

Salinity is the key water quality indicator of relevance to voids remaining in the landform at DS. The spoil within voids has the potential to release salts into the void water in addition to groundwater with high salinity contributing to the void waterbody. The voids subsequently have the potential to accumulate salts through evapo-concentration of the waterbody.

The water quality in the two voids remaining in the DS landform has been modelled over time and suggest both lakes will become saline (Table 3-42).

This is due to the salinity of groundwater contributing to the void and the evapo-concentration effects on the waterbody itself (evaporation far exceeds rainfall - Section 3.1.1.2). Dilution effects from direct rainfall and surface water inflow are small due to the relatively small catchment area of the voids.

The salt generation rate from spoil, runoff and groundwater has been assessed by:

- Quantifying the salt generation rate from spoil, runoff and groundwater using:
  - Monitoring of existing pit lakes;
  - Monitoring of source waters including rainfall and groundwater; and
  - Operational water balance model calibration
- Conducting a salt balance for pit lake

Groundwater quality was collected from the recently installed monitoring bores in DS over the period March 2021 and February 2023 and provide an indication of the groundwater quality in the vicinity of the pits. The average EC for the relevant geological horizons likely to contribute to the pit void are:

- Alluvium – 3665 µS/cm
- Permian Coal Measures – 5,420 µS/cm

Conservative water quality inputs were used to inform the water quality and balance modelling (Appendix 4.6). A summary of the water quality inputs is provided in Table 3-41 below.

Table 3-41 Water quality inputs into the GoldSIM model

Water Type	TDS (mg/L)
Runoff	
Pit surfaces	6,000
Spoil surfaces	6,000
Rehabilitated spoil	4,000
Other sources	
Direct precipitation	30
Groundwater inflow	8,000

It is possible existing groundwater monitoring bore locations may not be optimal for determining the likely contribution of groundwater to the proposed final landform voids. Additionally, geological faulting and structures intersecting the area could lead to compartmentalization of groundwater, resulting in the water quality of the bores being monitored not necessarily being representative of future pit water quality.

The salt source terms were coupled with the pit lake water balance model to generate salinity predictions for each pit lake. The results are summarised in Table 3-42 comparing the time to reach steady state water level and the TDS predictions after 100 years. It is important to note that the time taken to reach steady state water levels is expected to decrease for Pit 25 under climate change scenarios due to heightened evaporation rates, while similar or longer periods are anticipated for Pit 28 due to the lower surface area to volume ratio.

Table 3-42 Time to Steady State and EC Predictions after 100 years

Void ID	Estimated time to reach steady state water level (Years post closure)	TDS after reaching steady state water level
Pit 25	320	45,000
Pit 28	120	15,000

It is widely observed that the salt concentration of runoff from spoil reduces over time as rehabilitation becomes more established and the initial flush of mobile salts are removed from the leachable flow paths. A number of studies into the decay curve have been conducted for Bowen Basin spoil such as Jain (2001) and Edraki *et al* (2019).

Based on the outcome of the water quality assessment at Pit 2C West at DCN, simulation results indicated with the inclusions of an external catchment and the inclusions of an appropriate abstraction rate from the void, the pit can be used as a long-term water management and supply source if required (KCB 2020).

3.6.9.9 Limnology

The behaviour of water in the pit lake is dependent on the climatic drivers, water sources and quality and void geometry. Wind, temperature and rainfall are the dominant meteorological drivers that have the greatest effect on the stratification potential of water bodies predicted to form in Pit 25 and Pit 28. These factors are seasonally variable and have varying degrees of influence throughout the year.

The assessment approach of the limnology of water predicted to remain in the voids at DS is based on a study to investigate the options to improve water quality and ecological functioning of 2C West Pit Lake located in DCN. The study was undertaken to potentially mitigate some of the impacts associated with deep strip mining that occurs below the water table. Anglo American commissioned Stantec, to undertake a desktop review and environmental risk assessment in 2020 that contributes to the understanding of aquatic biota values associated with the 2C West pit post mining.

The following two closure scenarios were compared to the existing void condition:

- **Scenario 1** - based on output of the pit lake geochemical model, with no active mitigation to manage evapoconcentration and deteriorating water quality in the pit void over time; and
- **Scenario 2** - based on output of the pit lake geochemical model, assuming additional external catchment (~1000 ha) will be diverted into the void and constant pumping (7 L/sec) out of void water to reduce salt accumulation in the pit void over time.

The existing void water quality data (Nov 2019) was compared against ANZG (2018) Default guideline values (DGVs) and summarised as follows (Figure 3-31):

- The water level at the time of bathymetric survey was 58.73 m AHD (ALS 2019).
- the mine void was stratified with a prominent thermocline (distinct temperature layer), with the separation of waters below 10 m in depth from surface water. Water temperature was consistent at 26 ˚C to 5 m depth, showing a gradual decline to approx. 19.5 ˚C at 12.5 m depth and below.
- The pH ranged from 8.32 to 8.55, classified as alkaline (>7.5), exceeding the upper limit of the ANZG (2018) 95% DGV (pH 8.0). High alkalinity levels suggest a good buffering capacity against changes in pH.
- Salinity, measured as EC, ranged from 6630 µS/cm to 7040 µS/cm, classified as hyposaline (Hammer 1986). Salinity exceeded the ANZG (2018) 95% DGV (900 µS/cm). There was a prominent chemocline (salinity change), with surface water electrical conductivity (EC) approximately 7200 µS/cm to 6 m depth, showing a gradual decline to approximately 6150 µS/cm at 15 m depth and below. The dominance of cations followed Na>Mg>Ca>K. Anion concentrations were greatest for SO_4 compared to Cl.
- Nitrogen nutrient levels (N-NOX) exceeded the ANZG (2018) 95% DGV which suggests potential for eutrophication. No data were available for total or soluble Phosphorus.

Although no monitoring data were available for dissolved oxygen (DO) or turbidity, historic data for other Dawson mine pit lakes provide insight into likely concentrations (Ecoserve *et al.,* 2005, Austecology *et al.,* 2008, Young *et al.* 1999). A summary is provided below:

- DO saturation within the surface layer was >5 mg/L, however, major declines were observed below 3 to 5 m depth, with middle and bottom layer anoxic. It is likely that similar stratification of 2C West Pit Lake also occurs.
- Turbidity ranged from approximately 8 to 50 NTU, which suggests increased water clarity in the upper layer, and resuspension of accumulated organic material and/or sediments at depth.

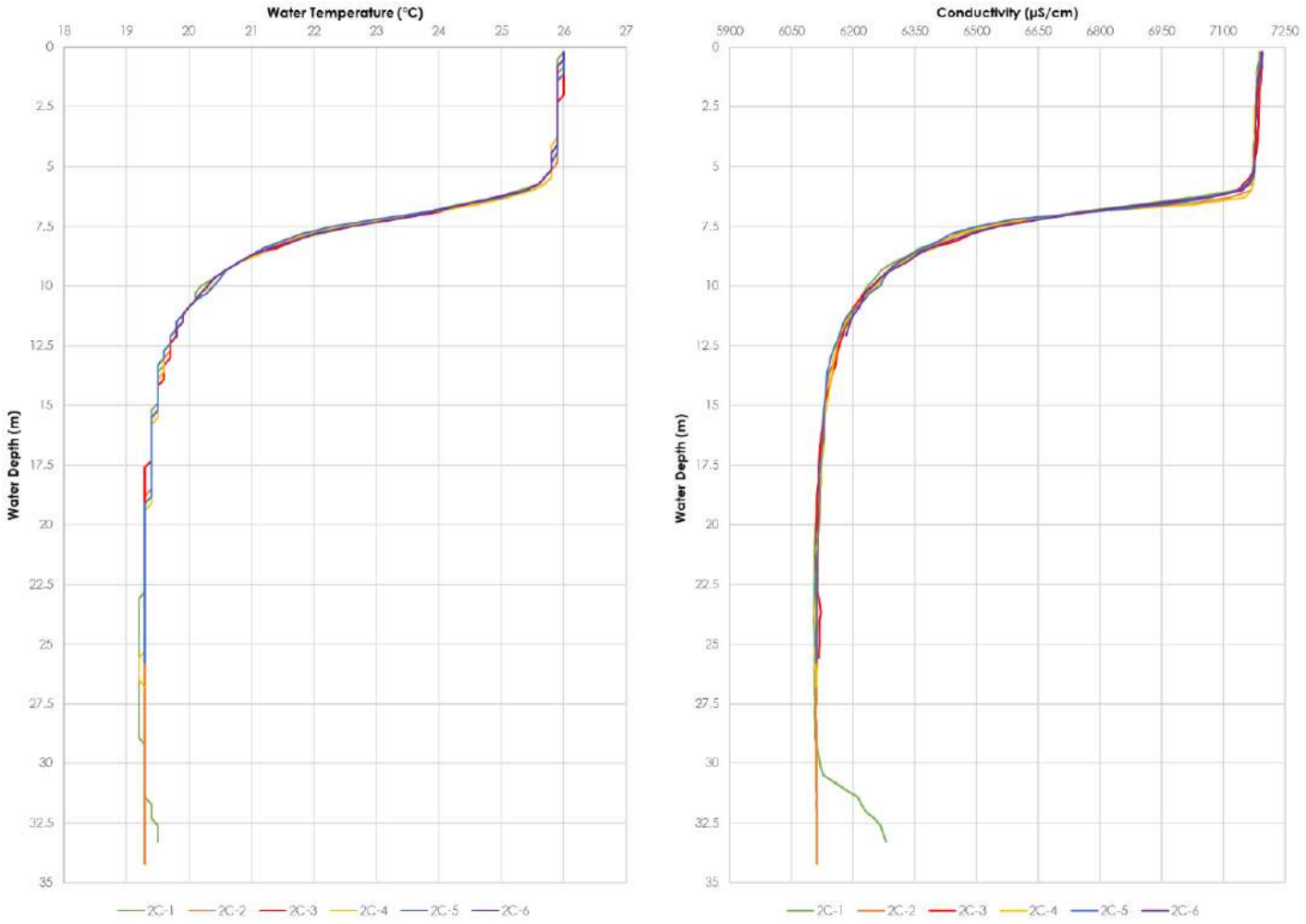


Figure 3-31 Vertical profile data for the water temperature (left) and salinity (right) recorded from six location in 2C West Pit Lake in November 2019

Under Scenario 1, with no active mitigation to manage evapoconcentration effects in 2C West Pit Lake post closure, water levels and quality will change over time as follows:

- Water level in the pit will decline steadily, only reaching partial equilibrium at approximately year 70 with the elevation approximately RL 32 m and RL 30 m for low and high evaporation cases and represents a decline in water level up to 28 m post closure. At this point, the pit acts as a sink for groundwater and surface water runoff from the surrounding catchment (KCB, 2020).

- Evapoconcentration will result in a near linear increase in salinity post closure, with TDS concentration at year 100 representing close to a five-fold increase with the concentration approximately 22,500 mg/L and 24,000 mg/L for low and high evaporation cases, respectively. Final void salinity would be classified as mesosaline by Hammer (1986).

Under Scenario 2, with the implementation of two strategies to mitigate water levels and quality; the provision of additional external catchment (approximately 1,000 ha) and constant pumping (7 L/s) out of void water to manage evapoconcentration effects post closure, water levels and quality will change over time as follows:

- Water level decline in the pit will be variable, between the low- and high-evaporation cases;

- For the low evaporation case, water level in the pit will decline gradually reaching partial equilibrium at approximately year 20, until year 40 where a more rapid decline is observed until approximately year 70. Water levels will continue to decline gradually reaching another partial equilibrium at approximately year 85 onwards. Predicted final void water level elevation is approximately RL 37 m;

- For the high evaporation case, water level in the pit will decline more rapidly, although will reach partial equilibrium at approximately year 20. Although a slight decline in water level will be observed around year 70, predicted final void water level elevation will be relatively stable, at approximately RL 40 m;

- Evapoconcentration has a negligible influence on salinity post closure, with predicted mean TDS concentrations relatively stable, increasing to approximately 5000 to 6000 mg/L under low and high evaporation cases, respectively. It should be noted that for the high evaporation case, there will be a degree of variability in predicted TDS levels, with the 95th percentile occasionally exceeding 7000 mg/L from approximately year 85 onwards. Final void salinity will be classified as hyposaline (Hammer, 1986); and

- Geochemical modelling outputs over the modelled salinity range (4585 to 8015 mg/L) indicate:

    - The pH will be circumneutral (7.66) to alkaline (8.46). The maximum predicted pH (8.46) exceeds the ANZG 95% DGV.

    - Void water has good buffering capacity with total-alkalinity (as CaCO3) ranging from 472 to 605 mg/L.

    - Nitrogen nutrients in the form of nitrate levels are low.

    - Dissolved metal concentrations remain low, however, there is potential for boron (mean 0.52 mg/L) and selenium levels (mean 0.006 mg/L) to exceed their respective ANZG (2018) 95% (0.37 mg/L) and 99%1 DGVs (0.005 mg/L).

The Stantec 2020 assessment highlights the following regarding the pit lake chemistry:

- pH - Modelling of the 2C West Pit Lake indicates that conditions are expected to remain circumneutral to slightly alkaline. This suggests direct low pH and associated direct and indirect impacts to aquatic biota are unlikely to occur post closure. Void water also has good capacity to buffer (or resist) changes in pH. Therefore, the risk ranking was Low.

- Salinity - Without intervention, the salinity in the void will continue to increase as the rate of evaporation exceeds the dilution effects of local run-off and rainfall. Evapoconcentration results in an elevated salinity under Scenario 1, at approximately 22,500 mg/L to 24,000 mg/L under low and high evaporation cases, respectively. This will exceed the known salinity tolerances of stenohaline but not euryhaline taxa. The 2C West Pit Lake under this scenario is likely to support only the most salt tolerant taxa post closure. Therefore, the risk ranking was Critical**.**

- Dissolved Oxygen - There is a high knowledge gap of impact predictions due to the absence of DO saturation data for the 2C West Pit Lake. However, historic vertical profiling data for other pit lakes associated with the Dawson Mine (Ecoserve et al. 2005, Austecology et al., 2008, Young et al. 1999), together with the thermal stratification evident in 2019, suggests the epilimnion (surface layer) is well oxygenated, while the hypolimnion (bottom layer) is anoxic.

There is also limited mixing potential in the 2C West Pit Lake, given the steep pit walls, water depth (approximately 40 m), and low surface area. However, changes can occur during rainfall and storm events when water mixes, which may result in anoxic conditions throughout the pit lake. This adversely effects aquatic biota and most notably can result in fish deaths. Mixing events of sufficient magnitude to cause anoxic conditions are considered unlikely. Therefore, the risk ranking was Medium.

- Nutrients - Nitrogen and phosphorus are essential nutrients for the growth of primary producers (ANZECC/ARMCANZ, 2000). Generally, phosphorus is the nutrient limiting algal and plant growth in freshwater environments, however, as salinity increases, this shifts towards nitrogen (Enell et al. 1995). Conversely, excessive nutrient input is associated with eutrophication, which can degrade aquatic environments (ANZECC/ARMCANZ, 2000).

  Although there is a medium knowledge gap of impact predictions due to the absence of phosphorus data (total and soluble), existing and predicted nitrogen concentrations are mostly below levels of concern up to salinity 8,000mg/L. Nutrient levels are unlikely to change seasonally due to limited inputs and current landform design. Therefore, the risk ranking was Low.

  Low nutrient availability has potential to limit primary production (algae, diatoms, aquatic plants) and food availability for higher trophic levels (i.e. aquatic invertebrates, fish, turtles).

- Dissolved metals - Although there is medium knowledge gap of impact predictions due to absence of metals data, existing and predicted dissolved metal concentrations (Ag, Cd, Cr, Cu, Hg, Pb, Sb and Se) are mostly below levels of concern up to salinity 8,000 mg/L. Elevated boron likely represents natural background levels in groundwater and broader catchment geology.

  While predicted total selenium levels exceed the ANZG (2018) 99% DGV post closure, speciation testing would be required to ascertain valency and ultimately the bioavailability and toxicity risk posed to aquatic biota. Existing and predicted alkaline pH however, suggests that more broadly, metal solubility and bioavailability is unlikely (ANZECC/ARMCANZ, 2000). Therefore, the risk ranking was Low.

- Turbidity - There is high knowledge gap of impact predictions due to absence of turbidity data for the 2C West Pit Lake. However, the historic data for other pit lakes associated with the Dawson Mine (Ecoserve et al. 2005, Austecology et al., 2008, Young et al. 1999) suggests water clarity in the surface layer is good, with the resuspension of accumulated fine sediments at depth. Therefore, the risk ranking was Low.

- Biological (Aquatic Biota) - The most comprehensive surveys of aquatic biota in the vicinity of the 2C West Pit Lake have been in surrounding pit lakes and nearby natural creek lines and semi-natural dams by Ecoserve et al. (2005), Austecology et al. (2008), Proctor and Grigg (2006) and Young et al. (1999). Annual monitoring of habitat, surface flows, water quality, and aquatic invertebrates was also undertaken as part of the Receiving Environment Monitoring Program (REMP) for the Dawson Mine (Hydrobiology, 2019).

  Based on database results and review of relevant literature, a total of at least 195 aquatic biota taxa are known to occur within the Dawson River drainage sub-basin, comprising 16 algae, 14 macrophytes, 83 aquatic invertebrates, 38 fish, 33 frogs, eight freshwater turtles and three mammals. Six species are listed as significant at the state and/or federal level. Taxa with confirmed records from Dawson Mine pit lakes and/or nearby natural creek lines and semi-natural dams are detailed in the Stantec report.

- Primary productivity - Database search results for the Dawson River drainage sub-basin indicated at least 16 primary producers are known to occur, including:

Blue green algae (Aphanothece stagnina, Limnothrix vacuolifera, Schizothrix calcicole, Scytonema hofman-bangii, Stigonema hormoides and Stigonema multipartitum), some species of which are known to contain toxic forms.

Green algae (*Klebsormidium flaccidum, Klebsormidium flaccidum, Spirogyra communis, Uronema confervicola, Zygnema cruciatum and Zygogonium ericetorum*), common in slow moving waters.

Charophytes (*Chara* sp., *Chara evanida*, *Nitella* sp., and *Nitella pseudoflabellata*), also considered macrophytes due to their size and submerged growth habit.

The findings from the Stantec report are consistent with the technical reports used to inform the PRCP. All the voids remaining in the DS final landform are likely to become hypersaline and unsuitable for any beneficial use. There are currently no plans to divert additional overland surface water flows or pump out saline water as outlined in Scenario 2 in Stantec, 2020.

3.6.9.10 Void rehabilitation strategies

Void rehabilitation strategies have been customised to the unique characteristics of each void. All voids will undergo reshaping works to minimise their footprint and maximise land use outcomes. The slopes will be shaped and graded at the appropriate design requirements – 16% for low walls and 33% for high walls (Appendix 4.8). A protection bund will be installed around each void to limit access during rehabilitation activities, and further reduce potential erosion of void slopes. All exposed coal seams remaining in the pit walls will be covered by spoil.

Ongoing monitoring will be conducted prior to mine closure to confirm the basis for final void design planning is met, and post closure monitoring will be completed to ensure that the final voids meet the designed criteria. This is to ensure the voids do not cause environmental harm to land, surface waters or aquifers. A summary of the proposed monitoring program is provided in Section 3.8.

3.6.10 Underground mining

No underground mining has been or will be undertaken at DS.

3.6.11 Built infrastructure

Limited infrastructure is located within DS; administration buildings, workshops, power infrastructure and the end of the conveyor are all located within the adjoining DCN MLs. It is currently planned that any built infrastructure under DS' remit will be decommissioned, demolished, salvaged and or disposed of .If infrastructure is to be formally retained by an appropriate stakeholder once a formal agreement is in place for retaining infratsructure.

There may be some items of infrastructure operated and installed by third parties within the DS MLs. Infrastructure not owned by the mine site could include coal seam gas infrastructure, boreholes, public roads, rail infrastructure, telephone lines, fibre optic lines, and electrical transmission lines and substations.

Execution of any demolition will be undertaken in accordance with relevant standards, policies and legislative requirements. A full demolition study will be undertaken as closure approaches, prior to demolition works commencing. Demolition of redundant plant and equipment has already taken place progressively when it is no longer needed.

3.6.11.1 Infrastructure to be decommissioned

Infrastructure in DS to be decommissioned includes access roads and laydowns, explosives magazines and mine water dams. Infrastructure will be progressively demolished and removed once no longer required. All areas that contain infrastructure or have historically been utilised for activities that are associated with an increased risk of contamination will be assessed as per milestone criteria and contaminated site assessment requirements.

Buildings, infrastructure and services

Currently, no fixed buildings, major infrastructure or services are located at DS owned or operated by DS.

Stockpile areas

Stockpile areas will be trimmed and reshaped, and, as required, rock raked and ripped to a depth of at least 1m.

Roads, tracks, hardstand

No mine bitumen surfaces are currently present within DS. Haul roads, hardstands/laydown areas stabilised with road base (or similar) will have the top 0.3 m scalped to remove the surface, base and sub-base layers prior to being re-contoured, growth medium applied, ripped and seeded as required to achieve the final land use.

Powerlines

All power lines established for the purposes of mining, will be removed, unless an arrangement has been agreed in writing through consultation with relevant stakeholders during detailed closure planning. Overhead power lines will be removed and the materials, including poles and wire, recovered for potential re-sale or recycling where practicable.

Explosives magazines

The explosive magazine will likely be used for the duration of closure execution. Once the bulk of the works have been completed the following activities will be undertaken:

- Remove explosives inventories;
- Decontaminate and decommission equipment, structures, appurtenances such as explosives storage sheds;
- Remove structures for sale or salvage;
- Remove slabs, footings and concrete pads;
- Undertake a contaminated site assessment and if required develop a Sampling and Analysis Plan to identify any land and/or local groundwater contamination; and
- Where contamination is identified, prepare a Remediation Action Plan and undertake remediation works in-line with relevant legislative requirements and good industry practice.

Once the infrastructure is removed, all areas will be reshaped, growth medium applied, deep ripped and seeded as required to achieve the final land use.

Landfills

There are currently no operating landfills in DS. Landfills located in DCN are currently used for disposal of all DS general waste in accordance with MOP 0022 Waste Management Mine Operating Procedure. Information and closure of this facility is covered under the PRCP for DCN.

Shovels and other mobile equipment

Shovels and other mobile equipment will be sold or re-used at other sites where possible. Surplus equipment will be demolished using conventional mechanical means. All materials will be removed from site and recycled where possible.

Dams

Dams will be dewatered before pushing in the dam walls using dozers. The surface profile will be smoothed to make it suitable for revegetation. Depressions and drainage features (drains, sediment traps, contour banks) will be installed where necessary to minimise erosion risks and increase water infiltration.

Roads, Tracks and Hardstands

Roadways and/or tracks and culverts may temporarily be required to provide ongoing access for rehabilitation monitoring and maintenance activities. They may also be retained permanently on-site for use by the post-mining landowner, where agreed in writing (including as stock mustering corridors and fire breaks).

Dams

Some clean freshwater dams may also be retained for stock water, where agreed in writing. Where no such agreements are forthcoming, dams will be demolished as noted above.

Other

Should any other infrastructure be considered a usable asset (e.g. powerlines, water transfer pipelines, fencing etc), arrangements will be agreed in writing through consultation with relevant stakeholders during detailed closure planning in the future. If no agreement can be made, any such infrastructure will be decommissioned as currently planned.

3.6.11.2 Maintenance requirements

DS uses an annual rehabilitation review and assessment process to provide specific details of works required to actively manage progressively rehabilitated areas. This process allows provisions and resources to be allocated annually. The care and maintenance works program is based on the outcomes and recommendations from the rehabilitation monitoring program, and any inspections or site observations. The program includes the requirement for weed control, pest control, fertiliser application, storm water management, re-seeding / planting, erosion control works, re-working of failed rehabilitation, fencing and controlled grazing of pasture areas.

3.7 Risk assessment

This section outlines the assessment undertaken to identify and analyse the range of risks potentially affecting the achievement of safe, stable, non-polluting, and self-sustaining PMLU conditions or safe, stable, and non-polluting NUMA conditions, identify the appropriate controls in place (or proposed) to minimise the risks to acceptable levels, people responsible, resource requirements, performance measures, monitoring, and timing.

For the PRCP, the risk assessment refers to the specific rehabilitation and management milestones as proposed within the PRCP Schedule and will assist in determining appropriate completion dates for the Schedule, by relating how potential risks, controls and events could affect the completion time of land being rehabilitated to a stable condition or managed as a NUMA. The results of the risk assessment are provided in Table 3-44. This risk assessment will be reviewed annually and updated (if appropriate) based on monitoring data collected for the purposes of informing the PRCP.

3.7.1 Risk assessment framework

DS considers a range of risks associated with rehabilitation, closure and post-closure phases. A closure risk assessment is maintained for DS, conducted in line with the requirements of the Anglo American Risk Management Standard and associated Risk Matrices. The procedure describes risk assessment as the overall process of communication and consultation (establishing the context), risk identification, risk analysis, risk evaluation, risk control, and monitoring and review.

3.7.1.1 Risk identification

Risk identification refers to the process of identifying risks against a pre-defined set of business objectives, taking into account the context, the previous risk assessments, incidents and the findings of audits performed onsite. It includes, the identification of the risks/unwanted event, cause(s) of the event, potential maximum consequences, current controls in place, and current risk control effectiveness. These were determined based on:

- Risks commonly encountered in mine rehabilitation as documented in the Guideline: Rehabilitation Risk Assessment (NSW Resources Regulator, 2021);
- DS Risk Register; and
- PRCP Risk Assessment workshop held with key DS stakeholders.

Key risk areas considered include health and safety, environmental impact, material losses/damage/business interruption, legal and regulatory, financial, and impacts on reputation/social/community.

3.7.1.2 Risk analysis and evaluation

A risk analysis and evaluation was conducted during the PRCP Risk Assessment workshop to explore potential risks and determining their causes and sources. The assessment considered their potential consequences and the likelihood that those consequences can occur. Consequence and likelihood of the unwanted event occurring were rated using the Anglo American Risk Matrix (Table 3-43). This table contains five rating levels for consequence and likelihood each. The basis for likelihood used in the assessment is the remaining lifetime of the mine until full relinquishment.

Options for addressing the risks are then selected for implementation. The most appropriate risk control options are selected after consideration of multiple factors including cost benefit, regulatory obligations, social responsibility and protection of the surrounding environment. The risk control step details a justification for selecting the option, details proposed activities, identifies parties responsible for implementation as well as resources required. Performance measures and constraints are

highlighted, reporting and monitoring requirements outlined and detail provided on timing and scheduling of each risk control option.

The risk controls options consider the need for rehabilitation trials to be completed, to improve the chances of achieving the intended PMLU, whilst managing and minimising the risks of a stable condition not being achieved.

3.7.2 Summary of key closure risks

As shown in Table 3-44, a total of 19 risks were identified and assessed. Following implementation of controls, no high risks and only one significant risk remained as follows: :

- Final landform is unstable and either not safe or polluting and rehabilitation milestones and closure criteria are not met.

onmental Impact	Lasting days or less; limited to small area (metres); receptor of low significance/ sensitivity (industrial area)	Lasting weeks; reduced area (hundreds of metres); no environmentally sensitive species/ habitat)	Lasting months; impact on an extended area (kilometres); area with some environmental sensitivity (scarce/ valuable environment).	Lasting years; impact on sub-basin; environmentally sensitive environment/ receptor (endangered species/ habitats)	Permanent impact; affe highly sensitive environ wetlands, protected hab
Community Impact	Insignificant impact on external stakeholders regarding their health and safety, and/or insignificant impact on external stakeholder / contractor worker economic welfare, personal and political security, and / or cultural heritage.	Minor impact on external stakeholders regarding their health and safety, and/or minor impact on external stakeholder / contractor worker economic welfare, personal and political security, and / or cultural heritage	Medium impact on external stakeholders regarding their health and safety, and/or medium impact on external stakeholder / contractor worker economic welfare, personal and political security, and / or cultural heritage	High impact on external stakeholders regarding their health and safety, and/or high impact on external stakeholder / contractor worker economic welfare, personal and political security, and / or cultural heritage	Major impact on externa health and safety, and/o stakeholder / contracto personal and political se
gal & Regulatory	Technical non-compliance. No warning received; no regulatory reporting required	Breach of regulatory requirements; report/involvement of authority. Attracts administrative fine	Minor breach of law; report/investigation by authority. Attracts compensation/ penalties/ enforcement action	Breach of the law; may attract criminal prosecution, penalties/ enforcement action. Individual licence temporarily revoked	Significant breach of the suits; permit to operate withdrawn
Damage / Business Interruption	< 0.01 % of Annual Revenue / Total Assets	0.01 - 0.1 % of Annual Revenue / Total Assets	0.1 - 1.0 % of Annual Revenue / Total Assets	1 - 5 % of Annual Revenue / Total Assets	> 5 % of Annual Revenu
Reputation	Minor impact; awareness/ concern from specific individuals	Limited impact; concern/ complaints from certain groups/ organizations (e.g. NGOs) period	Local impact; public concern/ adverse publicity localised within neighbouring communities	Suspected reputational damage; local/ regional public concern and reactions	Noticeable reputational public attention and repe
quence Type	**1 - Insignificant**	**2 - Minor**	**3 - Moderate**	**4 - High**	**5**
ELIHOOD	**RISK RATING**				
The unwanted event is almost certain to happen within the LOM (Life of Mine). In the case of repetitive/frequent tasks the unwanted event has or will occur in order of one or more times per year. In terms of major events, as also in the case of long term health, environmental or social impacts, it may happen only once in the LOM.	**11 (Medium)**	**16 (Significant)**	**20 (Significant)**	**23 (High)**	
There is a high probability that the unwanted event will occur within the LOM. In the case of repetitive/frequent tasks the unwanted event has occurred or is likely to occur in order of less than once per year. In terms of major events, as also in the case of long term health, environmental or social impacts, it might happen once in the LOM.	**7 (Medium)**	**12 (Medium)**	**17 (Significant)**	**21 (High)**	
It is possible that the unwanted event can occur within the LOM. In the case of repetitive/frequent tasks, the unwanted event has occurred or is likely to occur in order of once every 5-10 years. In terms of major events, as also in the case of long term health, environmental or social impacts, there is a low probability for the event to happen in the LOM.	**4 (Low)**	**8 (Medium)**	**13 (Significant)**	**18 (Significant)**	
There is a low probability for the unwanted event to occur within the LOM. In the case of repetitive/frequent tasks, the unwanted event has occurred some time or is likely to occur not more than once every 10-20 years. In terms of major events, as also in the case of long term health, environmental or social impacts, there is a low probability for the event to happen in the LOM.	**2 (Low)**	**5 (Low)**	**9 (Medium)**	**14 (Significant)**	**(Si**
There is a very low probability for the unwanted event to occur within the LOM. In the case of repetitive/frequent tasks there are no records of the event occurring or it is higly unlikely that it will occur within the next 20 years. In terms of major events, as also the case of long term health, environmental or social impacts, there is a very low probability for the event to ever happen.	**1 (Low)**	**3 (Low)**	**6 (Medium)**	**10 (Medium)**	**(Si**

Risk Level	**Guidelines for Risk Matrix**
High	A high risk exists that management's objectives may not be achieved. Appropriate mitigation strategy to be devised immediately.
Significant	A significant risk exists that management's objectives may not be achieved. Appropriate mitigation strategy to be devised as soon as possible.
Medium	A moderate risk exists that management's objectives may not be achieved. Appropriate mitigation strategy to be devised as part of the normal management process.
Low	A low risk exists that management's objectives may not be achieved. Monitor risk, no further mitigation required.

Milestone 1	Infrastructure not demolished to prescribed depth below ground or waste not removed				Regular progress meetings with responsible work crews during decommissioning process Infrastructure (asset) register to be maintained during decommissioning phase Progressive decommissioning program during life of operations	decommissioning, and demolition is completed in accordance with the closure schedule					as constructed drawings, resources for rehabilitation"	Represe
Financial impact if asset is unable to be handed over	Poor communication with relevant stakeholders Differing/conflicting interests Contamination or other reasons land or other infrastructure can't be passed on	3	3	13	Stakeholder engagement strategy Regular community meetings Internal Anglo American mine closure standard	The proposed actions will ensure decommissioning and hand-over of assets will occur in a timely and effective manner	2	3	9	Closure and community consultation team	Register of agreements, contaminated land consultant	Register place an current Sign off Compan represe
Delay of Rehabilitation Milestone 2	Inadequate site investigations of historical contaminating activities Poor historical record keeping of spills or other environmental impacts Poor rehabilitation practices in waste rock placement on final landform Poor construction design or inadequate capping procedures on mineral residue facilities or landfills	3	4	18	Environmental incidents are recorded in an appropriate register (eg asbestos register) Employees and visitors are made aware of their environmental obligations Contaminated sites register is regularly updated and maintained Preliminary and detailed site investigations are to be conducted as contamination is identified Remediation techniques are proven and effective at cleaning up contamination Environmental auditor approved clean up certificate issued QA/QC of structures such as mineral residue facilities are completed throughout LOM Regular site inspections of waste disposal areas Regular statutory surface water and groundwater monitoring is completed Ongoing waste characterisation of waste rock stockpiles and mineral residue facilities	Proposed PMLUs must be free of contamination, removed from the contaminated land register and suitable for the nominated PMLU. The works must be completed by an approved environmental professional and signed off by a suitably qualified environmental auditor.	2	3	9	Closure and Environment team	Contaminated land consultant, site remediation plan and monitoring records	Sign-off Compan Represe
Financial cost of increased remediation efforts	Emergence of previously unknown contaminants of concern such as PFAS Poor clean up results and inadequate decontamination	3	3	13	Environmental audit of remediation efforts and clean up certificate issued Remediation techniques are proven and effective at cleaning up contamination Preliminary and detailed site investigations Internal Anglo American mine closure standard	Proposed actions will ensure the PMLUs are free of contamination and rehabilitation schedule is achieved.	2	3	9	Closure and Environment team	Contaminated land consultant, site remediation plan and monitoring records	Sign-off Compan Represe

reworking and sourcing additional material	Incorrect volumes of appropriate material Poor consideration of drainage in the landform design Poor execution and implementation of landform design				Landform compliance to plan Inspections during landform construction using LiDAR and and other management tools Ongoing progressive rehabilitation during LOM including 5-year rehabiliation plans Feedback loop from monitoring into the LOM and future rehabilitation plans	The proposed landform design and criteria are based on extensive site experience handling and observing soil behaviours over time Soil characteristics are consistent with others in the Bowen Basin. Learnings from other sites have been incorporated into the design Progressive rehabilitation will continue to optimise landform design through closure						
Delay of rehabilitation milestone4 Limited or reduced establishment of vegetation impacting stability of the final landform Ongoing maintenance costs for revegetation Erosion of underlying landform due to absence or reduction of growth medium	Poor topsoil management Incorrect volumes of topsoil stockpiles Topsoil/growth quality insufficient due to incorrect amelioration	4	4	21	Continue operational practice of separating topsoil from underlying strata in new mining areas Harvest additional topsoil where possible Clear designation of topsoil stockpiles around site Topsoil volume reconciliation and quantification during operations Direct placement of topsoil where possible (remove rehandling process) Amelioration techniques are implemented to allow for revegetation Use of additional enhancements like geofabric to improve/assist vegetation Progressive rehabilitation certification on site (where topsoil has previsouly been absent or limited)	The proposed actions will ensure PMLU landforms are safe, stable and non polluting The proposed landform design and criteria are based on extensive site experience handling and observing soil behaviours over time Progressive rehabilitation will continue to optimise landform design through closure	2	3	9	Closure Team	Soil scientist	Annual and data update
Poor establishment of vegetation of the closure landform Weed growth or infestation in the final landform due to poor establishment of planned vegetation Elevated climatic risks such as fire	Inadequate de-weed and seed procedures No treating or maintenance of existing topsoils (i.e unknown erosion or contamination of topsoil) Limited spraying of weeds completed on site External weeds being brought in/blown onto site and not managed	5	3	20	Preventative management of weeds Trial biological agents Mechanical trials/treatment for selective weed species such as leucaena) Use of geospatial imagery to highlight areas of concern and target remediation Implement weed control procedure and update in line with 5 year rehabilitation plan Ongoing ACARP trial/research project on leucaena management	Extensive site knowledge on the management and control of weeds will assist in the achievement of this milestone Progressive rehabilitation will also assist in determining the extent of weed infestation and areas of potential concern	4	2	12	Closure and Environment team	Weed contractors	Annual surveys control underta

landform due to the failure of vegetation to establish Ongoing financial impact of maintaining seed bank longer than necessary Damaged or poor growth of vegetation Vegetation fails to establish itself due to erosion	Availability of suitable seed bank due to competing rehabilitation efforts from other mines Seeds fail to mature due to poor topsoil/substrate conditions Climatic conditions affect revegation efforts (rainfall, drought, fire, etc) Failure to fence/isolate vunerable areas to grazing animals Climate change (warming environment and elevated intensity of precipitation events) Insufficient ripping depth of landform				Register of species and volumes required is maintained Appropriate fire breaks will be established and maintained during initial landform construction Proven progressive rehabiliation onsite over extended period of time	The proposed landform design and criteria are based on extensive site experience handling and observing soil behaviours over time						time
Delay of rehabilitation milestone 7and 8 Non relinquishment or delayed relinquishment of the site One, or all PMLUs, are not stable	Climate change or natural variability causing rehabilitation failure Extended drought causing rehabilitation failure and/or increased climatic risks such as fire Introduction of weeds Introduction of pests or other wildlife	3	4	18	Rehabilitation monitoring Progressive rehabilitation and certification of PMLU eg grazing, native bushland, etc Prescribed rehabilitation methodologies Landform design and compliance Maintenance and aftercare monitoring programs Anglo American mine closure toolbox and assessment criteria	Early identification of potential failure of rehabilitation milestone will ensure the achievement of safe, stable and non-polluting PMLUs is achieved	2	3	13	Closure Team	Company representative	Rehabili monitor reports
Impact to surface water quality Impact of downstream waterways due to overtopping/collapse	Poor design of diversions or other water structures Poor understanding of water quality	3	2	13	Flood modelling to predict potential overtopping Surface water and groundwater monitoring Comprehensive understanding of background concentrations of water quality Revegetation reduces sediment runoff load	The proposed actions will ensure the background water quality of streams/creeks or other will not be compromised by the potential failure of these structures	2	2	8	Closure Team	Company representatives As constructed drawing	Sign-off Compan Represe Absence damage failed rehabili
Collapse or erosion of highwalls and low walls of the residual voids	Incorrect placement of material on pit walls Slope angles not consistent with design Walls do not achieve appropriate factor of safety Geotechnical instability Assumptions in the water balance/quality modelling are incorrect	3	3	13	Technical studies including hydrogeological, erosion, geotechnical and water quality/balance modelling Waste rock sampling characterisation Appropriate bunding and fencing or other hard barriers are installed to ensure access is not possible	Implementation of the listed controls and actions ensure the nominated NUMA will not be a risk to public or the environment	2	3	9	Closure Team	Geotechnical consultant As constructed drawings	Compan off
Injury or illness to public or wildlife	Assumptions in the water balance/quality modelling	2	2	5	Modelling suggests voids will act as terminal sinks- water outflow to the	Modelling suggests the voids will become	1	2	3	Closure Team	Company representative	Groundw monitor

Discharge to groundwater					modelling Validation of modelling assumptions during operations Water quality and level monitoring of residual voids to validate assumptions							

3.7.3 Rehabilitation Trials

Rehabilitation trials have been undertaken at Dawson Mine since the 1970s. The earliest studies focussed on trials to return the land to grazing capability post mining. This was in response to the 1962 Agreement under the *Thiess Peabody Coal Pty Ltd Agreement Act* 1962 that (S31(d) of the Agreement):

"the Company shall take competent advice as to what steps are possible (including the additional extent, if necessary, to which peaks and ridges may be struck off and valleys filled in) to encourage and promote regeneration of vegetation and shall proceed to promote such regeneration".

Trials were conducted for pasture grass evaluation, hydromulching, seed coating on different soil and spoil types, leucaena plantings, aerial seeding, and varying grass seed and fertiliser rates.

By the late 1980s, however, the potential for native tree establishment became recognised, and trial efforts from 1990/1991 onwards focussed primarily on the establishment of trees and shrubs.

Relevant trials included the use of a range of tree crops, use of tubestock and tree seed directly on coarse spoil, native tree plantings (including Semi-evergreen Vine Thicket species), and hardwood plantations using a variety of species.

The trials have generated extensive experience with different rehabilitation methods to best suit specific soil types and species. In general, the experience has shown that a grass cover benefits from topsoil, whereas tree establishment benefits from an absence of a dense grass cover, such as can be achieved by sowing directly in coarse spoil.

Seed sources and mixes are continuously adjusted as further experience is collected on previous trials, as documented in the rehabilitation monitoring undertaken across the rehabilitated areas of the site.

Trials have also been conducted to test the suitability of pit lakes for aquaculture of Barramundi and Silver Perch. The trials successfully demonstrated that, despite a low concentration of potassium (which is common in inland waters), Silver Perch can be grown equally successfully in raw void water and potassium fortified void water, while Barramundi was demonstrated to grow without compromise (relative to seawater grown Barramundi) after fortification with potassium to 100% equivalence with seawater.

Details of previous trials undertaken include:

- Pasture Grass Evaluation 1976: This trial was undertaken to evaluate the suitability of regraded coarse spoil as a growth medium for pasture grasses. The trial area was a 20 ha area at Pit 1C. Inputs included 4 kg/ha Rhodes Grass, American and Biloela Buffel Grass seed, 400kg/ha Crop King 700 fertiliser, resulting in excellent establishment.
- Hydro-mulching Trial 1977: Seeds of pasture grasses and legumes were applied to steep ungraded spoil at Pits 1C and 2C using a curasol hydro-mulching technique, resulting in excellent Siratro establishment, although the grasses failed.
- Coated Seed Trial 1978: Trials were conducted to compare the effectiveness of coated seed at various densities on different spoil types, including a 150mm topsoil over 17% sloping fine spoil (Pit 15B) and 25% coarse sandstone (Pit 8E). Neither was successful, probably due to poor surface treatment and inappropriate sowing times.
- Leucaena Legume Trial 1978: Small trials for this species were established in regraded 8E spoil north of Gibihi Road in 1978, with further plantings in 1987. Leucaena has proven to establish well, to the extent that it is now regarded as a weed on the mine site.

- Aerial Seeding Trial 1978: Areas of regraded and ungraded spoil at Pit 3C were aerially seeded using a mixture of 3.5kg/ha of Rhodes Grass, American and Biloela Buffel Grass, 2kg/ha Siratro, and 340kg/ha Crop King 700 fertiliser. Establishment during this trial and subsequent aerial seeding programmes in the early 1980s were highly successful.
- Tree Crops Trial 1986: This trial was established on regraded spoil at Pit 1B, using a trickle irrigation system to feed 43 advanced tree crops, including lemon, orange, mandarin, casimisoa, peach, pecan, mulberry, and avocado. None of the trees established.
- Seed and Fertiliser Trial 1987: Varying seed and fertiliser rates were tested on regraded and contour ripped coarse spoil at Pit 14D, using pelleted pasture seed, Japanese Millet with 200kg/ha sulphate of ammonia and Crop King 700, with a basic mix of 2kg/ha Biloela and Gayndah Buffel, Rhodes Grass, Purple Pigeon, Green Panic, and Siratro with 150kg/ha Crop King 700. The success of these trials was variable.
- Tree and Pasture Trial 1991: This trial compared a topsoiled pasture with a non-topsoiled Bushland PMLU on coarse spoil at Pit 13BL. The trial included planting of native tubestock as well as direct seeding into coarse spoil without topsoil. Native species included Acacia salicina, Casuarina cristata, and Corymbia citriodora. This trial was very successful, particularly in the successful establishment of trees that were sown directly onto coarse spoil without topsoil.
- Tree Planting Trial 1998: A total of 3,500 native trees were planted in area 1CN, of which 70% were reported to have survived.
- Native Tree and Shrub Species Trials 2000: Two sites, including one site (“Site 5”) at 9N Incline and the other (“Site 6”) at 17N, were regraded and direct sown with native trees and shrubs into bare spoil in November 2000. Seed application rate was 5kg/ha, and involving 26 native species (mostly Eucalypts and Acacias) as well as the exotic Leucaena. Site at 9N grew into a diverse community of trees and shrub species up to 3-6m in height two years after sowing, but with low ground cover. Growth of trees and shrubs at 17N was less successful, but with a higher ground cover. A later review of rehabilitation at Dawson Mine noted that the poor establishment at 17N was possibly due to sodic conditions there (CMLR 2001 and 2002). Nevertheless, the trial was overall considered highly successful.
- Suitability of Dawson Mine Water for Aquaculture 2008: Water from Void 13A was selected to assess the suitability of void water for aquaculture of Barramundi and Silver Perch. These species were selected due to their proven history in aquaculture and their tolerance to the elevated salinity of the void water. The trial successfully demonstrated that, despite a low concentration of potassium (which is common in inland waters), Silver Perch can be grown equally successfully in raw void water and potassium fortified void water, while Barramundi was demonstrated to grow without compromise (relative to seawater grown Barramundi) after fortification with potassium to 100% equivalence with seawater. While not tested in this study, it was suggested that the level of potassium could potentially be reduced to 25% equivalence, based on the then recent study by Partridge and Lymbery (2008).
- Grazing Trial 2015-ongoing: A grazing trial commenced in 2015 on revegetated spoil at Pit 25 is ongoing. This trial was set up to understand the most effective way to rehabilitate land at Dawson Mine to rehabilitate for grazing purposes. The trial involves 165ha of spoil which was graded to 1:6 slope, topsoiled, and seeded in 2012. A freshwater dam was constructed in the trial area also. Seeding was directly behind ripping lines by dozer. Species included native pasture grasses such as Queensland Bluegrass (Dichanthium spp.) and Curly Windmill Grass (Enteropogon acicularis) as well as native shrub and tree species such as Brigalow (Acacia harpophylla), Silver-leaved Ironbark (Eucalyptus melanophloia) and Bottle Trees (Brachychiton spp.). Weaners have been grazing the rehabilitated paddock since 2015. A control paddock of 161ha was set up adjacent to the rehabilitated area, with a similar vegetation and groundcover. Weight gain measurements of

weaners in both paddocks over multiple years indicates that weight gain is consistently higher within the rehabilitated paddock, indicating that rehabilitated land at DS can be capable of a successful grazing PMLU. Currently, this area consists of an open shrubland of 2-6m height with a diversity of shrub and tree species. The area was affected by grass dieback in 2017/2018 (L. Muirhead pers.comm.), resulting in an influx of non-grassy ground layer species, particularly Sida spp. The cover of Buffel Grass was, nevertheless, very dense as observed during the field inspection undertaken on 19 July 2022, indicating that it had fully recovered from the 2017/2018 dieback episode. This area has since been certified (see Section 3.1.4.3).

- Semi-evergreen Vine Thicket Trials 2011 and 2013: Semi-evergreen Vine Thicket (SEVT) trials commenced on 6.7ha of relatively steep (25%), recently re-contoured crushed rock of varying sizes at Pit 17D/E in 2011. Enrichment SEVT planting was also undertaken among established native vegetation in nearby small non re-contoured depressions. On the contoured slopes, SEVT plantings were created in "nuclei of 0.3-4.7ha in size, in areas deemed suitable with regard to location, cold air flow, frost, slope, aspect and ergonomics. Nuclei to be spaced at distances from 500 to 1000 metres. A temporary irrigation system was installed prior to planting in April 2011. A total of 6970 nursery grown seedlings of 17 species were planted, each with 200g application of an organic blend in and around the seedling hole prior to planting. Small areas were also planted in topsoil. Planting density was about 1000 stems/ha. Enrichment plantings on the non re-contoured slopes were undertaken to test the concept that minimum numbers of emergent and prolific fruiting species can be strategically introduced to enhance and facilitate the natural regeneration of SEVT over time at reduced costs. Monitoring indicated that the survival rate within the re-contoured area was approximately 75% by October 2011, and 50% for the non-recontoured areas by December 2011. Competition with established shrubs and dense Buffel Grass is considered to have contributed to the lower survival rate in the non-re-contoured sites compared with the re-contoured sites. Three of the 17 planted species failed to germinate. While the 2011 SEVT trial area remains, access to this area is no longer available and there are no recent data on this vegetation. However, recent satellite imagery indicates that the area revegetated during this trial remains well vegetated as a woodland with trees and/or tall shrubs.
- A "Second Generation" SEVT trial commenced at Pit 17B in 2013 on a slope considered too steep (>25%) for other types of vegetation. While no monitoring information is available for this trial, site inspection on 19 July 2022 for this Appraisal indicated that most individuals planted survived. However, SEVT plants were severely stunted, widely spaced at 3-4m, with virtually no other vegetation between. There was evidence of erosion, including rilling, gullying, and tunnel erosion. The poor state of this rehabilitation can be related to the dispersive nature of the substrate (Type 4), likely to be unsuitable to SEVT vegetation, and the steep slope and lack of topsoil application during revegetation, preventing the growth of a protective vegetative layer between the SEVT plants to mitigate erosion.
- Hardwood Plantation: Experimental hardwood plantations of Chinchilla Gum (Eucalyptus argophloia) were established at three sites at Dawson Mine during 2011 to test the feasibility as an alternative post mining land use to create income, employment and wildlife corridors for the region after the completion of mining activities. Plantations include:
    - 18 ha area on natural though previously disturbed flat ground near the Dawson Central main site entrance (Turner's Paddock). It is understood that new black topsoil was spread at this site prior to planting, although the origin of this topsoil is unknown. In addition to the Chinchilla Gum, Turner's Paddock incorporated two trial blocks of 1.7ha each in which eight additional species were planted, mostly Eucalypts, but also Brigalow (Acacia harpophylla). Inspection of this plantation on 19 July 2022 indicated that trees in this plantation are growing very poorly, with poor form, heights of only 4-8m, and diameters of less than 10cm, and usually around the 5 cm mark. Aerial imagery indicates that growth is better towards the eastern edge of the plantation (not accessed in the field), suggesting that edaphic conditions may be better in that

location. Much of this plantation has been cleared since establishment to make way for Three Chain Road.

- 2 ha area on spoil without topsoil adjacent to the 2011 SEVT trial at Pit 17. While this plantation is no longer accessible for inspection, aerial imagery shows rows of trees or shrubs at the planting location, indicating that planted trees have survived. The canopies appear, however, rather small, no more than 3-4m diameter, similar to those at Turner's Paddock, suggesting poor growth.
- 4 ha area on recontoured spoil with black topsoil at Dawson North. The site is located on top of the eastern slope of the southern spoil emplacement, and therefore receives no water runoff from up slope. Despite the relatively dry location, trees in this plantation have grown better than in the other locations, with some trees reaching estimated heights up to some 12m with good form, and with stem diameters of up to 10-15 cm at 1.4m above the ground. Trees are, however, widely and irregularly spaced, suggesting that many individuals may not have survived early establishment.

The success of hardwood plantations at Dawson Mine therefore is mixed. Most of the area planted in hardwood plantation has essentially failed, with surviving, but stunted trees. The only area with several good trees is the small plantation on Dawson North. More intensive management of that plantation may have yielded a greater survival rate of trees.

The above extensive list of rehabilitation trials indicates that Dawson Mine undertakes rehabilitation in a highly informed manner, without any further need for future trials. All of the lessons learned from the above rehabilitation trails have been applied to DS to achieve optimal rehabilitation success.

3.8 Monitoring and maintenance

3.8.1 Monitoring methodologies and standards

Monitoring at DS is undertaken for a range of environmental aspects, including for progressive rehabilitation, groundwater, surface water, air quality, and geotechnical aspects. Some of these are conducted separately under the EA and other regulatory requirements. This section focuses on monitoring methods used during progressive rehabilitation monitoring at DS (including erosion, soils and vegetation).

3.8.1.1 Overview and purpose

Progressive rehabilitation monitoring at DS is completed for the primary purpose of producing a concise and targeted rehabilitation dataset using repeatable methods which demonstrate compliance with pre-determined success criteria and support relinquishment of all approvals. The outcomes of the monitoring are used to determine the performance of the rehabilitation, and to identify any areas that are at risk of failing from a stability, safety, and non-pollution perspective.

DS rehabilitation monitoring program is summarised below.

3.8.1.2 Rehabilitation monitoring program

DS will monitor rehabilitation status to determine progress and to intervene and correct if progress is unsatisfactory. The monitoring program involves a combination of spatial and GIS-based planning processes, field monitoring techniques, and post-processing of field monitoring results for analysis and management decision-making.

3.8.1.2.1 Monitoring schedule

DS maintains a monitoring schedule based on the monitoring of representative transects when rehabilitation is at Year 1, Year 2, Year 5, Year 10 and five yearly thereafter until certified as complete by the regulatory agency. Table 3-45 shows the frequency of monitoring for rehabilitation and other environmental aspects monitored at DS.

Table 3-45 PRCP Monitoring Schedule

Aspect	Operational Frequency	Post-Closure Duration
Rehabilitated surface	Plot monitoring: 1, 2, 5, and 10 years where possible after rehabilitation	5 years or until trends indicate no change as reported in annual reports
	Walkover or flyover: Every year to 5 years to after rehabilitation	5 years or until trends indicate no change as reported in annual reports
Soils (growth medium)	1, and 10 years after rehabilitation where possible	5 years or until trends indicate no change as reported in annual reports
Erosion	1, 2, 5, and 10 years after rehabilitation where possible	5 years or until trends indicate no change as reported in annual reports

3.8.1.2.2 Field Monitoring

Field monitoring utilises best practice or new and innovative techniques for completing field monitoring. Details and methodologies outlined below are based on current best practice and existing technologies only, and will be subject to future changes and variations to ensure best practice is maintained.

For each rehabilitation unit (a contiguous area of rehabilitation with the same age and revegetation/PMLU prescription), multiple sites will be monitored, except for very small rehabilitation units. Multiple sites per unit will enhance the reliability that the data collected provides a true representation of the rehabilitation status of the unit.

Vegetation will be assessed using the indicative parameters and assessment method shown in below Table 3-46.

Table 3-46 Vegetation assessment parameters

Parameter	Assessment
Tree canopy height	Five 5x10m subplots in 10x50m plot. All species over 2m measured
Recruitment of dominant canopy spp.	See next cell below
Native tree spp. richness	10x50m plot
Tree canopy cover	100m point-height intercept transect
Shrub cover	100m point-height intercept transect
Native plant spp. richness (canopy, sub-canopy, shrub, ground)	10x50m plot.
Non-native cover	Ten 1x1m quadrats every 10m along transect
Native perennial grass cover	Ten 1x1m quadrats every 10m along transect
Native other grass, native forbs and others, organic litter, rock, bare, cryptograms cover	Ten 1x1m quadrats every 10m along transect
Pasture productivity (grazing PMLU only)	Comparions with Beef Queensland Pasture Photo Standard
Additional	
Habitat Complexity (score based on cover of tree, shrub, ground layers, logs, rock, leaf litter, free standing water, hollows)	20x50m plot
Disturbance (score based on mining activity, grazing, animal pads, feral animals, rubbish, weeds, fire, erosion)	
Soils	Bulk sample from five sub-samples at 20m intervals along transect. Assessed for suite of variables

Monitoring is conducted between February and June to facilitate identification of species prior to dieback and while grass flowers are still visible. Monitoring at this time also allows the impact of surface water movement following the wet season across the rehabilitation areas to be assessed in time for any required remedial actions to be completed before the following wet season.

3.8.1.2.3 Corrective Actions

Should monitoring of an area indicate a less than satisfactory outcome, DS undertakes an investigation to determine the root cause and to identify appropriate adaptive repair solutions. Key aspects considered during such an investigation include, but are not limited to:

- Landform and drainage design;
- Mine spoil geochemistry (propensity for acid, metalliferous and/or saline drainage and spontaneous combustion);
- Growth medium physical and chemical properties;
- Suitability of rehabilitation methods (e.g., site preparation, sowing methods and times);

- Suitability of the species mix and seed quality;
- Competition from weeds;
- Predation or excessive grazing by native herbivores or livestock; and
- Climatic conditions pre and post sowing, including effects of drought and frost.

Following the investigation, a rehabilitation repair procedure and/or design for relevant areas is developed and the proposed works are documented in the next annual plan for rehabilitation.

3.8.1.3 Annual Rehabilitation Inspections

The purpose of the annual flyover inspection is to provide a rapid assessment of all existing rehabilitation areas, including recently completed areas, across DS. The inspection aims to identify all rehabilitation deviation from criteria trajectory or maintenance issues that, if left unchecked, could hinder rehabilitation progress or result in expensive remediation.

The inspection includes, but is not limited to, identification of:

- Erosion (rill, gully and tunnel);
- Stability and functioning of erosion and sediment control and water management structures including contour banks and drop structures which may need repair or removal;
- Visual assessment of vegetation cover, species diversity, vegetation health and growth rates;
- Identified contamination / nutrient deficiencies;
- Presence of weeds and pests;
- Areas of bare ground and rock cover; and
- Mine rubbish and other waste (tyres, bulk containers, etc.).

The annual rehabilitation inspection is completed by a suitably qualified and experienced specialist to provide independent appraisal of performance. An Aftercare and Maintenance Plan is then prepared.

3.8.1.4 Reference Sites

At this stage no reference sites have been identified. , Rehabilitated vegetation is proposed to be assessed against the closure criteria as per Table 3-17(DETSI, 2025a). As per the condition in the PRCP schedule, by 31 March 2028, AA must submit to the administering authority a report that includes:

a) The proposed methodology of assessing rehabilitation against the reference site: and
b) An AQP review of the adequacy of reference sites listed in an attachment to be included in the PRCP schedule which at a minimum consider
    a. The location of the reference sites
    b. The number of reference sites
    c. The rehabilitaiton area/domain to which each reference site relates; and
    d. Justification for the suitability of each nominated reference site

Once endorsed by the administering authority, the methodology for assessing the rehabilitation against the reference sites attributes identified above will replace the BioCondition benchmark criteria listed in the rehabiltaiton milestones and Attachment 5 of the PRCP.

3.8.2 Surface Water Monitoring

Surface water monitoring is completed as part of the REMP and aligned with conditions set in the EA outlined in Schedule F: Water:

- Mine affected water will be released at the location stated in Table F1 of the EA
- Mine affected water released from site must not exceed the release limits stated in Table F2 of the EA
- The water quality of the release water will not exceed the contaminant trigger investigation limits listed in Table F3 of the EA (also provided in Table 3-35) and flow not exceede the criteria listed in Table F4 of the EA.
- The receiving waters contaminant trigger levels are provided in Table F5 of the EA and monitoring locations provided in Table F6 of the EA.

At closure, AA will transition surface water monitoring from alignmnet with the EA, to the PRCP milestone criteria provided in Appendix 4.1. The milestone criteria include:

- For a minimum of five (5) consecutive years immediately prior to the milestone completion date, surface water quality must be monitored at least once per month when a greater than 30mm rainfall event (24 hours period) and flow occurs at the monitoring point(s). Monitoring must occur at, but not limited to, downstream locations specified in in Attachment 6 – Surface Water Monitoring Locations. Surface water quality results must not exceed the limits specified in Attachment 7 – Surface Water Quality Limits. Both attachments are provided in Appendix 4.1.
- If the surface water quality results exceed the criteria above; and if there is flow at both the upstream and downstream monitoring location for each watercourse; then, each year an AQP must complete and provide to the administering authority an assessment of the cause of the exceedance and risk of rehabilitation not achieving a stable condition. Where the assessment concludes
- i) That there is a low risk to achieving a stable condition, then no further action is to be taken; or
- ii) That there is a risk greater than low to achieving a stable condition, then an assessment of potential environmental harm and any changes or rectification actions to rehabilitation activities must be determinged and implemented.
- If the above is triggered, then the five (5) year timeframe under the milestone is reset.

The upstream location of the surface water monitoring location is consistent with the EA. 3 new downstream locations have been added to the PRCP attachments (Appendix 4.1.). The locations of the surface water monitoring locations are provided in *Figure 3-32*. Surface water quality monitoring limits will be updated based on site specific data by October 2027.

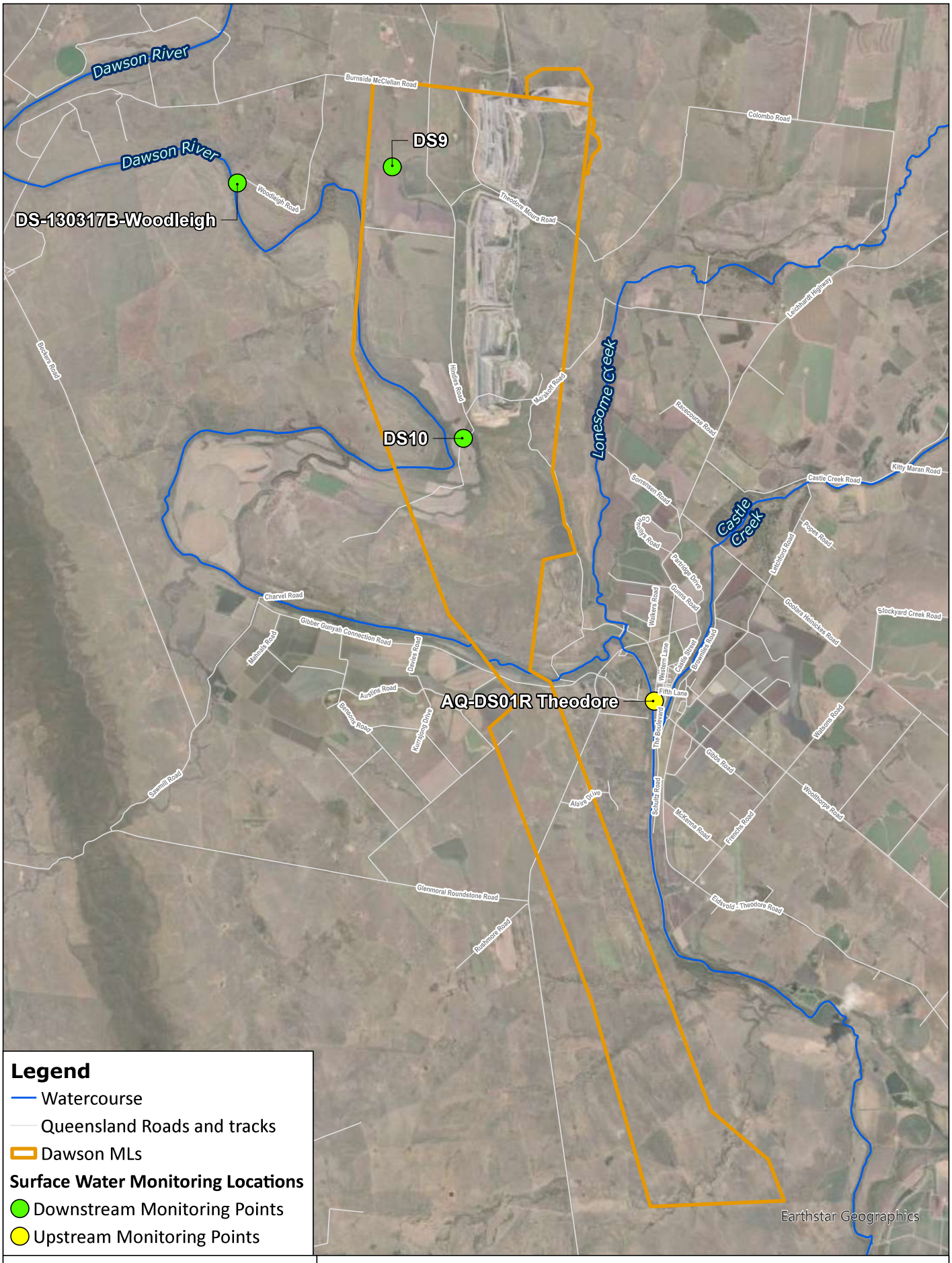


Figure 3-32 Surface Water Monitoring Locations

Dawson Mine Complex

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AngloAmerican

3.8.3 Groundwater Monitoring

Groundwater monitoring occurs onsite and is aligned with conditions set in the EA outlined in Schedule I: Groundwater. Monitoring occurs at locations outlined in Table I1, quality characteristics are specified in Table I2 and standing water levels in Table I3.

At closure, AA will transition groundwater monitoring from alignment with the EA, to the PRCP milestone criteria provided in Appendix 4.1. Groundwater monitoring being conducted as part of the EA are consistent with what is being proposed in the PRCP schedule. The schedule proposes that:

For a minimum of five (5) consecutive years, immediately prior to the milestone completion date groundwater quality must be monitored quarterly at, but not limited to, compliance bores/locations specified in Attachment 8 – Groundwater Monitoring Locations for all quality characteristics listed in Attachment 9 – Groundwater Quality Limits. Groundwater quality results must not exceed the limits in Attachment 9 – Groundwater Quality Limits, for three (3) consecutive results provided in Appendix 4.1.

Groundwater bores listed as being monitored in the EA and the PRCP schedule include bores that have not been installed yet, or which do not yet have sufficient data. As such, a transitional arrangement has been included in the EA. AA must:

a) for groundwater monitoring bores identified as “existing bores” in Table I1 (Groundwater Monitoring Locations and Frequency):

i. by 30 April 2025, commence monitoring in accordance with condition I5; and

ii. by 30 April 2026; submit a report to the administrating authority. The report must propose interim groundwater trigger values to populate Table I2 (Groundwater quality triggers), based on a minimum of eight (8) sampling events per bore; and

iii. by 30 April 2026, submit a report to the administering authority. The report must propose groundwater standing water level trigger thresholds, derived from the results of the groundwater model required by condition I13(a), to populate Table I3 (Groundwater standing water level trigger thresholds);

iv. by 30 April 2027; submit a report to the administrating authority. The report must review the interim groundwater trigger values and propose revised groundwater trigger values to populate Table I2 (Groundwater quality triggers) based on a minimum of eighteen (18) sampling events per bore; and

b) for groundwater monitoring bores identified as “new bores” in Table I1 (Groundwater Monitoring Locations and Frequency):

i. by 31 May 2025, provide planned location coordinates of new bores to administering authority; and

ii. by 30 June 2026, install and commission groundwater monitoring bores in accordance with condition I4 and provide bore reports to the administering authority in accordance with condition I3; and

iii. by 31 July 2026, commence monitoring in accordance with condition I5; and

iv. by 31 July 2027, submit a report to the administering authority. The report must propose interim groundwater trigger values to populate Table I2 (Groundwater quality triggers), based on a

minimum of eight (8) sampling events per bore; and v. by 31 July 2027, submit a report to the administering authority. The report must propose groundwater standing water level trigger thresholds, derived from the results of the groundwater model required by condition I13(a), to populate Table I3 (Groundwater standing water level trigger thresholds);

vi. by 31 July 2028; submit a report to the administrating authority. The report must review the interim groundwater trigger values and propose revised groundwater trigger values to populate Table I2 (Groundwater quality triggers) based on a minimum of eighteen (18) sampling events per bore; and c) by 30 April 2026, develop and implement the Groundwater Monitoring and Management Program in accordance with condition I12 of the EA.

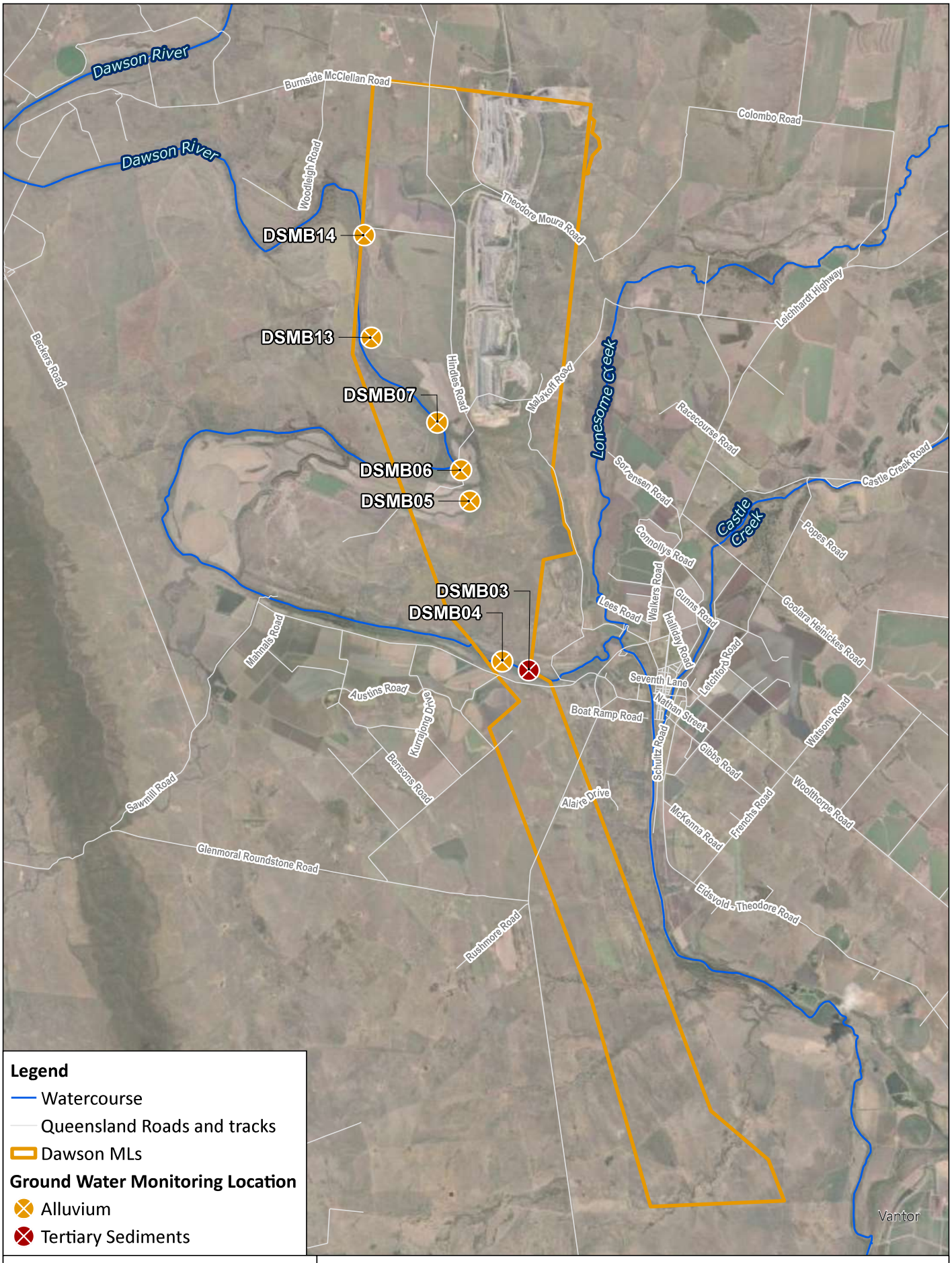


Figure 3-33 Groundwater Monitoring Bore Locations

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

3.8.4 Schedule for monitoring, reporting and review for each milestone

A schedule for monitoring, reporting and review for each of the milestones is described in Appendix 4.1. Additional information on the treatment of contingencies is provided in Section 3.7 (Risk Assessment).

3.8.5 Quality assurance and data management

All monitoring will be undertaken by appropriately qualified personnel. Data will be collected for storage in a database. The data will be reviewed by appropriately qualified personnel and evaluated for the purpose of trending, reporting, and future reference. Data will be kept for a minimum of five years.

3.8.6 Analysis and interpretation

The monitoring methodology assesses the field recorded values against agreed minimum targets for safe, stable and sustainable values, ie the PMLU criteria. Monitoring results will be compared across monitoring events to determine progress towards achieving the closure criteria. Where progress is lacking or less than desired, intervention will be undertaken to ensure progress in future years.

3.8.7 Reporting and review

Reports are prepared at the conclusion of each annual monitoring event. The purpose of the annual reports is to present an annual update of the rehabilitation progress towards the achievement of PMLU criteria . The results of each additional year of monitoring are compared to those of previous years by showing the trends towards the achievement of the safe, stable, non-polluting and self-sustaining PMLU criteria, and recommendations are provided to improve and further support the continued progression of the rehabilitation.

The reports may also describe corrective actions/contingency strategies, should these require implementation. These may include one or more of the following:

- Application of additional soil amelioration;
- Reshaping and stabilisation of erosion features;
- Reseeding and/or replanting;
- Review the seed mix, including species, supplier, viability, application method; and
- Weed and pest management.

The reports are reviewed by DS, for implementation of contingency strategies, as appropriate.

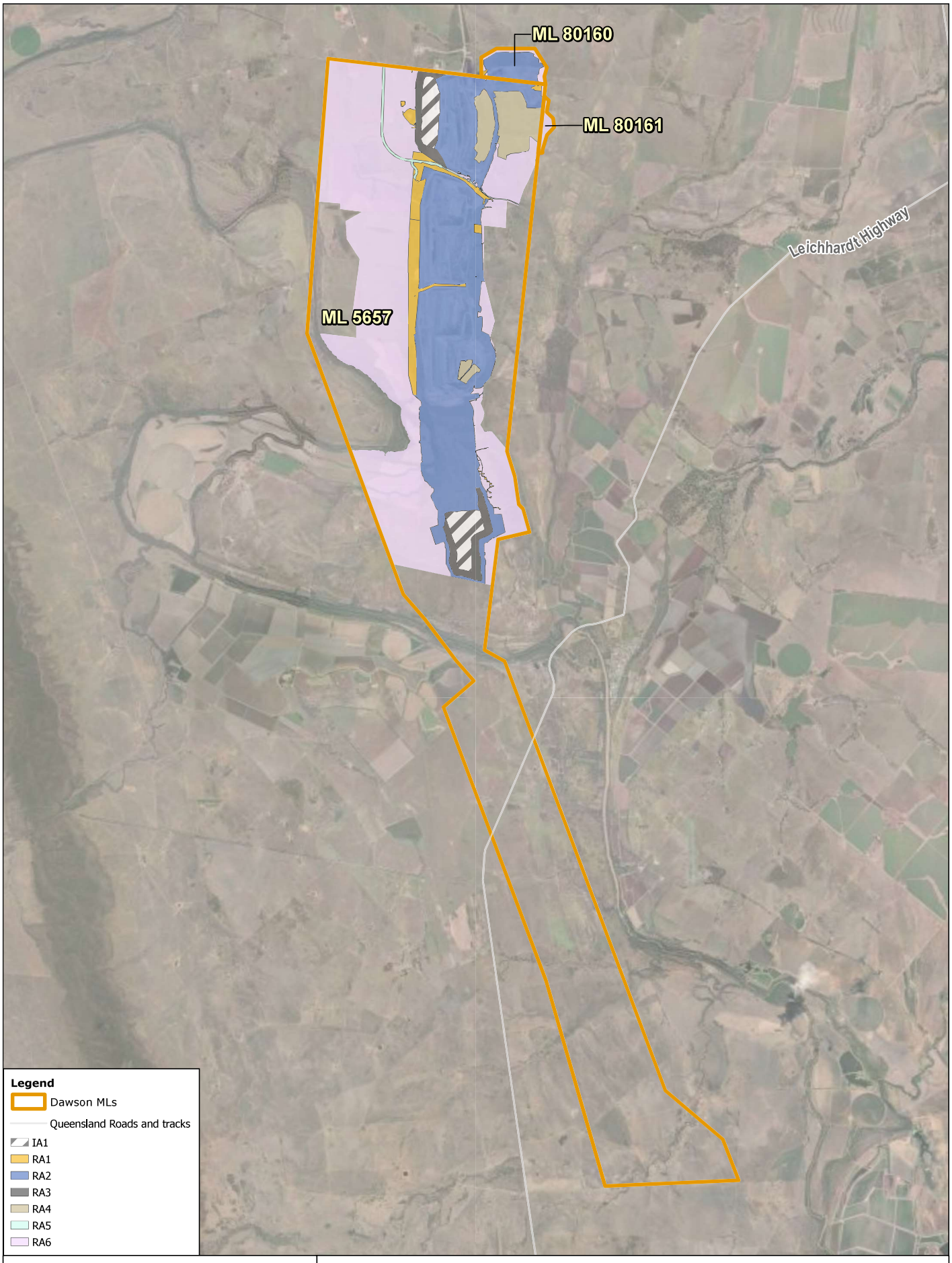
Appendix 4.9 provides a copy of the latest vegetation monitoring undertaken to date, based on trends in the data and benchmarking against critical values derived from reference sites.

3.9 PRCP Schedule

A PRCP Schedule has been provided in Appendix 4.1. The schedule has been populated with timeframes for completing rehabilitation over the life of operations. Rehabilitation areas (RAs) and Improvements Areas (IAs) and applicable milestones are provided below in Table 3-47 . A figure of each of the RAs and IAs is provided in Figure 3-34.

Table 3-47 Rehabilitation and Improvement Areas

Rehabilitation Area / Improvement Area	Description	Area (ha)	PMLU	Applicable Milestone
RA1	Infrastructure areas including cleared areas, access tracks, topsoil stockpiles, roads, etc	183.97	Grazing	RM1 RM2 RM3 RM4 RM5 RM6 RM7 RM8
RA2	Overburden Dumps including ramps, haul roads, spoil DRE, spoil TS, etc	1689.84	Grazing	RM1 RM2 RM3 RM4 RM5 RM6 RM7 RM8
RA3	Overburden Dumps including ramps, haul roads, spoil DRE, spoil TS, etc	121.84	Bushland	RM1 RM2 RM3 RM4 RM5 RM6 RM7 RM8
RA4	Existing Rehabilitation	221.70	Grazing	RM6 RM7 RM8
RA5	Theodore-Moura Road	29.21	Permanent Infrastructure	RM8
RA6	Ancillary and Exploration	2,398.52	Grazing	RM1 RM6 RM7 RM8



Coordinate System:
AGD 1966 AMG Zone 56

Date: 06/05/2026
Created By: CB/IY/IS
Drawing Size: A4

0 1 2 3km

Figure 3-34 Rehabilitation and Improvement Areas

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

3.9.1 Milestones and Milestones Criteria

Rehabilitation milestones and criteria have been developed in preparation of the PRCP schedule. They have been included in the PRCP schedule in Appendix 4.1.

3.10 Document information

3.10.1 References

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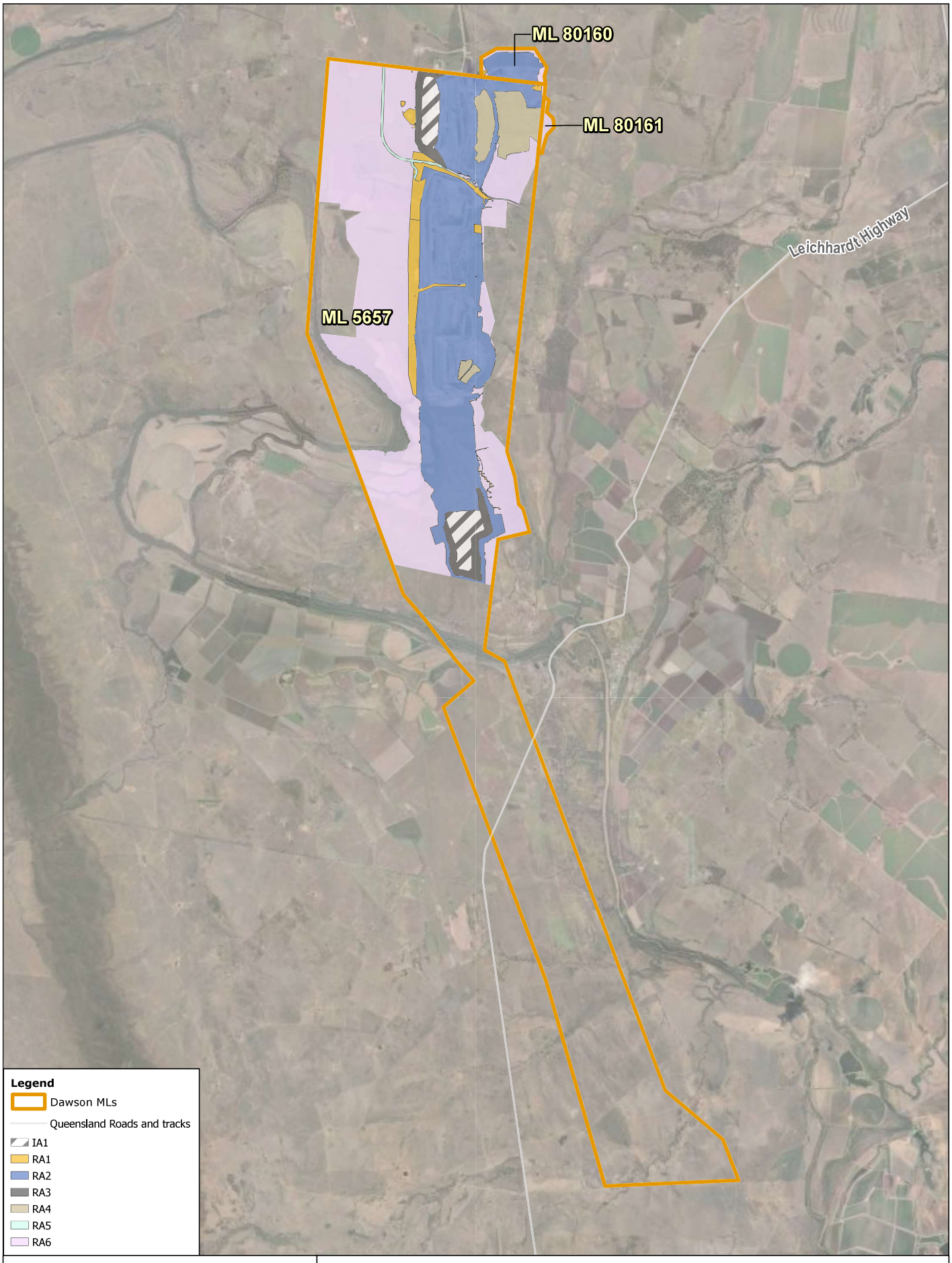
3.10.2 Spatial Information

The following spatial information has been prepared and submitted with this PRCP in accordance with the guideline 'Spatial Information Submission Guideline' (ESR/2018/4337- Version 6) (DETSI 2024):

- Location and maximum extent of disturbance footprint for the mine life;
- PMLU and NUMAs for the area within the resource tenure/s;
- Rehabilitation and improvement areas within the resource tenure/s (for a 10-year period minimum);
- Any sensitive receptors under the EA;
- Extent of a floodplain; and
- Existing rehabilitation.

The administering authority requires that the shape files and the associated attribute information are submitted in a defined format (schema) to ensure consistency in the data being received from sites across Queensland. The schema requirements outlined in Attachment 1 of the PRCP approved form have been followed, and each geometry type has been submitted in a separate file. Files have been named in accordance with the guideline 'Spatial Information Submission Guideline' (DETSI 2024)

Appendix 4.1 PRC Schedule



Coordinate System:
AGD 1966 AMG Zone 56

Date: 06/05/2026
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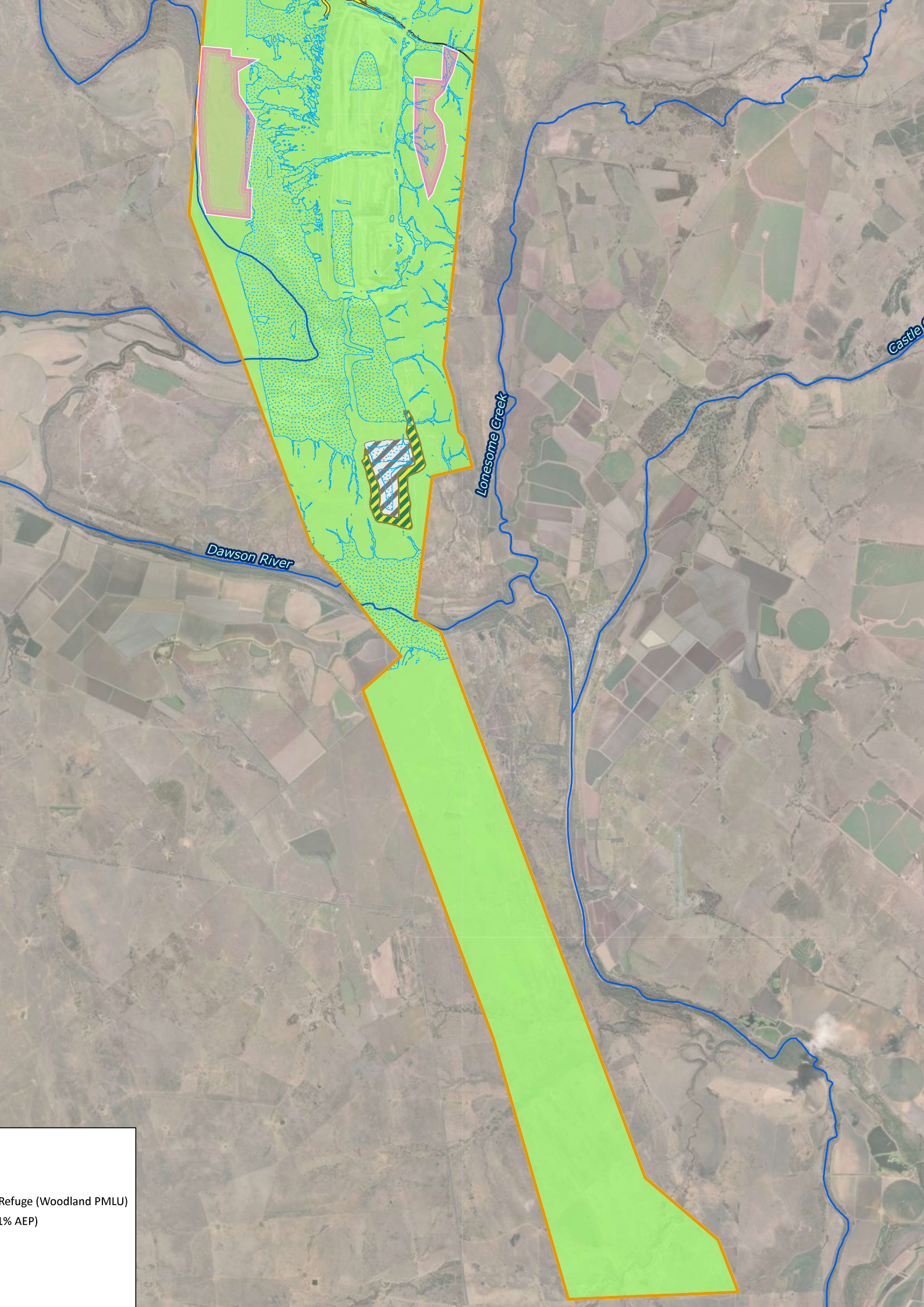
0 1 2 3km

Rehabilitation and Improvement Areas

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican


Lonesome Creek
Dawson River
Refuge (Woodland PMLU)
1% AEP)

Post-mining land uses (PMLU)																				
Rehabilitation area	RA1																			
Relevant activities	Infrastructure (includes: cleared areas, access tracks, topsoil stockpile, exploration pads, laydown yards, pipelines, powerlines, water management infrastructure)																			
Total rehabilitation area size (ha)	185.11																			
Commencement of first milestone: RM1	30/01/2026																			
PMLU	Grazing																			
Date area is available	10/12/25	10/12/31	10/12/36	10/12/41	10/12/46	10/12/51														
Cumulative area available (ha)	2.87	88.78	92.35	114.33	118.10	185.11														
Milestone completed by	10/12/35	10/12/40	10/12/45	10/12/50	10/12/55	10/12/60	10/12/65	10/12/70	10/12/75	10/12/80	10/12/85	10/12/00								
Milestone Reference	Cumulative area achieved (ha)																			
RM1	2.87	88.78	92.35	114.33	118.10	185.11														
RM2	2.87	88.78	92.35	114.33	118.10	185.11														
RM3		2.87	88.78	92.35	114.33	118.10	185.11													
RM4			2.87	88.78	92.35	114.33	118.10	185.11												
RM5			2.87	88.78	92.35	114.33	118.10	185.11												
RM6				2.87	88.78	92.35	114.33	118.10	185.11											
RM7						2.87	88.78	92.35	114.33	118.10	185.11									
RM8							2.87	88.78	92.35	114.33	118.10	185.11								

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)																				
Rehabilitation area	RA1																			
Relevant activities	Infrastructure (includes: cleared areas, access tracks, topsoil stockpile, exploration pads, laydown yards, pipelines, powerlines, water management infrastructure)																			
Total rehabilitation area size (ha)	183.97																			
Commencement of first milestone: RM1	30/01/2026																			
PMLU	Grazing																			
Date area is available	10/12/25	10/12/31	10/12/36	10/12/41	10/12/46	10/12/51														
Cumulative area available (ha)	2.87	88.78	92.35	114.33	118.10	183.97														
Milestone completed by	10/12/35	10/12/40	10/12/45	10/12/50	10/12/55	10/12/60	10/12/65	10/12/70	10/12/75	10/12/80	10/12/85	10/12/00								
Milestone Reference	Cumulative area achieved (ha)																			
RM1	2.87	88.78	92.35	114.33	118.10	183.97														
RM2	2.87	88.78	92.35	114.33	118.10	183.97														
RM3		2.87	88.78	92.35	114.33	118.10	183.97													
RM4			2.87	88.78	92.35	114.33	118.10	183.97												
RM5			2.87	88.78	92.35	114.33	118.10	183.97												
RM6				2.87	88.78	92.35	114.33	118.10	183.97											
RM7						2.87	88.78	92.35	114.33	118.10	183.97									
RM8							2.87	88.78	92.35	114.33	118.10	183.97								

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
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3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)																												
Rehabilitation area	RA2																											
Relevant activities	Overburden Dumps (includes: ramps, haul roads, spoil DRE, spoil TS, backfilled mining pits)																											
Total rehabilitation area size (ha)	1689.84																											
Commencement of first milestone: RM1	30/01/2026																											
PMLU	Grazing																											
Date area is available	10/12/25	10/12/31	10/12/36	10/12/41	10/12/46	10/12/51																						
Cumulative area available (ha)	25.18	181.41	819.20	1167.15	1229.52	1689.84																						
Milestone completed by	10/12/30	10/12/36	10/12/41	10/12/46	10/12/51	10/12/56	10/12/61	10/12/66	10/12/71	10/12/76	10/12/00																	
Milestone Reference	Cumulative area achieved (ha)																											
RM1	25.18	181.41	819.20	1167.15	1229.52	1689.84																						
RM2	25.18	181.41	819.20	1167.15	1229.52	1689.84																						
RM3		25.18	181.41	819.20	1167.15	1229.52	1689.84																					
RM4			181.41	819.20	1167.15	1229.52	1689.84																					
RM5			25.18	181.41	819.20	1167.15	1229.52	1689.84																				
RM6				25.18	181.41	819.20	1167.15	1229.52	1689.84																			
RM7					25.18	181.41	819.20	1167.15	1229.52	1689.84																		
RM8											1689.84																	

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)																	
Rehabilitation area	RA3																
Relevant activities	Overburden Dumps (includes: ramps, haul roads, spoil DRE, spoil TS, backfilled mining pits)																
Total rehabilitation area size (ha)	121.84																
Commencement of first milestone: RM1	1/01/2036																
PMLU	Bushland																
Date area is available	10/12/35	10/12/41	10/12/46	10/12/51	10/12/56	10/12/61											
Cumulative area available (ha)	51.06	51.06	121.84	121.84	121.84	121.84											
Milestone completed by	10/12/46	10/12/51	10/12/56	10/12/66	10/12/66	10/12/75	10/12/00										
Milestone Reference	Cumulative area achieved (ha)																
RM1	51.06		121.84														
RM2	51.06		121.84														
RM3		51.06		121.84													
RM4		51.06			121.84												
RM5			51.06		121.84												
RM6				51.06		121.84											
RM7				51.06		121.84											
RM8							121.84										

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA4									
Relevant activities	Existing Rehabilitation (81.77 ha progressively certified)									
Total rehabilitation area size (ha)	221.70									
Commencement of first milestone: RM1	1/01/2031									
PMLU	Grazing									
Date area is available	10/12/30									
Cumulative area available (ha)	221.70									
Milestone completed by	10/12/40	10/12/00								
	Cumulative area achieved (ha)									
RM6	221.70									
RM7	221.70									
RM8		221.70								

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA5									
Relevant activities	Theodore-Moura Road									
Total rehabilitation area size (ha)	29.21									
Commencement of first milestone: RM1	1/01/2081									
PMLU	Permanent Infrastructure									
Date area is available	10/12/80									
Cumulative area available (ha)	29.21									
Milestone completed by	10/12/00									
	Cumulative area achieved (ha)									
RM8	29.21									

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)																	
Rehabilitation area	RA6																
Relevant activities	Ancillary and Exploration																
Total rehabilitation area size (ha)	2398.52																
Commencement of first milestone: RM1	1/01/2081																
PMLU	Grazing																
Date area is available	1/01/80																
Cumulative area available (ha)	2398.52																
Milestone completed by	10/12/85	10/12/90	10/12/95	10/12/00													
Milestone Reference	Cumulative area achieved (ha)																
RM1	2398.52																
RM6			2398.52														
RM7			2398.52														
RM8				2398.52													

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	IA1									
Relevant activities	Void NUMA									
Total rehabilitation area size (ha)	152.45									
Commencement of first milestone: RM1	1/01/2047									
PMLU	NUMA									
Date area is available	1/01/46	10/12/52	10/12/57							
Cumulative area available (ha)	69.26	69.26	152.45							
Milestone completed by	10/12/52	10/12/57	10/12/62	10/12/67	10/12/72					
	Cumulative area achieved (ha)									
MM1	69.26	69.26	152.45							
MM2		69.26	69.26	152.45						
MM3			69.26	69.26	152.45					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Attachment 1 - Soil Quality Criteria

Parameter	Criteria
pH	6.0-8.5
Electrical Conductivity (EC) 1:5 (µS/cm)	2000
Sulphates (mg/kg)	4
Nitrate (mg/kg)	>12.5
Total Kjeldahl Nitrogen (mg/kg)	200
Total Phosphorus (mg/kg)	10
Chloride (mg/kg)	<800
Cation Exchange Capacity (CEC) and Exchangeable Cations (m eq /100g)	5
Exchangeable Sodium Percentage [ESP] (%)	<6
Organic matter (mg/kg)	2-3
Emerson aggregate class	4

Attachment 2 - Erosion Classification Framework

Erosion classification	Minor	Moderate	Severe
Sheet erosion	Shallow soil deposits downslope	Partial exposure of roots; moderate soil deposits downslope, etc	Loss of surface horizon; root exposure; moderate substantial soil deposits downslope
Rill erosion	<0.3m deep; <15 rills/transect*	<0.3m deep; 15-30 rills/transect*	<0.3m deep; >30 rills/transect*
Gully erosion	Absent	>0.3m deep; Gullies are linear, continuous, and restricted to primary or minor drainage lines	>0.3m deep; Gullies are continuous or discontinuous, and either tend to branch away from primary drainage lines and on to foot slopes, or have multiple branches within drainage lines
Tunnel erosion	Absent	Absent	Present
Mass movement	Absent	Absent	Present

Source: NCST (2009) Australian Soil and Land Survey Field Handbook, 3rd edition. The National Committee on Soil and Terrain. CSIRO Publishing, Collingwood, Australia.
*Transect linear 100 m across the contour (Source: Tongway, D. J. and Hindley, N. L. 2005. Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes. CSIRO Publishing, Canberra, Australia)

Attachment 3 - Species Seed Mixes

Species Name*	Common Name	Suitability		Rationale			Post Mining Land Use**
		Steep-rocky slopes	Flat/Gentle Topsoiled surfaces	Already present in rehabilitation area*	Typical dominant species in native ecosystems	Typical habitat	
Trees							
Corymbia citriodora	Lemon-scented Gum	✓	✓	✓	✓	In variety of situations	G
Corymbia clarksoniana	Clarkson's bloodwood	✓	✓			Both plains and skeletal soils	G
Corymbia erythrophloia	Red bloodwood	✓	✓		✓	Variety of habitats	G
Corymbia tessellaris	Moreton Bay ash		✓			Creek banks	G
Corymbia watsoniana	Yellow jacket	✓	✓		✓	Sandy soils on sandstone.	G
Eucalyptus cambageana	Dawson gum		✓	✓	✓	Often occurs with Brigalow, but could be good in slightly more saline areas	
Eucalyptus cloeziana	Gympie messmate	✓				Skeletal soil	
Eucalyptus crebra	Small-leaved ironbark	✓	✓	✓	✓	Variety of habitats	G
Eucalyptus longirostrata	Grey gum	✓		✓		Skeletal soil	G
Eucalyptus melanophloia	Silver-leaved ironbark		✓		✓	Upper floodplains	G
Eucalyptus microcarpa	Grey box		✓		✓	Grassy flats	
Eucalyptus orgadophila	Mountain coolabah		✓	✓	✓	Variety of habitats	G
Eucalyptus suffulgens	Blue mallee	✓				Skeletal soil	G
Eucalyptus tereticornis	Blue gum		✓	✓	✓	Variety of habitats.	G
Eucalyptus thozetiana	Thozet's gum	✓	✓	✓		Variety of habitats, pebbly soils, slight rises	G
Ficus rubiginosa	Rusty fig	✓	✓			Rocky locations in region	G
Lysicarpus angustifolius	Brown hazelwood		✓		✓	Poor nutrient soils	G
Lysiphyllum hookeri	Native bauhinia	✓	✓			Fixes nitrogen	G
Small Trees/Tall Schrubs							
Acacia bancroftiorum	Bancroft's wattle	✓	✓	✓	✓	Often present in rehab within region. Fixes nitrogen	
Acacia fasciculifera	Scrub ironbark	✓	✓		✓	Variety of habitats, including ridges and along creeks. Fixes nitrogen.	
Acacia conferta	Crowded-leaf wattle		✓		✓	Fixes nitrogen.	
Acacia crassa	Curacabbah	✓	✓		✓	Variety of habitats. Fixes nitrogen	
Acacia decora	Pretty wattle	✓		✓		Ridges and outcrops. Fixes nitrogen.	
Acacia leiocalyx	Black wattle		✓		✓	Variety of habitats. Fixes nitrogen.	
Acacia neriifolia	Oleander wattle	✓	✓			Rocky hillsides and ridgetops of granite or sandstone. Fixes nitrogen.	
Acacia oswaldii	Boree		✓			Loamy soil. Fixes nitrogen.	
Acacia rhodoxylon	Rosewood	✓	✓	✓		Skeletal soils on hills of the region. Fixes nitrogen.	
Acacia shirleyi	Lancewood	✓			✓	Rocky slopes of region. Fixes nitrogen	
Acalypha eremorum		✓	✓			Variety of habitats.	
Alectryon diversifolius			✓	✓		Clay soil	
Allocasuarina littoralis	Black she-oak	✓	✓		✓	Variety of habitats. Fixes nitrogen	
Alphitonia excelsa	Soap tree		✓	✓	✓	Variety of habitats. Common pioneer	
Alstonia constricta		✓	✓	✓	✓	Variety of habitats., including rocky slopes. Common pioneer	
Archidendropsis basaltica		✓	✓	✓		Variety of habitats	
Atalaya hemiglauca	Whitewood		✓	✓		Variety of habitats.. Common pioneer on clayey soils	
Cassia brewsteri	Leichhardt bean	✓	✓	✓		Variety of habitats. Fixes nitrogen.	
Croton insularis							
Denhamia oleaster							
Diospyros humilis							
Drypetes deplanchei							
Ehretia saligna var. membranifolia							
Eremophila deserti							
Eremophila mitchellii							
Excoecaria dallachyana							
Ficus opposita							
Flindersia dissosperma							
Geijera salicifolia							
Geijera parviflora							
Grevillea striata							
Leptospermum sericatum							
Leptospermum lamellatum							
Lophostemon suaveolens							
Macropteranthes leichhardtii							
Notelaea microcarpa							
Owenia acidula							
Petalostigma pubescens							
Pittosporum angustifolium							
Pittosporum spinescens							
Psydrax odorata		✓	✓	✓		Variety of habitats	
Psydrax oleifolia		✓	✓			Occurs in variety of habitats in region, including in RE adjacent to site typical of generally deep texture contrast with thick sandy surface horizons with some deep red earths	
Santalum lanceolatum	Sandalwood	✓	✓			Variety of habitats	
Senna gaudichaudii		✓	✓			Variety of habitats. Fixes nitrogen	
Terminalia oblongata	Yellowwood		✓			Black soil	
Small Schrubs							
Acalypha eremorum		✓	✓			Variety of habitats	
Bertya pedicellata		✓				Variety of habitats	
Boronia odorata		✓				Variety of habitats	
Breynia oblongifolia	Coffee bush		✓	✓		Variety of habitats	
Carissa ovata			✓	✓		Variety of habitats	
Clerodendrum floribundum	Lolollly bush		✓			Variety of habitats. Quite often used in rehab	
Corchorus trilocularis			✓			Variety of habitats. Used effectively in rehab elsewhere	
Dodonaea filifolia		✓				Variety of habitats	
Dodonaea viscosa	Sticky hopbush		✓	✓	✓	Variety of habitats. Used effectively in rehab elsewhere	
Dodonaea stenophylla		✓				Variety of habitats	
Dodonaea triangularis		✓				Variety of habitats	
Eremophila debilis			✓			Variety of habitats	
Erythroxylum australe	Ironwood	✓	✓	✓		Variety of habitats	
Grewia latifolia	Dog's balls	✓	✓	✓	✓	Variety of habitats	
Hibbertia cistoidea		✓	✓			Variety of habitats	
Hovea longipes		✓	✓			Variety of habitats Fixes nitrogen	
Hovea lorata		✓	✓			Variety of habitats. Fixes nitrogen	
Jacksonia scoparia	Dogwood	✓	✓			Variety of habitats. Fixes nitrogen	
Myoporum acuminatum	Boobialla		✓	✓		Variety of habitats	
Pultenaea spinosa			✓	✓		Variety of habitats. Fixes nitrogen	
Senna artemisioides	Wormwood	✓	✓	✓	✓	Variety of habitats. Drought tolerant. Fixes nitrogen	
Vines							
Boerhavia dominii			✓	✓		Variety of habitats, especially black soil	
Capparis lasiantha		✓	✓	✓		Variety of habitats	
Clematicissus opaca		✓	✓			Variety of habitats	
Desmodium brachypodum (NL)		✓	✓		✓	Variety of habitats. Nitrogen fixing	G
Desmodium rhytidophyllum (NL)		✓	✓		✓	Variety of habitats. Nitrogen fixing	G
Eustrephus latifolius	Wombat berry	✓	✓	✓		Variety of habitats	
Evolvulus alsinoides			✓	✓		Variety of habitats	
Galactia tenuiflora (NL)		✓	✓			Variety of habitats. Nitrogen fixing	G
Glycine tomentella (NL)		✓	✓			Variety of habitats. Nitrogen fixing	G
Hardenbergia violacea (NL)		✓	✓			Variety of habitats. Nitrogen fixing	G
Ipomoea plebeia			✓			Variety of habitats	
Jasminum didymum		✓	✓			Variety of habitats	
Kennedia rubicunda (NL)		✓	✓		✓	Variety of habitats. Nitrogen fixing	G
Neptunia gracilis (NL)			✓		✓	Variety of habitats. Often used in rehabilitation. Fixes nitrogen	G
Pandorea pandorana	Jasmin	✓	✓			Variety of habitats	
Parsonsia lanceolata	Monkey rope		✓		✓	Variety of habitats	
Passiflora aurantia		✓	✓			Variety of habitats	
Rhynchosia minima (NL)		✓	✓	✓	✓	Variety of habitats. Nitrogen fixing	G
Vigna spp. (NL)		✓	✓			Variety of habitats. Nitrogen fixing	G
Grasses							
Aristida calycina	Three awn	✓	✓	✓	✓	Variety of habitats, poor soils	G
Aristida caput- medusae	Three awn	✓			✓	Variety of habitats, poor soils	G
Aristida latifolia	Three awn	✓	✓	✓	✓	Variety of habitats, clay soils	

Attachment 3 - Species Seed Mixes

Species Name*	Common Name	Suitability		Rationale			Post Mining Land Use**
		Steep-rocky slopes	Flat/Gentle	Already present in rehabilitation area*	Typical dominant species in native ecosystems	Typical habitat	
			Topsoiled surfaces				
Arundinella nepalensis	Reedgrass		✓			Variety of habitats	G
Bothriochloa bladhii (3P)	Bluegrass	✓	✓	✓	✓	Variety of habitats	G
Bothriochloa decipiens	Pitted bluegrass	✓	✓	✓	✓	Variety of habitats	G
Brachyachne convergens			✓			Variety of habitats	
Chloris ventricosa			✓		✓	Variety of habitats. Clay soils	G
Chrysopogon fallax (3P)	Golden beard grass	✓	✓	✓	✓	Variety of habitats	G
Cleistochloa subjuncea	Wire grass	✓			✓	Adapted to skeletal soils. Tough species	G
Cymbopogon refractus	Barbed wire grass	✓	✓	✓	✓	Variety of habitats	G
Dactylotenium radulans			✓			Variety of habitats. Stoloniferous species	
Dichanthium sericeum (3P)	Bluegrass		✓	✓	✓	Black soils	G
Digitaria brownii (3P)			✓		✓	Variety of habitats	G
Digitaria ciliaris			✓		✓	Variety of habitats	
Dinebra decipiens			✓			Variety of habitats	
Enneapogon lindleyanus	Nineawn			✓	✓	Variety of habitats, skeletal soils	G
Enneapogon truncatus	Nineawn			✓	✓	Variety of habitats, skeletal soils	G
Enteropogon acicularis (3P)	Nineawn		✓		✓	Variety of habitats, clay soils	G
Entolasia stricta		✓	✓		✓	Adapted to skeletal soils. Tough species	G
Eragrostis lacunaria			✓		✓	Variety of habitats	G
Eriochloa crebra			✓			Variety of habitats	G
Heteropogon contortus (3P)	Black speargrass	✓	✓	✓	✓	Variety of habitats. Common on slopes and ridges of the region	G
Iseilema spp.			✓		✓	Variety of habitats, often on plains	
Panicum decompositum	Panic		✓		✓	Clayey, periodically flooded sites	G
Panicum effusum	Panic		✓		✓	Variety of habitats, especially clay soils	G
Paspalidium caespitosum	Brigalow grass		✓	✓	✓	Variety of habitats in more favourable sites	
Paspalidium gracile (3P)	Slender panic		✓		✓	Variety of habitats in more favourable sites	G
Sporobolus caroli	Fairy grass		✓		✓	Variety of habitats in more favourable sites	
Themeda triandra (3P)	Kangaroo grass	✓	✓	✓	✓	Wide variety of habitats, but with soil.	G
Triodia mitchellii	Buck Spinifex	✓			✓	Stony soils on hillslopes, ridges and plateaux	
FORBS							
Atriplex muelleri	Saltbush		✓		✓	Salt tolerant	
Basilicum polystachyon	Basil	✓	✓			Variety of habitats	
Brunoniella australis			✓	✓		Variety of habitats	
Cheilanthes sieberi	Rasp fern	✓	✓	✓	✓	Variety of habitats	
Cullen tenax	Emu foot		✓	✓		Variety of habitats. Nitrogen fixing	
Dampiera discolor			✓			Variety of habitats	
Dianella longifolia	Flax lily	✓	✓			Variety of habitats, damper sites	
Dysphania carinata			✓			Variety of habitats. Salt tolerant	
Einadia spp.	Saltbush		✓		✓	Variety of habitats. Salt tolerant	
Enchylaena tomentosa	Ruby saltbush						
Euphorbia drummondii							
Euphorbia tannensis subsp. eremophila							
Goodenia glabra							
Goodenia rotundifolia							
Gossypium sturtianum							
Hibiscus sturtii							
Lomandra confertifolia	Matrush						
Lomandra multiflora	Matrush						
Maireana enchylaenoides	Wingless bluebush						
Melhania oblongifolia							
Peripleura hispidula							
Phyllanthus virgatus							
Pterocaulon serrulatum							
Rostellularia adscendens							
Rutidosis crispata							
Seringia corollata							
Solanum elachophyllum	Nightshade						
Solanum ellipticum	Nightshade						
Solanum parvifolium	Nightshade						
Sida spp. (Native!)	Sida						
* 3P = Palatable, Perennial, Productive ; NL = Native Legume ** While all species are suitable for either PMLU (Grazing or Bushland), those marked G are highlighted for Grazing (fodder and shade)							
Bushland PMLU							
TREES							
(minimum of 3 species from the list with bulked seed at 3kg/ha (assuming some chaff and impurities in the seed lots). Use 1.5kg/ha if using pure seed)							
Lysicarpus angustifolius	Eucalyptus cambageana		Eucalyptus longirostrata			Corymbia watsoniana	
Eucalyptus thozetiana	Eucalyptus citriodora		Eucalyptus orgadophila				
Corymbia clarksoniana	Eucalyptus tereticornis		Eucalyptus suffulgens				
Corymbia erythrophloia	Eucalyptus crebra		Eucalyptus cloeziana				
TALL SHRUBS/SMALL TREES							
(minimum of 4 species from the list with bulked seed at 4 kg/ha). (assuming some chaff and impurities in the seed lots).							
Allocasuarina littoralis	Alectryon diversifolius		Cassia brewsteri			Lophostemon suaveolens	
Acacia bancroftiorum	Acacia rhodoxylon		Denhamia oleaster			Notelaea microcarpa	
Acacia fasciculifera	Acacia shirleyi		Ficus opposita			Petalostigma pubescens	
Acacia conferta	Alphitonia excelsa		Eremophila mitchellii			Terminalia oblongata	
Acacia crassa	Alstonia constricta		Leptospermum lamellatum			Psydrax odorata	
Acacia decora	Archidendropsis basaltica		Geijera salicifolia			Santalum lanceolatum	
Acacia leiocalyx	Atalaya hemiglauca		Pittosporum spinescens				
LOW SHRUBS							
(minimum of 1 species from the list with a bulked seed at 1kg/ha) (assuming some chaff and impurities in the seed lots).							
Breynia oblongifolia	Dodonaea viscosa		Erythroxylum australe			Dodonaea filifolia	
Carissa ovata	Jacksonia scoparia		Grewia latifolia			Eremophila debilis	
Hovea lorata	Dodonaea triangularis		Hovea longipes				

Attachment 4 - Seeding Rates

Bushland PMLU			
TREES			
(minimum of 3 species from the list with bulked seed at 3kg/ha (assuming some chaff and impurities in the seed lots). Use 1.5kg/ha if using pure seed)			
Lysicarpus angustifolius	Eucalyptus cambageana	Eucalyptus longirostrata	Corymbia watsoniana
Eucalyptus thozetiana	Eucalyptus citriodora	Eucalyptus orgadophila	
Corymbia clarksoniana	Eucalyptus tereticornis	Eucalyptus suffulgens	
Corymbia erythrophloia	Eucalyptus crebra	Eucalyptus cloeziana	
TALL SHRUBS/SMALL TREES			
(minimum of 4 species from the list with bulked seed at 4 kg/ha). (assuming some chaff and impurities in the seed lots).			
Allocasuarina littoralis	Alectryon diversifolius	Cassia brewsteri	Lophostemon suaveolens
Acacia bancroftiorum	Acacia rhodoxylon	Denhamia oleaster	Notelaea microcarpa
Acacia fasciculifera	Acacia shirleyi	Ficus opposita	Petalostigma pubescens
Acacia conferta	Alphitonia excelsa	Eremophila mitchellii	Terminalia oblongata
Acacia crassa	Alstonia constricta	Leptospermum lamellatum	Psydrax odorata
Acacia decora	Archidendropsis basaltica	Geijera salicifolia	Santalum lanceolatum
Acacia leiocalyx	Atalaya hemiglauca	Pittosporum spinescens	
LOW SHRUBS			
(minimum of 1 species from the list with a bulked seed at 1kg/ha) (assuming some chaff and impurities in the seed lots).			
Breynia oblongifolia	Dodonaea viscosa	Erythroxylum australe	Dodonaea filifolia
Carissa ovata	Jacksonia scoparia	Grewia latifolia	Eremophila debilis
Hovea lorata	Dodonaea triangularis	Hovea longipes	
GRASSES			
(minimum of 5 species from the list with bulked seed at 3kg/ha) (assuming some chaff and impurities in the seed lots).			
Aristida calycina	Cleistochloa subjuncea	Enneapogon lindleyanus	Chrysopogon fallax (3P)
Aristida caput-medusae	Cymbopogon refractus	Enneapogon truncatus	Digitaria brownii (3P)
Themeda triandra (3P)	Panicum effusum	Entolasia stricta	Eriochloa crebra (3P)
Paspalidium gracile (3P)	Heteropogon contortus (3P)	Eragrostis lacunaria	
Bothriochloa bladhii (3P)	Dichanthium sericeum (3P)	Enteropogon acicularis (3P)	
FORBS			
(minimum of 2 species from the list with bulked seed at 1kg/ha) (assuming some chaff and impurities in the seed lots).			
Euphorbia drummondii	Rostellularia adscendens	Melhania oblongifolia	Lomandra confertifolia
Euphorbia tannensis	Seringia corollata	Phyllanthus virgatus	Solanum parvifolium
Solanum ellipticum	Goodenia rotundifolia	Sida spp. (Native!)	Hibiscus sturtii
GRAZING PMLU			
SHADE TREES			
(minimum of 2 species from the list with bulked seed at 1kg/ha (assuming some chaff and impurities in the seed lots). Use 0.5kg/ha if using pure seed)			
Lysicarpus angustifolius	Eucalyptus cambageana	Eucalyptus longirostrata	Corymbia watsoniana
Eucalyptus thozetiana	Eucalyptus citriodora	Eucalyptus orgadophila	Corymbia erythrophloia
Corymbia clarksoniana	Eucalyptus tereticornis	Eucalyptus suffulgens	Eucalyptus crebra
GROUNDCOVER			
(minimum of 3 species from the list with bulked seed at 3kg/ha) (assuming some chaff and impurities in the seed lots)			
Boerhavia dominii	Eustrephus latifolius	Parsonsia lanceolata	Vigna spp. (NL)
Clematis opaca	Evolvulus alsinoides	Rhynchosia minima (NL)	Kennedia rubicunda (NL)
Desmodium brachypodum (NL)	Galactia tenuiflora (NL)	Neptunia gracilis (NL)	Entolasia stricta
Desmodium rhytidophyllum (NL)	Glycine tomentella (NL)	Pandorea pandorana	Eragrostis lacunaria
Euphorbia drummondii	Rostellularia adscendens	Melhania oblongifolia	Lomandra confertifolia
Euphorbia tannensis	Seringia corollata	Phyllanthus virgatus	Solanum parvifolium
Solanum ellipticum	Goodenia rotundifolia	Sida spp. (Native!)	Hibiscus sturtii
Aristida calycina	Cleistochloa subjuncea	Enneapogon lindleyanus	Panicum effusum
Aristida caput-medusae	Cymbopogon refractus	Enneapogon truncatus	
3P GRASSES			
(minimum of 3 species from the list with bulked seed at 3kg/ha) (assuming some chaff and impurities in the seed lots).			
Bothriochloa bladhii (3P)	Dichanthium sericeum (3P)	Enteropogon acicularis (3P)	Chrysopogon fallax (3P)
Paspalidium gracile (3P)	Heteropogon contortus (3P)	Eriochloa crebra (3P)	Digitaria brownii (3P)
Themeda triandra (3P)			

Note:
Where seed for a specific species is not available in sufficient quality or quantity as listed in this table, it will be supplemented by the equivalent weight of a comparable native species from the technical descriptions for suitable regional ecosystems.

Attachment 5 – BioCondition Benchmark Criteria

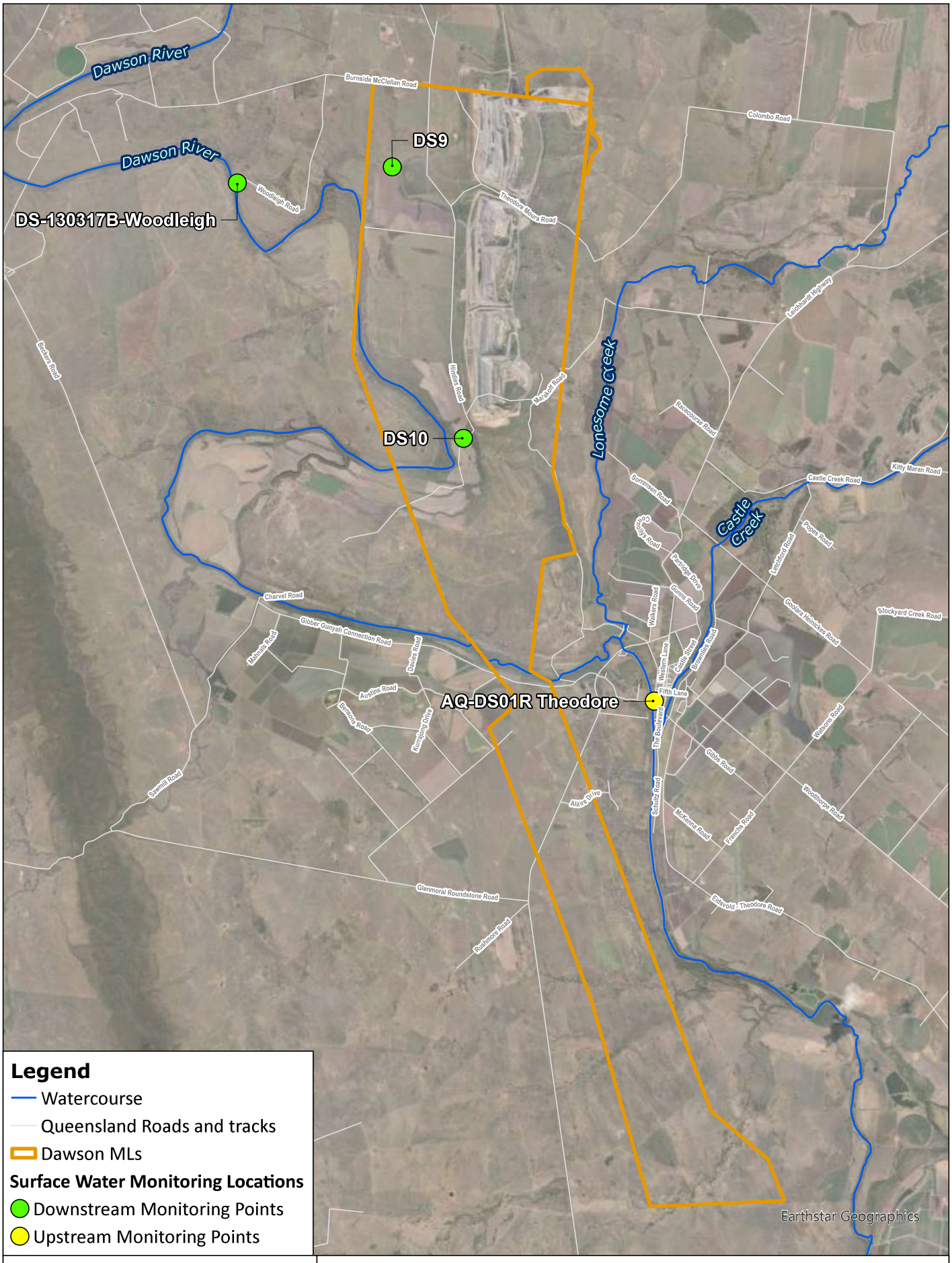
Regional Ecosystem RE11.10.1 Rehabilitated *Corymbia citriodora* and/or *Eucalyptus crebra* shrubby or grassy open forest.

BioCondition Assessable Attributes	BioCondition Assessable Attribute Weighting	BioCondition benchmark	Indicative [1] measure at c. 5yrs	BioCondition Score	Indicative [1] measure at c.15-20 yrs	BioCondition Score
Recruitment	5	100%	0	0	20%	3
Non-native plant cover (%)	10	0%	<25%	5	<25%	5
Tree species richness	5	4	1	2.5	4	5
Native shrub species richness	5	4	1	2.5	1	2.5
Native grass species richness	5	9	2	2.5	2	2.5
Native forb other species richness	5	17	4	2.5	4	2.5
Tree canopy height (m)	5	24	0	0	=6.0m	3
Tree canopy cover (%)	5	30	0.03	2	0.15	5
Shrub canopy cover (%)	5	13	0.01	3	0.065	3
Native perennial grass (%)	5	16	0.08	3	0.08	3
Litter ground cover (%)	5	50	0	0	0.05	3
Total BioCondition Assessable Score	**60**			**>20** (Total above = 23)		**>35** (Total above = 37.5)

[1] A site's total BioCondition score can be comprised of different attribute scores but must meet or exceed the minimum (modified) total BC score for the relevant milestone.

Attachment 6 - Surface Water Monitoring Locations

Monitoring Points	Receiving Waters Location Description	Latitude (decimal degree, GDA2020)	Longitude (decimal degree, GDA2020)
Upstream Monitoring Points			
AQ-DS01R Theodore	Dawson River 1.4 kilometres upstream of confluence with release water channel	-24.949	150.0736
Downstream Monitoring Points			
DS-130317B-Woodleigh	Dawson River main Channel at existing stream flow station at Woodleigh – 130317B	-24.83211532	149.9749957
DS9	Downgradient of Pit 25 and Pit 26	-24.82931846	150.0127133
DS10	Dawson River Anabranch, downstream of Pit 28	-24.8898177	150.0285621



Legend

- Watercourse
- Queensland Roads and tracks
- Dawson MLs

Surface Water Monitoring Locations

- Downstream Monitoring Points
- Upstream Monitoring Points

Coordinate System:
AGD 1966 AMG Zone 56

Date: 20/04/2026
Created By: CB/IY/IS
Drawing Size: A4

0 1 2 3km

Attachment 6 - Surface Water Monitoring Locations

Dawson Mine Complex

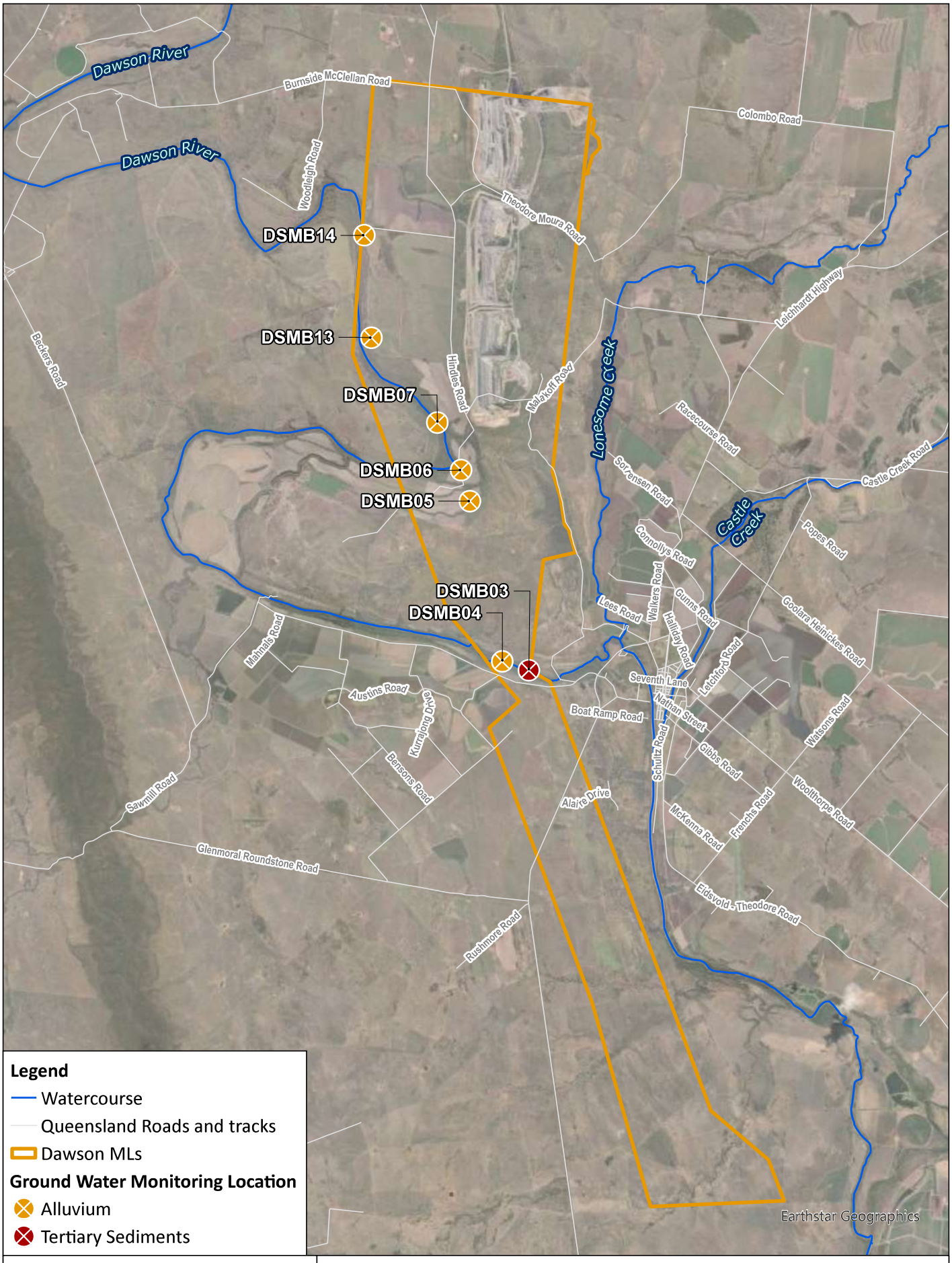
Anglo American Pty Ltd

AngloAmerican

Attachment 7 - Surface Water Quality Limits

Quality characteristic (units)	Limit	Comment on limit
pH	6.5-8.5	Lower Dawson River WQO
Electrical Conductivity (µS/cm)	340	Lower Dawson River WQO – Baseflow
Turbidity (NTU)	50	Lower Dawson River WQO
Sulphate (mg/L)	25	Lower Dawson River WQO
Fluoride (mg/L)	0.2	Site-specific – 95th percentile of upstream data
Aluminium - dissolved (µg/L)	160	Site-specific – 95th percentile of upstream data
Antimony - dissolved (µg/L)	9	ANZG 2018
Arsenic - dissolved (µg/L)	13	ANZG 2018
Boron - dissolved (µg/L)	90	Site-specific – 95th percentile of upstream data
Copper - dissolved (µg/L)	3	Site-specific – 95th percentile of upstream data
Iron - dissolved (µg/L)	270	Site-specific – 95th percentile of upstream data
Manganese - dissolved (µg/L)	63	Site-specific – 95th percentile of upstream data
Molybdenum - dissolved (µg/L)	2	Site-specific – 95th percentile of upstream data
Nickel - dissolved (µg/L)	11	ANZG 2018
Vanadium - dissolved (µg/L)	6	ANZG 2018
Zinc - dissolved (µg/L)	40	Site-specific – 95th percentile of upstream data
Nitrate (µg/L)	0.5	Site-specific – 95th percentile of upstream data
Total recoverable hydrocarbons (C6–C9) (µg/L)	20	
Total recoverable hydrocarbons (C10–C36) (µg/L)	100	
Major ions (mg/L) – Calcium, chloride, potassium, magnesium, sodium, bicarbonate, carbonate	For interpretation purposes	
Hardness (mg/L)	For interpretation purposes	

Notes:
All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample) and total (unfiltered).
Limits for metals and metalloids apply to dissolved results.
ANZG (2018) Aquatic ecosystem protection for moderately disturbed system (95% protection)
Lower Dawson WQOs- https://environment.desi.qld.gov.au/__data/assets/pdf_file/0030/88824/fitzroy_dawson_river_wqo_290911.pdf



Legend

- Watercourse
- Queensland Roads and tracks
- Dawson MLs

Ground Water Monitoring Location

- Alluvium
- Tertiary Sediments

Coordinate System:
AGD 1966 AMG Zone 56

Date: 24/04/2026
Created By: CB/IY/IS
Drawing Size: A4

0 1 2 3km

Attachment 7- Groundwater Monitoring Bore Locations

Dawson Mine Complex

Anglo American Pty Ltd

AngloAmerican

Attachment 8 - Groundwater Monitoring Locations

Monitoring Location	Hydrogeological Unit	Latitude (decimal degree, GDA2020)	Longitude (decimal degree, GDA2020)
DSMB03	Tertiary Sediments	-24.94157	150.04325
DSMB04	Alluvium	-24.93948	150.03683
DSMB05	Alluvium	-24.90379	150.0298
DSMB06	Alluvium	-24.89686	150.02784
DSMB07	Alluvium	-24.8862	150.02231
DSMB13	Alluvium	-24.86707	150.00675
DSMB14	Alluvium	-24.84432	150.00556
P25_MB02D	Tertiary Sediments	TBD	TBD
P25_MB_02S	Alluvium	TBD	TBD

Attachment 9 - Groundwater Quality Limits

Quality characteristic (units)	Monitoring Bore	Limit	Comment on limit
pH (pH units)	All bores	6.5 – 8.5	
Electrical conductivity (µS/cm)	All bores	4,600	WQO Zone 21
Sulfate (mg/L)	All bores	125	WQO Zone 21
Nitrate (mg/L)	All bores	1	WQO Zone 21
Fluoride (mg/L)	All bores	0.4	WQO Zone 21
Aluminium - dissolved (µg/L)	All bores	55	ANZG 2018
Antimony - dissolved (µg/L)	All bores	9	ANZG 2018
Arsenic - dissolved (µg/L)	All bores	13	ANZG 2018
Boron - dissolved (µg/L)	All bores	940	ANZG 2018
Copper – dissolved (µg/L)	All bores	60	WQO Zone 21
Iron - dissolved (µg/L)	All bores	280	ANZG 2018
Manganese - dissolved (µg/L)	All bores	270	WQO Zone 21
Molybdenum - dissolved (µg/L)	All bores	34	ANZG 2018
Nickel - dissolved (µg/L)	All bores	11	ANZG 2018
Vanadium - dissolved (µg/L)	All bores	6	ANZG 2018
Zinc - dissolved (µg/L)	All bores	150	WQO Zone 21
Major ions (mg/L) – Calcium, chloride, potassium, magnesium, sodium, bicarbonate, carbonate	All bores	For interpretation purposes	
Hardness (mg/L)	All bores	For interpretation purposes	
Water level (mAHD)	All bores	For interpretation purposes	

Notes:
All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample) and total (unfiltered). Limits for metals and metalloids apply to dissolved results.
ANZG (2018) Aquatic ecosystem protection for moderately disturbed system (95% protection)

Fitzroy Groundwater Basin Zone 21 WQOs - https://environment.desi.qld.gov.au/__data/assets/pdf_file/0030/88824/fitzroy_dawson_river_wqo_290911.pdf

Milestone reference	Rehabilitation milestone	Milestone Criteria	
RM1	Infrastructure decommissioning and removal	1.1	With the exception of any infrastructure to remain as part of the post-mining land use (PMLU), or where infrastructure is agreed to be retained by the landholder (as evidenced by a signed landholder agreement), the following are complete: (a) All buried services are decommissioned (b) All surface services are disposed of appropriately (e.g. polypipe water lines, overhead powerlines) (c) All buildings and associated infrastructure removed offsite (d) All hardstand decommissioned (e) All fencing and associated infrastructure disposed of appropriately (f) All waste that is not authorised to be disposed of onsite under EPML00657413 is removed (g) All boreholes not required for monitoring purposes are decommissioned (h) All sediment ponds and sumps decommissioned (i) All dams not part of the PMLU dewatered and desilted (j) All machinery and equipment not required for rehabilitation works are removed from site
RM2	Identification, remediation and removal of contaminated land	2.1	Contaminated land investigations (investigation, remediation and validation) completed by a Suitably Qualified Person (SQP) in accordance with appropriate guidance, including but not limited to the EP Act, ASC NEPM and National Remediation Framework (NRF).
		2.2	Where potentially contaminated sites are identified: (a) A preliminary site investigation (PSI) completed; and (b) If required, a detailed site investigation (DSI) is completed where the PSI completed under **RM2.2(a)** identified contamination is present, or is likely to be present, and said contamination material is likely to result in a risk to human health or cause environmental harm.
		2.3	Where contaminated material is identified under criterion **RM2.2(b)**, all contaminated material is either: (a) Remediated in-situ; (b) Removed and disposed of at a licensed facility; or (c) Disposed of as per the Contaminated Land Investigation Document (CLID) and Site Management Plan (SMP).
		2.4	Contaminated Land Auditor certifies, as per Environmental Protection Act 1994 (EP Act) (Qld), that all contaminated materials have been remediated, or removed and disposed of.
		2.5	Contaminated Land Investigation Document (CLID) completed in accordance with the EP Act, including: (a) Site Suitability Statement confirming the suitability of the property (all lot/plans within the mining lease area) for the PMLUs. (b) Site Investigation Report and, where required, a Validation Report and/or draft Site Management Plan provided
		2.6	Removal of land from the Environmental Management Register and the Contaminated Land Register, where applicable.
		2.7	Contaminated Land Auditor certifies that no contamination unsuitable for the PMLU remains or is occurring
RM3	Landform development, reshaping and reprofiling	All rehabilitation Areas	
		3.1	All major earthworks (including reshaping, pushing/trimming), where appropriate, are completed in accordance within tolerance of design specification provided by an AQP.
		3.2	The landform achieves the following slopes: (a) Externally draining slopes, internally draining slopes, top of dumps, roads infrastructure <16.7% (b) Void- Highwall/Endwall/Ramps <33%
		3.3	All landforms are predominantly shaped to be water shedding.
		3.4	Environmentally problematic materials are appropriately placed and located within the final landform, consistent with the relevant designs.
		Levee/Flood Protection Landform	
		3.5	Landform must: (a) Exceed the mAHD for 0.1% AEP water surface level +0.5m freeboard. (b) Prevent surface flow of floodwater into the void; (c) Be geotechnically stable when floodwater is against the batter; and (d) Not be constructed with dispersive material.
		3.6	Selective placement of non-erosive materials and/or rock mulch protection to ensure landform stability as per AQP's advice.
RM4	Surface Preparation	4.1	Assessment of growth media characteristics and the development of an amelioration and physical treatment plan to achieve the criteria in **Attachment 1 - Soil Quality Data** is completed by an AQP.
		4.2	Where the growth media (topsoil, rock mulch and subsoil) physical, chemical and biological properties tested does not meet the criteria in **Attachment 1 - Soil Quality Data**, ameliorants such as fertiliser, gypsum or other suitable matters are applied at a rate determined by a AQP and documented.
		4.3	Growth medium placed at a depth of ≥ 100 mm, except in areas where this would interfere with a PMLU bushland outcome, as determined by the underlying spoil management unit;
		4.4	Contour ripping of compacted surfaces completed up a depth of at least 200mm depending on the spoil management unit present
		4.5	Growth media health and suitability is assessed and documented by an SQP as suitable for the PMLU and target vegetation establishment.
RM5	Revegetation	All rehabilitation areas	
		5.1	With the exception of non-persistent cover crop species, the seed mix contains only those species listed in **Attachment 3 – Species Seed Mix** for the relevant PMLU.
		5.2	Seed mix applied at a rate as listed in **Attachment 4 - Seeding Rates** for key species.
		Grazing PMLU	
		5.3	Completed seeding with a selection of species and seeding rates listed in **Attachment 3 – Species Seed Mix** and **Attachment 4 – Seeding Rates** for grazing PMLU.
		5.4	The seed mix must include: (a) At least four species of 3P native pasture species; (b) two legumes; and (c) two shade tree species established.
		Bushland PMLU	
		5.5	Completed seeding with a selection of native vegetation species and seeding rates listed in **Attachment 3 – Species Seed Mix** and **Attachment 4 – Seeding Rates** for bushland PMLU, or as amended for additional native endemic species as recommended by an AQP and certified as suitable to achieve a stable condition.
RM6	Achievement of surface requirements	6.1	Weed presence is less than 10% of total vegetative cover confirmed by an AQP in annual monitoring.
		Grazing PMLU	
		6.2	Vegetative groundcover is ≥50%.
		Bushland PMLU	
		6.3	Vegetative groundcover and / or rock cover is ≥50%.
		Erosion and sediment control (All RAs)	
		6.4	No evidence of erosion classified as 'moderate' or 'severe' as defined by **Attachment 2 – Erosion Classification Framework.**
		6.5	Erosion requiring intervention has been remediated and does not impact achieving the PMLU.
RM7	Achievement of PMLU to a stable condition	7.1	Risk Assessment demonstrates risks in the rehabilitation area are similar to hazards in neighbouring unmined landscapes subject to a similar PMLU.
		7.2	The landform is geotechnically stable and achieved FoS ≥ 1.5.
		7.3	Weed presence is a maximum of 10% of total cover confirmed by an AQP in annual monitoring. Less than 5% of total vegetative groundcover are restricted weeds listed under the Biosecurity Act 2014 and showing sufficient improvement.
		7.4	No evidence of active scouring, gullying, or rilling in or adjacent to water management drainage infrastructure retained on the landform (including spine drains, contour drains and chutes).
		7.5	No evidence of erosion classified as 'moderate' or 'severe' as defined by **Attachment 2 – Erosion Classification Framework.**
		7.6	Surface water runoff collected from representative areas of rehabilitation when surface flow occur and safe to do so complies with **Attachment 7 – Surface water quality limits.**
		Grazing PMLU	
		7.7	60% established and self-sustaining vegetative groundcover.
		7.8	Biomass of 1,000kg/ha at a minimum.
		7.9	Minimum vegetation composition (per hectare (averaged)) of: (a) three species of 3P native pasture species, (b) two legumes, and (c) two shade tree species, present.
		7.10	Assessment of land condition and carrying capacity demonstrates a sustainable grazing outcome has been achieved
		7.11	Land suitability class assessed by an AQP that the land has achieved a post-mining land suitability class of ≤3 for cattle grazing, or not different from pre-mining suitability class, depicted in **Figure 3 – Pre Mining Land Suitability Classification** of the EA, if it is class 4.
		Bushland PMLU	
		7.12	A BioCondition assessment is completed by an AQP using the methodology outlined in the latest version of the Queensland Herbarium's 'BioCondition Assessment Manual'.
		7.13	The BioCondition assessment completed under RM7.12 complies with the PRCP Benchmark for the PMLU, as per **Attachment 5 – BioCondition Benchmark Criteria.**
		7.14	An assessment of BioCondition benchmarks for Bushland PMLU complies with the >35/60 PRCP benchmark for the PMLU as per **Attachment 5 – BioCondition Benchmark Criteria.**
		Storage	
		7.15	Retained dams are safe for native animals and stock access and have vegetated banks.
		7.16	All retained water storages are safe and stable.
		7.17	Water storages monitored quarterly, must not exceed the stock water guidelines (ANZECC 2000),
		Landform	
		7.18	Permanent fencing in place and maintained post closure which excludes stock.
		Rehabilitation	
		7.19	Existing progressive certification obtained or: a) >60% groundcover b) Biomass >1,000kg/ha c) Three species of 3P pasture species
		7.20	An AQP certifies that all infrastructure to be retained onsite as part of the post-mining land use (PMLU) or where infrastructure is agreed to be retained by the landholder as evidenced by a signed landholder agreement is safe, stable and will not cause environmental harm.

Milestone reference	Rehabilitation milestone	Milestone Criteria	
RM8	Achievement of post-mining land use water quality	8.1	For a minimum of five (5) consecutive years immediately prior to the milestone completion date, surface water quality must be monitored at least once per month when a greater than 30mm rainfall event (24 hours period) and flow occurs at the monitoring point(s). Monitoring must occur at, but not limited to, downstream locations specified in in **Attachment 6 – Surface Water Monitoring Locations**. Surface water quality results must not exceed the limits specified in **Attachment 7 – Surface Water Quality Limits**
		8.2	If the surface water quality results exceed the criteria in 8.1; and if there is flow at both the upstream and downstream monitoring location for each watercourse; then, each year an AQP must complete and provide to the administering authority an assessment of the cause of the exceedance and risk of rehabilitation not achieving a stable condition. Where the assessment concludes i) That there is a low risk to achieving a stable condition, then no further action is to be taken; or ii) That there is a risk greater than low to achieving a stable condition, then an assessment of potential environmental harm and any changes or rectification actions to rehabilitation activities must be determinged and implemented.
		8.3	If 8.2 is triggered, then the five (5) year timeframe under RM8.1 is reset.
		8.4	For a minimum of five (5) consecutive years, immediately prior to the milestone completion date groundwater quality must be monitored quarterly at, but not limited to, compliance bores/locations specified in **Attachment 8 – Groundwater Monitoring Locations** for all quality characteristics listed in **Attachment 9 – Groundwater Quality Limits.**
		8.5	Groundwater quality results must not exceed the limits in **Attachment 9 – Groundwater Quality Limits**, for three (3) consecutive results.

Milestone reference	Rehabilitation milestone	Milestone Criteria	
MM1	Achievement of final landform design	1.1	Pit walls achieve a Static Factor of Safety > 1.5.
		1.2	Pit walls and voids assessed as geotechnically stable.
		1.3	Pit walls achieve a maximum slope of ≤1V:3H (33.3%).
		1.4	The final design must be completed by an AQP based on the latest flood modelling and materials data prior to construction.
		1.5	The location of the voids and associated safety bunds does not cause instability or degradation to the land outside the NUMA.
		1.6	Final residual voids are not subject to inundation from floodwaters up to and including the 0.1% AEP
		1.7	Residual voids must not overtop
MM2	Achievement of safety requirements	2.1	Competent safety bund in place to prevent access to the residual void, at the geotechnical setback distance of a minimum of 15m.
		2.2	The safety bund is constructed in accordance with engineering requirements, including: (a) Constructed from non-weather, non-dispersive dumped rockfill; and (b) A minimum of 2m in height.
		2.3	Fencing erected, where required to prevent access to the residual void, around the perimeter of the safety bund
		2.4	Warning signage to deter public access and warn of void related risks are designed in accordance with Australian Standard AS1319-1994, and are erected at 100m intervals around the void rim.
MM3	Achievement of sufficient improvement	3.1	The final landform has been constructed in accordance with the final design.
		3.2	The water level and quality in the void do not and will not cause environmental harm to the receiving environment, as demonstrated by groundwater level, surface water and groundwater quality monitoring and modelling.
		3.3	Groundwater and void lake water level and quality monitoring confirms that the residual voids acts as groundwater sinks post-closure, as confirmed by an AQP.
		3.4	The residual voids are safe to humans.
		3.5	Voids retain flood immunity, supported by flood modelling re-run at end of life and calibrated against the final landform.
		3.6	The void will not present an unacceptable risk of environmental harm.
		3.7	Erosion of the landform within the NUMA area will not negatively impact on the stability any adjacent rehabilitation areas, or their ability to sustain their PMLU.
		3.8	Monitoring and maintenance of exclusion fences and bunds to be carried out to ensure they remain effective.

Appendix 4.2 Soil and Land Suitability

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SOIL AND LAND SUITABILITY SURVEY, IN POTENTIAL DISTURBANCE AREAS IN ADVANCE OF MINING, DAWSON NORTH

Prepared by
Bevan Emmerton
December 2004

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1. Overview

At the request of Alex Armstrong of E.H. and S. and acting of behalf of Anglo Coal, a soil survey was carried out in advance of mining to delineate soil types and land suitability present in the potential disturbance area of the Dawson North deposit (directly to the North of Moura Mine), and to determine useable soil stripping depths for rehabilitation.

The survey was carried out over portions of numerous properties starting from directly north of the Moura Mine and extending west to the Banana Moura road, and north to north east up to Banana Creek.

The area delineated is shown in Figure 1. Previous broad investigation has been in the QDPI Land Management Manual for the Dawson Callide Districts. In that document, almost all of the area is appraised as, Unit 2, "Mixed brigalow plains" with a minor area on the eastern border in the south mapped as Unit 3, "Softwood scrub uplands". According to the Queensland Government Planning Guidelines for the Identification of Good Quality Agricultural Land, both of these land units are appraised as good quality agricultural land in terms of crop land. That appraisal is considered to over estimate the quality of many of the soils encountered during this current survey.

A more recent survey of the Banana mapsheet by Peter Muller of DNRM has mapped part of the area investigated. Soils were mapped as follows.
Soils on unconsolidated Cainozoic alluvial-colluvial sediments.
- Major areas of Greycliffe and Greycliffe melonhole phase were mapped.
- Lesser areas of Earlsfield soil were mapped in the south and on the eastern boundary of the investigation area.
- Minor areas of Kilbernie and Bonwell soils were mapped in the north.

Soils on folded Permian sediments
- A small area of Fairview soil was mapped in the south.
- A small area of Bauhinia soil was mapped in the centre east.

Soils on unconsolidated Quaternary alluvium
- A minor area of Tarramba soil was mapped on Banana creek in the northern extremity of the investigation area.

The DNRM report for the soils mapped above has not yet been published, so soil descriptions, chemical characteristics and land suitability appraisals are not yet available.

In the current survey, the investigation area was mapped on the basis of the different soil types encountered. As DNRM descriptions were not available, soils encountered were not classified according to the DNRM map, although some soil types such as Greycliffe, Greycliffe melonhole phase, Earlsfield and Bauhinia were identified. Soil survey boundaries differ from those on the DNRM map however, the current survey had a higher intensity of investigation sites and better aerial photography available than was available to the DNRM investigators.

The purpose of this current survey was to;

- delineate and map the soil types present in the potential disturbance area,
- provide detailed descriptions of the soil profiles,
- provide data on the chemical and physical properties of the soils, for use in stripping and rehabilitation considerations, and
- provide an assessment of land suitability of the soil types investigated in terms of their usefulness for grazing or agriculture.

The soil types encountered and their location and significance have been assessed and mapped in Figure 1 and are briefly described below.

Four deep soil types originally supporting mainly brigalow vegetation and formed on *unconsolidated Cainozoic colluvial/alluvial material* were encountered.

- The "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow belah)" occur in slightly elevated areas on the east of the investigation area and appear to be a superior soil type, having good self mulching surface conditions and mainly being cropped.
- The "Pedal to coarsely self mulching grey/brown cracking clays with weak to moderate melonhole gilgai (brigalow yapunyah)" and "Pedal grey cracking clays with well developed melonhole gilgai (brigalow yapunyah)" occur in association with each other in slightly elevated to relatively flat areas in substantial expanses throughout the investigation area. They are inferior to the finely self mulching soils described above and are generally not cropped, apart from where they adjoin the better soils described above and have enhanced surface physical conditions and deeper rooting profiles.
- The "Deep non cracking to weakly cracking clay soils (open brigalow)" occur in one confined flat area in the south west of the investigation area. The soil type has been cleared and cultivated in the past but has been allowed to revert to pasture and is considered an inferior soil type in terms of surface physical conditions and plant available water.

Five shallower soil types originally supporting brigalow or more open vegetation and formed on *Permian sediments* were encountered.

- The "Shallow non cracking clays or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)" are present in upper slope positions in minor small areas the extreme north of the investigation area. Some of the area has been cultivated and is included in areas used for forage cropping, but plant available water is considered to generally be low for that purpose, however the soils are good soils for improved pasture production.
- The "Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)" are present in slightly elevated to relatively flat positions in substantial areas in the south of the investigation area, with a lesser area also present in the north. Two variants, a shallow variant and a deeper gilgaid variant are also present. The bulk of the soils are considered best suited to pasture, however, occasional better areas may be cropped or forage cropped.
- The "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" are present in slightly elevated areas in the south east of the investigation area, appearing to be associated with the coal bearing sediments of Moura Mine to the south. The soils are often shallow, which restricts plant available water in a percentage of the area and in spite of their good surface physical conditions are generally considered better suited to forage cropping than to grain cropping.
- The "Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)" are present in mid slope positions towards the north of the investigation area and are considered to be a minor soil type. The soil is considered best suited to pasture improvement due to poorer than desirable surface physical conditions and shallower rooting depth which is restricted either by presence of parent material or by salinity.
- The "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" are present in slightly elevated to midslope areas in significant areas in the north and south of the investigation area. A minor non cracking variant occurs in a lower slope position in the north. The soil type is considered suitable for cropping only in better areas.

Only one soil type originally supporting brigalow or more open vegetation and formed on *Quaternary alluviuum* was encountered.

- The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" are present in association with drainage lines which drain or cross the area and are a minor soil type apart from slightly larger areas in the extreme north and south west of the investigation area. Salinity may initially restrict plant available water

capacity but where cultivated this would leach to lower depths with time allowing cropping where there is not an elevated erosion risk.

Land suitability of the area has been assessed and mapped in Figures 2 and 3 and is briefly outlined below.

The only soils present in the area considered suitable for dryland cropping are soils which do not reach high salinity levels until relatively deep depths, and generally have a fine, or to a lesser degree, medium self mulching surface. These soils are considered to comprise only around 25% (or less) of the area of investigation, with the remainder of the area not being considered to be suited to dryland cropping (growing the full range of winter and summer crops). However, some of that area not considered suitable for dryland cropping may be considered suitable for either wheat or forage crops.

All soils are considered to be suitable for cattle grazing on improved pastures, with the exception of small areas of the alluvial soil where an erosion risk would be present during clearing and pasture improvement operations. It is considered that over 95% of the area investigated is suitable for improved pasture development.

2. Method of survey

The soil survey was carried out over a twelve day period from the 13th to the 21st of May and from the 8th to the 11th of June 2004. The survey was carried out using a 1:50,000 property boundaries map of the area supplied, and using 2004 - 1:10,000 colour aerial photographs of the majority of the future mining area, and 1987 - 1:25,000 black and white photographs of the remainder of the area along the Moura Banana road. A free survey was carried out. The survey was carried out using the maps and aerial photographs provided and marking investigation sites and soil boundaries according to surface features, vehicle odometer readings and hand held GPS readings.

Almost the entire investigation area had been cleared, and cropped or pasture improved prior to aerial photography and as such, there were few distinct features visible in the photo pattern. The soil boundaries should only be regarded as indicative as mosaics and intergrades of the soil types often occur, and boundaries are often not visible according to photopattern.

In all, 93 sites were investigated in detail with holes dug, profiles described and samples taken. A total of 675 samples were taken from the sites and tested for pH and electrical conductivity on a 1:5 soil:water basis (the results are presented in Appendix 1 along with broad descriptions of the soil profiles).

Using these results and the field descriptions, the soils were grouped into 10 soil groups which have relevance in terms of soil management in stripping operations and in terms of land suitability.

From these ten soil groups, 50 samples were selected from thirteen profiles and fowarded to analytical laboratories for analysis, to assist in definition of soil characteristics and stripping depths which would prove beneficial for rehabilitation of the mined area. The results would also assist in definition of land suitability of the soils.

Surface samples were analysed for physical and nutritional characteristics, while sub surface samples were analysed for physical characteristics only.

Analyses carried out on all samples were;

- pH, electrical conductivity, chloride and sulphate,
- exchangeable calcium, magnesium, potassium and sodium,
- cation exchange capacity,
- particle size analysis and R1 dispersion index, and
- 15 bar moisture content.

Additional nutritional analysis was carried out on the thirteen surface samples from the profiles and these analyses were for;

- organic carbon,
- nitrate and total nitrogen,
- extractable and total phosphorus, and
- copper, manganese, and zinc.

In addition the profile samples from the thirteen representative profiles were analysed to determine the plant available water in those profiles as a guide to the suitability of the land, in terms of moisture retention for cropping.

Explanations of the meaning and use of the analyses (as well as the analysis sheets from the analytical laboratories) are presented in Appendix 2.

3. Soil type, vegetation associations and analytical characteristics of representative profiles

The soils present in the area are described in this section with photographs used to assist in recognition of soils for site operations. Analytical characteristics for representative profiles are also discussed. The distribution of the soil types in the investigation area is shown in Figure 1, while the analytical results for representative profiles are shown in Tables 1 to 10.

Soils formed on unconsolidated Cainozoic colluvial/alluvial material

Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)
Black Vertosol

Occurrence, vegetation and landform

This soil type is present in slightly elevated areas on the east of the investigation area. The soil type only occurs in relatively small portions within the mapped area (Figure 1), but in the central part of the area extends into much larger expanses to the east of the investigation area.

The major part of the soil type is cleared and usually cropped. Natural vegetation has been brigalow and belah, with wilga in the understory and some occasional yapunyah also present. Gilgai are generally not present but occasional shallow melonhole gilgai may be present on around 10% of the area. Slopes are low and tend to be around 1% and occasionally up to 2%. The appearance of a cropped area with some natural vegetation remaining in a tree belt is shown in Plate 1.

Soil description

The soil surface tends to be a medium heavy clay which has a moderate to strong, fine or occasionally medium self mulch. Colour is dark grey to dark greyish brown (10YR3/1 to 3/2) and some slight surface silcrete and hard carbonate may be present. Below the self mulching surface, colour is maintained and texture is a medium heavy, to heavy clay (some hard carbonate nodules may be present) and this is maintained to 25 to 40cm below which, some hard and soft carbonate may be present. Colour may be maintained or may lighten slightly below 60 to 80cm with carbonate generally being absent (some mottling may occur below this depth). Below 80 to 110cm the mottling is very pronounced and the medium heavy, to heavy clays begin to grade to parent clays. Mottled mainly pinkish white/yellowish red/light olive brown parent tertiary clays (some my contain stone inclusions) are encountered below 90 to 130cm. An augered profile from Site 23 which was one of the best profiles encountered is shown in Plate 2.

The soil reaction trend may be acidic or alkaline. Salinity is low in the surface and upper B horizon, but increases below this down the profile to high levels which may restrict plant rooting depth by 80 to 110cm (in superior profiles rooting depth may be higher).

Laboratory analytical characteristics

In Table 1, Site 31 is considered representative of the soil type but with a deeper rooting depth than some profiles.

The profile is alkaline with low electrical conductivity and chloride in the surface. Electrical conductivity and to a lesser degree chloride increases down the profile, but not to levels which control effective rooting depth in the profile analysed (these factors would be considered to control rooting depth in some profiles investigated however). Exchangeable sodium percentage is low in the surface and increases with depth, to levels that are

considered to be sodic beyond 60 to 80cm. Calcium to magnesium ratios are high in the surface horizons and decline with depth to slightly imbalanced levels in the subsoil materials. Surface R1 dispersion index is relatively low (but the level indicates some structural instability in the surface) showing increasing dispersion down the profile to moderate levels below 60 to 80cm. The clay content of the soil is high and the clay activity ratio of above 0.7 indicates strong activity (cracking).

The soil has a slightly low level of organic carbon in the surface for the climatic area in which it is situated and slight rundown is indicated. Cation exchange capacity is at a high level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is only moderate and lower than would be expected with total phosphorus also being only moderate. (In view of the vegetation and growth present, normal extractable phosphorus levels would be considered to be elevated over 10ppm.) Total nitrogen level is only moderate indicating limited reserves and almost no available nitrogen was present (the area analysed had recently harvested sorghum stubble present). Sulphate levels appear low in the surface but adequate in the subsoil and cation levels are adequate. Levels of micronutrients appear adequate, with the exception of zinc which appears low.

Analysed plant available water was relatively high at 170mm for a rooting depth of 120cm. This level is considered representative of the better profiles, however where rooting depth is restricted to 80 to 90cm in more saline profiles, PAWC would be restricted to 125 to 135mm.

Table 1. Physical and chemical aspects of a representative soil profile from the "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 31													
0-10	7.8	60	7	5	1	2.3	0.50	3	14	22	59	0.81	48
20-30	8.3	100	8	5	2	2.0	0.57	3	13	22	61	0.74	45
50-60	8.8	190	12	14	5	1.4	0.62	4	14	24	61	0.69	42
80-90	8.9	340	38	91	8	1.1	0.69	3	12	23	64	0.73	47
110-120	8.7	750	116	377	11	0.9	0.78	3	10	20	65	0.68	44

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 31												
0-10	1.37	8	0.025	1	0.10	0.59	30.1	13.0	1.73	0.24	21	11
20-30				<1		0.25	29.0	14.6				
50-60				<1		0.20	22.0	16.0				
80-90				<1		0.19	21.2	18.7				
110-120				<1		0.25	19.3	20.6				

Topsoil stripping recommendations (non return of land suitability)

The surface 40cm should be salvaged for use as a seed source and topsoil material. If additional capping or root zone material is required then additional subsoil down to around 60cm in the more saline profiles, and 100cm in the less saline profiles could be taken (with some field testing).



Plate 1. The appearance of a cropped area with a remnant tree belt present on the "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)"



Plate 2. The appearance of an augered profile of the "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)" from Site 23 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)
Black, grey or brown Vertosol

Occurrence, vegetation and landform

This soil type is present in slightly elevated to relatively flat areas in substantial areas throughout the investigation area (Figure 1).

The major part of the soil type is cleared and some is, or has been, cropped. Where the soil grades into the superior strongly self mulching soil type previously discussed, it is a better soil type and appears capable of cropping. To the north of the area (generally north of the Banana Mungi road), texture is lighter and slopes are steeper and the soil is inferior to that found in the south of the area. Occasional areas (<5%) of high silcrete outcrop occur and these are not mappable separately. Natural vegetation appears to have been semi open brigalow with significant yapunyah often present. Melonhole gilgai are generally present to some degree, and are usually less than 40cm in depth. Slopes are low and tend to be less than 1% but may be up to 2% in the north of the area. The appearance of an area with some natural vegetation remaining is shown in Plate 3.

Soil description

The soil surface tends to be a medium to heavy clay which is cracking and either non self mulching (hard and blocky) or a weak, medium to coarse self mulch may be present. Colour is dark grey to dark brown (10YR3/1 to 3/2 or occasionally 3/3) and some surface silcrete is often present. Below the surface 25 to 40cm, colour may begin to lighten and texture is a medium heavy, to heavy clay (carbonate is generally absent). Below 60 to 80cm colour lightens further to dark brown to brown (7.5YR3/3 to 10YR5/3) and the material is generally mottled (carbonate is absent). Below 110 to 130cm the mottling is very pronounced and the material becomes strong brown to pale brown to light yellowish brown (7.5YR5/6 to 10YR6/3 to 2.5Y6/4) parent clays. An augered profile from Site 33, which was one of the profiles analysed is shown in Plate 4.

The soil reaction trend is generally acidic but may very occasionally be neutral or alkaline. Salinity is low in the surface, but increases below this down the profile to high levels which may restrict plant rooting depth by 30 to 50, or occasionally 80cm (in superior profiles closer to more self mulching soil types, rooting depth may be higher).

Laboratory analytical characteristics

In Table 2, one profile analysed was fallow (Site 32) and closer to the superior self mulching soil type "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)" while one profile analysed had recently harvested sorghum stubble present (Site 33). The profiles were considered representative of those investigated with mid range salinity for the soil type.

The pH of the profiles are alkaline in Site 32 and slightly acidic in Site 33. The soils have low electrical conductivity and chloride in the surface, and levels increase rapidly down the profile to levels which would control effective rooting depth of agricultural plants. Exchangeable sodium percentage is elevated (sometimes sodic) in the surface and increases with depth, to levels which are considered to be highly sodic beyond 30 to 50cm. Calcium to magnesium ratios are reasonable or slightly low in the surface and decline with depth, to levels which are less than desirable for the maintenance of structure below 10 to 20cm. Surface R1 dispersion index is relatively low or elevated (depending of sodicity and Ca/Mg ratio) showing increasing dispersion down the profile to very high levels below 20 to 50cm. The clay content of the soil is high and the clay activity ratio of above 0.5 indicates some cracking (soils closer to the better self mulching soils had a higher clay activity ratio).

The soil has a slightly low to moderate level of organic carbon in the surface indicating slight rundown in some cultivated areas. Cation exchange capacity is at a relatively high level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is moderate and levels of total phosphorus are low to moderate. Nitrate nitrogen levels are high and total nitrogen levels are moderate indicating reasonable reserves. Sulphate levels appear low in the surface but reasonable below and cation levels are adequate. Levels of micronutrients appear adequate with the exception of zinc which appears to be deficient or marginal.

In the profile analysed, plant available water was relatively low at 98mm for Site 32 and 105mm for Site 33, for an assessed rooting depth of 60cm (for Site 33 it would in fact be lower at 92mm for a depth of 50cm as both salinity and sodicity limit rooting depth). The overall levels present would be variable with higher levels present in the less saline depression sites and with even lower levels present in some of the more saline puff sites. It is considered that in general the majority of profiles would have 75 to 100mm of PAWC but better profiles such as Sites 24, 26 and 30, which are closer to the superior self mulching soil type may have PAWC's of 125 to 150mm.

Table 2. Physical and chemical aspects of representative soil profiles from the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 32													
0-10	8.7	260	131	10	4	2.3	0.46	8	19	21	51	0.75	38
20-30	9.1	400	282	14	11	1.3	0.68	9	20	18	54	0.63	34
50-60	8.3	740	814	9	17	1.0	0.94	7	18	20	57	0.68	39
Site 33													
0-10	6.9	180	138	9	7	1.3	0.57	14	20	14	53	0.55	29
20-30	7.1	360	407	13	14	1.0	0.88	9	16	14	61	0.54	33
50-60	5.2	910	1339	23	25	0.7	0.85	9	16	14	62	0.52	32

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 32												
0-10	1.38	14	0.020	37	0.12	0.44	24.2	10.6	0.88	0.21	15	7
20-30				17		0.18	19.0	14.2				
50-60				9		0.17	15.1	14.9				
Site 33												
0-10	1.55	29	0.037	32	0.12	0.63	14.7	11.3	3.83	0.69	57	30
20-30				5		0.28	14.0	13.6				
50-60				3		0.31	9.3	13.6				

Topsoil stripping recommendations (non return of land suitability)

The surface 15cm should be salvaged for use as a seed source and topsoil material, however it will only be suitable for replacement on relatively flat areas. If additional capping or root zone material is required then additional subsoil down to around 25cm could be taken in the majority of areas, while in the better soils around Sites 24, 26, 30 and 39 subsoil material may be able to be stripped to around 40 to 50cm with some field testing.



Plate 3. The appearance of natural vegetation remaining on the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)"



Plate 4. The appearance of an augered profile of the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" from Site 33 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)
Grey, black or brown Vertosol

Occurrence, vegetation and landform

This soil type is present in slightly elevated to relatively flat positions in substantial areas throughout the investigation area (Figure 1).

The majority of the soil type is cleared and some of the less gilgaid areas are, or have been cropped. Occasional areas (<5%) of high silcrete outcrop occur and these are not mappable separately. Natural vegetation appears to have been semi open brigalow with significant yapunyah often present. Melonhole gilgai are present but usually cover less than 30% of the area, and are in the order of 50cm and up to 90cm in depth. Slopes are low and tend to be less than 1% but may be up to 2% in the north of the area. The appearance of an area with some natural vegetation remaining is shown in Plate 5.

Soil description

The soil surface tends to be a medium, to medium heavy clay which is generally cracking (hard and blocky beneath the immediate surface flake) or may occasionally be non cracking, or at the other extreme weakly self mulching. Colour is normally dark grey (7.5YR to 2.5Y3/1) or occasionally very dark grey to very dark greyish brown (10YR3/1 to 3/2) and some surface silcrete is often present. Below the surface 25 to 50cm colour may begin to lighten and texture is a medium heavy, to heavy clay (carbonate is generally absent). Below 60 to 80cm colour lightens further to greyish brown to dark yellowish brown (7.5YR5/2 to 10YR4/4) and the material is generally mottled (carbonate is absent). Below 110 to 140cm the material may be very mottled and becomes dark greyish brown to yellowish brown (10YR4/2 to 5/3) parent clays. An augered profile from Site 25 is shown in Plate 6.

The soil reaction trend is generally acidic but may very occasionally be neutral. Salinity is low in the surface, but increases below this down the profile to high levels which may restrict plant rooting depth by 30 to 50cm in the puff or shelf profiles.

Laboratory analytical characteristics

In Table 3 the profile analysed was grassed and was considered representative of the puff or shelf profiles investigated with mid range salinity for the soil type.

The pH of the profile is alkaline in the upper layers but becomes acidic at depth. The soil has low electrical conductivity and chloride in the surface and levels increase rapidly down the profile to values that would control effective rooting depth of agricultural plants by 40 to 50cm. Exchangeable sodium percentage is elevated (sodic) in the surface and increases with depth, to levels that are considered to be highly sodic beyond 30cm. Calcium to magnesium ratios are reasonable or slightly low in the surface and decline with depth, to levels that are less than desirable for the maintenance of structure below to 20 to 30cm. Surface R1 dispersion index is high showing increasing dispersion down the profile to very high levels below 10 to 20cm. The clay content of the soil is high and the clay activity ratio of around 0.6 indicates some cracking (soils with higher clay contents crack more).

The soil has a slightly low level of organic carbon in the surface for the climatic area it is in. Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is moderate and the level of total phosphorus present is relatively low. Nitrate nitrogen levels are low as would be expected in a grassland and the total nitrogen level is slightly low indicating limited reserves. Sulphate level appears low in the surface and only moderate at depth and cation levels are adequate. Levels of micronutrients appear adequate with the exception of zinc which appears to be deficient.

In the profile analysed, plant available water was relatively low at 89mm for an assessed rooting depth of 60cm (it would in fact be lower at around 77mm for a depth of 50cm as both salinity and sodicity limit rooting depth). The overall levels present would be variable with higher levels present in the less saline depression sites and with even lower levels present in some of the more saline puff sites. It is considered that in general the majority of profiles would have 75 to 100mm of PAWC although occasional puff profiles may have lower levels.

Table 3. Physical and chemical aspects of a representative soil profile from the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 22													
0-10	7.8	120	113	3	8	2.1	0.73	12	26	23	41	0.63	26
20-30	8.3	290	335	6	14	1.8	0.94	14	23	19	43	0.63	27
50-60	6.5	1010	1554	7	30	1.1	0.99	4	19	20	56	0.59	33

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 22												
0-10	1.42	12	0.017	1	0.10	0.50	14.6	7.1	1.77	0.25	34	9
20-30				<1		0.38	14.8	8.1				
50-60				<1		0.19	11.8	11.2				

Topsoil stripping recommendations (non return of land suitability)

The surface 15cm should be salvaged for use as a seed source and topsoil material. The material is only marginally suitable for a topsoil and will have elevated sodicity and possibly salinity and is only suitable for replacement on relatively flat areas. If additional capping or root zone material is required then additional subsoil down to around 20cm may be taken but sodicity and dispersion will also be relatively high.



Plate 5. The appearance of remnant/regrowth natural vegetation on the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)"



Plate 6. The appearance of an augered profile of the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" from Site 25 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Deep non cracking to weakly cracking clay soils (open brigalow)
Brown Dermosol

Occurrence, vegetation and landform

This soil type is present in one confined flat area in the south west of the investigation area (Figure 1).

All of the soil type is cleared and some has been cultivated in the past but has reverted to pasture. The soil grades into the "Pedal to coarsely self mulching grey brown cracking clays with weak to moderate melonhole Gilgai (brigalow/yapunyah)" and the "Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)". Soil boundaries are indistinct and should be regarded as indicative only. Natural vegetation appears to have been relatively low open brigalow with limebush, bauhinia, whitewood and false sandalwood also present. Occasional melonhole gilgai to less than 30cm may be present. Slopes are low and tend to be less than 1%. The appearance of an area with some regrowth vegetation on a fence line is shown in Plate 7.

Soil description

The soil surface is usually a light to medium clay which is non cracking (occasionally weakly cracking in the gilgai depressions) and may be hardset or have a weak firm surface flake. Colour is dark brown to very dark greyish brown (7.5YR4/3 to 10YR3/2) and the material below the surface is very hard and blocky. The A horizon is 15 to 25cm in depth and overlies a medium clay upper B horizon which is brown (7.5YR4/4 to 10YR4/3) in colour (carbonate may occasionally be present). Below 60 to 80cm colour lightens slightly to brown to dark yellowish brown (7.5YR4/4 to 10YR3/4) (carbonate is absent). Below 90 to 140cm the material becomes strong brown to dark yellowish brown (7.5YR5/6 to 10YR4/3) light medium to medium clay B3 material. An augered profile from Site 92 which was the profile analysed is shown in Plate 8.

The soil reaction trend is generally acidic but may also be alkaline. Salinity is low in the surface, but increases below this down the profile to high levels which may restrict plant rooting depth by 50cm.

Laboratory analytical characteristics

In Table 4, the profile analysed was grassed and was considered representative of the profiles investigated, but had lower salinity at depth than the other two profiles encountered.

The pH of the profile is alkaline. The soil has low electrical conductivity and chloride in the surface and this increases rapidly with depth, but in the profile analysed does not appear to control rooting depth. In the other profiles investigated rooting depth would be considered to be limited to 50 to 60cm by salinity. Exchangeable sodium percentage is relatively low in the surface and increases with depth, to levels which are considered to be sodic beyond 10 to 20cm and highly sodic beyond 30 to 50cm. Calcium to magnesium ratios are reasonable in the surface and decline with depth, to levels which are less than desirable for the maintenance of structure below to 30 to 50cm. Surface R1 dispersion index is high indicating poor structural characteristics and instability and increases further to extreme levels below 30 to 50cm. The clay content of the soil is relatively high and the clay activity ratio of around 0.6 indicates some cracking (soils lower clay contents may not crack and soils with higher clay contents crack).

The soil has a moderate level of organic carbon in the surface for the climatic area it is in. Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is relatively low (but adequate for pasture improvement) and the level of total phosphorus present is relatively low. Nitrate nitrogen levels are low as would be expected in a grassland and total nitrogen

level is moderate indicating reasonable reserves. Sulphate level appears low and cation levels are adequate. Levels of micronutrients appear adequate with the exception of zinc which appears to be deficient.

In the profile analysed, plant available water was relatively low at 106mm for an assessed rooting depth of 90cm (it would in fact be lower at around 91mm for a depth of around 75cm as sodicity limits rooting depth). In the other two profiles investigated rooting depths were lower (restricted by salinity) and PAWC would be considered to be restricted to around 75mm.

Table 4. Physical and chemical aspects of a representative soil profile from the "Deep non cracking to weakly cracking clay soils (open brigalow)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 92													
0-10	7.9	70	30	3	2	1.9	0.77	22	26	13	40	0.58	23
20-30	9.1	210	80	5	8	1.9	0.64	23	26	12	42	0.57	24
50-60	8.9	590	666	5	19	1.0	0.95	23	25	12	42	0.60	25
80-90	8.7	600	768	3	29	0.7	0.99	27	26	10	39	0.49	19

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 92												
0-10	1.57	7	0.031	2	0.13	0.60	13.7	7.2	1.85	0.34	19	9
20-30				<1		0.21	14.8	7.7				
50-60				<1		0.18	9.8	10.3				
80-90				1		0.12	5.9	8.3				

Topsoil stripping recommendations (non return of land suitability)

The surface 15cm should be salvaged for use as a seed source and topsoil material. The material is only marginally suitable for a topsoil and will have elevated dispersion and is only suitable for replacement on relatively flat areas. If additional capping or root zone material is required then additional subsoil down to around 30cm may be taken but sodicity and dispersion will be elevated.



Plate 7. The appearance of an area of the "Deep non cracking to weakly cracking clay soils (open brigalow)" with some regrowth vegetation present on a fenceline.



Plate 8. The appearance of an augered profile of the "Deep non cracking to weakly cracking clay soils (open brigalow)" from Site 92 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Soils formed on Permian sediments

Shallow non cracking clays or occasionally duplex soils on permian sediments (softwood scrub or eucalypt vegetation)
Red or brown Dermosol, occasional red Chromosol

Occurrence, vegetation and landform

This soil type is present in upper slope positions in small areas the extreme north of the investigation area (Figure 1).

The majority of the soil type is cleared and some has been cultivated and used for forage cropping. Natural vegetation appears to have been either softwood scrub or broad leafed ironbark with minor brigalow also present. Slopes are relatively low and tend to be less than 2%. The appearance of a pasture improved area with some regrowth vegetation present is shown in Plate 9.

Soil description

The soil surface is usually a light, to light medium clay which is firm to friable (or may be a hardset loam to clay loam in occasional duplex profiles). Silcrete is present on the surface and appears to be more prominent where the soil is duplex. The A horizon is around 15 to 25cm in depth and is dark reddish brown to dark brown (5YR to 7.5YR3/3). Below this is a dark red to dark brown (2.5YR3/6 to 7.5YR3/3) medium clay B21. Below 60 to 90cm parent sediments are encountered and carbonate is often present. An augered profile from Site 50 which was the profile analysed (and one of the deeper profiles encountered) is shown in Plate 10.

The soil reaction trend is generally alkaline but may be neutral. Salinity is low in the surface, but increases in deeper profiles to only moderate levels (which would not limit rooting depth) below 90cm.

Laboratory analytical characteristics

In Table 5, the profile analysed is considered to be representative of the soil type, however some profiles investigated were shallower and would have lower PAWC.

The pH of the profile analysed is around neutral in the surface, becoming alkaline with depth. Electrical conductivity and chloride are low in the surface and increase to only moderate levels down the profile. Exchangeable sodium percentage is low in the surface with the upper B horizon also being non sodic. Sodicity increases only slowly down the profile with the subsoil material still not being considered sodic. Calcium to magnesium ratios are at high levels in the surface and down the majority of the profile, declining slightly at depth. R1 dispersion index is elevated in the surface and indicates some poorer surface physical conditions. The dispersion index of the lower B horizon is relatively high. The clay content of the A horizon is only moderate (and the material does not have a clay matrix) and the B horizon has relatively high clay content. The clay activity ratio indicates that only very slight movement may take place in the clays present.

The soil has a good level of organic carbon in the surface for the climatic area in which it occurs. Cation exchange capacity is at a reasonable level in the surface and down the profile indicating a reasonable ability to hold nutrients. The level of extractable phosphorus measured is very high and the total phosphorus level present is relatively high. Available nitrogen levels are low as would be expected in a grassland, and total nitrogen level is at a good level indicating good nutritional reserves. Sulphate levels appear low in the surface with adequate levels in the deeper subsoil. Cation and micronutrient levels appear adequate.

In the profile analysed, the DNRM returned value for plant available water was 107mm for a 90cm rooting depth. This is considered representative of PAWC content in the deeper profiles, but profiles with parent sediments at 60cm may have only in the order of around 77mm of PAWC present.

Table 5. Physical and chemical aspects of a representative soil profile from the "Shallow non cracking clays or occasionally duplex soils on permian sediments (softwood scrub or eucalypt vegetation)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 50													
0-10	7.1	50	9	4	<1	3.7	0.56	21	35	16	31	0.58	18
20-30	7.8	30	8	4	<1	5.0	0.54	19	32	15	37	0.46	17
50-60	8.1	160	43	17	3	2.4	0.74	14	25	12	51	0.45	23
80-90	8.9	260	153	41	4	1.6	0.76	17	25	20	42	0.45	19

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 50												
0-10	2.42	72	0.057	<1	0.22	1.01	11.1	3.0	1.65	0.99	44	11
20-30				<1		0.26	12.4	2.5				
50-60				<1		0.15	13.2	5.5				
80-90				<1		0.16	11.9	7.5				

Topsoil stripping recommendations (non return of land suitability)

The surface and upper subsoil to 30cm should be salvaged for use as a seed source and topsoil material, however it is has some propensity for sheet erosion and should only be replaced on flatter slopes similar to pre mining slopes. If additional volume of material for a capping or root zone material is required then additional subsoil down to parent strata (60 to 90cm) could be taken but the material has slightly elevated sodicity, and is relatively dispersive and should only be replaced on flat areas. Under no circumstances should it be mixed with the topsoil material or exposed as a surface material.



Plate 9. The appearance of a pasture improved area of the "Shallow non cracking clays or occasionally duplex soils on permian sediments (softwood scrub or eucalypt vegetation)" with some regrowth vegetation present.



Plate 10. The appearance of an augered profile of the "Shallow non cracking clays or occasionally duplex soils on permian sediments (softwood scrub or eucalypt vegetation)" from Site 50 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Reddish brown non cracking to weakly self mulching cracking clays on sediments (brigalow scrub)
Brown, or lesser black Vertosol, occasional brown Dermosol

Occurrence, vegetation and landform

This soil type is present in slightly elevated to relatively flat positions in substantial areas, mainly in the south of the investigation area, but a small portion is also present in the north (Figure 1). The main soil type is a non gilgaid cracking clay but two variants occur, a non cracking shallow variant, and a deeper gilgaid variant.

Almost all of the soil type is cleared and much of the area has been cropped in the past but has reverted to pasture (or may be occasionally forage cropped). Natural vegetation has been semi open tall brigalow with occasional bauhinia and Dawson gum also present, and with a significant understory of wilga and some carissa. Slopes are low and tend to less than 2%. The appearance of natural vegetation is shown in Plate 11.

Soil description

Main soil type
The soil surface tends to be a medium, to medium heavy clay which is cracking. The surface is hardset or may have a weak surface flake, or may be weakly self mulching (hard and blocky beneath the immediate surface). Colour is normally dark brown (7.5YR3/3 to 10YR3/3) or may sometimes be very dark grey to very dark greyish brown (10YR3/1 to 3/2). Some surface silcrete is often present. Slight hard and sometimes soft carbonate may be present below 15 to 25cm but quickly declines with depth. Below the surface 30 to 60cm colour may begin to lighten to brown to strong brown (7.5YR4/4 to 4/6) and texture is a medium heavy, to heavy clay. Below 70 to 110cm there may be some inclusion of parent sediments (generally siltstone), and parent material is encountered below 100 to 140cm. An augered profile from Site 1 (the profile analysed) is shown in Plate 12a.

Shallow variant
This soil type lies in scattered areas within the main soil type. Where areas are larger it is mapped separately, but this was not always possible as the soil often forms a mosaic with the main soil type. The soil surface is non cracking and hardset or may have a firm surface flake and is a light medium, to medium clay. Colour is dark brown (7.5YR3/3 to 10YR3/3) and some surface silcrete is often present. Slight hard and sometimes soft carbonate may be present below 15 to 25cm but quickly declines with depth. Below the surface 15 to 25cm texture increases to a medium or occasionally medium heavy clay and colour may begin to lighten to dark brown to dark yellowish brown (7.5YR3/4 to 10YR4/4). Below 50cm there may be some inclusion of parent sediments (generally sandstone), and parent material is encountered below 50 to 80cm. An augered profile from Site 2 (with mudstone present below 80cm) is shown in Plate 12b.

Gilgaid variant
This soil type occurs in relatively small areas within the main soil type and has gilgai to 40 to 60cm. The soil surface is cracking with a weak to strong surface flake and is a hard coarse blocky medium, to medium heavy clay under the flake. Colour is dark brown to brown (7.5YR3/3 to 4/4) and some surface silcrete is often present. Below the surface 25cm, colour lightens to strong brown to dark yellowish brown (7.5YR4/6 to 10YR4/4) and slight siltstone inclusions may be present. Below 60 to 120cm the material is essentially strong brown (7.5YR4/6 to 5/6) heavy clay B3 material with significant siltstone inclusions present. Parent material was not encountered and carbonate was absent down the profile. An augered profile from Site 83 is shown in Plate 12c.

The soil reaction trend is alkaline or acidic (acidic in the deeper profiles or profiles over mudstone). Salinity is low in the surface, but increases below this in the main soil type and gilgaid variant, to high levels which may restrict plant rooting depth by 50 to 80cm. In the

shallow variants salinity often remains low but rooting depth is restricted by the presence of parent material.

Laboratory analytical characteristics

In Table 6, the main profile analysed was grassed and was considered representative of the profiles investigated. The gilgaid profile was a variant soil type with gilgai and apparent poor surface physical conditions present.

The pH of the main profile is alkaline while the gilgaid variant is neutral in the surface and becomes acidic with depth. The main soil type has low electrical conductivity and chloride in the surface which increases rapidly down the profile below 30cm to reach levels that would control rooting depth by 60cm. Salinity and chloride in the surface of the gilgaid variant is higher and these levels also increase rapidly down the analysed profile. Exchangeable sodium percentage is elevated (non sodic) in the surface of the main soil type and is sodic by 20cm, rising to highly sodic levels by 50cm. In the gilgaid variant, the surface material is sodic, and high sodicity is exhibited below 20cm with very high sodicity (which would be considered to limit rooting depth) present by 50cm. Calcium to magnesium ratios are only reasonable in the surface of the main soil type, but poor in the gilgaid variant and decline further with depth in both soils. Surface R1 dispersion index is reasonable in the main soil type increasing to very high levels below 30 to 50cm, while in the gilgaid variant the whole profile is highly dispersive. The clay content of the soils are high and the clay activity ratio of above 0.5 indicates some cracking.

The soil has a lower than desirable level of organic carbon in the surface for the climatic area it is in. Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is low (but just adequate for pasture improvement) and the level of total phosphorus present is moderate. Nitrate nitrogen levels are low as would be expected in a grassland (some is present at depth, indicating limited rooting depth) and total nitrogen level is lower than desirable indicating limited reserves. Sulphate level appears low in the surface but higher at depth and cation levels are adequate. Levels of micronutrients appear adequate with the exception of zinc which appears to be deficient.

In the main profile analysed, plant available water was relatively low at 103mm for an assessed rooting depth of 60cm (this is considered to be representative of the soil type, with soils around Sites 1, 47, 48, 76, 80 and 87, having higher PAWC at 100 to 120mm, and other more saline soils having 75 to 100mm). In the gilgaid variant, PAWC was assessed as 105mm for a rooting depth of 60cm (rooting depth was limited by sodicity and a 50cm rooting depth would give a PAWC of 92mm).

Table 6. Physical and chemical aspects of representative soil profiles from the "Reddish brown non cracking to weakly self mulching cracking clays on sediments (brigalow scrub)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 1 (main soil type)													
0-10	8.3	60	16	5	3	1.9	0.44	5	15	21	58	0.55	32
20-30	8.7	170	110	4	8	1.7	0.60	5	16	21	59	0.54	32
50-60	8.6	790	1076	8	19	1.2	0.82	6	14	21	59	0.54	32
80-90	8.5	840	1118	11	22	1.0	0.97	6	13	20	61	0.52	32
Site 75 (gilgaid variant)													
0-10	7.3	180	194	5	11	0.8	0.92	15	16	16	54	0.56	30
20-30	6.5	410	506	11	19	0.7	0.88	10	12	20	61	0.59	36
50-60	5.6	560	752	10	27	0.5	0.95	11	14	18	61	0.56	34

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 1 (main soil type)												
0-10	1.17	5	0.045	1	0.09	0.85	19.0	10.1	2.27	0.27	18	10
20-30				<1		0.62	19.8	11.9				
50-60				<1		0.29	15.3	12.8				
80-90				6		0.61	13.2	13.0				
Site 75 (gilgaid variant)												
0-10	1.17	5	0.035	<1	0.08	0.62	12.0	14.3	2.04	0.31	29	14
20-30				<1		0.40	11.4	16.9				
50-60				<1		0.41	7.8	16.2				

Topsoil stripping recommendations (non return of land suitability)

In the main soil type and shallow variant the surface and upper subsoil to 20cm should be salvaged for use as a seed source and topsoil material. If additional volume of material for a capping or root zone material is required then additional subsoil down to around 40cm could be taken but the material has elevated sodicity, and is relatively dispersive and should only be replaced on flat areas. In the gilgaid variant (which has very poor physical conditions) stripping should probably not take place if adequate volumes of topsoil can be sourced elsewhere.



Plate 11. The appearance of natural vegetation on the "Reddish brown non cracking to weakly self mulching cracking clays on sediments (brigalow scrub)"



Plate 12a. The appearance of an augered profile of the main soil type of the "Reddish brown non cracking to weakly self mulching cracking clays on sediments (brigalow scrub)" from Site 1 showing the surface in the top left and continuing across and then down the plate in 10cm increments



Plate 12b. The appearance of an augered profile of the shallow variant of the "Reddish brown non cracking to weakly self mulching cracking clays on sediments (brigalow scrub)" from Site 2 showing the surface in the top left and continuing across and then down the plate in 10cm increments



Plate 12c. The appearance of an augered profile of the gilgaid variant of the "Reddish brown non cracking to weakly self mulching cracking clays on sediments (brigalow scrub)" from Site 83 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)
Black Vertosol, occasional brown Vertosol

Occurrence, vegetation and landform

This soil type is present in slightly elevated positions in the south east of the investigation area, appearing to be associated with the coal bearing sediments of Moura Mine to the south. The soil type only occurs in a significant area in the south east (Figure 1).

The soil type has been cleared and the majority has been cropped in the past. Natural vegetation appears to have been open brigalow and bauhinia with some whitewood, limebush and emu apple also present. In some shallower areas vegetation appears to have also consisted of mixed eucalypts including Moreton bay ash. Sandstone or dolomite floaters may be present and gilgai are absent. Slopes are low and tend to be less than 2% and generally less than 1%. The appearance of a cropped area is shown in Plate 13.

Soil description

The soil surface tends to be a medium, to medium heavy clay which has a moderate to strong very fine to fine self mulch. Colour is generally black to dark grey (10YR2/1 to 3/1) or may occasionally be dark reddish brown to dark brown (5YR3/2 to 7.5YR3/3). Below the self mulch, colour is maintained and texture is a medium heavy to heavy clay. Some hard and soft carbonate nodules may be encountered below 20 to 40cm. Colour lightens below 40 to 60cm and some mottling may occur below this depth in deeper profiles. Parent material is generally encountered below 50 to 75cm and was either sandstone or decomposed calcareous material (one deep clay profile in which parent material was not present was also encountered). An augered profile from Site 20 (the profile analysed) which was considered to be a representative profile is shown in Plate 14.

The soil reaction trend is alkaline. Salinity is low in the surface and is usually low down the profile, although it may rise to moderate levels at depth in occasional profiles and to high levels at depth where isolated profiles are deeper and parent material may be clay or mudstone.

Laboratory analytical characteristics

In Table 7, Site 20 is considered representative of the majority of the soil type with shallower soils present.

The profile is alkaline, becoming more alkaline with depth, with low electrical conductivity and chloride in the surface. Electrical conductivity and to a lesser degree chloride increases down the profile, but not to levels which control effective rooting depth in the profile analysed (these factors would however be considered to control rooting depth in occasional deeper profiles investigated). Exchangeable sodium percentage is low in the surface and increases with depth, to levels that are considered to be sodic beyond 20cm and highly sodic below 50cm. Calcium to magnesium ratios are high in the surface horizons and decline with depth to slightly imbalanced levels in the subsoil materials. Surface R1 dispersion index is slightly elevated (indicating some structural instability in the surface) showing increasing dispersion down the profile to extreme levels below 30 to 50cm. The clay content of the soil is relatively high and the clay activity ratio of around 0.7 indicates strong activity (cracking).

The soil has a moderate level of organic carbon in the surface for the climatic area in which it is situated. Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is moderate with total phosphorus being low to moderate. Total nitrogen level is reasonable indicating moderate reserves and little available nitrogen was present (the area analysed had recently harvested sorghum stubble present). Sulphate levels appear low in the surface but

adequate in the subsoil and cation levels are adequate. Levels of micronutrients appear adequate, with the exception of zinc which appears low.

Analysed plant available water was only moderate at 106mm for a rooting depth of 80cm. This level is considered representative of the majority of the soil type, however occasional deeper profiles such as at Site 63 may have in excess of 125mm of PAWC present.

Table 7. Physical and chemical aspects of a representative profile from the "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 20													
0-10	7.8	60	14	4	2	2.5	0.61	16	24	18	42	0.71	30
20-30	8.8	170	20	5	6	2.1	0.71	16	22	18	45	0.69	31
50-60	9.2	340	102	17	15	1.3	0.98	15	20	17	49	0.65	32
70-80	9.3	380	236	19	18	1.3	0.99	27	23	14	35	0.63	22

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 20												
0-10	1.63	11	0.020	3	0.13	0.70	18.6	7.5	1.01	0.26	21	8
20-30				1		0.27	19.5	9.5				
50-60				<1		0.16	13.8	10.5				
70-80				<1		0.17	10.7	8.1				

Topsoil stripping recommendations (non return of land suitability)

The surface 25cm should be salvaged for use as a seed source and topsoil material. If additional capping or root zone material is required then additional subsoil down to around 40 to 50cm could be taken (with some field testing).



Plate 13. The appearance of a cropped area on the "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)"



Plate 14. The appearance of an augered profile of the "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" from Site 20 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)
Brown or black Dermosol, some brown or black Vertosol

Occurrence, vegetation and landform

This soil type is present in mid slope positions towards the north of the investigation area (Figure 1), appearing to be associated with similar sediments to the coal bearing sediments of Moura Mine to the south. The soil type is a minor soil type. It has a distinct photopattern, but the shallower clay soils are not able to be distinguished from the deeper clay soils.

The soil type has been cleared and pasture improved. Natural vegetation appears to have been open brigalow with some Dawson gum or yapunyah, and with some whitewood and limebush also present. Gilgai are not present. Slopes are relatively low and tend to be less than 2.5%. The appearance of a pasture improved area with some remnant vegetation present is shown in Plate 15.

Soil description

The soil surface is firm to hardset and is generally non cracking, but some cracking areas may occasionally be present. Significant surface silcrete is often present and some surface sand is also present. Colour is very dark greyish brown to brown (10YR3/2 to 4/3) and texture is a light, to light medium clay. The A horizon is very hard and 15 to 25cm in thickness. This is underlain by a similar coloured B21 that is a light medium, to medium clay and some hard and soft carbonate may be present. In shallower profiles decomposed calcareous sandstone is encountered at 45 to 55cm, while in the deeper clay profiles a similar coloured medium clay B22 without carbonate is present below this level. Below 70 to 80cm brown (7.5YR4/3 to 4/4) light medium, to medium clay B3 material with sandstone siltstone inclusions is present. Hard parent material was not encountered in the deeper profiles. Augered profiles from Site 54 (the shallow profile analysed) and Site 46 (the deep profile analysed) are shown in Plates 16a and 16b respectively.

The soil reaction trend is alkaline apart from a deep profile which was an intergrade to a deeper colluvial soil where the reaction trend was acidic. Salinity is low in the surface and is relatively low down the profile in the shallow soils. In the deeper soils salinity rises to levels that would be considered to restrict crop rooting depth below 50 to 80cm.

Laboratory analytical characteristics

In Table 8, both profiles were grassed and the deep and shallow sites analysed were considered representative of the range of soils within the soil type. The shallow soil type is the more common soil type encountered.

The pH's of the soils analysed are slightly alkaline in the surface becoming highly alkaline with depth. The soils have low electrical conductivity and chloride in the surface and this only increases to moderate levels with depth in the shallow profile, while increasing to high levels which would restrict rooting depth to 60 to 80cm in the deeper soil type. Exchangeable sodium percentage is low in the surface of both soils and only rises to moderate (sodic) levels in the shallow soil, while rising to highly sodic levels by 50cm in the deeper soil type (levels at depth in the deeper soil type are extreme and would also limit rooting depth). Calcium to magnesium ratios are at good levels in the surface of both soils, remaining at good levels with depth in the shallow soil type and declining to relatively low and imbalanced levels by 30 to 50cm in the deeper clay soil. Surface R1 dispersion index is slightly elevated indicating slight instability in both soils analysed, and rises to high levels down the profile in the shallow soil, while rising to extreme levels by 50cm in the deeper soil type. The clay contents of the soils are moderate to high and the clay activity ratio of above 0.5 indicates

some cracking where a clay matrix is present (more cracking would be exhibited where clay contents are higher).

The soils have moderate to good levels of organic carbon in the surface for the climatic area they are in. Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is moderate to good and the level of total phosphorus present is moderate to high. Nitrate nitrogen levels are low as would be expected in a grassland and total nitrogen levels are good indicating significant reserves. Sulphate level appears low (but is higher at depth in the deeper soil) and cation levels are adequate. Levels of micronutrients appear adequate with the exception of zinc which appears deficient in the shallower soil type.

In the deeper profile analysed, plant available water was moderate at 109mm for an assessed rooting depth of 90cm (this is considered to be an overestimate for the deeper soil as rooting depth is restricted by salinity and sodicity, with the soil having a PAWC of around 95mm for a 75cm rooting depth. For the shallower Site 54, the assessed PAWC of 86mm for a rooting depth of 60cm is considered to be representative.

Table 8. Physical and chemical aspects of representative profiles from the "Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 46 (deep NCC)													
0-10	7.6	70	19	3	<1	3.4	0.55	17	24	20	40	0.68	27
20-30	9.1	150	25	3	6	2.2	0.70	17	22	17	45	0.56	25
50-60	9.3	650	719	10	22	0.9	0.96	19	21	16	46	0.54	25
80-90	9.2	810	1028	5	32	0.7	0.95	27	25	16	37	0.49	18
Site 54 (shallow NCC)													
0-10	7.5	40	10	2	2	3.6	0.58	19	26	18	38	0.71	27
20-30	8.6	100	52	3	6	3.4	0.64	16	22	17	50	0.68	34
50-60	9.3	290	213	3	9	2.6	0.78	33	18	15	37	0.57	21

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 46												
0-10	2.54	27	0.064	<1	0.24	1.57	17.4	5.1	2.78	0.85	39	16
20-30				<1		0.37	14.9	6.8				
50-60				<1		0.42	8.9	10.2				
80-90				2		0.29	5.3	8.0				
Site 54												
0-10	1.80	11	0.028	1	0.14	0.56	17.9	5.0	1.35	0.39	26	15
20-30				<1		0.29	24.4	7.1				
50-60				<1		0.48	16.1	6.1				

Topsoil stripping recommendations (non return of land suitability)

The surface material to 20cm should be salvaged for use as a seed source and topsoil material. If additional volume of material for a capping or root zone material is required then additional subsoil down to around 40cm could be taken but the material will have elevated sodicity, and will be relatively dispersive.



Plate 15. The appearance of a pasture improved area of the "Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)" with some remnant vegetation present



Plate 16a. The appearance of an augered shallow profile of the "Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)" from Site 54 showing the surface in the top left and continuing across and then down the plate in 10cm increments



Plate 16b. The appearance of an augered deep profile of the "Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)" from Site 46 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)
Black Vertosol, occasional black/brown Dermosol

Occurrence, vegetation and landform

This soil type is present in slightly elevated to midslope positions in significant areas in the north and south of the investigation area (Figure 1) and appears to be associated to some degree with some of the coal bearing sediments of Moura Mine. The major soil type is a weakly linear gilgaid self mulching cracking clay. A minor variant occurs, this being a non cracking clay with inferior surface conditions in a lower slope position in the north.

All of the soil type appears to have been cleared to some degree and some of the area has been cropped in the past but has either reverted to pasture, or some areas may occasionally be forage cropped. Natural vegetation appears to have been fairly open, and appears to have been comprised of clumps of bauhinia, with some isolated shrub species such as limebush, whitewood and emu apple, and occasional low brigalow clumps. Slopes are low and tend to be less than 2%. The appearance of remnant vegetation is shown in Plate 17.

Soil description

Main soil type
The soil may or may not have weakly developed linear gilgai present. The surface tends to be a medium, to medium heavy clay that is cracking and weakly to moderately self mulching, with a very fine to fine self mulch. Small surface silcrete, quartz or carbonate nodules may be present. Colour is normally very dark grey to very dark greyish brown (10YR3/1 to 3/2) and this is maintained down the profile to around 70 to 90cm. Below the surface the clays are strongly structured and become medium heavy, to heavy clays. Some hard and soft carbonate may be encountered below 20 to 40cm but declines with depth. Below 70 to 90cm colour lightens and there may be some inclusion of parent sediments (generally siltstone or mudstone). Parent material is encountered below 80 to 140cm and is usually brown to yellowish brown siltstone or mudstone, but may occasionally be colluvial material. An augered profile from Site 56 is shown in Plate 18.

Non cracking variant
This soil type was only encountered in one low lying position in the north and appears to have some alluvial influence from poorer soil types further up the catchment. The soil surface is non cracking and hardset and some surface structural problems are indicated. Apart from the surface the profile is similar to, but slightly lighter in colour and texture than the main soil type described above. The variant is considered to be a minor and slightly inferior soil type.

The soil reaction trend is generally alkaline but may be neutral or acidic. Salinity is low in the surface, but in the main soil type may only reach non limiting levels down the profile or may occasionally reach levels which would be considered to limit crop rooting depth by 60 to 80cm. In the inferior non cracking variant, salinity reached high levels by 40 to 60cm.

Laboratory analytical characteristics

In Table 9, Site 72 is considered representative of the better profiles of the soil type with non limiting salinity in the profile.

The profile analysed is alkaline in the surface, becoming more alkaline with depth, with low electrical conductivity and chloride in the surface. Electrical conductivity and chloride increases down the profile, but not to levels which control effective rooting depth in the profile analysed (these factors would however be considered to control rooting depth in some profiles investigated). Exchangeable sodium percentage is low in the surface and increases with depth, to levels that are considered to be sodic beyond 20 to 50cm, but in the profile analysed did not reach highly sodic levels. Calcium to magnesium ratios are high in the surface horizons and decline with depth to slightly imbalanced levels in the subsoil materials. Surface R1 dispersion index is elevated (indicating some structural instability in the surface)

showing increasing dispersion down the profile to high levels below 60 to 80cm. The clay content of the soil is relatively high and the clay activity ratio of around 0.7 indicates strong activity (cracking).

The soil has a lower than desirable level of organic carbon in the surface for the climatic area in which it is situated (the soil had been previously cropped and some rundown was indicated). Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is low (lower than would be expected), with total phosphorus being at a moderate level. Total nitrogen level is lower than desirable indicating only moderate reserves and little available nitrogen was present in the surface horizons. Sulphate levels appear low and cation levels are adequate. Levels of micronutrients appear adequate, with the exception of zinc which appears low.

Analysed plant available water was high at 148mm for a rooting depth of 120cm. This level is considered representative of the majority of the soil type with non limiting salinity at depth, however more saline profiles such as at Sites 37, 69 and 78 would be considered to have only 100 to 120mm of PAWC present, while the more saline non cracking variant at Site 45 would only have 75 to 90mm of PAWC present.

Table 9. Physical and chemical aspects of a representative profile from the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 72													
0-10	8.2	50	10	3	2	3.5	0.56	16	23	18	45	0.80	36
20-30	8.2	50	18	2	4	3.1	0.70	15	22	19	48	0.73	35
50-60	8.9	290	203	6	9	2.1	0.73	15	18	17	54	0.76	41
80-90	8.9	590	591	6	13	1.6	0.88	15	16	17	55	0.73	40
110-120	9.0	620	673	3	12	1.4	0.87	12	18	20	53	0.62	33

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 72												
0-10	1.17	5	0.029	1	0.08	0.62	24.2	7.0	0.88	0.18	11	3
20-30				2		0.38	22.8	7.3				
50-60				2		0.37	24.8	11.6				
80-90				6		0.45	20.6	13.1				
110-120				12		0.33	15.4	10.7				

Topsoil stripping recommendations (non return of land suitability)

In the main soil type the surface material to 30cm should be salvaged for use as a seed source and topsoil material. If additional volume of material for a capping or root zone material is required then additional subsoil down to around 50cm could be taken but the material will have elevated sodicity, and may be relatively dispersive.



Plate 17. The appearance of remnant vegetation on the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)"



Plate 18. The appearance of an augered profile of the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" from Site 56 showing the surface in the top left and continuing across and then down the plate in 10cm increments

Soils in lower slope positions on alluvium and colluvium

Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)
Black Vertosol, occasional black Dermosol

Occurrence, vegetation and landform

This soil type is present in association with drainage lines that drain or cross the area and is generally minor in extent apart from slightly larger areas in the extreme north and south west of the investigation area (Figure 1).

Natural vegetation is brigalow and occasional coolibah, yapunyah or river gum, and with some wilga, bauhinia, and limebush also present. Some of the area away from the immediate drainage lines has been cleared and pasture improved while a small area has been cultivated. Gilgai appear to generally not have been present although some gilgai to 20cm were observed in the extreme north of the investigation area. Slopes are low and tend to be less than 0.5% apart from areas directly leading into drainage lines. The appearance of a farmed area with remnant natural vegetation present in the background is shown in Plate 19.

Soil description

The soil surface tends to be a medium to heavy clay which generally has a strongly developed fine to medium self mulch. Some lighter profiles however may be non cracking and non self mulching with a strong surface flake. Hard carbonate nodules may be present on the surface and continue down the profile, and some slight small silcrete may be present on the surface. Below the surface, soil structure is coarse and blocky. Soft carbonate may be present down the profile below 40 to 60cm. Surface colours are very dark grey to very dark greyish brown (10YR3/1 to 3/2) and this is maintained to 50 to 110cm, below which some colour lightening occurs, becoming brown to dark yellowish brown (10YR4/3 to 4/4) at around 80 to 120cm. Surface texture is a medium to heavy clay and clay content increases slightly down the profile, with some texture lightening below 110 to 130cm where the material is essentially parent alluvium (some buried soils may also be encountered at this depth). An augered profile from Site 12 (the profile analysed) is shown in Plate 20.

The soil reaction trend is neutral to alkaline and salinity increases down the profile below 30 to 60cm, often appearing to provide some limitation to crop growth below 50 to 80cm. However, under cultivation salinity profiles would be expected to leach to deeper depths.

Laboratory analytical characteristics

In Table 10, Site 12 is considered representative of the better profiles of the soil type where salinity has leached to deeper depths under cultivation.

The profile analysed is alkaline in the surface, becoming more alkaline with depth, with low electrical conductivity and chloride in the surface layers. Electrical conductivity and chloride increase down the profile, to levels that control effective rooting depth in the profile analysed. Exchangeable sodium percentage is slightly elevated (non sodic) in the surface and increases with depth, to levels that are considered to be sodic beyond 30 to 50cm and highly sodic beyond 60 to 80cm. Calcium to magnesium ratios are high in the surface horizons and decline with depth to slightly low levels in very deep subsoil. Surface R1 dispersion index is elevated (indicating some structural instability in the surface) showing increasing dispersion down the profile to high levels below 30 to 50cm. The clay content of the soil is relatively high and the clay activity ratio of around 0.7 indicates strong activity (cracking).

The soil has a lower than desirable level of organic carbon in the surface for the climatic area in which it is situated (the soil is cropped and some rundown is indicated). Cation exchange capacity is at a good level in the surface and down the profile indicating a good ability to hold nutrients. The level of extractable phosphorus present is only moderate (lower than would be

expected), with total phosphorus being at a moderate level. Total nitrogen level is relatively low indicating only limited reserves and little available nitrogen was present (the area had recently harvested sorghum stubble present). Sulphate levels appear low in the surface layers but higher at depth and cation levels are adequate. Levels of micronutrients appear adequate, with the exception of zinc which appears deficient.

Analysed plant available water was high at 168mm for a rooting depth of 120cm. This level is considered too high, as salinity limited rooting depth and a rooting depth of 105cm would give a PAWC of 150mm. The majority of profiles would be considered to have 125 to 150mm of PAWC, while more saline profiles with rooting depth limited 50 to 80cm may presently only have 100 to 125mm of PAWC present (however this would improve under cultivation).

Table 10. Physical and chemical aspects of a representative profile from the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)"

Sample	pH	E.C. uS/cm	Cl ug/g	SO4	ESP	Ca/Mg	R1	CS %	FS %	S %	C %	CEC/ clay	CEC
Site 12													
0-10	8.2	70	14	4	3	3.1	0.55	8	17	20	54	0.70	38
20-30	8.4	70	11	2	5	2.9	0.61	6	14	21	61	0.67	41
50-60	8.6	100	34	5	9	2.6	0.82	5	13	21	63	0.67	42
80-90	8.7	360	360	12	15	2.0	0.88	5	12	21	65	0.68	44
110-120	8.6	820	1081	9	19	1.6	0.91	8	15	16	63	0.62	39

Sample	O.C. %	Ext P ug/g	Tot P %	NO3 ug/g	Tot N %	K meq	Ca meq	Mg meq	Cu ug/g	Zn ug/g	Mn ug/g	Fe ug/g
Site 12												
0-10	0.98	8	0.027	1	0.07	0.70	26.1	8.5	1.64	0.19	15	6
20-30				<1		0.65	27.3	9.4				
50-60				1		0.50	27.2	10.5				
80-90				<1		0.50	24.3	12.4				
110-120				<1		0.37	18.7	11.8				

Topsoil stripping recommendations (non return of land suitability)

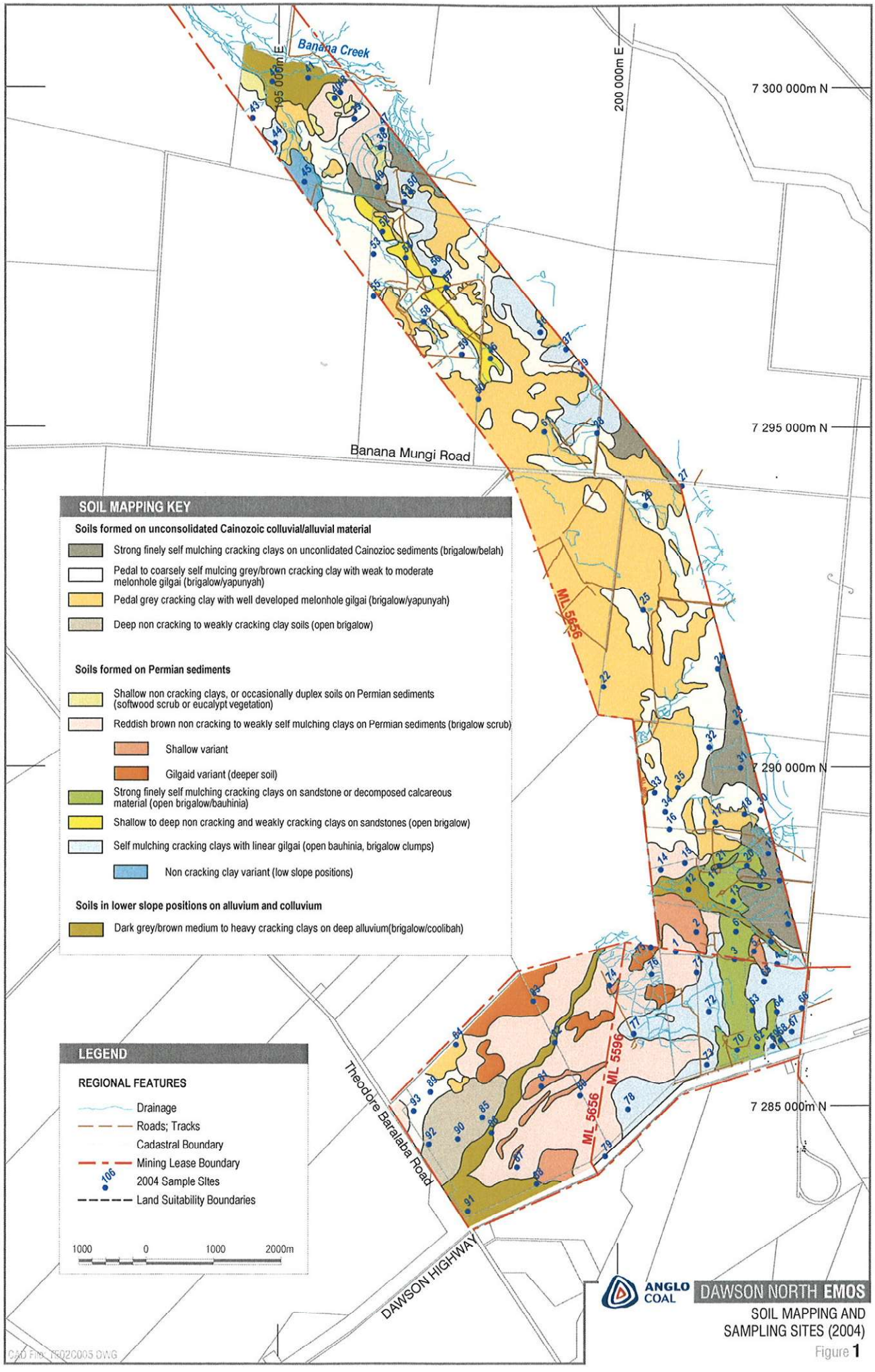
The surface material to 30cm should be salvaged for use as a seed source and topsoil material. If additional volume of material for a capping or root zone material is required then additional subsoil down to around 50cm could be taken (with some salinity testing in non cleared areas) but the material will have elevated sodicity, and may be relatively dispersive.



Plate 19. The appearance of a cropped area of the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" showing remnant natural vegetation present in the background



Plate 20. The appearance of an augered profile of the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" from Site 12 showing the surface in the top left and continuing across and then down the plate in 10cm increments



ANGLO COAL

DAWSON NORTH EMOS

SOIL MAPPING AND SAMPLING SITES (2004)

Figure 1

CAD File: F02C005.DWG

4. Land suitability of representative soil types within the appraisal area

Land suitability of the investigation area has been assessed largely using criteria provided in the DME Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland. The criteria provided in these guidelines are reproduced in Appendix 3.

Information provided in QDPI Guidelines for Agricultural Land Evaluation in Queensland and in Shields and Williams' Land resource survey and evaluation of the Kilcummin area, Queensland has also been used as well as personal communication with Peter Muller who is currently completing the Soil and land suitability study of the Banana mapsheet for QDPI.

Using suitability assessment methods, land has been allocated into five possible classes (with land suitability decreasing progressively from Class 1 to Class 5) on the basis of a specified land use which allows optimum production with minimal degradation to the land resource in the long term.

The classes are described as:

Class 1 Suitable land with negligible limitations which is highly productive requiring only simple management practices to maintain economic production.

Class 2 Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.

Class 3 Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production.

Class 4 Marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production outweigh the benefits in the long term (presently considered unsuitable due to the uncertainty of the land to achieve sustained economic production).

Class 5 Unsuitable land with extreme limitations that preclude its use for the proposed purpose.

Land is considered less suitable as the severity of limitations for a land use increase. Increasing limitations may reflect any combination of the following;

- reduced potential for production,
- increased inputs to achieve an acceptable level of production, and/or
- increased inputs required to prevent land degradation.

The first three classes (Class 1 to 3) are considered to be suitable for the specified land use as the benefits from using the land for that use should outweigh the inputs required to initiate and maintain production.

Class 4 land is marginal land where the benefits from using it probably approximate the inputs required and its long term suitability for the specified use is doubtful. (In contrast there is no doubt regarding the suitability of Classes 1 to 3 land or the unsuitability of Class 5 land).

Class 5 land has limitations that in aggregate are so severe that the benefits would not justify the inputs required to initiate and maintain production.

Dryland cropping and beef cattle grazing on improved pastures are the predominant land uses in the Dawson North area and these are the uses examined in the assessment of agricultural land suitability in this area.

The two assessments of suitability are considered separately.

4.1 Land suitability for dryland cropping

The suitability classification evaluates the broadacre potential of the land to grow a range of dryland crops normally grown in the area. In personal communication with Peter Muller regarding PAWC in particular, it appears that the range of soils which wheat specifically can be grown on is wider than the range of soils which summer crops can be grown on. This assessment considers the full range of crops so that rotations can be carried out. Some areas of the land which are therefore classed as Class 4 for dryland cropping as a whole may in fact be Class 3 for wheat specifically.

Limitations used to assess land suitability for dryland cropping for the Dawson North area are as follows.

Water availability (m)
Nutrient deficiency (n)
Soil physical factors (p)
Soil workability (k)
Salinity (sa)
Rockiness (r)
Microrelief (g)
Wetness (w)
Water erosion (e)
Flooding (f)

These limitations are discussed individually below in terms of the soils present in the Dawson North area, while individual limitations for the soils are presented in summarised tabular form in Table 11 and presented in mapped form in Figure 2. One of the major limitations is water availability and this is discussed in more detail, while soils with insufficient moisture for cropping are not discussed in detail in terms of some other limitations. Another major limitation to cropping use is potential for erosion.

Water availability (m) Plant available water capacity (PAWC) cut off levels have been obtained from P Muller (pers. comm.) from his recent survey work on the Banana map sheet to the north of this investigation area.

The cut off levels are as follows for crops apart from wheat. For wheat specifically the levels for suitable land (Classes 1 to 3) maybe reduced by 20mm.

m1 - > 180mm
m2 - 150-180mm
m3 - 120-150mm
m4 - 50-120mm
m5 - < 50mm

All soils are considered to have a severe (m4) limitation due to shallow depth or salinity at relatively high levels in the profile, with the exception of the "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow belah)", "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" and the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow coolibah)". Some areas of the "Pedal to coarsely self mulching grey/brown cracking clays with weak to moderate melonhole gilgai (brigalow/yapunyah)" and "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" are also considered to only have moderate (m3) limitation while the majority of those soil types have a severe (m4) limitation.

Nutrient deficiency (n) DME guidelines have been largely used in the assessment, with soils with brigalow vegetation and available phosphorus above 10ppm having a negligible limitation. In addition, the "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)" are also considered to have a negligible limitation as nutrition is considered to normally be higher than that level measured in the sample analysed. Some soils as noted in the text (Section 4) also appear to suffer from nutrient rundown over time with lower than desirable levels of organic carbon and total nitrogen and these soils are given a minor to moderate (n2-3) limitation as are soils which may have low sulphate or zinc levels.

Soil physical factors (p) DME guidelines have been used in the assessment. The "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow belah)", "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" and the bulk of the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" have very fine to fine self mulching surfaces and are given a negligible limitation. The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" are sometimes non cracking and are given a negligible to minor limitation (p1-2). The "Pedal to coarsely self mulching grey/brown cracking clays with weak to moderate melonhole gilgai (brigalow/yapunyah)" are considered to have a minor to moderate (p2-3) limitation depending on surface condition, while the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" has a coarse and hard surface structure and is assigned a moderate (p3) limitation.

All other soils have variable surface conditions and are assigned variable limitations, (negligible where soft, loose or firm and moderate where hardset).

Soil workability (k) DME guidelines have been largely used in the assessment. The "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow belah)", "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" and the bulk of the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" have very fine to fine self mulching surfaces and are given a negligible limitation. The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" are tighter and sometimes non cracking and are given a minor limitation (p2). The "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" is considered to have a minor to moderate (k2-3) limitation due to varying surface condition, varying wetness between mounds and depressions, and narrower range of moisture for working, while the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" is assigned a moderate (p3) limitation due to the previous factors, and increased difficulty of working.

All other soils have variable surface conditions and are assigned variable limitations, (negligible where soft, loose or firm, minor where hardset and moderate where extremely stiff).

Salinity (sa) DME guidelines are largely used. The "Shallow non cracking clays, or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)" are considered to have a negligible limitation as does the majority of the area of the "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)", with deeper areas having a minor limitation. All other soils have a negligible to minor limitation, with the exception of the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" and the majority of the area of the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" which has relatively high salinity in the rooting profile and is assigned a moderate (sa3) limitation.

Rockiness (r) This refers to rock outcrop and coarse fragments within the plough zone that impede cultivation and damage machinery. All soils are considered to have a negligible limitation, with the exception of minor areas of the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" and the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" which are considered to have a minor (r2) limitation. Small areas of the "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/belah) are considered to have a moderate (r3) limitation.

Microrelief (g) This limitation covers the effect microrelief has on uneven cultivation and impeding trafficability of machinery. The majority of soils have a negligible limitation. The "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow yapunyah)" is assigned a minor to moderate (g2-3 limitation). The "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" has a high incidence of gilgai and is assigned a moderate to severe limitation (g3-4). The gilgaid variant of the "Reddish brown non cracking to weakly self mulching cracking clay on Permian sediments (brigalow scrub)" is assigned a moderate (g3) limitation.

Wetness (w) This limitation covers the adverse effects of excess water on crop production through reduction in plant growth and yield and restrictions on the use of machinery following rain. All soils would be considered to have a minor (w2) limitation where they are present on flatter more low lying areas, however gilgaid soils have a greater degree of limitation and are assigned a moderate (w3) limitation.

Water erosion (e) This limitation covers accelerated soil loss which results in declining productivity, increasing difficulty to cultivate and eventually an inability to produce a crop in most years. DME guidelines are generally used.

The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" generally have a negligible limitation (unless in drainage lines, where the limitation is extreme).

The "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" has low slope and melonhole gilgai and is considered to have a negligible to minor (e1-2) limitation.

The "Deep non cracking to weakly cracking clay soils (open brigalow)" and the "Shallow non cracking clays or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation" are considered to have a minor (e2) limitation.

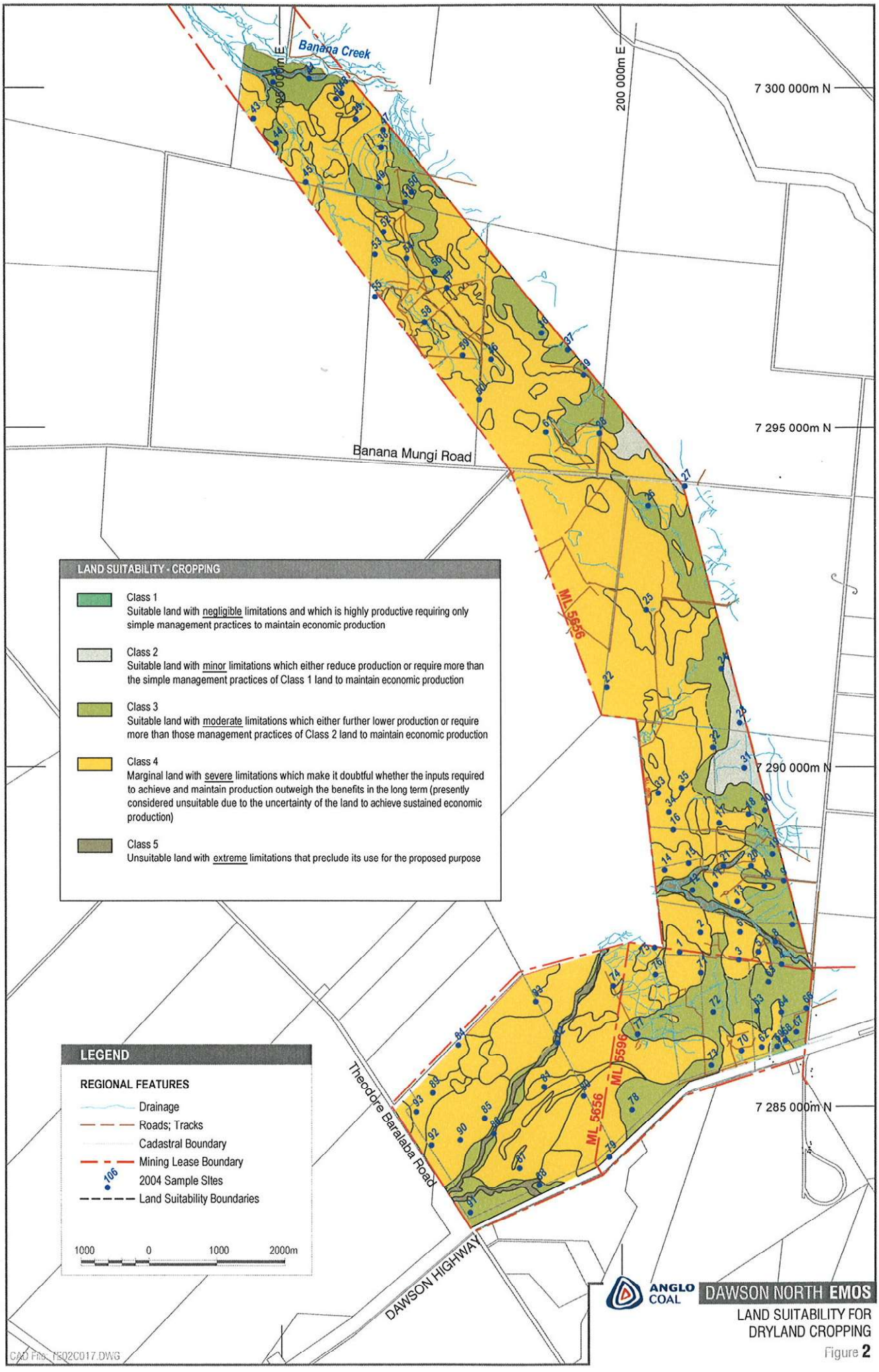
The "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" are considered to have a moderate (e3) limitation, while the "Shallow to deep non cracking and weakly cracking clays on sandstones" are considered to have a moderate to severe (e3-4) limitation due to their respective slopes.

All other soils are considered to have a minor to moderate (e2-3) erosion limitation.

Flooding (f) This limitation accounts for periodic inundation with damage caused by fast flowing water or submersion. The limitation is largely ignored as it relies heavily on local knowledge and only an extreme limitation has been imposed in and close to drainage channels where they are present on the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)".

Table 11. Land suitability limitations for dryland broadacre cropping in the Dawson North area

Soil Group	Limitations	Suitability
Soils formed on unconsolidated Cainozoic colluvial/alluvial material		
Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)	m2 and 3, sa1-2, e2-3	Classes 2 and 3
Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)	m4, some m3, p2-3, k2-3, sa3 some sa2, minor r2, g2-3, w3, e2-3	Class 4, some Class 3
Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)	m4, p3, k3, sa3, minor r2, g3-4, w3, e1-2	Class 4
Deep non cracking to weakly cracking clay soils (open brigalow)	m4, n2, p1-3, k1-2, sa1-2, w2, e2	Class 4
Soils formed on Permian sediments		
Shallow non cracking clays, or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)	m4, p1-3, k1-2, e2	Class 4
Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)	m4, n2-3, p1-3, k1-2, sa2, w1-2, e3	Class 4
Shallow variant	m4, n2-3, p1-3, k1-2, sa1-2, e3	Class 4
Gilgaid variant (deeper soil)	m4, n2-3, k3, sa2, g3, w3, e2	Class 4
Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)	m4, occasional m3, minor sa2, minor r3, e2-3	Class 4 occasional Class 3
Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)	m4, p1-3, k1-2, sa1-2, e3-4	Class 4
Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)	m3, n2, sa1-2, e3	Class 3
Non cracking clay variant (low slope positions)	m4, n2, p3, k2, sa2, w2, e3	Class 4
Soils in lower slope positions on alluvium and colluvium		
Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)	m3, n2, p1-2, k2, sa1-2, w2, some e5, some f5	Class 3, Some Class 5


Banana Creek
195 000m E
200 000m E
7 300 000m N
7 295 000m N
7 290 000m N
7 285 000m N
Banana Mungi Road
Theoddore Baralaba Road
DAWSON HIGHWAY
ML 5656
ML 5596
LAND SUITABILITY - CROPPING
Class 1
Suitable land with negligible limitations and which is highly productive requiring only simple management practices to maintain economic production
Class 2
Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production
Class 3
Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production
Class 4
Marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production outweigh the benefits in the long term (presently considered unsuitable due to the uncertainty of the land to achieve sustained economic production)
Class 5
Unsuitable land with extreme limitations that preclude its use for the proposed purpose
LEGEND
REGIONAL FEATURES
Drainage
Roads; Tracks
Cadastral Boundary
Mining Lease Boundary
106 2004 Sample SItes
Land Suitability Boundaries
1000 0 1000 2000m
ANGLO COAL
DAWSON NORTH EMOS
LAND SUITABILITY FOR DRYLAND CROPPING
Figure 2
CAD File: I502C017.DWG

4.2 Land suitability for grazing on improved pastures

The suitability classification evaluates the potential of the land to support beef cattle grazing on improved pastures.

Class 1 to 3 land is considered to be suitable for grazing sown pastures, however, the range of suitable species and the available options for establishment decrease from Class 1 to 3.

Class 4 land represents marginal land for grazing sown pastures. For the Dawson North area this is confined to minor areas associated with drainage ways that have an increased erosion risk during pasture establishment.

Class 5 land is not suitable for extensive pasture improvement but is suitable for grazing native pastures of relatively low productivity. This land is still useful grazing land, however is not suitable for establishment of the highly productive improved pastures. No areas of this type of land were found in the Dawson North investigation area.

Limitations used to assess land suitability for grazing of improved pastures for the Dawson North area are as follows.

Water availability (m)
Nutrient deficiency (n)
Soil physical factors (p)
Salinity (sa)
Rockiness (r)
Microrelief (g)
Wetness (w)
Water erosion (e)
Flooding (f)
Vegetation (v)

These limitations are discussed individually below in terms of the soils present in the Dawson North area, while individual limitations for the soils are presented in summarised tabular form in Table 12 and in mapped form in Figure 3. The major limitations are moisture availability and water erosion and these limitations are discussed in more detail.

Water availability (m) Plant available water capacity (PAWC) cut off levels have been given in the DME guidelines.

The "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow belah)", "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" and the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow coolibah)" have high PAWC and are considered to have a negligible limitation. Some areas of the "Pedal to coarsely self mulching grey/brown cracking clays with weak to moderate melonhole gilgai (brigalow/yapunyah)" are also considered to have a negligible or minor limitation. The "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" are considered to only have a minor (m2) limitation over the majority of their area, while some areas have a negligible limitation. All other soils are considered to have a moderate (m3) moisture limitation with the exception of occasional areas of the "Shallow non cracking clays, or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)", and much of the (Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)" which are considered to have a minor (m2) limitation.

Nutrient deficiency (n) - DME guidelines have been used but modified in the assessment. Soils with brigalow vegetation and available phosphorus above 10ppm have a negligible limitation. In addition, the "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)" are also considered to have a negligible limitation as nutrition is considered to normally be higher than that level measured in the sample

analysed. Some soils as noted in the text (Section 4) also appear to suffer from lower phosphorus levels and nutrient rundown over time with lower than desirable levels of organic carbon and total nitrogen and these soils are given a minor (n2) or moderate (n3) limitation (they still have mainly brigalow vegetation which indicates reasonable nutrition). No soils had less than 5ppm of available phosphorus (the lower limit for pasture improvement).

Soil physical factors (p) DME guidelines have largely been used in the assessment. The "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow belah)", "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" and the bulk of the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" have very fine to fine self mulching surfaces and are given a negligible limitation. The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" are sometimes non cracking and are given a negligible to minor limitation (p1-2). The "Pedal to coarsely self mulching grey/brown cracking clays with weak to moderate melonhole gilgai (brigalow/yapunyah)" are considered to have a minor to moderate (p2-3) limitation depending on surface condition, while the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" has a coarse and hard surface structure and is assigned a moderate (p3) limitation.

The majority of other rigid soils often have variable surface conditions and are assigned variable limitations, (negligible where soft, loose or firm and minor where hardset).

Salinity (sa) DME guidelines are largely used, however, effective rootzones for pastures are generally considered to be shallower than for crops and so milder limitations often exist where rooting profiles are deeper. However, in the soils encountered in the Dawson North area, salinity often occurs at relatively shallow depths and so limitations are often similar to those assigned for crops. The assessment is made on a 60cm rootzone.

The "Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)", "Shallow non cracking clays, or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)", "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)" and majority of the area of the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)", are considered to have a negligible limitation. All other soils have a negligible to minor limitation, with the exception of the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" and the majority of the area of the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" which have relatively high salinity in the rooting profile and are assigned a moderate (sa3) limitation.

Rockiness (r) This refers to rock outcrop and coarse fragments within the plough zone that impede cultivation and damage machinery. Cultivation is occasionally required for pasture improvement and similar but lower limitations apply as they do for cropping. All soils are considered to have negligible limitation, including the minor areas of the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" and the "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" which have significant surface stone present. Minor areas of the "Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/belah)" are considered to have a minor (r2) limitation.

Microrelief (g) This limitation covers the effect microrelief has on uneven cultivation impeding trafficability of machinery and reducing the effectiveness of fire to produce an ashbed, and as an initial control of woody weeds.

The majority of soils have a negligible limitation. The "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow yapunyah)" is assigned a negligible to minor (g1-2) limitation. The "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" has a high incidence of gilgai and is assigned a moderate limitation (g3). The gilgaid variant of the "Reddish brown non cracking

to weakly self mulching cracking clay on Permian sediments (brigalow scrub)" is assigned a minor (g2) limitation.

Wetness (w) This limitation covers the adverse effects of excess water on pasture production through reduced persistence of a range of introduced species and restrictions on use of machinery following rain. All soils would be considered to have minor (w2) limitation where they are present on flatter more low lying areas or where they are gilgaid, however the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)" has a greater degree of limitation and is assigned a minor to moderate (w2-3) limitation.

Water erosion (e) This limitation covers accelerated soil loss which results in declining productivity. Grazing generally increases the potential for soil loss during rainfall, compared to land with little disturbance. Clearing and increased grazing pressure can reduce cover. Occasional cultivation for preparation for seeding or renovation results in temporary exposure. Erosion will result in declining productivity. Limitations are similar to the cropping limitations but are less severe, and DME guidelines are generally used.

Most clay soils have a negligible limitation due to their cracking nature and low slope.

The shallow variant of the "Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)", the "Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)" and the non cracking clay variant of the "Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)" are assigned a minor (e2) limitation.

The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" generally have a negligible limitation but within drainage lines that traverse them and on the bank of Banana Creek in the north are given a severe limitation (e4).

Flooding (f) This limitation accounts for periodic inundation with damage caused by fast flowing water or submersion. The limitation is largely ignored as it relies heavily on local knowledge and only a minor limitation has been imposed in and close to drainage channels where they are present on the "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)".

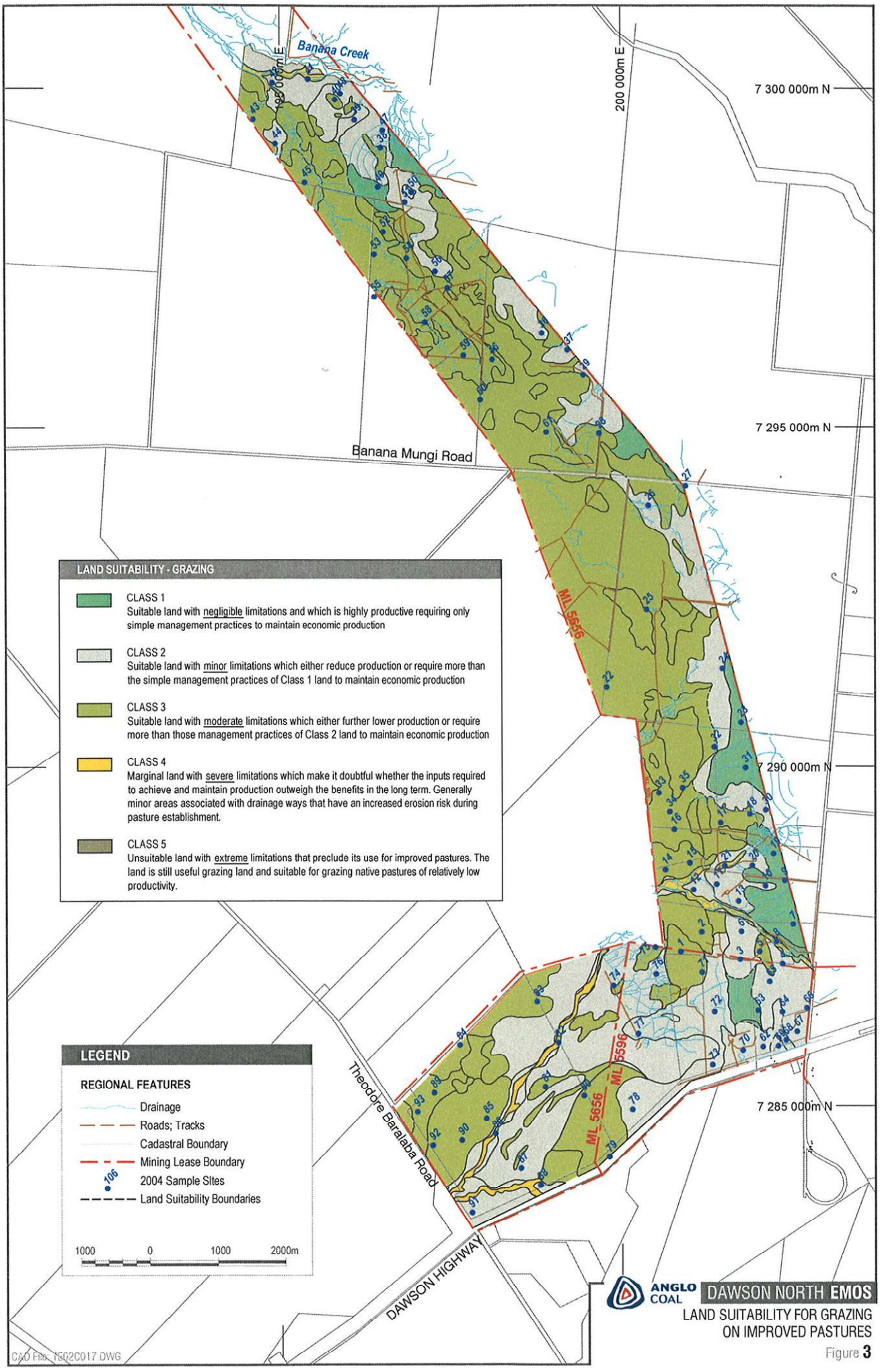
Vegetation (v) Timber clearing is necessary for the establishment of, and increasing dry matter production of pasture species. Long term benefits may be reduced by regrowth. Guidelines from the Kilcummin survey have largely been used.

The soils which have either softwood scrub vegetation or a fine to very fine self mulching surface are given a negligible limitation as little regrowth will occur. The majority of soils have a coarser surface structure and brigalow vegetation and have the potential for some regrowth and are given a minor limitation where they are non gilgaid. The "Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)" may have minor gilgai or coolibah growth and are also assigned a minor (v2) limitation.

The "Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)" is given a minor to moderate limitation (v2-3) depending on the extent of gilgai present, while the "Pedal grey cracking clay with well developed melonhole gilgai (brigalow yapunyah)" and the gilgaid variant of the "Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)" are given a moderate (v3) limitation.

Table 12. Land suitability limitations for beef cattle grazing on improved pastures in the Dawson North area

Soil Group	Limitations	Suitability
Soils formed on unconsolidated Cainozoic colluvial/alluvial material		
Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)	Nil	Class 1
Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)	m3, some m1 and 2, p2-3, sa2-3, g1-2, w1-2, v2	Class 3 some Class 2
Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)	m3, p3, sa2-3, g3, w2-3, v2	Class 3
Deep non cracking to weakly cracking clay soils (open brigalow)	m3, n2, p1-2, sa1-2, w1-2	Class 3
Soils formed on Permian sediments		
Shallow non cracking clays, or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)	m3 occasional m2, p1-2, w1-2	Class 3 occasional Class 2
Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)	m3 some m2, n3, p1-2, sa1-2	Class 3 Some Class 2
Shallow variant	m3, n3, p1-2, sa1-2, e2	Class 3
Gilgaid variant (deeper soil)	m3, n3, sa2, g2, w2, v2	Class 3
Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)	m2 occasional m1, minor r2	Class 2, Minor Class 1
Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)	m3, p1-2, sa1-2, e2	Class 3
Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)	m1 some m2, n2	Class 2
Non cracking clay variant (low slope positions)	m3, n2, p2, sa2, w2, e2	Class 3
Soils in lower slope positions on alluvium and colluvium		
Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)	m1-2, n2, p1-2, sa1-2, w1-2, some e4, some f2, v1-2	Class 2 some Class 4


Banana Creek
195 000m E
200 000m E
7 300 000m N
7 295 000m N
7 290 000m N
7 285 000m N
Banana Mungi Road
Theoddore Baralaba Road
DAWSON HIGHWAY
ML 5656
ML 5596
LAND SUITABILITY - GRAZING
CLASS 1
Suitable land with negligible limitations and which is highly productive requiring only simple management practices to maintain economic production
CLASS 2
Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production
CLASS 3
Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production
CLASS 4
Marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production outweigh the benefits in the long term. Generally minor areas associated with drainage ways that have an increased erosion risk during pasture establishment.
CLASS 5
Unsuitable land with extreme limitations that preclude its use for improved pastures. The land is still useful grazing land and suitable for grazing native pastures of relatively low productivity.
LEGEND
REGIONAL FEATURES
Drainage
Roads; Tracks
Cadastral Boundary
Mining Lease Boundary
106 2004 Sample SItes
Land Suitability Boundaries
1000 0 1000 2000m
ANGLO COAL
DAWSON NORTH EMOS
LAND SUITABILITY FOR GRAZING ON IMPROVED PASTURES
Figure 3
CAD File: 1502C017.DWG

5. Final land use and topsoil stripping considerations

The topsoil stripping recommendations will vary depending on the final desired use of the rehabilitated land (and will also vary depending on the hostility of the spoil medium to be rehabilitated). For instance, if the EMOS commitments undertake to completely reinstate pre mining cropping or grazing capability then this will possibly require removal of at least the soil rooting depth in three to four separate layers.

These recommendations relate to stripping of soil material which may be considered to be useful for topsoil and subsoil material for establishment of tree or pasture species, for rehabilitation and stabilisation of moderate slopes.

In topsoil stripping, stockpiling and replacement, the whole process should follow a detailed topsoil management plan which takes into account the nature of the waste to be rehabilitated and therefore the method of rehabilitation (depths of topsoil and cover required, and vegetation to be established).

This plan should outline,
- areas to be disturbed,
- volumes of individual soil and cover types required for eventual rehabilitation,
- optimum method of management during stockpiling,
- area of placement of individual topsoil and cover types, and
- volumes of topsoil and cover material to be stripped.

Some general rules, however, apply.

- Two stage stripping and replacement is recommended to preserve optimum surface physical conditions and any seed source that may be present. The material stripped by this process is generally referred to as topsoil and root zone material respectively.
- Topsoil salvage should be maximised from all disturbed areas.
- Topsoil should be segregated into stockpiles that have similar reuse characteristics, i.e. soils with good surface physical characteristics should not be stockpiled with soils where some poorer surface physical characteristics are indicated.
- Topsoil should also be segregated into stockpiles that may contain some native seed source, separated from topsoil from cropped or pasture improved land which will contain very little native seed source.
- The actual topsoil stockpiles (generally from the surface down to 20 or 30cm) should be formed no more than 1.5m in height and should be immediately deep ripped and seeded on their formation.
- The topsoil stockpiles which may contain some native seed source (from non pasture improved areas) should be reused first to obtain the maximum benefit from the native seed source, providing that this fits in with the rehabilitation plan of soil and cover types required for rehabilitation.
- The root zone material (generally material stripped from more than 20 to 30cm deep) can be stockpiled to greater depths than the topsoil but should only be stockpiled on areas from which the topsoil has first been stripped.

Initial stripping recommendations (two stage stripping which is the preferred option) for individual soil types are summarised in Table 13. It must be born in mind that the recommendations are given without the knowledge of the spoil characteristics and they may vary depending on the characteristics of the spoil material to be rehabilitated. Also, if single stage stripping is to be utilised then these recommendations will need to be reworked.

Table 13. Summary of two stage stripping recommendations for soil types in advance of mining, Dawson North area (recommendations are for two stage stripping of material useful for establishment of tree and pasture species, the recommendations do not allow for the reinstatement of land suitability), (the surface should not be mixed with the root zone material) (root zone recommendations will vary depending on spoil hostility)

Topsoil Recommendation	Root Zone recommendation
Soils formed on unconsolidated Cainozoic colluvial/alluvial material	
Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/belah)	
Strip the surface 40cm separately as a topsoil and a seed source. The material has reasonably good structural characteristics but is still not suited to replacement on steep slopes. Tree establishment on this soil type will be extremely difficult.	The material from 40cm down to around 60cm in more saline profiles, or 100cm in less saline profiles could be taken (with some field testing for salinity).
Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)	
Strip the surface 15cm separately as a topsoil and a seed source. The material has poorer structural characteristics and is only suited to replacement on relatively flat areas. Tree establishment on this soil type will be extremely difficult.	The material from 15cm down to around 25cm in the majority of areas, or around 40 to 50cm in better soils around Sites 14, 26, 30 and 39 may be able to be stripped (with some field testing for salinity).
Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)	
Strip the surface 15cm separately as a topsoil and a seed source. The material is only marginally suitable for use as a topsoil (elevated sodicity and possibly salinity) and is only suited to replacement on relatively flat areas. Tree establishment on this soil type will be difficult.	The material from 15cm down to around 20cm may be taken but sodicity and dispersion will be relatively high.
Deep non cracking to weakly cracking clay soils (open brigalow)	
Strip the surface 15cm separately as a topsoil and a seed source. The material is only marginally suitable for a topsoil and will have elevated dispersion and is only suited to replacement on relatively flat areas. Tree establishment on this soil type will be difficult.	The material from 15cm down to around 30cm in the majority of areas may be taken but sodicity and dispersion will be elevated.
Soils formed on Permian sediments	
Shallow non cracking clays, or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)	
Strip the surface and upper subsoil to 30cm as a topsoil and a seed source. The soil should only be replaced on flatter slopes not exceeding normal premining slopes, as some propensity for sheet erosion was observed.	The material from 30cm down to parent strata (60 to 90cm) could be taken but the material has slightly elevated sodicity and is relatively dispersive and should only be replaced on flat areas.
Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)	
In the main soil type and shallow variant the surface and upper subsoil to 20cm should be salvaged for use as a topsoil and a seed source. Surface soil from the gilgaid variant has very poor physical conditions and should not be salvaged if adequate volumes of topsoil can be sourced elsewhere. The soil is only suited to replacement on relatively flat areas. Tree establishment on this soil type will be difficult.	In the main soil type and shallow variant additional material from 20 to 40cm could be salvaged for use as a root zone or capping material.

Table 13 cont. Summary of two stage stripping recommendations for soil types in advance of mining, Dawson North area (recommendations are for two stage stripping of material useful for establishment of tree and pasture species, the recommendations do not allow for the reinstatement of land suitability), (the surface should not be mixed with the root zone material) (root zone recommendations will vary depending on spoil hostility)

Topsoil Recommendation	Root Zone recommendation
Strong finely self mulching cracking clays on sandstone or decomposed calcareous material open brigalow/bauhinia)	
Strip the surface 25cm separately as a topsoil and a seed source. Tree establishment on this soil type will be extremely difficult.	The material from 25cm down to around 40 to 50cm could be taken (with some field testing for salinity).
Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)	
Strip the surface 20cm separately as a topsoil and a seed source. The material is only suited to replacement on relatively flat areas. Tree establishment on this soil type will be difficult.	The material from 20cm down to around 40cm may be taken but sodicity and dispersion may be elevated.
Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)	
In the main soil type, strip the surface 30cm separately as a topsoil and a seed source (only strip 20cm in the non cracking variant). The material has moderate structural characteristics and should only be placed on slopes similar to premining slopes. Tree establishment on this soil type will be extremely difficult.	The material from 30cm down to around 50cm could be taken in the main soil type but it will have elevated sodicity and may be relatively dispersive. In the non cracking variant stripping should be limited to 30cm.
Soils in lower slope positions on alluvium and colluvium	
Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)	
Strip the surface 30cm separately as a topsoil and a seed source. The material has slightly inferior structural characteristics and is only considered to be suited to replacement on relatively flat slopes. Tree establishment on this soil type will be difficult.	The material from 30cm down to around 50cm could be taken (with some field testing for salinity in non cleared areas).

6. Summary and recommendations

The soils ahead of mining in the future area of disturbance at Dawson North are clay dominated soils with the majority having originally supported brigalow. The brigalow soils generally have good nutrition and are usually well suited to pasture improvement while minor areas of soils that may have supported eucalypt or mixed vegetation are considered to have lower nutrient levels but are still considered to be suited to pasture improvement.

The soils consist mainly of deep soils formed on unconsolidated Cainozoic colluvial/alluvial material and shallower soils formed on Permian sediments, with minor areas of alluvial soil on Quaternary alluvium. The majority of soils have salinity at depth which limits effective rooting depth and therefore limits plant available water capacity of the soils.

The only soils present in the area which are considered suitable for dryland cropping are soils which do not reach high salinity levels until deeper depths, and generally have a fine or to a lesser degree, medium self mulching surface. These soils occur on all parent material types, (unconsolidated Cainozoic, Permian and Quaternary alluvial materials) and are considered to comprise only around 25% (or less) of the area of investigation, with the remainder of the area not being considered to be suited to dryland cropping (defined as, growing the full range of winter and summer crops). However, some of that area not considered suitable for dryland cropping may be considered suitable for either wheat or forage crops.

All soils are considered to be suitable for cattle grazing on improved pastures, with the exception of small areas of the alluvial soil where an erosion risk would be present during clearing and pasture improvement operations. It is considered that over 95% of the area is suitable for improved pasture development.

Resources of topsoil for rehabilitation are located right across the area to be disturbed, while some additional resources of second grade material suitable for use as a root zone or capping material are also available from the lower soil horizons (final selection of root zone materials will vary depending on the actual characteristics of the of the spoil material to be covered and rehabilitated).

Maps of topsoil types, distribution and land suitability are provided in the report along with summary tables of suggested stripping depths (for two stage stripping, maximising quantities of useable material).

Appendix 1. Soil descriptions, pH and electrical conductivity (uS/cm, 1:5 basis), for soil profiles examined in the Dawson South Stage 2 area

Soils formed on unconsolidated Cainozoic colluvial/alluvial material

Strong finely self mulching cracking clays on unconsolidated Cainozoic sediments (brigalow/yapunyah)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
7	0 202 504E 7 287 685N (moderate fine self mulch, slight silcrete on surface and down profile		
0-10	Moderate fine very dark greyish brown MC A1 to 3cm underlain by very dark greyish brown MHC B21 with slight hard CO^3 present	8.3	103
10-20	Very dark greyish brown MHC B21 with slight hard CO^3 present	8.7	119
20-30	As above	8.9	165
30-40	As above, grading to B22 below	8.9	273
50-60	Brown MHC B22, slight hard CO^3 present	8.9	540
80-90	As above	8.6	1160
110-120	Mottled pinkish grey/yellowish red parent clays	7.0	1409
140-150	As above	5.1	1689
9	0 202 378E 7 288 330N (strong fine to medium self mulch, slight silcrete on surface and slight hard CO^3)		
0-10	Very dark greyish brown MHC A1 to 4cm underlain by very dark greyish brown HC B21 with some hard CO^3 present	8.1	119
10-20	Very dark greyish brown HC B21 with some hard CO^3 present	8.4	163
20-30	As above	8.6	211
30-40	As above, grading to B22 below	8.8	366
50-60	Very dark grey HC B22, some soft and hard CO^3 present	8.5	997
80-90	Dark yellowish brown HC B3	7.8	1348
110-120	Mottled pinkish white/ red parent clays	4.8	1363
140-150	As above	4.5	1362
19	0 202 215E 7 288 725N (strong fine self mulch)		
0-10	Very dark greyish brown MHC A1 to 4cm underlain by very dark greyish brown MHC B21	8.4	179
10-20	Very dark greyish brown MHC B21	8.5	145
20-30	Very dark greyish brown HC B22, with slight soft CO^3 present in the upper profile	8.7	184
30-40	As above	9.0	281
50-60	Mottled very dark greyish brown/dark yellowish brown HC B23	8.9	602
80-90	Mottled yellowish brown (slight light brownish grey) HC B3	6.2	1462
110-120	As above	4.6	1573
140-150	Mottled dark red/dark greyish brown weakly consolidated parent clays	4.4	1354
23	0 201 735E 7 290 656N (strong fine self mulch, some hard surface carbonate)		
0-10	Very dark grey HC A1 to 4cm underlain by black HC B21	7.9	120
10-20	Black HC B21	8.4	108
20-30	As above	8.4	105
30-40	As above, grading to B22 below	8.6	116
50-60	Black HC B22, some soft and hard CO^3 present	9.1	198
80-90	As above, grading to B3 below	9.2	228
110-120	Slightly mottled dark grey HC B3, no CO^3	9.0	288
140-150	Mottled dark grey/light olive brown HC PM no CO^3	8.1	344
27	0 200 932E 7 294 133N (weak fine self mulch, some surface silcrete)		
0-10	Very dark grey MHC A1 to 2cm underlain by very dark grey MHC B21	7.3	98
10-20	Very dark grey MHC B21	7.6	99
20-30	As above	8.0	106
30-40	As above, grading to B22 below	8.4	113
50-60	Very dark grey HC B22, some soft and hard CO^3 present	9.2	264
80-90	As above, grading to B3 below	9.0	569
110-120	Slightly mottled dark grey HC B3, no CO^3	7.4	790
140-150	Mottled dark grey/light olive brown MC PM no CO^3	5.7	761

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
31	0 201 801E 7 289 986N (strong fine self mulch, some surface silcrete)		
0-10	Very dark grey HC A1 to 4cm underlain by very dark grey HC B21	7.4	129
10-20	Very dark grey HC B21	7.3	120
20-30	As above, grading to B22 below 25cm	8.0	190
30-40	Very dark grey HC B22, slight soft and hard CO^3 present	8.3	205
50-60	As above	8.4	258
80-90	Slightly mottled brown HC B23, slight hard CO^3 present	8.5	451
110-120	As above	8.4	950
140-150	Mottled strong brown/reddish yellow parent clays, some siltstone and stone inclusions	8.3	1170
49	0 196 447E 7 298 542N (moderate fine self mulch, significant surface silcrete and slight hard CO^3 on the surface and down the profile)		
0-10	Very dark greyish brown MHC A1 underlain by very dark greyish brown HC B21	7.9	105
10-20	Very dark greyish brown HC B21	8.1	108
20-30	As above	8.3	110
30-40	As above	8.3	111
50-60	Black HC B22	8.4	130
80-90	As above	8.3	377
110-120	Brown B3	8.1	641
140-150	Mottled brown/light yellowish brown colluvium (basaltic) below 120cm	7.7	824

Pedal to coarsely self mulching grey/brown cracking clay with weak to moderate melonhole gilgai (brigalow/yapunyah)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
16	0 200 755E 7 289 076N (cracking, non self mulching, weakly developed firm crust, some small surface silcrete and coarse quartz sand)		
0-10	Dark grey very hard blocky MC A	6.6	571
10-20	As above	7.5	808
20-30	As above to 25cm, grading to dark grey HC B21 below	7.9	1016
30-40	Dark grey HC B21	7.2	1208
50-60	As above	5.2	1713
80-90	Brown HC B22, colour lightening	4.9	1917
110-120	As above	4.4	2239
140-150	Light brown B3/PM HC	4.3	2132
24	0 201 465E 7 291 441N (cracking, weak medium self mulch, slight surface quartz and silcrete, slight billy outcrops in nearby area)		
0-10	Very dark greyish brown MHC A1 over very dark greyish brown MHC B21	6.7	101
10-20	Very dark greyish brown MHC B21	7.4	94
20-30	As above to 25cm, grading to dark grey HC B22 below	7.7	95
30-40	Dark grey HC B22	7.7	118
50-60	As above	5.8	232
80-90	Dark brown/dark yellowish brown HC B23	4.8	487
110-120	Mottled yellowish brown (some very pale brown/reddish brown) MC PM (no CO^3)	4.7	483
140-150	As above	4.6	576

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
26	0 200 391E 7 293 841N (cracking,medium to coarse self mulch, some surface silcrete,)		
0-10	Very dark grey HC A1 over very dark grey HC B21	8.7	176
10-20	Very dark grey HC B21	8.7	162
20-30	As above to 25cm, grading to very dark grey HC B22 (with slight hard and soft CO^3)	9.0	183
30-40	Very dark grey HC B22 (with slight hard and soft CO^3)	9.2	215
50-60	As above	9.3	331
80-90	Dark greyish brown HC B23, no CO^3	8.8	191
110-120	Mottled greyish brown/yellowish brown HC B3 (no CO^3)	5.1	760
140-150	Dark yellowish brown HC parent clays	4.8	1056
28	0 199 679E 7 294 907N (cracking, weak fine self mulch, some areas non cracking)		
0-10	Very dark greyish brown A1 to 2cm, very dark greyish brown MC B21 with slight hard CO^3 below	8.2	138
10-20	Very dark grey MC B21slight hard CO^3	8.4	139
20-30	As above	8.8	194
30-40	Very dark greyish brown MHC B22 (with slight hard and soft CO^3)	9.1	272
50-60	As above	8.8	929
80-90	Dark brown MHC B23, some hard CO^3	8.7	1365
110-120	Light olive brown MHC B3 (no CO^3)	8.7	1343
140-150	Light yellowish brown MHC parent clays	8.5	1338
30	0 202 100E 7 289 367N (cracking, medium self mulch, slight surface silcrete and occasional hard carbonate)		
0-10	Very dark greyish brown A1 to 3cm, very dark greyish brown HC B21 below	8.0	147
10-20	Very dark greyish brown HC B21	8.2	155
20-30	Very dark greyish brown HC B22, slight hard and soft CO^3	8.4	194
30-40	As above	8.5	239
50-60	As above, slightly mottled dark brown/brown HC B23, CO^3 declining	8.7	278
80-90	As above	8.7	538
110-120	Weakly consolidated strong brown/brownish yellow parent clays	8.3	984
140-150	As above	7.7	1085
32	0 201 340E 7 290 292N (cracking, medium self mulch)		
0-10	Very dark greyish brown A1 to 2-3cm, very dark grey HC B21 with slight hard CO^3 below	8.3	359
10-20	Very dark grey HC B21 with slight hard CO^3	8.4	403
20-30	As above	8.6	506
30-40	As above, colour lightening to B22 below	8.6	614
50-60	Very dark greyish brown/dark greyish brown HC B22	7.8	872
80-90	Brown HC B23/B3	5.3	1111
110-120	As above	4.4	1156
130-140	Greyish brown/brown parent clays, some sandstone inclusions	4.4	970
33	0 200 534E 7 289 616N (cracking, weak coarse self mulch, some surface silcrete and small quartz)		
0-10	Very dark greyish brown A1 to 2cm, very dark grey HC B21 below	6.3	248
10-20	Very dark grey HC B21	6.7	311
20-30	As above	6.8	438
30-40	As above, colour lightening to B22 below	5.9	742
50-60	Dark brown HC B22	5.3	1114
80-90	Slightly mottled brown HC B23	4.9	1905
110-120	Brown parent clays	4.3	2196
140-150	As above	4.1	2195
34	0 200 691E 7 289 339N (cracking, moderate coarse self mulch, some surface silcrete and small quartz)		
0-10	Very dark grey A1 to 3cm, very dark grey MHC B21 below	6.9	192
10-20	Very dark grey MHC B21	7.1	194
20-30	Dark grey HC B22	8.0	293
30-40	As above, colour lightening to B23 below	7.9	468
50-60	Brown HC B23	5.3	852
80-90	Slightly mottled brown HC B3	4.7	1023
110-120	Strong brown parent clays	4.5	864
140-150	As above	4.3	1036

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
39	0 196 107E 7 299 535N (weak medium self mulch)		
0-10	Very dark greyish brown MHC A1 underlain by very dark greyish brown MHC B21	8.4	209
10-20	Very dark greyish brown MHC B21	8.9	171
20-30	Dark greyish brown HC B22, slight hard CO^3 present	9.2	181
30-40	As above	9.3	262
50-60	As above	8.5	700
80-90	Mottled brown/yellowish brown HC B3	7.7	1187
110-120	As above	4.9	1450
140-150	Mottled light brownish grey/light yellowish brown parent clays	4.7	1457
43	0 194 609E 7 299 541N (cracking, slightly crusting, shelf profile, gilgai to 40cm)		
0-10	Dark brown to brown very hard blocky MHC A	7.7	242
10-20	As above	7.5	372
20-30	Strong brown whole coloured MHC B21, no CO^3	6.8	623
30-40	As above	6.0	951
50-60	As above	5.4	1294
80-90	As above	5.0	1353
110-120	As above	4.9	1450
140-150	As above	4.9	1549
53	0 196 391E 7 297 554N (cracking, non self mulching, significant surface silcrete and small quartz)		
0-10	Very dark greyish brown MC A	7.2	101
10-20	As above	6.6	101
20-30	Very dark greyish brown MHC B21	6.9	219
30-40	As above	7.7	526
50-60	As above, silcrete stopped augering below 60cm	8.0	760
59	0 197 685E 7 296 074N (weakly cracking, non self mulching, significant surface silcrete, very minor gilgai)		
0-10	Very dark greyish brown hard blocky MC A	6.1	117
10-20	As above to 15cm, dark brown MHC B21 with slight hard CO^3 under	6.4	116
20-30	Dark brown MHC B21 with slight hard CO^3	5.9	356
30-40	As above, no CO^3	5.1	527
50-60	As above	4.7	850
80-90	Brown HC B22, no CO^3	4.5	1054
110-120	As above	4.3	1862
140-150	Brown HC B3, no CO^3	4.3	1977
89	0 197 232E 7 285 202N (non self mulching, friable moderately developed surface flake)		
0-10	Dark brown hard blocky MC A	7.4	124
10-20	As above	8.2	232
20-30	As above to 25cm, very dark greyish brown MHC B21 under	8.5	479
30-40	Very dark brown MHC B21	8.4	800
50-60	As above	6.8	1144
80-90	Dark brown MHC B22	5.3	1357
110-120	As above	4.9	1292
140-150	Dark yellowish brown MHC (sandy) B3	4.7	1244
93	0 196 989E 7 284 923N (non self mulching, slightly cracking, weakly developed, firm to hard surface flake)		
0-10	Dark brown hard blocky MHC A	6.7	302
10-20	As above	6.7	441
20-30	As above to 25cm, dark yellowish brown HC B21 under	6.4	611
30-40	Dark yellowish brown HC B21	5.9	769
50-60	As above	5.1	1009
80-90	Brown HC B22	4.7	1110
110-120	As above	4.6	1119
140-150	Brown HC B3, slight siltstone inclusions	4.6	1149

Pedal grey cracking clay with well developed melonhole gilgai (brigalow/yapunyah)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
17	0 201 433E 7 289 179N (cracking, non self mulching, weak firm surface flake, occasional sandstone floaters, gilgai to 40cm)		
0-10	Dark grey very hard blocky MC A	8.3	151
10-20	As above	8.5	163
20-30	Dark grey MHC B21, slight hard CO^3 present	8.7	270
30-40	As above	8.7	493
50-60	As above, grading to MHC B22 under	8.2	838
80-90	Brown MHC B22, slight sandstone chips present, no CO^3	5.5	848
110-120	As above	5.1	822
130-140	As above, sandstone floater encountered	5.0	753
18	0 201 863E 7 289 307N (cracking, non self mulching, weak firm surface flake, gilgai to 50 or occasionally 80cm)		
0-10	Dark grey very hard blocky MC A	8.8	184
10-20	As above	8.6	229
20-30	As above to 25cm, grading to slightly mottled dark yellowish brown HC B21 under	8.2	577
30-40	Slightly mottled dark yellowish brown HC B21, no CO^3	6.6	1141
50-60	As above	5.4	1288
80-90	As above, B3 under	4.8	1319
110-120	Mottled pinkish grey/reddish brown tertiary clays	4.7	1353
22	0 199 778E 7 281 176N (cracking, non self mulching, weak firm surface flake, gilgai to 70cm, reduced to 40cm where ploughed)		
0-10	Dark grey very hard blocky LMC A	7.4	178
10-20	As above	7.7	195
20-30	As above, grading to dark grey HC B21 under	8.1	272
30-40	Dark grey HC B21, no CO^3	8.4	747
50-60	As above	6.6	1127
80-90	Dark grey HC B22 (possible slight gypsum)	5.4	1176
110-120	As above	4.8	1297
140-150	Dark greyish brown HC B3/PM	4.5	1395
25	0 200 360E 7 292 311N (cracking, weak firm surface flake, gilgai to 90cm in adjoining areas, some non cracking stony areas present nearby, not mappable separately)		
0-10	Very dark grey hard blocky MHC A	6.8	202
10-20	As above	7.0	206
20-30	Very dark grey HC B21, no CO^3	7.8	380
30-40	As above	8.3	602
50-60	Dark brown HC B22, no CO^3	5.4	1048
80-90	Brown HC B23	4.5	1776
110-120	Light yellowish brown HC parent clays	4.1	2394
140-150	As above	4.1	2448
29	0 199 452E 7 295 777N (cracking, non self mulching, firm surface flake, weak linear or melonhole gilgai)		
0-10	Very dark grey MC A	7.7	164
10-20	As above	8.0	173
20-30	Very dark grey MHC B21 slight hard and soft CO^3	8.7	251
30-40	As above	8.9	443
50-60	As above	8.7	817
80-90	Mottled very dark greyish brown/dark brown MHC B22, CO^3 declining	8.4	1290
110-120	As above (no CO^3)	5.9	1075
140-150	Yellowish brown HC parent clays, no CO^3	5.0	1053
35	0 200 879E 7 289 692N (cracking, friable surface flake, occasional gilgai to 50cm)		
0-10	Dark grey hard blocky MHC A	8.3	216
10-20	As above	8.4	179
20-30	Dark grey HC B21, no CO^3	8.8	243
30-40	As above	8.8	489
50-60	Greyish brown HC B22, no CO^3	7.4	934
80-90	As above	5.2	1578
110-120	Grey HC B23/B3, PM not encountered	5.2	1521
140-150	As above	5.2	1505

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
58	0 197 126E 7 296 561N (cracking, shelf profile, firm surface flake, occasional melonholes to 90cm)		
0-10	Brown hard blocky MC A	7.8	306
10-20	As above to 15cm, brown MHC B21 with soft CO^3 under	8.3	558
20-30	Brown MHC B21 with soft CO^3	8.6	1122
30-40	As above, HC B22 under	8.2	1849
50-60	Yellowish brown HC B22, no CO^3	5.4	2384
80-90	Yellowish brown HC B23/B3, no CO^3	5.0	2361
110-120	As above	4.7	2395
140-150	As above	4.7	2350
60	0 197 931E 7 295 404N (non self mulching, friable well developed surface flake, some gilgai present)		
0-10	Very dark greyish brown hard blocky MC A	7.4	209
10-20	As above	8.1	278
20-30	Grey HC B21 with slight hard CO^3	8.5	422
30-40	As above	8.6	1052
50-60	As above, no CO^3	8.0	1744
80-90	Greyish brown HC B22, no CO^3	5.0	1706
110-120	Brown HC B3, no CO^3, some soft sandstone inclusions	4.6	1368
140-150	As above	4.4	1508
61	0 198 901E 7 294 926N (cracking, shelf profile, friable surface flake, melonholes to 90cm)		
0-10	Dark grey hard blocky MHC A	7.6	208
10-20	As above	7.9	210
20-30	Grey HC B21 with slight hard CO^3	8.2	225
30-40	As above	8.5	334
50-60	As above, HC B22 under	8.4	767
80-90	Slightly mottled grey/dark greyish brown HC B22, no CO^3	8.6	1291
110-120	As above	7.9	1376
140-150	As above	7.5	1499
84	0 197 606E 7 285 905N (cracking, puff profile, weak coarse self mulch)		
0-10	Coarse A1 to 2cm, hard blocky brown MHC B21 below	7.8	648
10-20	Brown MHC B21	8.4	791
20-30	As above	8.4	1346
30-40	As above	8.5	1742
50-60	Dark yellowish brown HC B22	7.4	2284
80-90	As above	5.8	2413
110-120	As above	5.4	2131
140-150	As above	5.3	2135

Deep non cracking to weakly cracking clay soils (open brigalow vegetation)

85	0 197 998E 7 284 827N (weakly cracking clay, weak, firm surface flake)		
0-10	Brown hard LC A	8.3	158
10-20	As above	8.8	207
20-30	As above to 25cm, grading to brown MC B21, with slight soft CO^3	8.9	412
30-40	Brown MC B21, with slight soft CO^3	8.9	516
50-60	As above	8.8	957
80-90	Brown MC B3, with strong brown siltstone/mudstone inclusions increasing, no CO^3	9.0	986
110-120	As above	8.2	965

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
90	0 197 635E 7 284 508N (non cracking clay, hardset surface, occasional cracking areas and gilgai around)		
0-10	Dark brown hardset LC A	7.3	103
10-20	As above to 15cm, brown MC B21 with soft CO^3 present below	8.3	150
20-30	Brown MC B21 with soft CO^3 present	9.1	325
30-40	As above	9.1	648
50-60	As above, MC B22 with no CO^3 below	8.9	1146
80-90	Brown MC B22, no CO^3	8.9	1234
110-120	As above	7.6	1019
140-150	Strong brown LMC (sandy) B23/B3	5.2	957
92	0 197 211E 7 284 431N (non cracking clay, friable surface flake, occasional cracking areas and gilgai to 30cm around)		
0-10	Very hard very dark greyish brown LMC A	7.7	123
10-20	As above	8.6	167
20-30	Dark brown LMC B21, slight soft CO^3 present	8.9	234
30-40	As above	8.9	373
50-60	As above	8.7	676
80-90	Dark yellowish brown LMC B22, no CO^3	8.6	737
110-120	As above	6.0	779
140-150	Dark yellowish brown B3 with parent mudstone inclusions	5.3	857

Soils formed on Permian sediments

Shallow non cracking clays or occasionally duplex soils on Permian sediments (softwood scrub or eucalypt vegetation)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
38	0 196 487E 7 299 120N (non cracking, firm granular surface, some surface sandstone and slight silcrete)		
0-10	Dark brown LMC A	6.8	121
10-20	As above to 15cm, tight dark brown MC B21 under	6.9	116
20-30	Tight dark brown MC B21, no CO^3	7.0	123
30-40	As above	7.1	134
50-60	Brown MC B3 (some CO^3)	8.2	174
80-90	Brownish yellow decomposed siltstone, some CO^3 present	8.4	160
110-120	As above	8.6	156
40	0 195 819E 7 299 835N (non cracking, hardset surface, high silcrete and quartz in surface and down the profile)		
0-10	Dark reddish brown clay loam to light clay A	6.8	120
10-20	As above	6.9	78
20-30	As above to 25cm, abrupt interface to dark red MC B21	7.0	72
30-40	As above	6.9	90
50-60	As above, grading to siltstone PM	7.7	111
50	0 196 936E 7 298 468N (non cracking clay, firm surface, some quartz in the surface and down the profile)		
0-10	Dark reddish brown LC A	6.9	94
10-20	As above	7.1	87
20-30	As above to 25cm, dusky red to dark red MC B21 under	7.4	81
30-40	Dusky red to dark red MC B21	7.6	81
50-60	As above	7.5	137
80-90	Dark red MC B22, slight hard CO^3 present	8.6	278
100-110	Yellowish brown sediments, some CO^3/limestone present	8.6	430

Reddish brown non cracking to weakly self mulching cracking clays on Permian sediments (brigalow scrub)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
1	0 200 848E 7 287 280N (cracking clay, weakly self mulching)		
0-10	Weak fine A1 to 2cm underlain by dark brown hard angular MHC B21	7.8	95
10-20	Dark brown hard angular MHC B21	8.3	122
20-30	As above	8.7	191
30-40	Brown HC B22, very slight hard CO^3	8.9	402
50-60	As above	8.6	881
80-90	Mottled brown/reddish brown MHC B23/B3, slight siltstone inclusions	8.4	975
110-120	Dark yellowish brown non calcareous parent siltstone	8.2	800
2	0 201 154E 7 287 568N (cracking clay, non self mulching, moderate surface flake, very occasional gilgai) (shallow variant)		
0-10	Fine dark brown MC A	6.9	132
10-20	As above	7.4	112
20-30	As above, grading to dark brown MHC B21	7.8	171
30-40	Dark brown MHC B21	8.1	500
50-60	Dark brown MHC B22, slight CO^3	8.5	1593
80-90	Decomposed reddish brown/yellowish red mudstone parent material	7.9	1677
110-120	As above	5.2	1530
5	0 202 004E 7 287 285N (cracking clay, non self mulching, soft surface flake, friable granular under) (shallow variant)		
0-10	Very hard blocky dark brown LMC A	6.8	112
10-20	As above	7.2	207
20-30	Dark brown MC B21	7.4	172
30-40	As above	7.8	250
50-60	Slightly mottled dark brown/brown MC B22, slight soft and hard CO^3	8.2	459
80-90	Brownish yellow augerable sandstone	8.6	467
100-105	As above to 105cm, too hard to dig under	8.9	371
14	0 200 626E 7 288 484N (cracking clay, weakly self mulching)		
0-10	Weak fine A1 to 2cm underlain by dark brown MC B21	7.3	111
10-20	Dark brown hard angular MHC B21 with slight hard CO^3	8.1	170
20-30	Dark brown MHC B22, slight CO^3	8.3	420
30-40	As above, no CO^3	8.2	651
50-60	As above	7.6	1244
80-90	Strong brown HC B23, no CO^3	5.2	1438
110-120	As above, augerable mudstones below	4.4	1381
140-150	Strong brown/reddish yellow soft mudstone PM	4.3	1297
15	0 200 983E 7 288 583N (cracking clay, non self mulching, soft friable surface flake, minor surface silcrete)		
0-10	Hard dark brown MC A	7.5	156
10-20	As above	7.9	163
20-30	Very dark greyish brown MHC B21, slight hard and soft CO^3	8.7	254
30-40	As above	8.9	433
50-60	As above, changing to dark brown B22 with no CO^3 below	8.4	879
80-90	Mottled brown/strong brown MHC B3, no CO^3	8.1	1298
110-120	Yellowish red parent mudstones	7.7	1380
140-150	As above	5.7	1296
47	0 196 515E 7 299 379N (cracking clay, weak medium self mulch, slight surface silcrete)		
0-10	Medium A1 to 2cm, very dark grey MC B21 under	8.0	122
10-20	Very dark grey MC B21	8.2	113
20-30	As above to 25cm,very dark grey MHC B22 below, slight hard CO^3	8.5	134
30-40	As above	8.7	185
50-60	As above	8.8	299
80-90	Mottled very dark greyish brown/brown MHC B23	8.6	422
110-120	Strong brown parent sandstone under 105cm	8.9	429

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
48	0 195 901E 7 299 923N (cracking clay, moderate fine self mulch, slight surface quartz and silcrete)		
0-10	Medium A1 to 3cm, very dark greyish brown MHC B21 under	8.0	151
10-20	Very dark greyish brown MHC B21	8.7	186
20-30	Very dark greyish brown MHC B22, some hard and soft CO^3	8.9	282
30-40	As above, CO^3 declining	9.0	369
50-60	As above	9.0	709
80-90	Brown MHC B23	8.5	1763
110-120	Brown/dark yellowish brown MHC B3, some sandstone inclusions	8.7	1468
140-150	Dark yellowish brown sandstone material below 140cm	8.6	1549
71	0 201 160E 7 286 971N (cracking clay, weak fine self mulch, slight surface silcrete)		
0-10	Fine A1 to 2cm, dark brown MC B21 under	7.9	205
10-20	Dark brown MC B21	8.4	202
20-30	Dark brown MHC B22, no CO^3 down profile	8.8	272
30-40	As above	8.8	486
50-60	As above	8.4	1092
80-90	Mottled reddish brown/strong brown MHC B23	6.4	1618
110-120	As above	4.9	1544
140-150	Yellowish red/brown MHC B3, some siltstone inclusions	4.6	1637
74	0 199 870E 7 286 776N (non cracking clay, hardset, some surface silcrete and occasional sandstone floaters) (shallow variant)		
0-10	Dark brown LMC A	6.4	97
10-20	As above to 15cm, dark yellowish brown MC B21 under	6.6	87
20-30	Dark yellowish brown MC B21	7.0	93
30-40	As above	7.5	109
50-60	Hard sandstone below 50cm	8.1	181
75	0 200 481E 7 287 343N (cracking clay, non self mulching, weak flake, some surface silcrete, shelf profile, gilgai to 40cm) (gilgaid variant)		
0-10	Coarse blocky brown HC A (slight siltstone inclusions)	7.0	196
10-20	As above	6.7	378
20-30	As above, grading to strong brown HC B21, some siltstone inclusions	6.0	492
30-40	As above, no CO^3 down profile	5.6	622
50-60	Strong brown HC B22, some siltstone inclusions	5.4	712
80-90	As above	5.4	869
110-120	As above	5.4	877
140-150	Mottled strong brown/dark yellowish brown B3, containing significant siltstone	5.4	1011
76	0 200 493E 7 286 943N (cracking clay, non self mulching, firm to hardset crust)		
0-10	Brown hard MC A	7.7	484
10-20	As above	8.6	506
20-30	As above to 25cm, brown MHC B21 under	8.5	568
30-40	Brown MHC B21, no CO^3 down profile	8.4	623
50-60	As above	7.2	765
80-90	Brown/dark yellowish brown B3, 30 to 50% mudstone/siltstone inclusions	5.5	860
110-120	As above	5.1	998
140-150	As above	4.9	1106
79	0 199 812E 7 284 258N (cracking clay, non self mulching or occasionally weakly self mulching)		
0-10	Dark brown hard MC A	7.4	183
10-20	As above	7.8	207
20-30	Dark brown MHC B21, moderate soft CO^3 present, declining with depth	8.7	282
30-40	As above	8.8	575
50-60	Slightly mottled brown/strong brown MHC B22, no CO^3	8.6	996
80-90	Strong brown MHC B3, some mudstone inclusions	7.7	1149
110-120	Strong brown/yellowish brown parent mudstone, no CO^3	6.1	968

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
80	0 199 438E 7 285 155N (cracking clay, weak fine self mulch)		
0-10	Dark brown hard MHC A	7.9	441
10-20	As above	8.3	155
20-30	Brown HC B21, slight CO^3 present, declining with depth	8.6	254
30-40	As above	8.7	361
50-60	As above	8.5	816
80-90	Brown/strong brown HC B23, no CO^3	7.4	1219
110-120	Strong brown MHC B3, mudstone inclusions, no CO^3	5.2	1224
81	0 198 865E 7 285 287N (non cracking clay, firm moderate surface flake, slight surface silcrete and sandstone, occasional gilgai around) (shallow variant)		
0-10	Dark brown granular LMC A	8.7	138
10-20	As above	9.1	188
20-30	Dark brown MC B21, soft CO^3 present	6.2	227
30-40	As above	9.3	291
50-60	Brown MC B3, sandstone inclusions	9.5	394
80-90	Brown parent sandstone below 70cm	9.7	425
83	0 198 745E 7 286 543N (cracking clay, non self mulching, strong friable flake, some surface silcrete, shelf profile, gilgai to 60cm) (gilgaid variant)		
0-10	Coarse blocky dark brown MC A	8.1	222
10-20	As above	8.6	381
20-30	As above to 25cm, grading to dark yellowish brown HC B21, some siltstone inclusions	8.7	511
30-40	Dark yellowish brown HC B21, some siltstone inclusions, no CO^3 down profile	8.7	781
50-60	As above, B3 below	7.8	1026
80-90	Strong brown HC B3, with brownish yellow siltstone/mudstone inclusions increasing	5.3	1050
110-120	As above	5.0	1076
87	0 198 509E 7 284 093N (cracking clay, non self mulching, firm surface flake)		
0-10	Dark greyish brown hard blocky MHC A	8.4	159
10-20	As above	8.4	174
20-30	As above	8.6	215
30-40	Very dark greyish brown HC B21, very occasional CO^3	8.8	265
50-60	As above	8.5	321
80-90	Dark yellowish brown HC B22	8.4	655
110-120	As above, parent siltstone below 115cm	8.6	785

Strong finely self mulching cracking clays on sandstone or decomposed calcareous material (open brigalow/bauhinia)

3	0 201 718E 7 287 165N (cracking clay, moderate fine self mulch)		
0-10	Black MC A to 3cm, underlain by black MHC B21	7.7	114
10-20	Black MHC B21	7.8	105
20-30	As above, grading to black HC B22 with high hard CO^3 present	8.5	128
30-40	Black HC B22 with high hard CO^3 present	8.6	138
50-60	As above	8.6	172
80-90	Dark grey/very pale brown loose calcareous material	8.9	151
6	0 201 737E 7 287 574N (cracking clay, moderate fine self mulch, some sandstone and dolomite floaters)		
0-10	Black MHC A to 3cm, underlain by black HC B21 slight hard CO^3 on the surface and down the profile	8.4	124
10-20	Black HC B21, slight hard CO^3	8.5	124
20-30	As above	8.6	119
30-40	As above	8.6	124
50-60	Dark grey/brown HC B22 some hard CO^3, unstructured calcareous material containing stone below	8.7	138

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
10	0 202 093E 7 288 252N (weakly self mulching cracking clay, occasionally non cracking, significant surface silcrete)		
0-10	Fine dark reddish brown MHC B21, underlain by dark reddish brown MHC B21	7.0	102
10-20	Dark reddish brown MHC B21	7.5	101
20-30	As above to 25cm grading to slightly mottled reddish brown MHC B22	7.6	114
30-40	Slightly mottled reddish brown MHC B22	7.9	113
50-60	Slightly mottled reddish brown MHC B23, significant hard and soft CO^3	8.5	206
80-90	Brown soft parent sandstone (calcareous in surface) below 70cm, too hard to dig below 100cm	8.9	206
11	0 201 375E 7 288 273N (cracking clay, strong fine self mulch)		
0-10	Very dark grey MHC A to 4cm, underlain by very dark grey MHC B21	7.3	92
10-20	Very dark grey MHC B21	7.4	85
20-30	As above	7.8	114
30-40	As above, mottled B3 under	8.0	119
50-60	Light brown loose calcareous parent material (still part of the root zone)	8.6	148
80-90	As above, hard material not augerable below 90cm	8.9	134
13	0 201 696E 7 288 024N (cracking clay, medium fine self mulch, some surface silcrete and dolomite)		
0-10	Very dark grey MHC A to 3cm, underlain by very dark grey MHC B21	8.0	131
10-20	Very dark grey MHC B21	7.5	98
20-30	Black MHC B22, slight hard CO^3	7.7	102
30-40	As above	8.2	139
50-60	As above, changing to B3 under	8.5	178
70-75	Very dark greyish brown MHC B3 with large hard CO^3 present, preventing augering below 75cm	8.7	171
20	0 201 898E 7 288 545N (cracking clay, strong very fine self mulch, some sandstone floaters)		
0-10	Very dark grey MC A to 4cm, underlain by very dark grey MHC B21	7.2	111
10-20	Very dark grey MC B21	7.4	96
20-30	Black MC B22, some hard and soft CO^3 present	8.6	184
30-40	As above	8.9	233
50-60	As above	9.0	309
70-80	As above, while parent sandstone encountered at 75cm and prevents digging below 80cm	9.1	407
62	0 202 055E 7 285 873N (cracking clay, weak fine self mulch)		
0-10	Black MC A to 2cm, underlain by very hard blocky black MHC B21	8.3	135
10-20	Very hard blocky black MHC B21	8.4	121
20-30	As above	8.7	188
30-40	As above, B22 under	8.9	294
50-60	Very dark greyish brown MHC B22 to 55cm, light yellowish brown non calcareous sandstone below	8.9	654
80-90	Light yellowish brown non calcareous sandstone	-	-
63	0 201 983E 7 286 412N (cracking clay, moderate medium self mulch, some small surface carbonate and silcrete)		
0-10	Very dark grey MHC A to 3cm, underlain very dark grey MHC B21	7.9	125
10-20	Very dark grey MHC B21	8.2	133
20-30	As above to 25cm, very dark grey HC B22 under	8.5	154
30-40	Very dark grey HC B22, moderate hard CO^3 present	8.9	206
50-60	As above	8.6	541
80-90	Slightly mottled very dark grey/dark greyish brown HC B22, some soft CO^3 present	8.6	904
110-120	As above	8.4	1122
140-150	Light grey HC B3, grading to parent clays	8.3	1086

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
64	0 202 342E 7 286 392N (cracking clay, moderate, very fine self mulch)		
0-10	Very fine MC A to 3cm, underlain by dark brown MC B21	8.0	200
10-20	Dark brown MC B21	8.1	210
20-30	As above	8.0	205
30-40	As above, B22 under	8.1	168
50-60	Strong brown calcareous material (decomposed sediments or colluvium?)	8.4	143
68	0 202 399E 7 285 973N (cracking clay, weak fine self mulch, some sandstone floaters)		
0-10	Dark brown LC A, underlain by dark brown LC B21	6.9	86
10-20	Dark brown LC B21, over brown to strong brown LMC B22	6.8	78
20-30	Brown to strong brown LMC B22	7.1	87
30-40	As above, hard sandstone below 40cm	8.4	135
70	0 201 760E 7 285 820N (cracking clay, moderate fine self mulch, some small surface silcrete, some sandstone floaters present)		
0-10	Very dark grey MC A to 3cm, underlain very dark grey MC B21	7.0	132
10-20	Very dark grey MC B21	8.1	170
20-30	As above	8.7	269
30-40	Dark grey MHC B22, moderate hard and slight soft CO^3 present	8.9	575
50-60	As above	8.4	1194
80-90	Slightly mottled dark grey/ brown MHC B3	8.1	2318
100-110	Brown/strong brown decomposed mudstone (non calcareous)	8.5	1029

Shallow to deep non cracking and weakly cracking clays on sandstones (open brigalow)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
46	0 198 109E 7 296 013N (non cracking clay, firm surface, some surface quartz and silcrete)		
0-10	Hard dark brown LC A	7.9	141
10-20	As above	8.6	150
20-30	Dark brown MC B21, slight hard and soft CO^3 present	9.0	179
30-40	As above	9.2	213
50-60	Brown MC B22, CO^3 declining	9.1	712
80-90	Brown MC B3	8.9	942
110-120	Brown colluvial clay material	8.6	946
52	0 196 521E 7 297 880N (firm to hardset non cracking surface with some structural problems and prone to sheet erosion (some surface sand))		
0-10	Dark brown LC A	6.9	107
10-20	As above to 15cm, brown LMC B21 under	7.4	138
20-30	Brown LMC B21	8.9	239
30-40	As above	9.1	271
50-60	Decomposed sandstone (calcareous) below 45cm, stone stopped augering	9.4	298
54	0 196 861E 7 297 499N (firm weak surface flake, non cracking surface (sandy) with some structural problems and prone to sheet erosion)		
0-10	Very dark greyish brown LC A	6.9	89
10-20	As above	7.6	102
20-30	Very dark greyish brown MC B21	7.9	142
30-40	As above, B22 with some CO^3 under	8.8	273
50-60	Dark brown B3 with CO^3 present underlain by brownish yellow decomposed calcareous sandstone	9.1	328
80-90	Brownish yellow decomposed calcareous sandstone	9.2	352

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
55	0 196 390E 7 296 931N (hardset surface, non cracking surface (sandy) with some structural problems and prone to sheet erosion)		
0-10	Brown LC A	6.6	93
10-20	As above	7.0	83
20-30	Brown LMC B21, stone stopped digging below 30cm	8.2	151
57	0 197 454E 7 297 063N (firm to hardset non cracking surface) (deep soil, intergrade to Greycliff soil)		
0-10	Very dark greyish brown LMC A	6.9	113
10-20	As above	7.2	137
20-30	As above to 25cm, very dark grey MC B21 with hard and soft CO^3 below	8.7	402
30-40	Very dark grey MC B21 with hard and soft CO^3	8.9	745
50-60	Very dark greyish brown MC B21, no CO^3	6.9	1069
80-90	Brown sandy LMC B3, sandstone siltstone inclusions	4.9	1193
110-120	As above	4.6	1209
140-150	As above	4.5	1325

Self mulching cracking clays with linear gilgai (open bauhinia, brigalow clumps)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
4	0 202 346E 7 287 098N (cracking clay, weakly self mulching, depression profile		
0-10	Weak fine A1 to 2cm underlain by very dark greyish brown HC B21	8.0	91
10-20	Very dark greyish brown HC B21	7.6	89
20-30	As above	8.0	103
30-40	As above	8.1	112
50-60	Very dark grey lenticular HC B22, slight hard CO^3	8.1	234
80-90	Dark yellowish brown yellowish brown HC B3, grading to parent mudstone	8.7	349
110-120	Yellowish brown parent mudstone	8.0	301
36	0 198 840E 7 296 399N (cracking clay, fine moderately self mulching, weak linear gilgai)		
0-10	Moderate fine A1 to 2-3cm underlain by black MHC B21	7.9	150
10-20	Black MHC B21	8.1	142
20-30	As above	8.4	148
30-40	Very dark greyish brown to dark greyish brown HC B22, moderate hard and soft CO^3 present	8.8	165
50-60	As above	9.1	338
80-90	As above, B3 under	8.9	730
110-120	Dark greyish brown to light olive brown HC B3, decomposed mudstone with hard CO^3 below	8.9	756
37	0 199 220E 7 296 152N (cracking clay, fine moderately self mulching, weak linear gilgai, some small surface silcrete and quartz)		
0-10	Moderate fine A1 underlain by very dark greyish brown MC B21	8.0	207
10-20	Very dark greyish brown MC B21	7.7	170
20-30	As above	8.2	196
30-40	As above, B22 under	8.7	355
50-60	Very dark grey MHC B22, moderate hard and soft CO^3 present	8.9	758
80-90	As above	8.2	1923
110-120	Yellowish brown MHC B3, decomposed mudstone inclusions, no CO^3	6.2	1388
140-150	As above	4.9	1268

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
44	0 194 939E 7 299 178N (cracking clay, fine weak self mulch, weak linear gilgai, some small surface quartz)		
0-10	Weak fine A1 underlain by very dark greyish brown MC B21	7.4	152
10-20	Very dark greyish brown MC B21	7.8	117
20-30	Very dark greyish brown MHC B22 some hard CO^3 present	8.6	178
30-40	As above	9.0	233
50-60	As above	8.7	730
80-90	Brown MHC B23, hard CO^3 present	8.3	1458
110-120	As above	8.2	1557
140-150	Unconsolidated parent colluvium, some siltstone and basalt	7.2	1197
45	0 195 373E 7 298 608N (non cracking clay, some surface structural problems) (lower area variant)		
0-10	Hardset dark brown LMC A	7.1	102
10-20	As above	7.6	116
20-30	Very dark greyish brown MC B21	8.7	274
30-40	As above	9.1	678
50-60	Brown to strong brown MC B22, some hard CO^3 present	8.9	1365
80-90	As above, B3 below	8.8	1428
110-120	Reddish yellow parent sandy clay	8.9	1099
140-150	As above	8.2	852
51	0 196 839E 7 298 318N (weakly cracking clay, weak very fine self mulch, weakly developed linear gilgai, slight surface stone)		
0-10	Very fine MHC A1 to 2cm, with very dark greyish brown HC B21 under	7.4	108
10-20	Very dark greyish brown HC B21	7.5	94
20-30	As above	7.8	87
30-40	As above, B22 under	8.2	95
50-60	Brown HC B22	8.2	149
80-90	Dark yellowish brown decomposed siltstone	8.8	194
110-120	As above	9.1	186
56	0 197 277E 7 297 300N (cracking clay, fine moderate self mulch, linear gilgai remanats, some small surface quartz and silcrete)		
0-10	Moderate fine A1 underlain by very dark grey MC B21	7.4	103
10-20	Very dark grey MC B21	7.6	93
20-30	Very dark grey MHC B22 slight hard CO^3 present, increasing with depth	7.9	118
30-40	As above	8.5	254
50-60	As above, some soft CO^3 also present	8.5	545
80-90	As above, colour lightening under	8.4	831
110-120	Dark greyish brown/brown MHC B23	7.2	959
140-150	Very pale brown parent sandstone below 130cm	5.8	556
65	0 202 154E 7 286 837N (cracking clay, fine moderate self mulch, some small surface silcrete)		
0-10	Moderate fine A1 underlain by very dark grey MHC B21	7.5	157
10-20	Very dark grey MHC B21	7.6	143
20-30	Very dark grey HC B22	7.8	149
30-40	As above	7.6	274
50-60	Black HC B23, slight hard CO^3 present	7.7	256
80-90	As above	7.6	455
110-120	Mottled yellowish brown/dark grey HC B3, no CO^3	7.2	2002
140-150	Yellowish brown decomposed mudstone, no CO^3	7.1	1722
66	0 202 706E 7 286 449N (cracking clay, fine moderate self mulch, some surface silcrete)		
0-10	Moderate fine A1 underlain by very dark greyish brown MHC B21	7.8	269
10-20	Very dark greyish brown MHC B21	7.9	181
20-30	Very dark grey HC B22	7.9	146
30-40	As above	8.0	161
50-60	As above	8.1	252
80-90	As above, B3 below	8.1	394
110-120	Dark yellowish brown siltstone below 115cm, some CO^3	7.9	722

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
67	0 202 562E 7 286 096N (cracking clay, strong, medium self mulch, moderate surface silcrete)		
0-10	Strong medium A1 to 4cm underlain by very dark grey HC B21	7.4	95
10-20	Very dark grey HC B21	7.6	98
20-30	Black HC B22	7.7	109
30-40	As above	8.3	142
50-60	Black lenticular HC B22, slight hard CO^3 present	8.5	247
80-90	As above, B3 below	8.7	474
100-110	Dark yellowish brown siltstone below 110cm	8.8	456
69	0 202 283E 7 285 886N (cracking clay, medium self mulch, shallower version, intergrade to shallower soils nearby)		
0-10	Medium A1 to 3cm underlain by very dark grey MHC B21	8.2	139
10-20	Very dark grey MHC B21	8.8	142
20-30	As above	8.5	172
30-40	As above, B22 under	8.8	263
50-60	Very dark grey lenticular MHC B22	8.7	628
80-90	B3, parent siltstone inclusions	8.5	1006
110-120	Brown to strong brown parent siltstone	8.3	1611
72	0 201 343E 7 286 393N (cracking clay, strong fine self mulch)		
0-10	Fine A1 to 4cm underlain by very dark greyish brown MC B21	7.7	105
10-20	Very dark greyish brown MC B21	7.7	101
20-30	Black HC B22, slight hard CO^3 present	7.7	106
30-40	As above	8.0	122
50-60	As above	8.6	274
80-90	Mottled dark greyish brown/dark yellowish brown HC B23	8.6	766
110-120	Light brownish grey/yellowish brown decomposed mudstone	8.7	749
140-150	As above	8.5	703
73	0 201 314E 7 285 605N (cracking clay, weak fine self mulch)		
0-10	Fine A1 to 2-3cm underlain by very dark greyish brown HC B21	8.5	177
10-20	Very dark greyish brown HC B21, slight hard CO^3 present	8.4	153
20-30	Very dark greyish brown HC B22, slight hard CO^3 present	8.8	201
30-40	As above	8.8	255
50-60	As above	8.6	433
80-90	Strong brown HC B3	8.3	845
110-120	Strong brown decomposed parent mudstones	6.1	919
140-150	As above	4.8	880
77	0 200 230E 7 286 062N (cracking clay, moderate fine self mulch, slight surface carbonate)		
0-10	Fine A1 to 3cm underlain by very dark greyish brown HC B21 slight hard CO^3 present	7.5	116
10-20	Very dark greyish brown HC B21, slight hard CO^3 present	7.7	114
20-30	As above	7.9	124
30-40	As above	8.0	140
50-60	Dark greyish brown HC B22	8.2	299
80-90	As above	8.3	625
110-120	Mottled dark grey/strong brown HC B3, decomposed mudstone below	8.2	889
140-150	Dark yellowish brown/yellowish brown decomposed mudstone	7.8	939
78	0 200 147E 7 284 953N (cracking clay, moderate fine self mulch, some surface silcrete)		
0-10	Fine A1 to 3cm underlain by very dark grey HC B21 slight hard CO^3 present	737	155
10-20	Very dark grey HC B21, slight hard CO^3 present	8.0	143
20-30	As above	8.6	337
30-40	As above	8.6	392
50-60	Dark greyish brown HC B22	8.5	627
80-90	As above to 85cm, mottled brown/strong brown B3 below	8.2	963
110-120	Mottled brown/strong brown HC B3	5.8	1150
140-150	String brown/pinkish grey decomposed mudstone	4.9	1099

Soils in lower slope positions on alluvium and colluvium

Dark grey/brown medium to heavy cracking clays on deep alluvium (brigalow/coolibah)

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
8	0 202 257E 7 287 433N (cracking clay, weakly self mulching, some small surface silcrete and carbonate)		
0-10	Weak fine A1 to 2cm underlain by very dark greyish brown HC B21	7.1	102
10-20	Very dark greyish brown HC B21	7.4	131
20-30	As above	8.0	175
30-40	As above	8.7	227
50-60	Very dark grey is brown HC B22, slight hard CO^3	8.6	647
80-90	As above	8.3	872
110-120	As above, silcrete prevented augering below 120cm	8.1	766
12	0 201 038E 7 288 190N (cracking clay, strong medium self mulch, some surface silcrete and rounded gravels)		
0-10	Strong medium HC A1 to 4cm underlain by very dark greyish brown HC B21, slight hard CO^3 from the surface down	8.3	122
10-20	Very dark greyish brown HC B21, slight hard CO^3	8.2	116
20-30	As above	8.1	109
30-40	Very dark grey HC B22, slight hard CO^3	8.1	102
50-60	As above	8.4	152
80-90	Mottled very dark grey/brown HC B23, slight hard CO^3	8.4	362
110-120	Brown alluvial clays, slight hard CO^3	8.4	947
140-150	As above	8.5	1138
21	0 201 494E 7 288 542N (cracking clay, medium self mulch)		
0-10	Medium HC A1 to 2-3cm underlain by very dark greyish brown HC B21, slight small silcrete from the surface down	7.8	167
10-20	Very dark greyish brown HC B21	7.5	128
20-30	As above	7.8	136
30-40	As above	8.4	183
50-60	Very dark grey HC B22, some hard and soft CO^3	8.6	677
80-90	Very dark grey HC B23, lesser CO^3	8.2	1198
110-120	As above, grading to B3 below	8.3	1426
140-150	Light brownish grey calcareous alluvial clays	8.4	1380
41	0 195 425E 7 300 132N (cracking clay, normal gilgai to 20cm, weak coarse self mulch, some areas non self mulching and have friable surface flake)		
0-10	Coarse HC A1 to 2cm underlain by very dark greyish brown HC B21, slight hard CO^3 from the surface down	8.0	104
10-20	Very dark grey hard blocky HC B21, slight hard CO^3	8.3	125
20-30	As above	9.3	271
30-40	As above	9.3	579
50-60	As above	8.8	1189
80-90	Very dark greyish brown lenticular HC B22, increasing hard and soft CO^3	8.6	1326
110-120	Mottled brown alluvial clays, high hard CO^3, slight soft	8.0	2250
140-150	As above	7.9	1944
42	0 194 898E 7 300 080N (cracking clay, well developed friable surface flake, some areas slightly scalding)		
0-10	Very dark greyish brown hard blocky silty MC A	7.8	119
10-20	As above	8.0	102
20-30	As above	8.6	114
30-40	Very dark grey MHC B21, slight CO^3	9.1	233
50-60	As above	9.1	582
80-90	As above, lighter dark brown B22 below	8.7	1095
110-120	Dark brown MHC B22, hard and soft CO^3 present	8.5	1648
140-150	As above, PM not encountered	8.7	1368

Sample and depth (cm)	Profile location and sample description	pH	E.C. 1:5 (uS/cm)
82	0 199 062E 7 285 936N (cracking clay, weak fine self mulch)		
0-10	Dark brown fine A1 to 2cm, dark brown silty MC B21 under	7.6	103
10-20	Dark brown silty MC B21	7.6	100
20-30	As above	7.9	99
30-40	As above	8.1	111
50-60	Dark brown MHC B22	7.7	224
80-90	As above	7.4	497
86	0 198 133E 7 284 602N (cracking clay, firm surface flake to weak self mulch)		
0-10	Weak fine A1 with very dark greyish brown silty MC B21 below	7.2	110
10-20	Very dark greyish brown silty MC B21	7.3	92
20-30	As above	7.5	89
30-40	As above	8.0	104
50-60	Very dark grey MHC B22, no CO^3	8.3	188
80-90	As above	8.6	501
110-120	Brown MC B3/2D, CO^3 present	8.7	795
88	0 198 798E 7 283 844N (non cracking clay, weakly developed firm surface flake, some algal mat)		
0-10	Very dark grey silty clay A	7.4	105
10-20	As above	7.5	106
20-30	Very dark grey MC B21	7.8	160
30-40	As above	8.1	368
50-60	Dark brown MHC B22, some hard and soft CO^3	8.2	842
80-90	As above	8.6	1004
110-120	Less consolidated brown MHC B3, slight hard CO^3 present	8.6	836
91	0 197 784E 7 283 442N (non cracking clay, weakly developed hard surface flake)		
0-10	Black MC A	6.7	117
10-20	As above	7.3	140
20-30	Very dark grey HC B21	8.6	379
30-40	As above	8.8	584
50-60	Very dark greyish brown HC B22, some hard CO^3 present	8.4	1158
80-90	Brown HC B23	8.5	1331
110-120	As above	8.1	1255
140-150	Less consolidated yellowish brown MHC parent clays, slight CO^3 present	7.7	1085

Appendix 2. Explanatory notes for interpretation of soil analysis results, and analysis sheets from the Analytical Laboratories

Explanatory notes - soil and spoil analysis

pH is measured on a 1:5 solid:water extract and indicates acidity or alkalinity, which influences nutrient availability or toxicity. Very high pH's above 8.5 often indicate a very high sodicity and associated physical problems. The accepted range for plant growth is considered to be 5.5 to 8.5.

E.C. is electrical conductivity of the soil or spoil solution measured on a 1:5 solid:water extract. It indicates the salinity of the growth medium. Different plants can tolerate different levels of salinity, however, levels over 600uS/cm are considered to be quite saline. The appraisal generally depends on the selection of the most hospitable media available.

In this report all results are quoted on a 1:5 basis, however, for conversion to a saturated extract value, multiplication by 6.4 is the accepted value for soils, while for spoils the factor can be as high as 8 to 9 due to the lower incidence of large pores. Alternatively the factor can be lower if CaSO4 is present.

Cl is the concentration of chloride in the 1:5 solid:water extract and high levels of chloride are generally associated with high levels of salinity. The Cl level is a more reliable indicator of salinity than E.C. alone. Depending on the species of plant being grown, levels above 200 to 600ug/g are generally undesirable.

Extr. P indicates the level of phosphate available for plant growth. The extraction is carried out with a weak bicarbonate solution. Levels of less than 11ug/g are considered very low and usually limiting to crops while levels of 30ug/g are considered non limiting for plant growth, however, very few Australian soils ever contain these levels.

Tot. P is the total phosphorus content of the soil which averages 550ppm for surface soils and 380ppm for subsoils for Australian soils.

NO3 indicates the level of nitrogen available for plant growth in the soil solution. The analysis is carried out on a !:5 solid:water extract and ignores other forms which may be present. Levels of 20 to 30ug/g are considered non limiting for plant growth in soils, however few Australian soils ever contain these levels.

Tot. N is the total nitrogen content of the soil and Queensland soils usually lie within the range 0.05 to 0.2%. Values less than 0.1% may indicate potential problems of availability for plant growth.

SO4 indicates the level of sulphate available for plant growth in the soil solution. The extraction is carried out with a CaHPO4 solution. A level of 15 is considered non limiting for plant growth. In certain situations, for example where gypsum is present in soils or where pyrite oxidation has occurred in spoil material, levels may be present which are far in excess of plant requirements.

Exchangeable cations, Ca, Mg, Na and K are measured in milliequivalents per 100g of soil by alcoholic extraction and as well as indicating nutrient status of these elements indicates physical soil properties, by use of relationships which take into account the relative abundance of Na, Mg and Ca on the exchange complex.

Non limiting levels for plant growth are considered to be:

K - 0.2-0.3meq/100g
Ca - 2.0meq/100g
Mg - 1.0-2.0meq/100g

Zn, Cu, Mn, and Fe are extracted with a D.T.P.A. solution and the levels indicate availability of these nutrients for plant growth.

Non limiting levels for plant growth are considered to be:

Fe - 2.5-4.5ug/g
Mn - 2ug/g above pH 6
Cu - 0.1ug/g on acid soils, and 0.4ug/g on alkaline soils
Zn - 0.2-0.5ug/g on acid soils, and 0.8ug/g on alkaline soils

Although soil tests may indicate micronutrient deficiency, these deficiencies rarely become evident in the field (except under irrigated conditions) due to the greater limitations of major nutrients. Toxicities of these elements, especially Mn may be a problem under acidic conditions.

CEC is the cation exchange capacity of the soil and indicates its ability to hold nutrients. Leaching of cations used in plant growth can become a problem in a soil with a very low cation exchange capacity (eg. 5). The analysis is also used in the calculation of soil exchangeable sodium percentage.

E.S.P. is the exchangeable sodium percentage of the soil and is the percentage of the cation exchange capacity which is taken up by sodium. The measurement is an indication of how prone the soil is to dispersion by rainfall and resultant structural problems.

An E.S.P. of less than 6 has generally been acceptable for conventional soils, however, some workers consider that a level of 3 is a better value to indicate a sodic soil for surface soils in Queensland. Soils with E.S.P. levels of 6 to 14 are strongly sodic.

Ca/Mg is used to express the relative proportions of calcium and magnesium on the exchange complex. The two elements are competetive in their nutritional characteristics so that an excess of one may cause a shortage of another (even though it may be adequate in absolute terms). An imbalance of Mg, however, may promote dispersion in soils with a low exchangeable sodium percentage. Soils with Ca/Mg ratios of <2 should be regarded with some suspicion.

CEC/clay% indicates in general terms the type of clay which is present in the soil or spoil. For kaolinite, CEC/clay is <0.2, for non expanding clays or illites, CEC/clay is 0.3-0.5 and for montmorillonite or expanding clays, the ratio is >0.8. The soils generally contain a variety of clay types however so the results are only indicative.

R1 dispersion ratio is obtained by comparing the proportion of the clay and silt fraction which is dispersed in water with shaking, with the amount of clay and silt in the soil which is obtained with conventional particle size analysis (using calgon and shaking).

In soils, levels below 0.6 generally indicate generally low levels of dispersion, while levels between 0.6 and 0.8 indicate moderate dispersion and presence of some problems, and levels above 0.8 indicate high dispersion and soil instability.

For spoil material these level are considered by the author to be too high. The levels are by no means defined, however, the spoil material is composed of actual sedimentary rock fragments which should be less subject to dispersion than soils. A level less than 0.4 is considered to be more appropriate for relative stability in a spoil material.

Particle size analysis is the proportions of the individual fractions which make up the soil or spoil. It is expressed as the percentage of coarse sand, fine sand, silt and clay in the soil or spoil. This gives the soil texture and an indication of the ability of the soil or spoil to hold water for plant growth.

An additional use of particle size analysis is to provide an indication of whether the soil or spoil may have poor infiltration and hydraulic conductivity, the rules are however by no means defined.

The soil fraction which promotes aggregation is the clay fraction. For pure sands pores are large, while for a pure non aggregated clay pores will be very small. For mixtures of sand, silt and clay the finer particles will pack into pores created by the larger particles, reducing porosities until the pores are full. Minimum porosity of non aggregated soils occurs when the clay content is 30 to 40%. If there is a high percentage of fine sand and silt in the soil the soils can be unstable to rapid wetting if organic matter levels are low. The silt sized particles are more disruptive to aggregation and maintenance of hydraulic conductivity.

SOLUTIONS 2 Aust. Pty. Ltd.

Soil Analysis Report

Corrections for solutions 2 19/11/2004.

110 19/11/2004

Reference Number: 04-03684-01
Sample Status: dried and ground

Date Received: 31/7/2004
Date Completed: 9/11/2004
Printed: 9/11/2004

Lab No	Number	Profile	Depth	pH	EC	Cl	NO3-N	Pbic	OC	SO4-S	Ca	Mg	Na	K	CEC	ECEC	ESP	Al	H+
					mS/cm	mg/kg	mg/kg	mg/kg	%	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	meq/100g
04/03684	1	1	0-10	8.3	0.06	15.9	0.9	5.2	1.17	4.5	19.0	10.1	0.86	0.85	32		3		
04/03685	2		20-30	8.7	0.17	~~394~~	<0.7			4.3	19.8	11.9	2.54	0.62	32		8		
04/03686	3		50-60	8.6	0.79	1076	<0.7			7.8	15.3	12.8	6.05	0.29	32		19		
04/03687	4		80-90	8.5	0.84	1118	5.5			10.7	13.2	13.0	6.97	0.61	32		22		
04/03688	5	12	0-10	8.2	0.07	~~281~~	1	7.8	0.98	3.6	26.1	8.5	1.01	0.70	38		3		
04/03689	6		20-30	8.4	0.07	10.8	<0.7			2.1	27.3	9.4	1.97	0.65	41		5		
04/03690	7		50-60	8.6	0.10	34.1	1.4			5.3	27.2	10.5	3.82	0.50	42		9		
04/03691	8		80-90	8.7	0.36	360	<0.7			11.5	24.3	12.4	6.59	0.50	44		15		
04/03692	9		110-120	8.6	0.82	1081	<0.7			8.9	18.7	11.8	7.49	0.37	39		19		
04/03693	10	20	0-10	7.8	0.06	13.5	2.5	11.0	1.63	3.6	18.6	7.5	0.58	0.70	30		2		
04/03694	11		20-30	8.8	0.17	19.8	0.8			5.1	19.5	9.5	1.82	0.27	31		6		
04/03695	12		50-60	9.2	0.34	102	<0.7			17.2	13.8	10.5	4.89	0.16	32		15		
04/03696	13		70-80	9.3	0.38	236	<0.7			18.8	10.7	8.1	3.94	0.17	22		18		

Lab No	Number	Profile	Depth	Cu	Zn	Mn	Fe	Total-N	Total-P	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	15 Bar	ADMC	PAWC
				mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%			%	
04/03684	1	1	0-10	2.27	0.27	18.41	9.59	0.09	0.045	5.2	14.8	20.5	57.6	0.44	20	6.5	
04/03685	2		20-30							5.3	15.7	20.7	58.5	0.60	22	7.7	
04/03686	3		50-60							5.6	13.7	20.8	59.1	0.82	23	9.4	103
04/03687	4		80-90							5.9	12.6	19.5	61.3	0.97	24	7.2	136
04/03688	5	12	0-10	1.64	0.19	14.50	5.94	0.07	0.027	8.0	16.6	20.2	53.7	0.55	19	7.8	
04/03689	6		20-30							5.6	13.9	21.3	61.1	0.61	25	7.6	
04/03690	7		50-60							4.8	13.1	20.7	63.0	0.82	25	8.2	
04/03691	8		80-90							4.6	12.1	20.7	64.8	0.88	26	8.2	
04/03692	9		110-120							8.3	14.6	16.0	62.5	0.91	25	8.7	168
04/03693	10	20	0-10	1.01	0.26	21.36	8.01	0.13	0.02	16.4	24.3	17.8	42.4	0.61	17	5.6	
04/03694	11		20-30							15.7	22.2	17.9	45.1	0.71	20	6.1	
04/03695	12		50-60							14.7	19.6	16.7	48.7	0.98	22	6.1	
04/03696	13		70-80							27.2	23.2	13.9	35.0	0.99	16	4.5	106

SOLUTIONS 2 Aust. Pty. Ltd.

Soil Analysis Report

Reference Number: 04-03684-01
Sample Status: dried and ground

Date Received: 31/7/2004
Date Completed: 9/11/2004
Printed: 9/11/2004

Lab No	Number	Profile	Depth	pH	EC	Cl	NO3-N	Pbic	OC	SO4-S	Ca	Mg	Na	K	CEC	ECEC	ESP	Al	H+
					mS/cm	mg/kg	mg/kg	mg/kg	%	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	meq/100g
04/03697	14	22	0-10	7.8	0.12	113	1.1	11.5	1.42	3.3	14.6	7.1	2.05	0.50	26		8		
04/03698	15		20-30	8.3	0.29	335	<0.7			6.1	14.8	8.1	3.91	0.38	27		14		
04/03699	16		50-60	6.5	1.01	1554	<0.7			6.9	11.8	11.2	9.9	0.19		33	30		
04/03700	17	31	0-10	7.8	0.06	7.1	1.4	7.6	1.37	4.9	30.1	13.0	0.40	0.59	48		1		
04/03701	18		20-30	8.3	0.10	8.4	<0.7			5.2	29.0	14.6	1.06	0.25	45		2		
04/03702	19		50-60	8.8	0.19	12.3	<0.7			13.8	22.0	16.0	2.18	0.20	42		5		
04/03703	20		80-90	8.9	0.34	37.9	<0.7			91.4	21.2	18.7	3.63	0.19	47		8		
04/03704	21		110-120	8.7	0.75	116	<0.7			377	18.3	20.6	4.94	0.25	44		11		
04/03705	22	32	0-10	8.7	0.26	131	36.9	14.1	1.38	9.6	24.2	10.6	1.48	0.44	38		4		
04/03706	23		20-30	9.1	0.40	282	17.2			14	19.0	14.2	3.64	0.18	34		11		
04/03707	24		50-60	8.3	0.74	814	8.9			9.4	15.1	14.9	6.65	0.17	39		17		

Lab No	Number	Profile	Depth	Cu	Zn	Mn	Fe	Total-N	Total-P	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	15 Bar	ADMC	PAWC
				mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%			%	
04/03697	14	22	0-10	1.77	0.25	33.90	8.98	0.10	0.017	11.5	26.3	23.1	41.1	0.73	19	4.6	
04/03698	15		20-30							13.5	22.7	19.1	42.9	0.94	20	5.7	
04/03699	16		50-60							4.4	18.5	19.9	55.5	0.99	23	6.1	89
04/03700	17	31	0-10	1.73	0.24	21.13	11.40	0.10	0.025	3.2	14.2	21.8	59.1	0.50	24	7.1	
04/03701	18		20-30							3.1	13.0	22.1	61.0	0.57	26	9	
04/03702	19		50-60							3.6	14.2	23.8	61.2	0.62	26	8.7	
04/03703	20		80-90							2.8	11.6	23.0	64.0	0.69	25	8.2	
04/03704	21		110-120							3.0	10.2	20.3	64.7	0.78	25	8.6	170
04/03705	22	32	0-10	0.88	0.21	14.52	6.77	0.12	0.02	8.4	18.7	21.2	51.0	0.48	20	5.8	
04/03706	23		20-30							8.9	19.9	17.8	54.2	0.68	23	7.1	
04/03707	24		50-60							6.5	17.9	20.0	57.1	0.94	24	8.5	98

SOLUTIONS 2 Aust. Pty. Ltd.

Soil Analysis Report

Reference Number: 04-03684-01
Sample Status: dried and ground

Date Received: 31/7/2004
Date Completed: 9/11/2004
Printed: 9/11/2004

Lab No	Number	Profile	Depth	pH	EC	Cl	NO3-N	Pbic	OC	SO4-S	Ca	Mg	Na	K	CEC	ECEC	ESP	Al	H+
					mS/cm	mg/kg	mg/kg	mg/kg	%	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	meq/100g
04/03708	25	33	0-10	6.9	0.18	138	32.3	29.1	1.55	9.2	14.7	11.3	2.15	0.63		29	7		
04/03709	26		20-30	7.1	0.36	407	4.7			13.2	14.0	13.6	4.65	0.28		33	14		
04/03710	27		50-60	5.2	0.91	1339	2.8			22.8	9.3	13.6	8.1	0.31		32	25	0.34	0.42
04/03711	28	46	0-10	7.6	0.07	18.9	<0.7	26.8	2.54	2.9	17.4	5.1	0.04	1.57	27		<1		
04/03712	29		20-30	9.1	0.15	24.7	<0.7			3.4	14.9	6.8	1.54	0.37	25		6		
04/03713	30		50-60	9.3	0.65	719	<0.7			10.3	8.9	10.2	5.51	0.42	25		22		
04/03714	31		80-90	9.2	0.81	1028	1.9			4.8	5.3	8.0	5.69	0.29	18		32		
04/03715	32	50	0-10	7.1	0.05	9.4	<0.7	71.6	2.42	4.3	11.1	3.0	<0.1	1.01	18		<1		
04/03716	33		20-30	7.8	0.03	8	<0.7			3.5	12.4	2.5	<0.1	0.26	17		<1		
04/03717	34		50-60	8.1	0.16	43.2	<0.7			16.6	13.2	5.5	0.62	0.15	23		3		
04/03718	35		80-90	8.9	0.26	153	<0.7			41	11.9	7.5	0.72	0.16	19		4		

Lab No	Number	Profile	Depth	Cu	Zn	Mn	Fe	Total-N	Total-P	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	15 Bar	ADMC	PAWC
				mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%			%	
04/03708	25	33	0-10	3.83	0.69	56.49	29.92	0.12	0.037	13.6	19.5	14.2	53.2	0.57	19	5.1	
04/03709	26		20-30							9.2	16.3	14.1	60.8	0.88	22	6.2	
04/03710	27		50-60							9.1	15.5	14.4	62.4	0.85	23	3.6	105
04/03711	28	46	0-10	2.78	0.85	39.48	16.23	0.24	0.064	17.2	23.7	20.3	40.0	0.55	18	6.2	
04/03712	29		20-30							17.2	22.3	17.1	45.1	0.70	18	7.2	
04/03713	30		50-60							18.7	21.4	15.8	46.0	0.96	18	7.3	
04/03714	31		80-90							27.2	24.9	15.9	36.9	0.95	14	6	109
04/03715	32	50	0-10	1.65	0.99	44.24	11.40	0.22	0.057	20.9	34.6	16.2	31.3	0.56	14	4.2	
04/03716	33		20-30							19.3	32.0	14.8	37.2	0.54	14	5.3	
04/03717	34		50-60							13.9	24.5	11.6	50.9	0.74	19	7.9	
04/03718	35		80-90							16.6	25.0	19.5	41.5	0.76	16	5.4	107

SOLUTIONS 2 Aust. Pty. Ltd.

Soil Analysis Report

Reference Number: 04-03684-01
Sample Status: dried and ground

Date Received: 31/7/2004
Date Completed: 9/11/2004
Printed: 9/11/2004

Lab No	Number	Profile	Depth	pH	EC	Cl	NO3-N	Pbic	OC	SO4-S	Ca	Mg	Na	K	CEC	ECEC	ESP	Al	H+
					mS/cm	mg/kg	mg/kg	mg/kg	%	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	meq/100g
04/03719	36	54	0-10	7.5	0.04	10	1.4	11.1	1.80	2.4	17.9	5.0	0.49	0.56	27		2		
04/03720	37		20-30	8.6	0.10	51.9	<0.7			2.9	24.4	7.1	2.02	0.29	34		6		
04/03721	38		50-60	9.3	0.29	213	<0.7			2.6	16.1	6.1	1.91	0.48	21		9		
04/03722	39	72	0-10	8.2	0.05	10.1	1.2	4.9	1.17	2.5	24.2	7.0	0.73	0.62	36		2		
04/03723	40		20-30	8.2	0.05	18.4	1.6			2.2	22.8	7.3	1.42	0.38	35		4		
04/03724	41		50-60	8.9	0.29	203	2			6.4	24.8	11.6	3.64	0.37	41		9		
04/03725	42		80-90	8.9	0.59	591	6.4			6.1	20.6	13.1	5.27	0.45	40		13		
04/03726	43		110-120	9.0	0.62	673	11.6			2.9	15.4	10.7	4.05	0.33	33		12		
04/03727	44	75	0-10	7.3	0.18	194	<0.7	4.5	1.12	4.9	12.0	14.3	3.31	0.62		30	11		
04/03728	45		20-30	6.5	0.41	506	<0.7			10.7	11.4	16.9	7.0	0.40		36	19		
04/03729	46		50-60	5.6	0.56	752	<0.7			9.6	7.8	16.2	9.2	0.41		34	27		

Lab No	Number	Profile	Depth	Cu	Zn	Mn	Fe	Total-N	Total-P	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	15 Bar	ADMC	PAWC
				mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%			%	
04/03719	36	54	0-10	1.35	0.39	25.59	14.90	0.14	0.028	19.1	25.5	18.4	37.6	0.58	16	4.6	
04/03720	37		20-30							15.8	21.5	16.9	49.7	0.64	22	9.6	
04/03721	38		50-60							33.0	18.3	15.3	36.5	0.78	15	6.2	86
04/03722	39	72	0-10	0.88	0.18	10.66	2.98	0.08	0.029	16.3	22.8	18.3	44.9	0.56	20	8.5	
04/03723	40		20-30							14.7	21.8	19.3	47.9	0.70	23	9.3	
04/03724	41		50-60							14.8	18.3	17.4	53.8	0.73	27	6.9	
04/03725	42		80-90							15.1	16.3	16.5	55.4	0.88	26	7.1	
04/03726	43		110-120							12.4	18.1	19.6	53.4	0.87	22	10.0	148
04/03727	44	75	0-10	2.04	0.31	29.42	14.36	0.08	0.035	15.2	16.3	16.0	53.7	0.92	20	6.4	
04/03728	45		20-30							9.5	12.0	19.6	61.0	0.88	23	8.0	
04/03729	46		50-60							11.0	13.5	17.8	61.1	0.95	23	8.7	105

SOLUTIONS 2 Aust. Pty. Ltd.

Soil Analysis Report

Reference Number: 04-03684-01
Sample Status: dried and ground

Date Received: 31/7/2004
Date Completed: 9/11/2004
Printed: 9/11/2004

Lab No	Number	Profile	Depth	pH	EC	Cl	NO3-N	Pbic	OC	SO4-S	Ca	Mg	Na	K	CEC	ECEC	ESP	Al	H+
					mS/cm	mg/kg	mg/kg	mg/kg	%	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	meq/100g
04/03730	47	92	0-10	7.9	0.07	30.1	2.4	7.2	1.57	2.5	13.7	7.2	0.54	0.60	23		2		
04/03731	48		20-30	9.1	0.21	80.1	<0.7			4.8	14.8	7.7	1.83	0.21	24		8		
04/03732	49		50-60	8.9	0.59	666	<0.7			4.8	9.8	10.3	4.81	0.18	25		19		
04/03733	50		80-90	8.7	0.60	768	0.9			3.1	5.9	8.3	5.43	0.12	19		29		

Lab No	Number	Profile	Depth	Cu	Zn	Mn	Fe	Total-N	Total-P	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	15 Bar	ADMC	PAWC
				mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%			%	
04/03730	47	92	0-10	1.85	0.34	18.63	9.16	0.13	0.031	21.9	26.3	12.5	40.4	0.77	15	5.1	
04/03731	48		20-30							22.6	26.0	12.4	41.9	0.64	16	6.2	
04/03732	49		50-60							23.2	25.2	11.9	42.3	0.95	16	6.8	
04/03733	50		80-90							26.5	25.8	9.5	38.5	0.99	16	5.8	106

SOLUTIONS 2 AUST. PTY. LTD

METHOD DESCRIPTIONS

Soil

Methods used to Analyse Samples

Analyte	Method	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
pH	SICT15.2	4A1	1.1	0.1	pH	pH	1:5 water extr, pH meter
EC	SICT12.2	3A1	5.4	0.01	dS/m	Electrical conductivity	1:5 water extr, EC meter
Cl	SICT21.2	5A2	10.0	10.0	mg/kg	Chloride	1:5 water extr, (AA) colorimetric
NO3-N	SICT13.2	7C2	6.7	0.7	mg/kg	Nitrate-nitrogen	1M KCl extr, (AA) colorimetric
NH4-N	SICT13.2	7C2	7.8	0.6	mg/kg	Ammonium-nitrogen	1M KCl extr, (AA) colorimetric
Bicarb.P	SICT23.2	9B2	16.8	1.0	mg/kg	Bicarb.ext.phosphorus	0.5M NaHCO3 @ pH 8.5, (AA) colorimetric
TN	SICT51.2	7A2	12.9	0.01	%	Total Nitrogen	Sulphuric acid digest, (AA) colorimetric
OC	SICT11.2	8B1	9.7	0.02	%	Organic Carbon	Walkley & Black, (H2SO4/K2Cr2O7), abs.600nm
Ca (Neut)	SICT32.2	15A1	10.3	0.10	meq/100g	Exchangeable calcium	1M NH4Cl @ pH 7.0 shake, AAS
Mg (Neut)	SICT32.2	15A1	6.6	0.10	meq/100g	Exchangeable magnesium	1M NH4Cl @ pH 7.0 shake, AAS
Na (Neut)	SICT32.2	15A1	7.3	0.03	meq/100g	Exchangeable calcium	1M NH4Cl @ pH 7.0 shake, AAS
K (Neut)	SICT32.2	15A1	3.9	0.02	meq/100g	Exchangeable calcium	1M NH4Cl @ pH 7.0 shake, AAS
ECEC		15J1	5.0	1	meq/100g	Effective cation ex.capacity	Sum of exchangeable cations
ESP		15N1	5.0	3	%	Exchangeable Na%	(Exchangeable Na/sum of exch.cations)%
Sand	SICT04.2	no ref	22.1	1.0	%	Particle size, sand	Chemicl & mech. dispersion/hydrometer, gravimetric
Silt	SICT04.2	no ref	16.6	1.0	%	Particle size, silt	Chemicl & mech. dispersion/hydrometer, gravimetric
Clay	SICT04.2	no ref	12.7	1.0	%	Particle size, clay	Chemicl & mech. dispersion/hydrometer, gravimetric

* Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)

SOLUTIONS 2 AUST. PTY. LTD

METHOD DESCRIPTION

Soil

Methods used to Analyse Samples

Analyte	Method	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
Ca (Alc)	SICT31.2	15C1	7.2	0.18	meq/100g	Exchangeable calcium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
Mg (Alc)	SICT31.2	15C1	4.7	0.31	meq/100g	Exchangeable magnesium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
Na (Alc)	SICT31.2	15C1	9.6	0.09	meq/100g	Exchangeable calcium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
K (Alc)	SICT31.2	15C1	4.8	0.02	meq/100g	Exchangeable calcium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
CEC	SICT34.1	15I3	5.7	1.0	meq/100g	Cation Exchange Capacity	KNO3 + Ca(NO3)2 extr, (AA) colorimetric
DTPA-Cu	SICT42.2	12A1	17.1	0.26	mg/kg	DTPA ext. copper	DTPA extraction, AAS
DTPA-Zn	SICT42.2	12A1	16.4	0.10	mg/kg	DTPA ext. zinc	DTPA extraction, AAS
DTPA-Mn	SICT42.2	12A1	9.0	0.32	mg/kg	DTPA ext. manganese	DTPA extraction, AAS
DTPA-Fe	SICT42.2	12A1	13.0	0.23	mg/kg	DTPA ext. iron	DTPA extraction, AAS
ADMC	SICT03.2	2A1	11.9	0.4	%	Air Dried Moisture Content	Gravimetric oven dry @ 105C
R1	SICT50.1	NA	20.2	NA		Dispersion Ratio	Ratio [Aqueous dispersible (Silt + Clay):Total (Silt + Clay)]
SO4-S	SICT51.1	10B3	11.5	0.6	mg/kg	Sulfate sulfur	Ca(H2PO4)2 @ pH 4.0 extractable sulfate-sulfur, ICPOES
Al	SICT52.1	15G1	NA	NA	meq/100g	Exchangeable Aluminium	Exch. Hydrogen and Aluminium by 1M KCl
H+	SICT53.1	15G1	NA	NA	meq/100g	Exchangeable Acidity	Exch. Hydrogen and Aluminium by 1M KCl
15 Bar	SICT54.1		NA	NA		15 Bar Analysis	Pressure Plate/Gravimetric oven dry @ 105C

* Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)

QUALITY CONTROL DATA

Soil

SOLUTIONS 2 Aust. Pty. Ltd

Reference: 04-03684-01

* Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)

Quality Control

Test Method	Units	23-8-2004	Actual Value	Acceptance Criteria [Range]
pH	pH	B	5.19, 5.19	5.02 - 5.28
EC	dS/m	B	0.29, 0.29	0.279 - 0.321
Cl	mg/kg	B	23.9, 21.1	7.7 - 27.8
NO3-N	mg/kg	B	13.0, 12.5	11.7 - 15.7
NH4-N	mg/kg	NA	NA	NA
Bicarb.P	mg/kg	B	66.3, 63.3	51.3 - 74.2
Total Kjeldahl N	%	S10	0.16, 0.17	0.15 - 0.18
Total P	%	ALS	See ALS Report	See ALS Report
Organic Carbon	%	S10	1.61	1.55 - 1.69
Ca (Exch. cations)	meq/100g	A	34.4, 31.5	27.7 - 35.4
Mg (Exch. cations)	meq/100g	A	30.6, 29.0	27.6 - 35.2
Na (Exch. cations)	meq/100g	A	5.46, 5.14	5.12 - 6.58
K (Exch. cations)	meq/100g	A	2.27, 2.04	2.07 - 2.55
Al (Exchangeable)	meq/100g		NA	NA
H+ (Exchangeable)	meq/100g		NA	NA
ECEC	meq/100g	A	NA	NA
CEC	meq/100g	A	68, 70	57.8 - 78.3
ESP	%	A	NA	NA

Test Method	Units	Test Soil	Actual Value	Acceptance Criteria [Range]
DTPA-Cu	mg/kg	B	3.12, 2.96	2.37 - 3.25
DTPA-Zn	mg/kg	B	3.00	3.15 - 3.81
DTPA-Mn	mg/kg	B	NA	97.7 - 105.0
DTPA-Fe	mg/kg	B	NA	29.3 - 32.6
Sulfate-sulfur	mg/kg	B	107, 107	95.8 - 116.6
Sand (Coarse)	%	B	2.4	1.4 - 2.8
Sand (Fine)	%	B	19.1	13.1 - 19.1
Silt	%	B	20.5	20.2 - 26.1
Clay	%	B	57.9	55.5 - 60.2
ADMC	%	GR	9.0	8.7 - 9.5
Dispersion Ratio (R1)		B	0.21	0.187 - 0.288
15 Bar	%	GA	27	26.8 - 38.5

Comments: All QC checks passed acceptance criteria.

SOLUTIONS 2 Aust. Pty. Ltd.

Soil Analysis Report

Reference Number: 04-03684-01
Sample Status: dried and ground

Date Received: 31/7/2004
Date Completed: 9/11/2004
Printed: 9/11/2004

Lab No	Number	Profile	Depth	pH	EC	Cl	NO3-N	Pbic	OC	SO4-S	Ca	Mg	Na	K	CEC	ECEC	ESP	Al	H+
					mS/cm	mg/kg	mg/kg	mg/kg	%	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%	meq/100g	meq/100g
04/03684	1	1	0-10	6.3	0.05	15.9	0.9	5.2	1.17	4.5	19.0	10.1	0.86	0.85	32		3		
04/03685	2		20-30	8.7	0.17	110	<0.7			4.3	19.8	11.9	2.54	0.62	32		8		
04/03686	3		50-60	8.6	0.79	1070	<0.7			7.8	15.3	12.8	6.05	0.29	32		19		
04/03687	4		80-90	8.5	0.84	1118	5.5			10.7	13.2	13.0	6.97	0.61	32		22		
04/03688	5	12	0-10	8.2	0.07	14.4	1	7.8	0.98	3.6	26.1	8.5	1.01	0.70	38		3		
04/03689	6		20-30	8.4	0.07	10.8	<0.7			2.1	27.3	9.4	1.97	0.65	41		5		
04/03690	7		50-60	8.6	0.19	34.1	1.4			5.3	27.2	10.5	3.82	0.50	42		9		
04/03691	8		80-90	8.7	0.36	360	<0.7			11.5	24.3	12.4	6.59	0.50	44		15		
04/03692	9		110-120	8.6	0.62	1081	<0.7			8.9	16.7	11.5	7.49	0.37	39		19		
04/03693	10	20	0-10	7.8	0.06	13.5	2.5	11.0	1.63	3.6	18.6	7.5	0.58	0.70	30		2		
04/03694	11		20-30	8.8	0.17	19.8	0.8			5.1	19.5	9.5	1.82	0.27	31		6		
04/03695	12		50-60	9.2	0.34	102	<0.7			17.2	13.6	10.5	4.89	0.18	32		15		
04/03696	13		70-80	9.3	0.38	236	<0.7			18.8	10.7	8.1	3.94	0.17	22		18		

Lab No	Number	Profile	Depth	Cu	Zn	Mn	Fe	Total-N	Total-P	PSA-CS	PSA-FS	PSA-Silt	PSA-Clay	R1	15 Bar	ADMC	PAWC
				mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%			%	
04/03684	1	1	0-10	2.27	0.27	18.41	9.59	0.09	0.045	5.2	14.8	20.5	57.6	0.44	20	6.5	
04/03685	2		20-30							5.3	15.7	20.7	58.5	0.60	22	7.7	
04/03686	3		50-60							5.8	13.7	20.8	59.1	0.82	23	9.4	103
04/03687	4		80-90							5.9	12.8	19.5	61.3	0.97	24	7.2	136
04/03688	5	12	0-10	1.64	0.19	14.50	5.94	0.07	0.027	8.0	16.6	20.2	53.7	0.55	19	7.6	
04/03689	6		20-30							5.8	13.9	21.3	61.1	0.81	25	7.6	
04/03690	7		50-60							4.8	13.1	20.7	63.0	0.82	25	8.2	
04/03691	8		80-90							4.6	12.1	20.7	64.8	0.88	26	8.2	
04/03692	9		110-120							6.3	14.6	16.0	62.5	0.91	25	8.7	168
04/03693	10	20	0-10	1.01	0.26	21.36	8.01	0.13	0.02	16.4	24.3	17.8	42.4	0.61	17	5.6	
04/03694	11		20-30							15.7	22.2	17.9	45.1	0.71	20	6.1	
04/03695	12		50-60							14.7	19.6	16.7	48.7	0.98	22	6.1	
04/03696	13		70-80							27.2	23.2	13.9	35.0	0.99	16	4.5	106

Appendix 3. Land suitability cut off levels from The Department of Minerals and Energy, Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland (1995)

ATTACHMENT 2

LAND SUITABILITY CLASSIFICATION FOR CROPPING AND GRAZING IN THE SEMI-ARID SUB-TROPICS OF QUEENSLAND

The following ratings tables present criteria for determining land suitability for rainfed broadacre cropping and for beef cattle grazing in the semi-arid sub-tropics (see Note 1). These tables are based upon Queensland Department of Primary Industries guidelines for agricultural land evaluation (Land Resources Branch 1990). The criteria used in these tables are necessarily general to be applicable over a wide area. The Department of Primary Industries is developing land suitability classifications for several specific locations within the semi-arid sub-tropics (Shields and Williams 1991) as part of detailed land resource surveys and the Department's detailed land suitability criteria may be more appropriate for each of these locations.

TABLE 2.1
SUITABILITY FOR RAINFED BROADACRE CROPPING

Limitation	Land suitability class				
	1	2	3	4	5
Water availability (See Table 1.3)	PAWC >150 mm	PAWC 125-150 mm	PAWC 100-125 mm	PAWC 75-100 mm	PAWC <75 mm
Nutrient deficiency	Bicarbonate P >10 ppm	Bicarbonate P 5-10 ppm and Exchangeable K >0.3 meq. %	Bicarbonate P 5-10 ppm and Exchangeable K ≤0.3 meq. % or pH <5 60-90 cm below surface or pH >9 60-90 cm below surface	Bicarbonate P <10 ppm and Exchangeable K ≤0.3 meq. %, and Exchangeable Ca <3 meq.%, or pH <5 30-60 cm below surface, or pH >9 30-60 cm below surface	pH <5 within 30 cm of surface or pH >9 within 30 cm of surface
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm)	Cracking clays with coarse self-mulch (peds 10-20 mm) or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds at the surface (≥20 mm)	
Soil workability	Friable cracking clays (indicated by very fine self-mulch), or Rigid soils with a loose, soft or firm surface when dry	Firm cracking clays (indicated by fine self-mulch) or Rigid soils with a hard setting surface when dry	Stiff cracking clays (indicated by coarse self-mulch with peds>10 mm, crusting or hard setting surface)		
Salinity	Rootzone EC <0.15mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15 -0.3 mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm or Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm, or Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm or Rootzone Cl ≥1500 ppm
Rockiness	<10% coarse surface gravel (>6 cm diam.) and rock outcrop	10-20% coarse surface gravel and rock outcrop	20-50% surface cobble (6-20 cm diam.)and rock outcrop	50-90% surface cobble and rock outcrop, or 20-50% stone and boulders (>20 cm diam.)	>90% surface cobble and rock outcrop, or >50% stone and boulders and rock outcrop
Microrelief	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	Melonholes 30-60 cm deep cover <20% surface area or Melonholes >60 cm deep cover <10% surface area	Melonholes 30-60 cm deep cover 20-50% of surface area or Melonholes >60 cm deep cover 10-20% surface area	Melonholes 60-100 cm deep cover 50 % surface area	Melonholes at least 100 cm deep cover 50% surface area
Wetness	Undulating terrain or elevated plains	Low-lying level plains with melonholes covering <25% surface area, or Rigid soils with sodic subsoil (ESP 6-14) within 80 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 75 cm of the surface	Low-lying level plains with melonholes covering 25-50% surface area, or Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Seasonal swamps and low-lying run-on areas	Permanent swamps and lakes
Topography	No gully dissection	Occasional deep gullies impede cultivation slightly	Many deep gullies reduce arable area by < 33% or require major changes to cultivation practices	Many deep gullies make the arable areas too small to cultivate	Abundant deep gullies prevent any practical cultivation
Water erosion	Slopes <0.5% on cracking clays without melonholes, or Slopes <1% on melonhole clays, or Slopes <1% on non-sodic rigid soils, or Slopes <0.5% on sodic rigid soils	Slopes 0.5-1% on cracking clays without melonholes or Slopes 1-3% on melonhole clays, or Slopes 1-2% on non-sodic rigid soils, or Slopes 0.5-1% on sodic rigid soils	Slopes 1-3% on cracking clays without melonholes or Slopes 2-4% on non-sodic rigid soils or Slopes 1-2% on sodic rigid soils	Slopes 3-5% on all cracking clays or Slopes 4-6% on non-sodic rigid soils or Slopes 2-3% on sodic rigid soils	Slopes >5% on all cracking clays or Slopes >6% on non-sodic rigid soils or Slopes >3% on sodic rigid soils
Flooding	No flooding	Rare flooding (only during abnormal 1 in 50 to 100 year events)	Infrequent flooding (inundation occurs <half the times that stream flow increases)	Occasional flooding (inundation occurs ≥half the times that stream flow increases)	Regular flooding (inundation occurs *whenever stream flow* increases)

TABLE 2.2
SUITABILITY FOR BEEF CATTLE GRAZING

Limitation	Land suitability class (see Table 2.4)				
	1	2	3	4	5
Water availability (See Table 1.3)	PAWC >125 mm	PAWC 100-125 mm	PAWC 75-100mm	PAWC 50-75 mm	PAWC ≤50 mm
Nutrient deficiency	Brigalow, gidgee, blackwood or softwood scrub soils and former scrub soils with Bicarbonate P >10 ppm	Eucalypt vegetation and downs with Bicarbonate P >10 ppm	Other soils with Bicarbonate P 5-10 ppm except Sands and loams at least 75 cm deep or overlying rock at shallow depth	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with Bicarbonate P 5-10 ppm, or Bicarbonate P ≤4 ppm	
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm), or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds (peds ≥10 mm) or crust on the surface		
Salinity	Rootzone EC < 0.15 mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15-0.3 mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm or Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm or Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm or Rootzone Cl ≥1500 ppm
Rockiness	<20% coarse surface gravel (>6 cm diam.) and rock outcrop	20-50% coarse surface gravel and rock outcrop	50-90% surface cobble and rock outcrop	>90% surface cobble and rock outcrop	Rock outcrop and surface coarse fragments cover total area
Microrelief	Melonholes cover <20% surface area (semi-circular depressions at least 30 cm deep and usually surrounded by mounds)	Shallow melonholes (30-60 cm deep) cover 20-50% surface area	Deep melonholes (>60 cm deep) cover 20-50% of surface area		
pH (1:5)	5.6-8.6	6.6-8.0 5.0-5.6	8.0-9.0 4.5-5.0	9.0-10.0 4.0-4.5	>10.0 < 4.0
ESP (10cm)% Exchangable Sodium Percentage	<5.0	5-10	10-15	15-30	>30
Wetness	Undulating terrain or elevated plains	Low-lying level plains, or Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Shallow seasonal and permanent swamps		Permanent lakes and deep swamps
Topography				Many deep gullies make cultivation for sowing pastures impractical, or Slopes >15% make cultivation along contours impractical	Strongly dissected terrain over ≥75% of the area preventing adequate herd management
Water erosion	Slopes <1% on sodic rigid soils or Slopes <3% on all other soils	Slopes 1-3% on sodic rigid soils or Slopes 3-6% on cracking clays, or Slopes 3-12% on non-sodic rigid soils	Slopes 3-6% on sodic rigid soils or Slopes 6-9% on cracking clays, or Slopes 12-20% on non-sodic rigid soils	Slopes 6-12% on sodic rigid soils or Slopes 9-15% on cracking clays or Slopes 20-45% on non-sodic rigid soils	Slopes >45%
Flooding	No flooding	Periodic flooding (from once in 50 years to whenever stream flow increases)			
Vegetation regrowth (management limitation)	Softwood, brigalow, gidgee or blackwood scrub without melonholes, or Queensland bluegrass grasslands, or Mountain coolabah, bloodwood and ironbark open woodlands	Brigalow, gidgee or blackwood scrub with melonholes, or Box and ironbark woodlands without wattle understorey, or Coolabah woodlands on flooded country		Eucalypt woodlands with wattle understorey or Broad-leaved teatree woodlands	

Appendix 4.3 Community Consultation Plan and Register

AngloAmerican

Dawson Mine PRCP Community Consultation Plan and Register

Issue: 1

Date: 2024



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1 Introduction

1.1 Purpose

The PRCP Community Consultation Plan (CCP) is comply with section 126C(1)(c) of the EP Act. The CCP sets out how the community has been engaged to develop the PRCP and how ongoing consultation will be undertaken. As the Dawson Mine PRCP is a transitional PRC, the community consultation register includes all recorded previous engagements with the community in relation to mine closure.

1.2 Context with existing Anglo American policies and procedures

Anglo American has been undertaking community consultation with its stakeholders since acquiring the Dawson Mine (formally known as the Moura Mine) in 2002. Community consultation is integrated into the Social Performance Management System and guided by the Anglo American Social Way 3.0 Policy, Toolkit, and Assurance Framework (AASW)[1] and other relevant Anglo American Standards such as the Mine Closure Standard and Toolbox[2]

The AASW is aligned with internal standards, including:

- International Finance Corporation's Environmental and Social Performance Standards
- UN Guiding Principles on Business and Human Rights
- Voluntary Principles on Security and Human Rights
- International Council on Mining and Metal's Position Statement and Good Practice Guide on Indigenous Peoples and Mining
- Initiative for Responsible Mining Assurance
- OECD Guidelines for Multinational Enterprises.

Alignment between Social Way 3.0 and the Mine Closure Standard and Toolbox and the CCPR requirements set out in the PRCP Guideline is shown in Table 1. At this point in time, as the Dawson Life of Mine is 2079, the Dawson Mine is in the Draft Mine Closure Plan phase.

Table 1: CCPR Requirements (PRCP Guidelines), AASE and AA Mine Closure Toolbox

PRCP Guideline	AA Social Way (AASW) 3.0	AA Mine Closure Toolbox (2019)
The administering authority expects applicants to identify, notify and engage the community regarding the proposed project and to provide them with an opportunity to comment. If the community does not respond, the PRC plan application will not be impacted. However, the applicant must demonstrate that sufficient effort has been made in engaging the community. The community may include, but are not limited to: • affected landholders (such as underlying and adjoining landholders, and holders of land necessary for access to	Section 1 Governance • Establishment of the Dawson Mine Social Performance Management Committee (Dawson Mine Senior Leadership Team) Section 2 Review and Planning • Social Management Plan (SMP) which sets out the long term social performance objectives and how they will be achieved. The SMP includes appendices such as:	*Preliminary Closure Plan - 25 to 15 years remaining to closure* Interested and affected parties (I&APs) have been engaged at the appropriate level of influence related to the mine closure plan by providing them with balanced and objective information to improve their understanding of the issues, alternatives and/or solutions and to enable them to submit their issues and concerns. Integration with Social Way processes set out in:

[1] https://socialway.angloamerican.com/en/about updated from the system formally known as SEAT and SEAT2

[2] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/sustainability/mine-closure-toolbox-version-3-2019.pdf updated from the 2007 version

PRCP Guideline	AA Social Way (AASW) 3.0	AA Mine Closure Toolbox (2019)
the land to which the proposed PRC plan relates) • traditional owners • Local government • Local community groups To comply with section 126C(1)(c)(iii) of the EP Act, the rehabilitation planning part must include a community consultation register identifying the consultation carried out in developing the PRC plan. The community consultation register must include: • consultation dates • identification of each community member • description of consultation type (workshop, meeting, etc) • information provided to the community • issues raised/ discussed by the community • how issues have been considered • decisions/ outcomes of engagement and • commitments made by the applicant.	• Social and Human Rights Impact and Risk Analysis (SHIRA) • Stakeholder Engagement Plan • Socio-Economic Development Plan • Site Induced Management Plan • Cultural Heritage Management Plans Section 3A Stakeholder Engagement which includes the requirements to: • Understand impacts, risks and opportunities • Stakeholder mapping • Maintain a commitments register • Stakeholder Engagement Plan • Monitor and evaluation • Track and analyse stakeholder perspectives and feedback • Adjust and report • Section 3B Incident and grievance management which includes the requirement to: • Develop a grievance management procedure (ensuring the grievance process follows UNGP principles) • Monitoring and evaluation of the grievances, incidents and the overall procedure. • Dawson Mine assessed for its compliance with Social Way on an annual basis by external, independent assessors.	• 4A Socio-Economic Development • 4C Community Health and Safety Management *Draft Closure Plan 15 -10 years to closure* The previously identified socioeconomic needs, health needs and the closure vision are well recognised. These aspects have been discussed with I&APs and updated accordingly. The operational budgets are geared towards addressing the social transition mitigation measures (e.g. economic diversification), by using current vehicles such as the AASW. The intention is to address all social transition requirements through operational management and not have any closure liabilities. Social transition criteria have been updated and costed (mostly operational expenditure). I&APs have been given the opportunity to review the revised mine closure plan and be part of the closure plan development, by means of ongoing engagement with the operation at the appropriate level of influence. Feedback from stakeholders on issues, alternatives and/or decisions has been considered and incorporated into the closure plan, where appropriate. *Detailed Closure Plan 10-5 years to closure* The confirmed social transition requirements and final land-use objectives have been identified in more detail and re-confirmed by means of I&APs involvement. Impacts on community health and well-being are managed (mitigated and/ or enhanced) in partnership with key stakeholders. The social transition process is managed through the AASW and success is tracked and measured to ensure an

PRCP Guideline	AA Social Way (AASW) 3.0	AA Mine Closure Toolbox (2019)
		acceptable residual social risk profile post closure. I&APs are directly engaged at the appropriate level of Influence throughout the process, to ensure that issues and concerns are consistently understood and considered, and offered the opportunity to make substantive changes to the closure plan and its criteria, where appropriate

1.3 Principles and functions of AASW stakeholder engagement

Under the AASW, stakeholder engagement is underpinned by the following guiding principles:

- Dialogue-based - Stakeholder engagement should create opportunities for a two-way discussion and for stakeholders to input into company decisions that affect their lives. This dynamic is the cornerstone of all aspects of social performance, from discovery through to closure.
- Strategic - Engagement should be outcomes based. A site's potential impacts, risks and long-term objectives should inform engagement priorities and be informed by stakeholder perspectives.
- Proactive - Activities should be pre-planned as far as possible. Early and regular communication is critical, allowing space for stakeholders to express any concerns and for the site to adjust its approach accordingly. Communication should provide stakeholders with the necessary information to meaningfully inform their position on issues and policies that affect them and our sites.
- Clear and direct - Information relevant to stakeholders should be communicated in ways that the audience will understand, based on their language, education, literacy level, interests and concerns. Engagement should be underpinned by openness and honesty about any potential adverse impacts and include explanations of who may be affected, when and how.
- Inclusive - It is important to engage with all affected stakeholders, including vulnerable groups, by using tailored engagement approaches. Engagement approaches should be designed to avoid creating or exacerbating any intra or inter community conflicts or power imbalances in communities.
- Ongoing - Engagement is a continuous, regular and iterative process. Reporting back to stakeholders is vital to explain how their feedback and views were considered.
- Shared and understood internally - Social Performance teams must be able to translate what they hear 'outside the fence' in a manner that resonates with internal management so that engagement results in action.

Key functions of stakeholder engagement that are undertaken when planning and implementing the Dawson Mine Stakeholder Engagement Plan are shown in Figure 1.

Figure 1: Functions of AASW Stakeholder Engagement



The purpose of the Dawson Mine Stakeholder Engagement Plan (SEP) is to improve dialogue, enhance partnerships and promote wider engagement at the local and regional level, while continuing to responsibly meet the needs of the business. The SEP identifies the Dawson Mine's:

- Approach to stakeholder engagement (alignment to functions shown in Figure 1)
- Implementation tools and action plan
- Monitoring and evaluation (including recording and tracking stakeholder engagements) and
- Reporting.

Under Social Way, the Dawson Mine is required to maintain a Commitment Procedure and Register[3].

1.4 Regulatory Context

This CCPR has been prepared to comply with Sections 126C(1)(c)(iii) and (iv) of the Environmental Protection Act 1994 (Qld) ('EP Act'), which requires the PRCP to include:

- detail as to the consultation undertaken by the applicant in developing the PRCP; and
- detail as to how the applicant will undertake ongoing consultation in relation to the rehabilitation to be carried out under the PRCP.

As per the PRCP Guideline (DES, 2019), the Applicant is expected to identify, notify, and engage the community regarding closure and provide an opportunity to comment. The relevant aspects of the PRCP Guideline (DES, 2019) that outline how the CCPR complies with Sections 126C(1)(c)(iii) and (iv) of the EP Act are outlined in Table 2.

[3] https://socialway.angloamerican.com/en/toolkit/review-and-planning/review-and-planning/guidance/do/task-7-update-the-social-management-plan

Table 2: CCPR Requirements and Location in CCPR

PRCP Guideline	Requirement	Location in CCPR
To comply with section 126C(1)(c)(iii) of the EP Act, the rehabilitation planning part must include a community consultation register identifying the consultation carried out in developing the PRC plan.	The community consultation register must include: • consultation dates • identification of each community member • description of consultation type (workshop, meeting, etc) • information provided to the community • issues raised/ discussed by the community • how issues have been considered • decisions/ outcomes of engagement and • commitments made by the applicant.	Section 4
To comply with section 126C(1)(c)(iv) of the EP Act, the rehabilitation planning part must include a community consultation plan detailing how ongoing consultation will be carried out in relation to the rehabilitation to be carried out under the PRC plan.	The community consultation plan must include details of: • the objectives for community consultation • how the community will be engaged • proposed consultation frequency • what information will be released for community consultation • how feedback/comments will be considered.	Section 5

2 Engagements for 2012 Preliminary Mine Completion Plan

2.1 2006 – 2007 Engagements under SEAT and 2008 – 2009 SEAT2

During SEAT and SEAT2 engagements undertaken in 2006-2007 and 2008-2009 respectively, mine closure was raised as an issue by stakeholders participating in the processes. The actions and benefits set out in Table 3 were included in the 2010 Dawson Mine Preliminary Mine Completion Plan.

Table 3: Actions and Benefits of mine closure identified in the 2006/07 and 2008/09 SEAT engagement processes

Action	Benefit
Maximising rehabilitation of the mine site	Land use post mine closure will be appropriate with regards to classification
Skills transfer for mine employees Joint approach to developing other industries in the community	To enable retention of the local population
Use of the mine and equipment	Development of: • A historical museum • Forest plantation • Grazing land • Waste management site Using the pits for: • Aquaculture • Water storage from water allocations
Develop a long term plan to manage the impacts of mine closure	Foster relationships with other industries and neighbouring mines to support a future skills transfer program. Explore further opportunities to use the mine site post operations phase in accordance with the AA Mine Closure Toolbox.

Source: AECOM 2010 Dawson Mine Preliminary Mine Completion Plan

2.2 2010 Community Mine Closure Meetings

The actions set out in Table 3 were used as the basis for discussions with stakeholders in 2010 to develop the Dawson Mine Preliminary Mine Completion Plan, to:

- Verify that the ideas, issues, matters raised were still current
- Confirm the commitment (at the time) from stakeholders to further pursue the ideas/issues/matters raised to identify new ideas/issues/matters for consideration and
- Validate key stakeholder support for further consideration of new ideas/issues/matters.

Anglo American undertook a round of community engagements to inform the development of the Preliminary Mine Completion Plan for the Dawson Mine to meet a number of purposes:

- Anglo American corporate and financial reporting requirements
- Regulatory criteria

- Financial assurance requirements
- Effective operational planning for future closure and lease relinquishment.

A range of engagement techniques were utilised, one on one meetings, workshops, and open community meetings. Community meetings were held in Moura, Theodore and Biloela. The results of the stakeholder and community consultation were incorporated into the Dawson Preliminary Mine Completion Plan and were summarised as set out in Table 4.

Table 4: Summary of issues for inclusion in Preliminary Mine Completion Plan

Theme	Details
Water	Water Storage Water re-allocation Water quality and Irrigation
Final landforms	Back to previous state (expressed by a minority) Half way between present and past (expressed by a majority)
Social infrastructure	Need to improve the 'liveability' of the area Need improved access to social infrastructure: Health services: • dental • mental health support services • aged care Long day childcare Entertainment: restaurants, movies, theatre, sporting Large culture change will need to be supported
Air quality	Interim and final activities need to ensure quality of air
Weed control	Interim and final activities need to ensure weed control
Legacy	Need to leave a positive legacy from both and environmental and social perspective
Royalties	Greater share of royalties to government should return to the towns that support the mining activities
Alternative industry	Need to investigate further, and need to be sustainable. Ideas include: • brick works • forestry • aquaculture • tourism (grey nomads, establish a Miner's Hall of Fame, retain some • 'historical infrastructure' for display • manufacturing • return to farming • education facilities • power station • pork farming and processing (previous industry) • Nathan Dam (construction of)

Theme	Details
	• gas industry • regional centre (similar to Emerald) • source of public housing • olive groves • wild game • solar energy • wind energy • development of airport
Land fill	Partner with Council to establish appropriate land fill facilities (mulch/green waste)
Education, training and re-skilling	Alternative industry will require retraining or alternative education paths for youth Need local access to skills training Explore the idea of becoming a provider of high quality education (e.g. Toowoomba)
Housing	Major impact on house values Likely to lead to excess housing stock Current issues with Single Persons Quarters versus miners and families living in houses in the township)
Rehabilitation	Expect improvement on current visible rehabilitation Best model is to rehabilitate as mining occurs Recognition of fauna returning to current rehab area Understanding that if rehabilitation requirements are too onerous, mining will cease earlier – need a balanced view Rehabilitate to previous condition and return to grazing at all costs (including social) – expressed by one stakeholder only
Land valuations	Land used by mines should be subject to similar rates as residential
Infrastructure	Gibihi Road overpass shutdown Return roads and other related infrastructure
Impact of closure of towns	Moura would shrink significantly/die Biloela has other industries to rely on – likely to survive Theodore would focus on traditional industry of farming Education facilities in Moura would contract
Role of government	Policy changes will be needed to manage reduction in numbers in schools – change to funding and staffing models Greater share of royalties to government should return to the towns that support the mining activities Government needs to incorporate the PMCP into its regional and community plans

Source: AECOM 2012 Dawson Mine Preliminary Mine Completion Plan

3 Engagements for current Preliminary Mine Closure Plan

3.1 Community Perception Surveys

As part of the Dawson Mine SEP and Dawson Mine PRCP, Anglo American undertakes annual community impact/community perception surveys are undertaken focusing on the people who live and work in the Dawson Local Area of Influence, Moura, Banana and Theodore. The surveys are:

- voluntary and anonymous
- advertised by Anglo American using social media, posters, stakeholder meetings and word of mouth
- survey design, data analysis and reporting is undertaken by a separate company.

Results of the annual perception surveys are discussed with the DCRF.

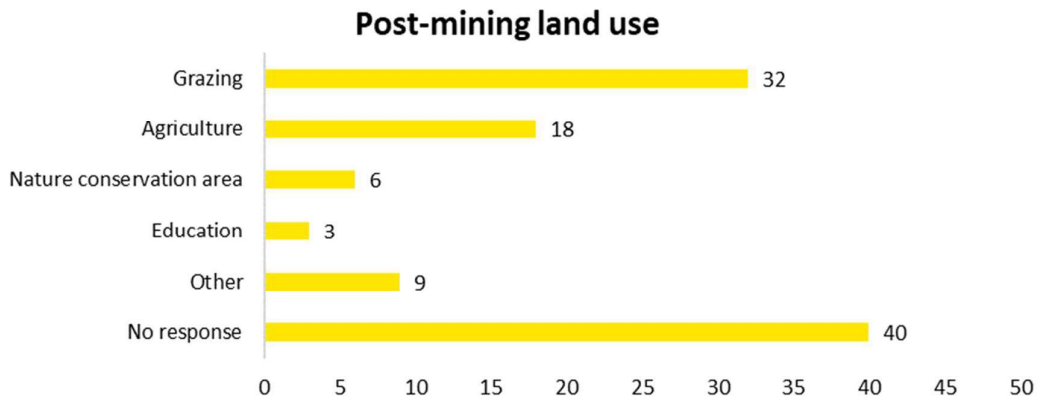
3.1.1 2020 Community Impact Survey

The 2020 108 surveys were completed from people living and working in Moura, Theodore and Banana.

Post-mining land uses

When asked the question "What post-mining land uses do you envisage for the area", the majority of responses were grazing followed by agriculture and other, see Figure 2. Other responses included multiple combinations of grazing, agriculture, and education. The question received 40 non responses.

Figure 2: 2020 Community Impact Survey - Post mining land use



Key considerations when planning for post mine use

When asked about key considerations when planning for post mine use were:

- Rehabilitation
- Post mine land use, including soil productivity
- Final land form
- Employment
- Alternative industries, including tourism and renewable energy

Support for a sustainable long-term future

Themes raised in response to support for a diversified and sustainable local economy in the future were:

- Rehabilitation
- Final land use
- Employment opportunities, training and education
- Support for local businesses to adapt to new industries
- Water management

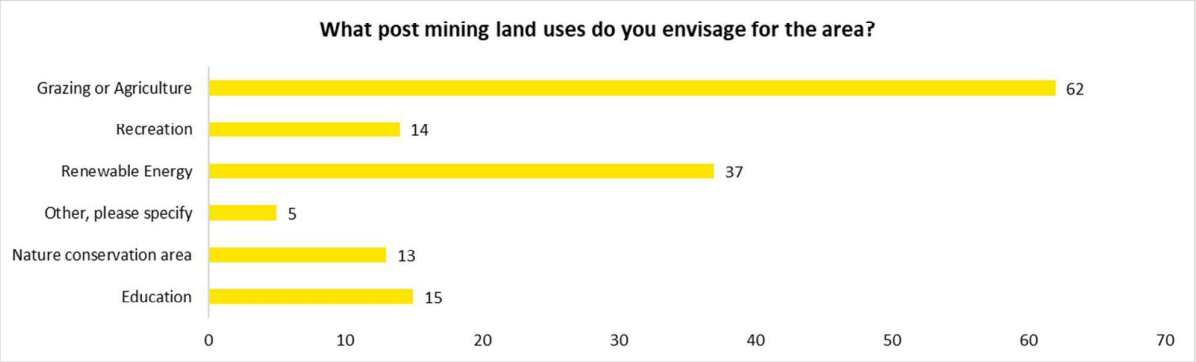
3.1.2 2021 Community Perception Survey

The 2021 124 surveys were completed from people living and working in Moura, Theodore and Banana.

Post-mining land uses

The purpose of the post land use question in the 2021 Community Perception Survey was focusing on testing if grazing and agriculture remained the preferred post land use option. Again, the majority of responses to were grazing or agriculture, followed by renewable energy and education, see Figure 3.

Figure 3: 2021 Community Perception Survey - Post mining land use



Key considerations when planning for post mine use

Themes raised in response key considerations when planning for post mine use were:

- Community/town sustainability post mining, and the economy to maintain existing services
- Employment opportunities, training and education
- Land form and suitability
- Rehabilitation
- Consultation and stakeholder involvement in decision making and
- Water quality.

Support for a diversified and sustainable local economy

Themes raised in response to support for a diversified and sustainable local economy in the future were:

- Diversified economy – renewable energy, tourism, agriculture

- Upskilling local residents for a diversified economy
- Support for local businesses to adapt to changing economy
- Community services

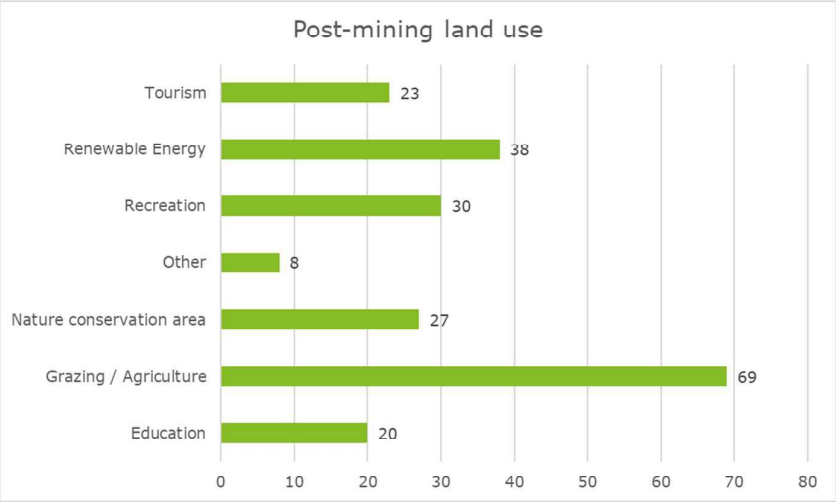
3.1.3 2022 Community Perception Survey

The 2022 122 surveys were completed from people living and working in Moura, Theodore and Banana.

Post-mining land uses

Again, the type of post mining land use was tested, with grazing and agriculture being the preferred option, followed by renewable energy and recreation, see Figure 4.

Figure 4: 2022 Community Perception Survey - Post mining land use



3.1.4 2023 Community Perception Survey

Given the consistent response of the preferred post mining land uses being grazing, agriculture and renewable energy from 2020 through to 2022, the decision was made not to ask the question in the 2023 Community Perception Survey.

3.2 Gangulu Cultural Heritage Coordination Committee Meeting

Under the Cultural Heritage Investigation and Management Agreement between Dawson Mine and Gangulu Endorsed Parties, the Coordination Committee meetings are held "from time to time to further the purposes of the CHIMA". During the 2020 and 2021 meetings, mine rehabilitation was discussed.

3.3 Neighbours Dinners

Anglo American hosts an annual Neighbours Dinner for the Dawson Mine. At each of the dinners a presentation is made providing an update on the operation with a focus on progress on rehabilitation programs. Neighbours dinners have been held in[4]:

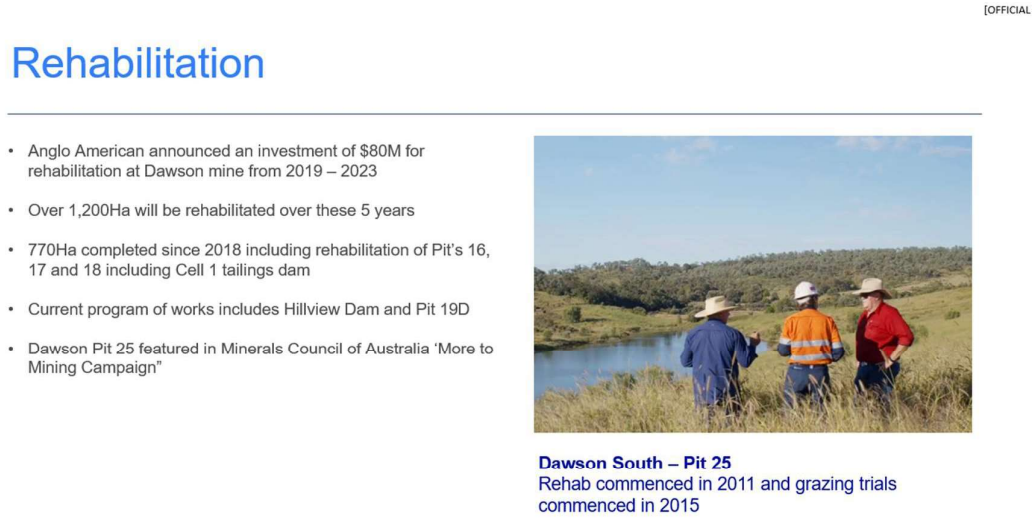
- 2018
- 2019

[4] A neighbours Dinner was not held in 2020 due to COVID restrictions at the time

- 2021
- 2022
- 2023

As an example, at the 2021 Neighbours Dinner, see Figure 5. The MCA video title More to Mining which features the rehabilitation at Dawson was also shown as part of the dinner, see https://www.moretomining.com.au/case-studies/rehabilitation-at-anglo-americans-dawson-mine

Figure 5: Slide from 2021 Neighbours Dinner on rehabilitation



3.4 Dawson Community Reference Forum (DCRF)

Anglo American established the Dawson Community Reference Forum (DCRF) in 2018 to facilitate open and accountable dialogue between Anglo American and the community stakeholders and build greater mutual trust between both parties. The DCRF is comprised of community members who represent different industries, with the expectation that information presented at the forum will be disseminated post-meeting to the relevant industry groups (i.e. Local Emergency Services, Health sector, local council, chamber of commerce).

The DCRF Members include Banana Shire Council (Government), Moura Progress Association (Tourism), Moura Chamber of Commerce (Business), Queensland Fire Service – Moura (Emergency Services), Moura Hospital Auxiliary (Health Services), Moura State School (Education) and Agforce Queensland Farmers (Agriculture).

The DCRF is chaired by the Dawson Mine General Manager who invites relevant members from the Senior Leadership Team (SLT) to attend to present on matters that have been raised by the DCRF.

The DCRF meets on a quarterly basis during which the Dawson Mine's management team provides updates on mine activities and issues. Discussions include, but are not limited to, potential post-mining land uses, rehabilitation performance, targeted vegetation, and other monitoring results.

In May 2022, Mine Closure Planning was one of the DCRF agenda items, with the following information presented and discussed:

- What is mine closure planning

- Overview of the Anglo American Mine Closure Standard
- Integrated planning
- Post mine land uses and specifications in the Dawson Mine EPML00565813 and EPML00657413,
    - Creation of native ecosystem (onsite and in offset areas)
    - Creation of Semi Evergreen Vine Thicket (SEVT)
    - Creation of hardwood plantation; and
    - Agriculture (low intensity grazing on rehabilitated areas, high intensity in buffer areas, potential cropping on Dawson River Alluvial Floodplain in the south-west).

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4 Community Consultation Register

Table 6 sets out the PRCP Community Consultation Action Plan within the context of the Anglo American Mine Closure Standard. The PRCP Community Consultation Action Plan will be delivered in the broader context of the Dawson Mine Social Management Plan, of which the Stakeholder Engagement Plan is a main component.

Table 6 sets out the Community Consultation Register for engagements undertaken since the 2012 Dawson Mine Preliminary Completion Plan.

Table 5: Community Consultation Register

Stakeholder	Year/Frequency	Method	What did the site present/what was discussed	Issues/concerns or opportunities raised	How issues have been considered and this decisions and outcomes of engagement	Commitments made by Anglo American or existing commitment[5]
Moura, Banana and Theodore	2020, 2021 and 2022	Community Impact/Perception Survey	See Section 3.1	See Section 3.1	Rehabilitation, final land form and final land use Concerns (e.g. sustainability of Moura post mining) considered in Dawson Mine Social Management Plan	n/a
Gangulu	2020 and 2021	Coordination Committee Meeting	See Section 3.2	See Section 3.2	Rehabilitation	Gangulu to be continued to be involved in the mine closure process
Neighbours	2018, 2019, 2021, 2022 and 2023	Neighbours Dinner	See Section 3.3	See Section 3.3	Rehabilitation, final land form and final land use	As per agreements with neighbours
DCRF	2022	Meeting	See Section 3.4	See Section 3.4	Rehabilitation, final land form and final land use Concerns (e.g. sustainability of Moura post mining) considered	To maintain the DCRF meetings

[5] From the Dawson Mine Commitments Register

Stakeholder	Year/Frequency	Method	What did the site present/what was discussed	Issues/concerns or opportunities raised	How issues have been considered and this decisions and outcomes of engagement	Commitments made by Anglo American or existing commitment[5]
					in Dawson Mine Social Management Plan	

5 Community Consultation Plan (CCP)

The Dawson Mine Preliminary Community Consultation Plan is incorporated into the existing Dawson Mine Stakeholder Engagement Plan, which is part of the Social Performance Management System and guided by the Anglo American Social Way 3.0 Policy, Toolkit, and Assurance Framework (AASW)[6] and other relevant Anglo American Standards such as the Mine Closure Standard and Toolbox[7]

5.1 Objectives of Community Consultation

This CCP aligns with the existing Dawson SEP, however, has a specific focus on the implement of the engaging and collaborating with stakeholders in relation to the Dawson Mine's Progressive Rehabilitation and Closure Plan (PRCP).

The objectives of this CCP for the Dawson Mine are to continue to:

- Identify, notify, and engage the community in relation to the rehabilitation and closure of Dawson Mine
- Provide mechanisms to allow ongoing community consultation throughout the remaining stages of the Dawson Mine to communicate progressive rehabilitation, socio-economic and environmental impacts related to mine closure
- Collaborate with the community to identify rehabilitation and closure opportunities and constraints that could influence effectiveness of final land outcomes.

Once Dawson is within 10 – 5 years of closure, the mine closure process will have more of a focus on the Dawson Social Management Plan and Stakeholder Engagement Plan.

5.2 How the community will be engaged

The community will continue to be proactively engaged through existing systems and processes established under the Dawson Mine Stakeholder Engagement Plan:

- One on one meetings
- Gangulu CHIMA Coordination Committee Meetings
- Meetings with Wullli Wulli
- Quarterly DCRF meetings
- Annual Neighbours Dinners
- Issue/topic focus groups/workshops or one on one meetings as required/requested.

Anglo American will continue to maintain established other systems and processes where the stakeholders, including traditional owners, neighbours and other community members can raise, issues, concerns, grievances or opportunities with us:

- Walk in to the Anglo American town office based in Moura
- Call/e-mail the Moura town office
- Grievance procedure.

[6] https://socialway.angloamerican.com/en/about updated from the system formally known as SEAT and SEAT2

[7] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/sustainability/mine-closure-toolbox-version-3-2019.pdf updated from the 2007 version

5.3 Community Consultation Plan

Table 6 sets out the PRCP Community Consultation Action Plan within the context of the Anglo American Mine Closure Standard. The PRCP Community Consultation Action Plan will be delivered in the broader context of the Dawson Mine Social Management Plan, of which the Stakeholder Engagement Plan is a main component.

Table 6: Community Consultation Action Plan

Stakeholder Group	Purpose of Engagement (IAP² Spectrum)[8]	Engagement Method	Engagement Frequency	Information released for community consultation	How feedback/comments will be considered
Draft Closure Plan (15 -10 years from closure)[9]					
Gangulu	Provide updates on rehabilitation and mine closure (consult)	Meeting	As part of CHIMA scheduling	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Wulli Wulli	Provide updates on rehabilitation and mine closure (consult)	Meeting	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Neighbours	Provide updates on rehabilitation and mine closure (consult)	One on one meetings and annual Neighbours Dinner	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Banana Shire Council	Provide updates on rehabilitation and mine closure (consult)	Meeting	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Moura, Banana and Theodore	Respond to any questions or concerns (inform)	One on one meetings	As required	Progress on rehabilitation and progress on PRCP	If any changes need to be made based on feedback.
Detailed Closure Plan (10 -5 years from closure)[10]					
Gangulu	Management of cultural heritage as part of rehabilitation and closure (collaborate)	Meetings and site visits	As required	Information as relevant to the management of cultural heritage	Development and implementation of management plan/s

[8] IAP² International Association for Public Participation Engagement Spectrum

[9] See Table 1

[10] See Table 1

Stakeholder Group	Purpose of Engagement (IAP[2] Spectrum)[8]	Engagement Method	Engagement Frequency	Information released for community consultation	How feedback/comments will be considered
Wullli Wulli	Management of cultural heritage as part of rehabilitation and closure (collaborate)	Meetings and site visits	As required	Information as relevant to the management of cultural heritage	Development and implementation of management plan/s
Neighbours	Management of impacts on neighbours (involve)	Meetings and site visits Neighbours dinner	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s
Banana Shire Council	Management of impacts on infrastructure and services provided in and between Moura, Theodore and Banana (involve)	Meetings	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s
Moura, Theodore and Banana	Management of social and economic impacts (involve)	Meetings/focus groups/workshops	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s
State Government	Management of impacts on infrastructure and services provided in and between Moura, Theodore and Banana (involve)	Meetings	As required	Information as relevant to the management of impacts	Development and implementation of management plan/s

Appendix 1: IAP2 Spectrum

IAP2 Spectrum of Public Participation

IAP2's Spectrum of Public Participation was designed to assist with the selection of the level of participation that defines the public's role in any public participation process. The Spectrum is used internationally, and it is found in public participation plans around the world.

INCREASING IMPACT ON THE DECISION →

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

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Appendix 4.4 Flooding Assessment

TECHNICAL MEMORANDUM

TO: A. McLellan (ERM) **DATE:** March 20, 2024

FROM: L. Palmen (KCB) **FILE NO:** DX70088A01

SUBJECT: Final Landform Flood Modelling Rev.1

INTRODUCTION

KCB Australia Pty Ltd (KCB) have been commissioned by ERM to complete hydrology and flood modelling to support Anglo American's (Anglo) Progressive Rehabilitation and Closure Plan (PRCP).

The Dawson Mining Complex is located within Queensland's Bowen Basin, located approximately 175 km southwest of Gladstone. The mining complex extends over 50 km (north to south) and comprises three distinct operating areas; Dawson North, Dawson Central, and Dawson South. Anglo American are required to prepare a PRCP for submission to the Queensland Government. A PRCP is an element of the Queensland Government's Mined Land Rehabilitation Policy (State of Queensland 2021a) and the Environmental Protection Act 1994 (EP Act). The EP Act (State of Queensland 2022b) requires that all areas disturbed within the relevant mining tenure are rehabilitated to a post-mining land use (PMLU), or managed as a non-use management area (NUMA).

When mining at Dawson ceases in 2079, the site will enter a closure phase. Rehabilitation strategies for the residual voids have been considered as part of the overarching PRCP scope (completed by others), and a final landform design has been provided to KCB for the flood modelling of the site. The results of the flood modelling will provide information on the expected flood immunity of pits and general hydrologic behaviour of the final landform surface.

DESIGN BASIS

Table 1 summarises the inputs and assumptions relating to the final landform flood modelling.

Table 1 Design Basis

Item		Design Basis	Reference
1.0	**Spatial Data**		
1.1	Datum	AGD66 / AMG zone 56 (primary)	
1.2	Model Extent	▪ Hydrologic: Catchment watershed for Kianga, Lonesome, Borehole and Dawson catchments to the downstream (western) side of Dawson Mine. ▪ Hydraulic: Dawson Mining Complex (approx. 5 km wide and 58 km long).	
1.3	Topographic Survey and Surfaces	▪ DEM_Landforms_Closure_Updated_5m_20241501_R2, by others supplied by ERM. ▪ NORTH_1_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ CENTRAL_1_20220417_Dawson_Local_z56_25cm.xyz as 1m grid	(Anglo 2022) (Anglo 2022)

Item		Design Basis	Reference
		▪ CENTRAL_2_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ CENTRAL_3_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ CENTRAL_4_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ RGTCT_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ SOUTH_1_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ SOUTH_2_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ SOUTH_3_20220417_Dawson_Local_z56_25cm.xyz as 1m grid ▪ Moura_2012_Twn_SW_1m grid ▪ Theodore_2011_Twn_SW_1m grid ▪ PRJ40001_GIBIHI_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_KIANGA_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_MOURA-NORTH_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_MOURA-SOUTH_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_NIPAN_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_NORTH_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_SOUTH_Aug21_AMG66z56.dwg as 2 m grid ▪ PRJ40001_THEODORE_Aug21_AMG66z56.dwg as 2 m grid ▪ Regional Survey ALOS World 3D V 3.2 – 30 m grid	(Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (DNRME 2011) (DNRME 2011) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (Anglo 2022) (JAXA 2021)
1.4	Aerial Photography and Features	Bing and Google sourced imagery	Bing Maps Google Maps
2.0	**Hydrology**		
2.1	Flood Events	▪ 1:20 AEP, 1:50 AEP, 1:100 AEP, 1:200 AEP, 1:500 AEP ,1:1,000 AEP, 1:2,000 AEP, 1:5,000 AEP, 1:10,000 AEP, PMPF	
2.2	Design Rainfall Guidelines	▪ Rainfall durations up to 6 hours: Generalised Short Duration Method (GSDM) ▪ Rainfall durations between 6 and 24 hours: interpolation ▪ Rainfall durations between 24 and 120 hours: Generalised Tropical Storm Method (Revised)	(BOM, 2003) (BOM 2005)
2.3	Hydrologic Model	RORB V6.45	(HARC, 2019)
2.4	Hydrologic Model Configuration	Borehole Creek ▪ Catchment Area: 57.3 km^2 ▪ k_c: 7.52 ▪ m: 0.8 ▪ Initial Loss: 47 mm (0 mm PMF) Continuing Loss: 0.7 mm/hr (1 mm PMPF) Kianga Creek ▪ Catchment Area: 307.6 km^2 ▪ k_c: 18.33 ▪ m: 0.8 ▪ Initial Loss: 41 mm (0 mm PMF) Continuing Loss: 1.1 mm/hr (1 mm PMPF) Dawson River ▪ Catchment Area: 26,477 km^2 ▪ k_c: 194.36 ▪ m: 0.8 ▪ Initial Loss: 59 mm (0 mm PMPF) Continuing Loss: 2.1 mm/hr (1 mm PMPF) Local Rainfall (adopted representative catchment) ▪ Catchment Area: 12.7 km^2	(Ball, et al., 2019)

<table>
<tr><th colspan="2">Item</th><th>Design Basis</th><th>Reference</th></tr>
<tr><td></td><td></td><td>

k_c: 3.38
m: 0.8
Initial Loss: 25 mm (0 mm PMF)
Continuing Loss: 1.1 mm/hr (1 mm PMPF)

</td><td></td></tr>
<tr><td>2.5</td><td>Design Rainfall Critical Event</td><td>Adopted critical events (h) and temporal pattern (TP)
<table>
<tr><th>Event (AEP)</th><th>Borehole</th><th>Kianga</th><th>Dawson</th><th>Local</th></tr>
<tr><td>1:20</td><td>12h TP25</td><td>24h TP3</td><td>48 h TP6</td><td>2h TP13</td></tr>
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<tr><td>1:500</td><td>9h TP11</td><td>12h TP4</td><td>36h TP6</td><td>1.5h TP2</td></tr>
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</td><td></td></tr>
<tr><td>2.6</td><td>Climate Change</td><td>Long-term (2081-2100), using a climate scenario of SSP3-7.0 (2.7 - 5.0), adopting a median of median of 3.6°C. Factors to extreme rainfall depth, initial and continuing losses applied as per the draft update to the Climate Change Considerations chapter in Australian Rainfall and Runoff: A Guide to Flood Estimation.</td><td>(DCCEEW 2023)</td></tr>
<tr><td>3.0</td><td colspan="3">Hydraulic Model</td></tr>
<tr><td>3.1</td><td>Hydraulic Model</td><td>TUFLOW Single Precision 2023-03-AC (latest release at the time of modelling), heavily parallelised compute (HPC) solution scheme.</td><td></td></tr>
<tr><td>3.2</td><td>Model Time Step</td><td>Variable, automatically selected to maintain model stability.</td><td></td></tr>
<tr><td>3.3</td><td>Grid Size</td><td>6 m hydraulic computation, 3 m output resolution, sub-grid sampling to 1 m.</td><td></td></tr>
<tr><td>3.4</td><td>Boundary Conditions</td><td>

Regional Upstream: QT boundaries
Regional Downstream: HQ boundaries
Local Catchment Upstream: Direct rainfall (excess)
Local Catchment Downstream: Various HQ boundaries based on normal depth at the specific location.

</td><td></td></tr>
<tr><td>3.6</td><td>Hydraulic Structures</td><td>No hydraulic structures have been included in the model</td><td></td></tr>
<tr><td>3.7</td><td>Hydraulic Roughness</td><td>Varies, spatially distributed using vegetation-density relation to Manning’s ‘n’ roughness value, consistent with KCB (2022b).</td><td>(Gill, et al. 2017)</td></tr>
<tr><td>3.8</td><td>Result Mapping</td><td>Results are an envelope of modelled maximums.
Following results provided as raster data:
Inundation extent, maximum elevation, and maximum depth.
Final Landform
Dawson_20y_d_HR_Max.tif
Dawson_20y_h_HR_Max.tif
Dawson_50y_d_HR_Max.tif
Dawson_50y_h_HR_Max.tif
Dawson_100y_d_HR_Max.tif
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Dawson_1k_h_HR_Max.tif</td><td></td></tr>
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Item		Design Basis	Reference
		Dawson_2k_d_HR_Max.tif Dawson_2k_h_HR_Max.tif Dawson_5k_d_HR_Max.tif Dawson_5k_h_HR_Max.tif Dawson_10k_d_HR_Max.tif Dawson_10k_h_HR_Max.tif Dawson_PMF_d_HR_Max.tif Dawson_PMF_h_HR_Max.tif Final Landform with Climate Change SSP3-7.0 at 2100 Dawson_FLCC_1k_d_HR_Max.tif Dawson_FLCC_1k_h_HR_Max.tif Following results provided as pdf layout data: MAXIMUM DEPTH - 1_1K AEP FINAL LANDFORM.pdf MAXIMUM DEPTH - 1_1K AEP FINAL LANDFORM CLIMATE CHANGE SSP3-7.0 2100.pdf	

HYDROLOGY

The hydrologic assessment has used four separate hydrologic models to estimate the critical rainfall events across the site. The arrangement allows the major regional waterways (Borehole Creek, Kianga Creek and the Dawson River) to be estimated separately from the local site rainfall. The local rainfall was estimated by adopting a representative catchment within the runoff routing model. The critical rainfall duration and temporal pattern for each and annual exceedance probability (AEP) was selected based on the hydrologic model results (refer Table 1). The respective flows and rainfall events were adopted for using within the hydraulic model.

Consideration of Climate Change

The recently released draft update to the Climate Change Considerations chapter in Australian Rainfall and Runoff: A Guide to Flood Estimation (DCCEEW 2023) provides updated guidance in relation to the estimated impact of climate change upon extreme rainfall and flood risk. While it is acknowledged that the guidance is in draft, it is considered suitable for estimation of future flooding impact given it is based on recent climatic science, projections and observations.

The assessment has adopted the SSP3-7.0 (high) socioeconomic pathway with the long-term projected date of 2100. The median of published estimates has been used to factor event depths and losses.

HYDRAULICS

The assessment has used the two-dimensional Tuflow hydrodynamic model to simulate the flood flows using the final landform surface. Details of the topographical arrangement and simulation are provided in Table 1. The regional hydrologic model inputs are based on the runoff routing flows from the respective hydrologic models. The local rainfall was simulated using a direct rainfall method, utilising the rainfall excess hyetograph from the hydrologic assessment. This approach provides a detailed estimate of the inundation locations and flow paths across the final landform.

The hydraulic outputs for the multiple hydraulic models were combined to present the estimated maximum flood depths and extents across the site.

RESULTS

The results of the flood modelling are provided in raster format for the AEPs considered, for both the current and climate change scenarios. The 1:1,000 AEP, maximum depth results for the existing and climate change scenarios are also provided as layouts in Attachment I.

SUMMARY

This memorandum provides a comparative assessment of flood behaviour based on the final landform design surface developed as part of the wider PRCP project. The results of the assessment may be used to assess the hydrologic behaviour of the design surface, including the expected flood immunity of pits and conveyance of regional waterways through the site.

CLOSING

This memorandum is an instrument of service of Klohn Crippen Berger (KCB). The memorandum has been prepared for the use of ERM (Client) for the specific application to the Dawson Central and North GW PRCP, and may be published or disclosed by the Client to Anglo American.

KCB has prepared this memorandum in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered; however, the use of this memorandum will be at the user's sole risk absolutely and in all respects, and KCB makes no warranty, express or implied. This memorandum may not be relied upon by any person other than the Client or Anglo American without KCB's written consent.

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2. The observations, findings and conclusions in this memorandum are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.

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4. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the memorandum.

5. This memorandum is electronically signed and sealed and its electronic form is considered the original. A printed version of the original can be relied upon as a true copy when supplied by the author or when printed from its original electronic file.

Yours truly,

KCB AUSTRALIA PTY LTD.

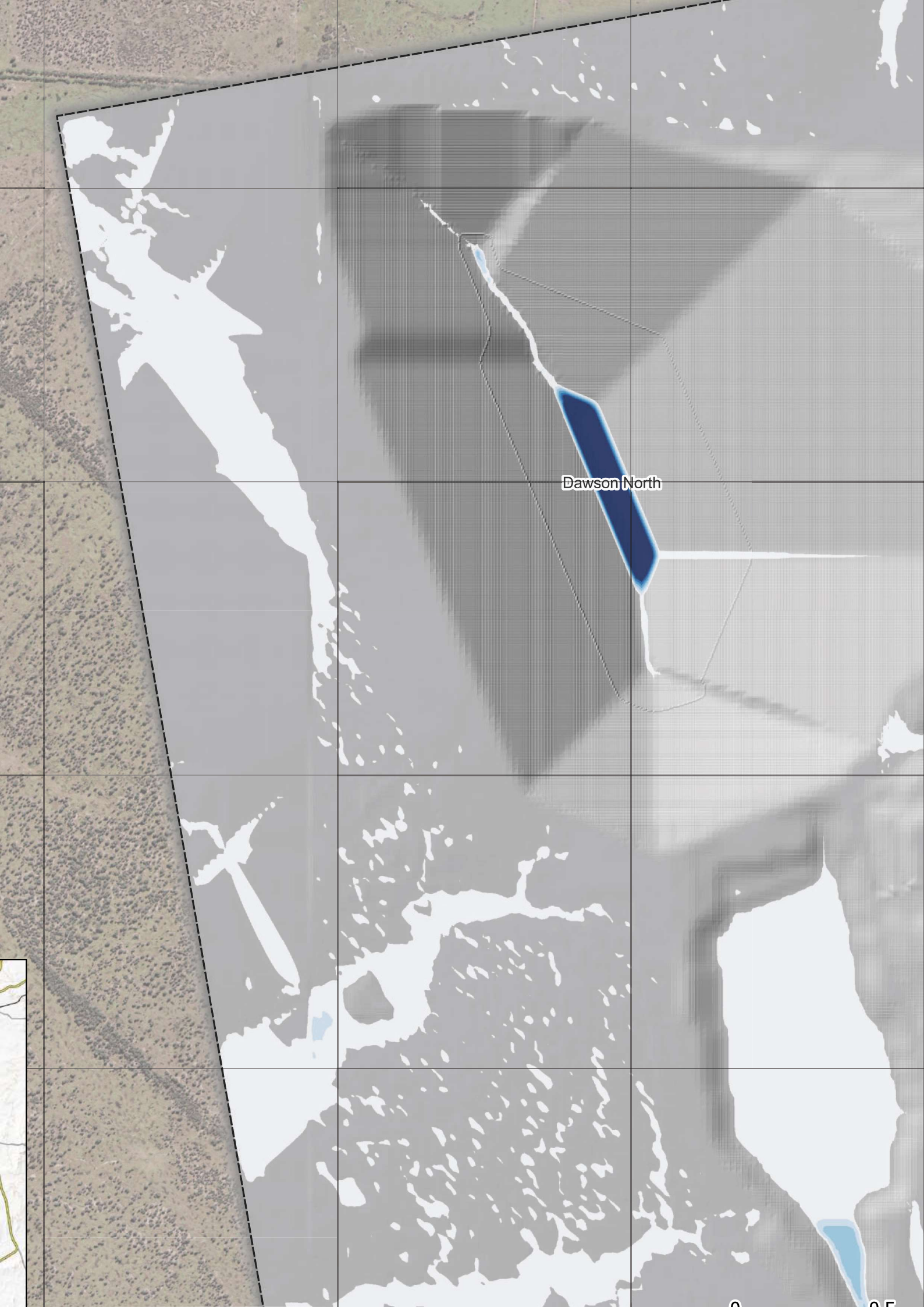
Luke Palmen CPEng RPEQ
Senior Civil Engineer

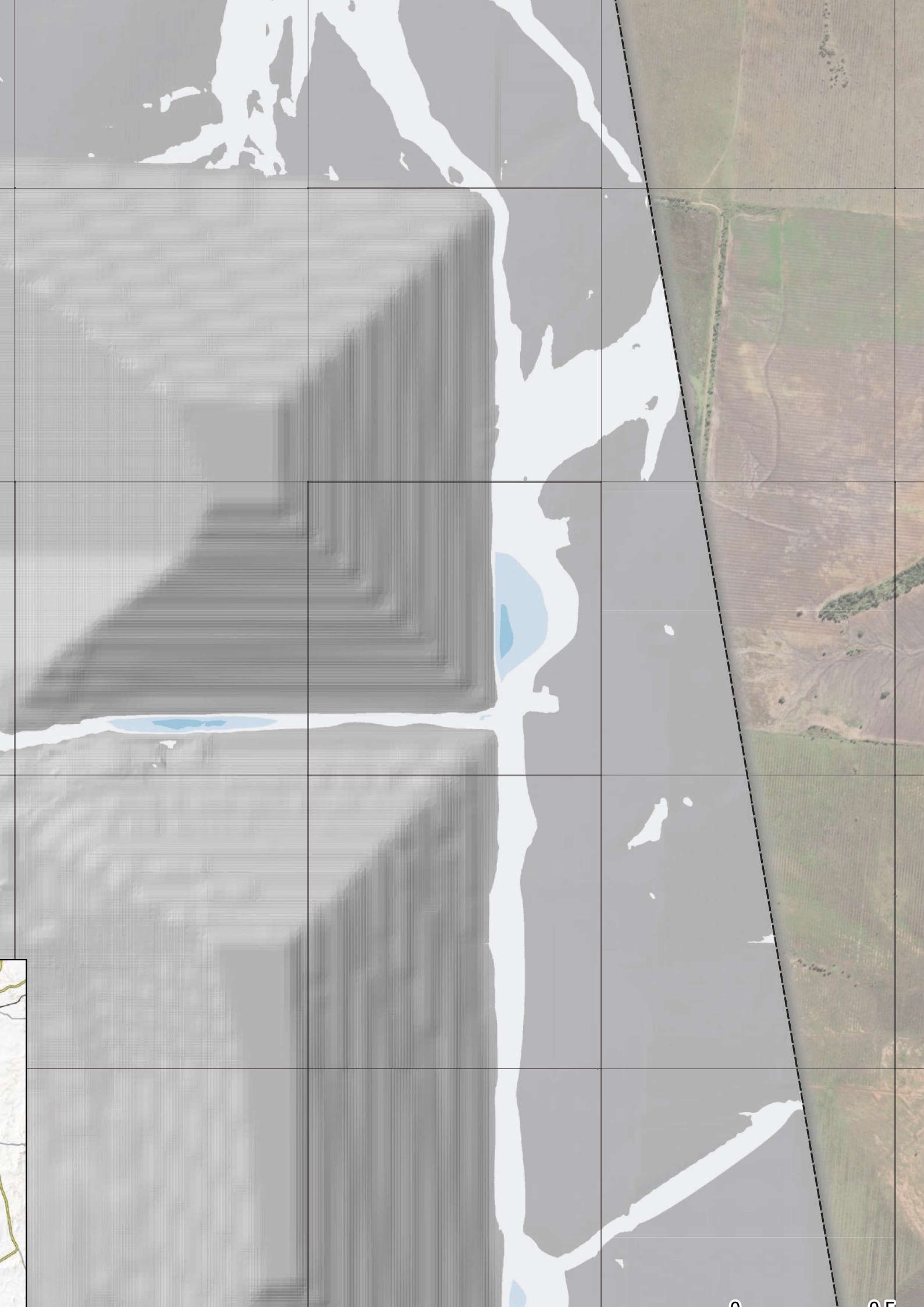
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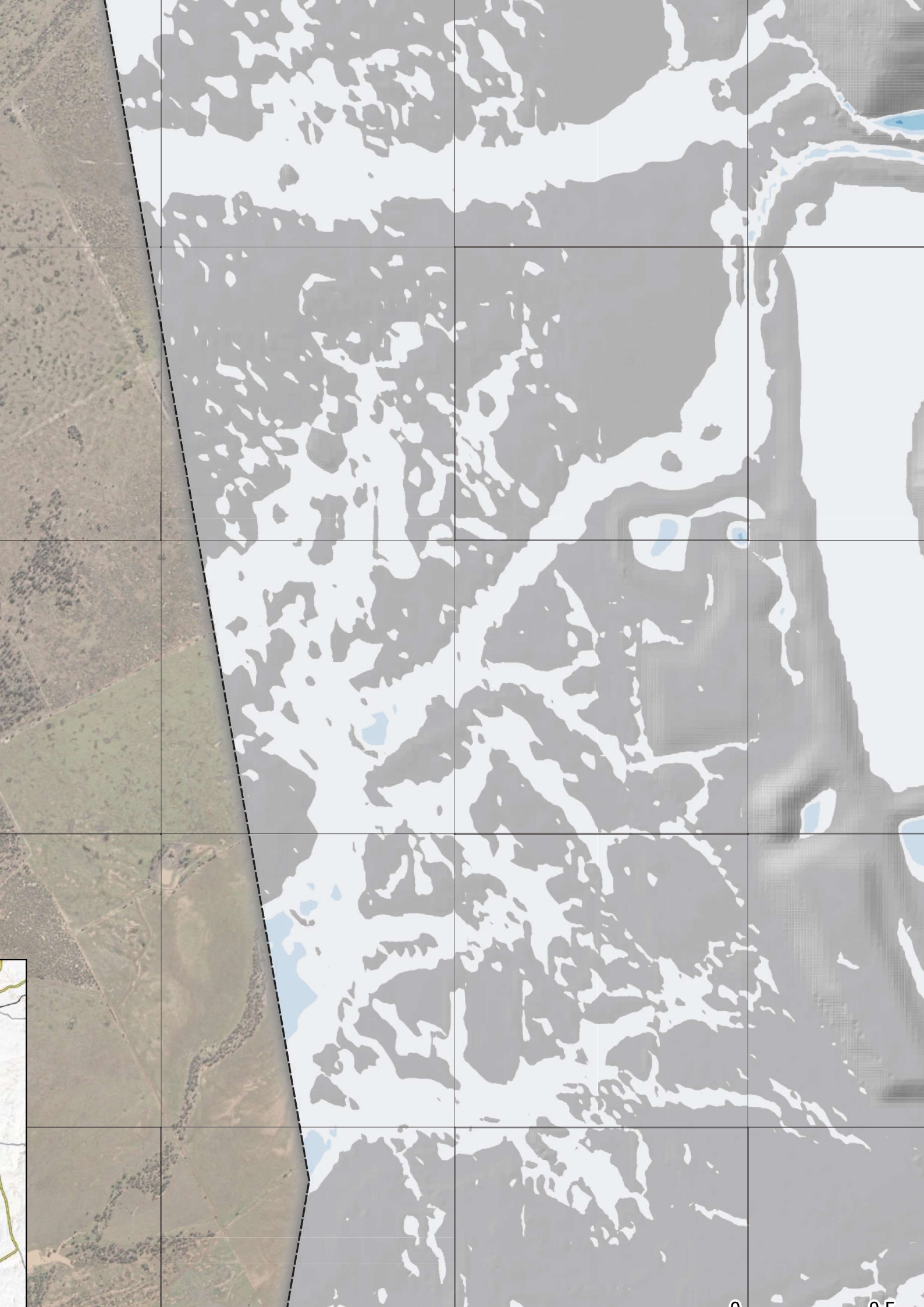
ATTACHMENT I

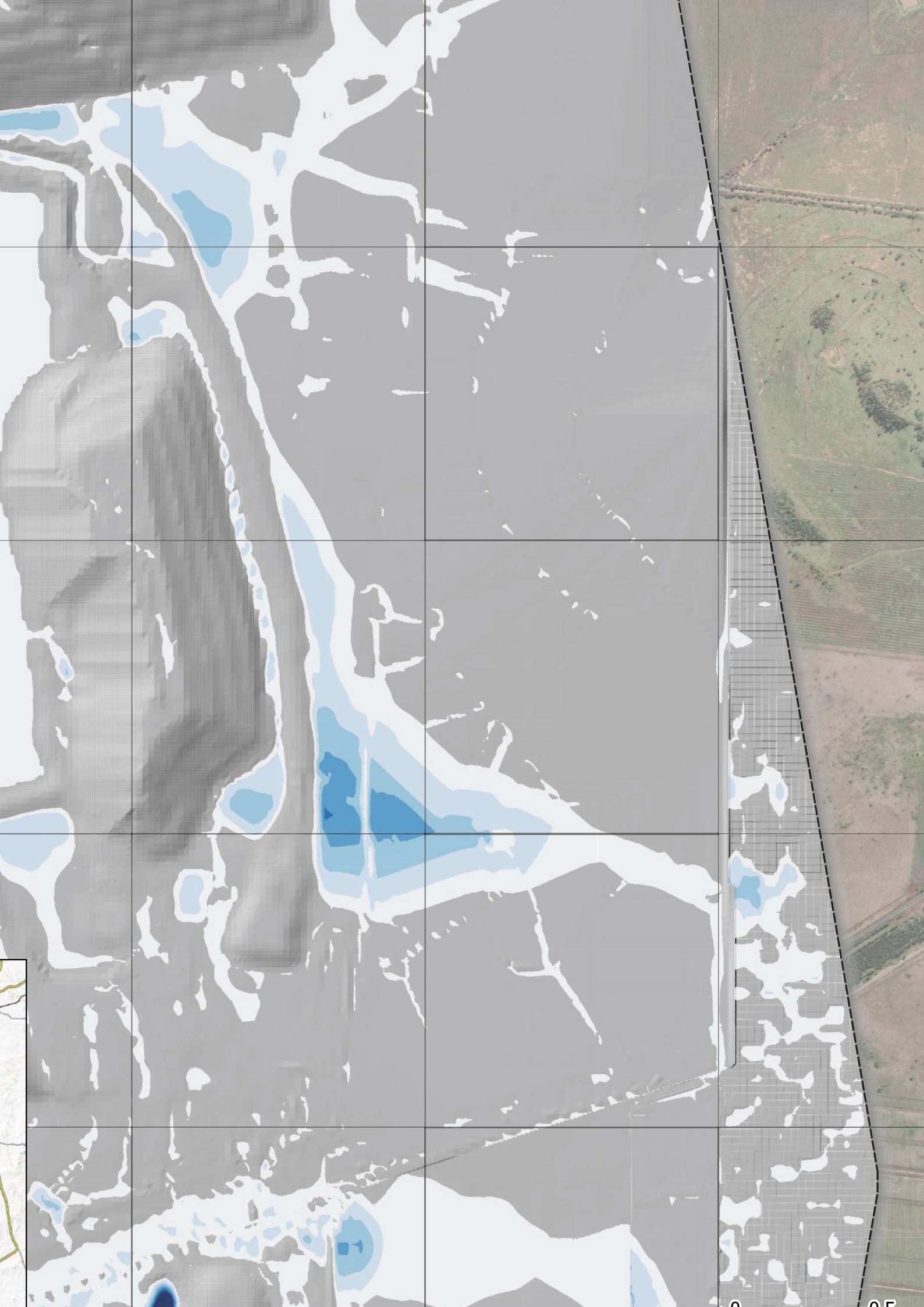
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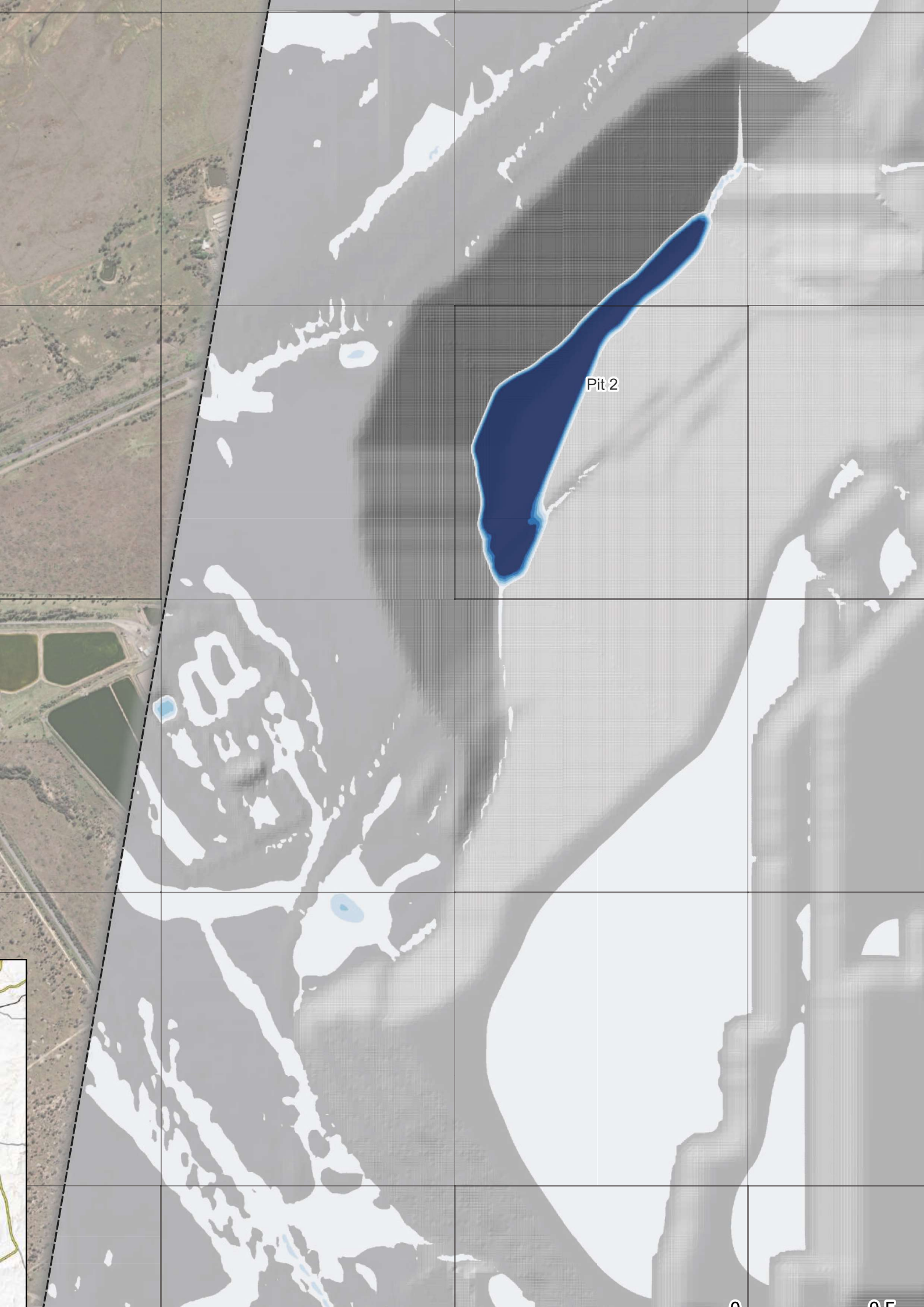
1:1,000 AEP Maximum Depth
1:1,000 AEP Maximum Depth Climate Change

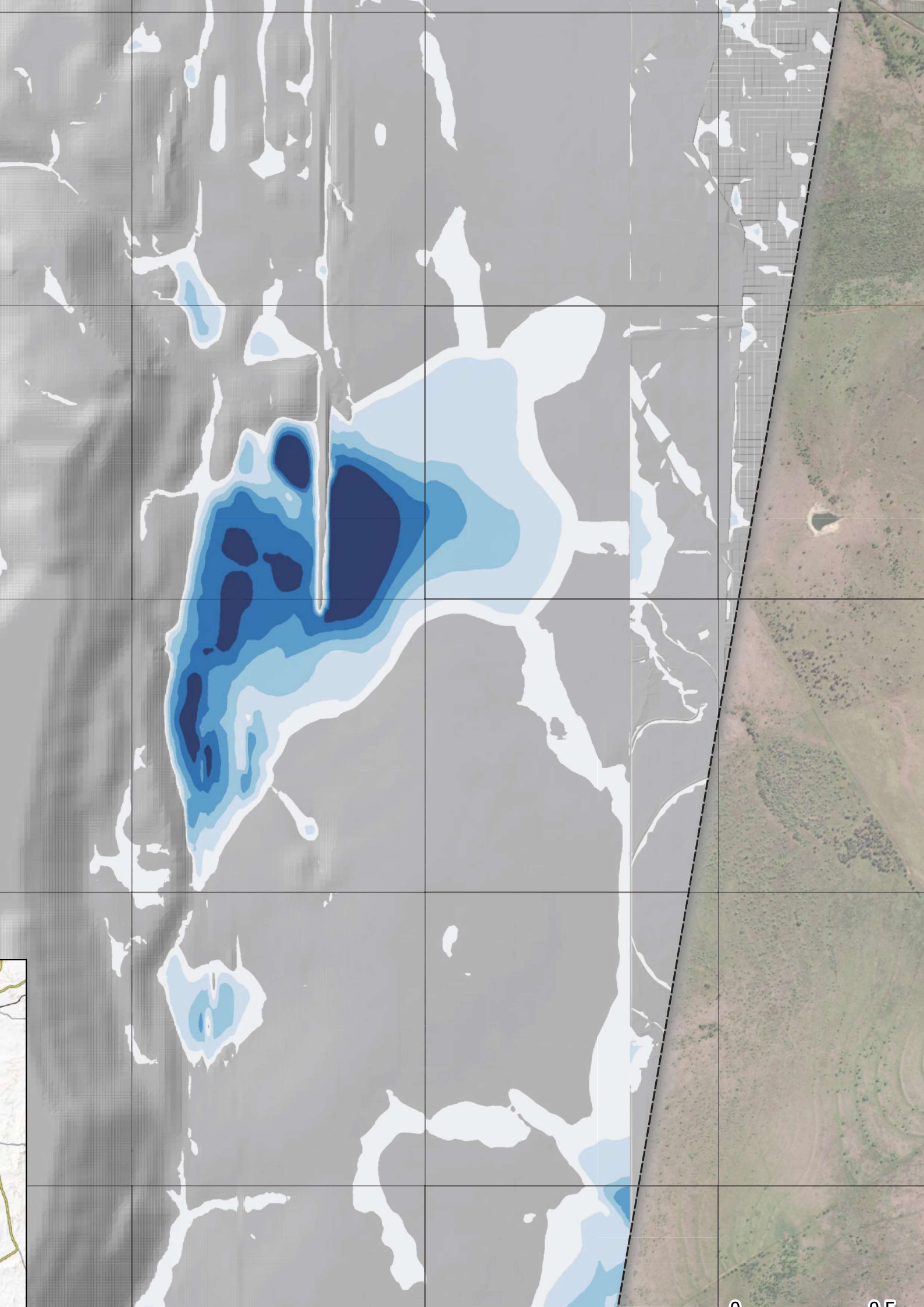

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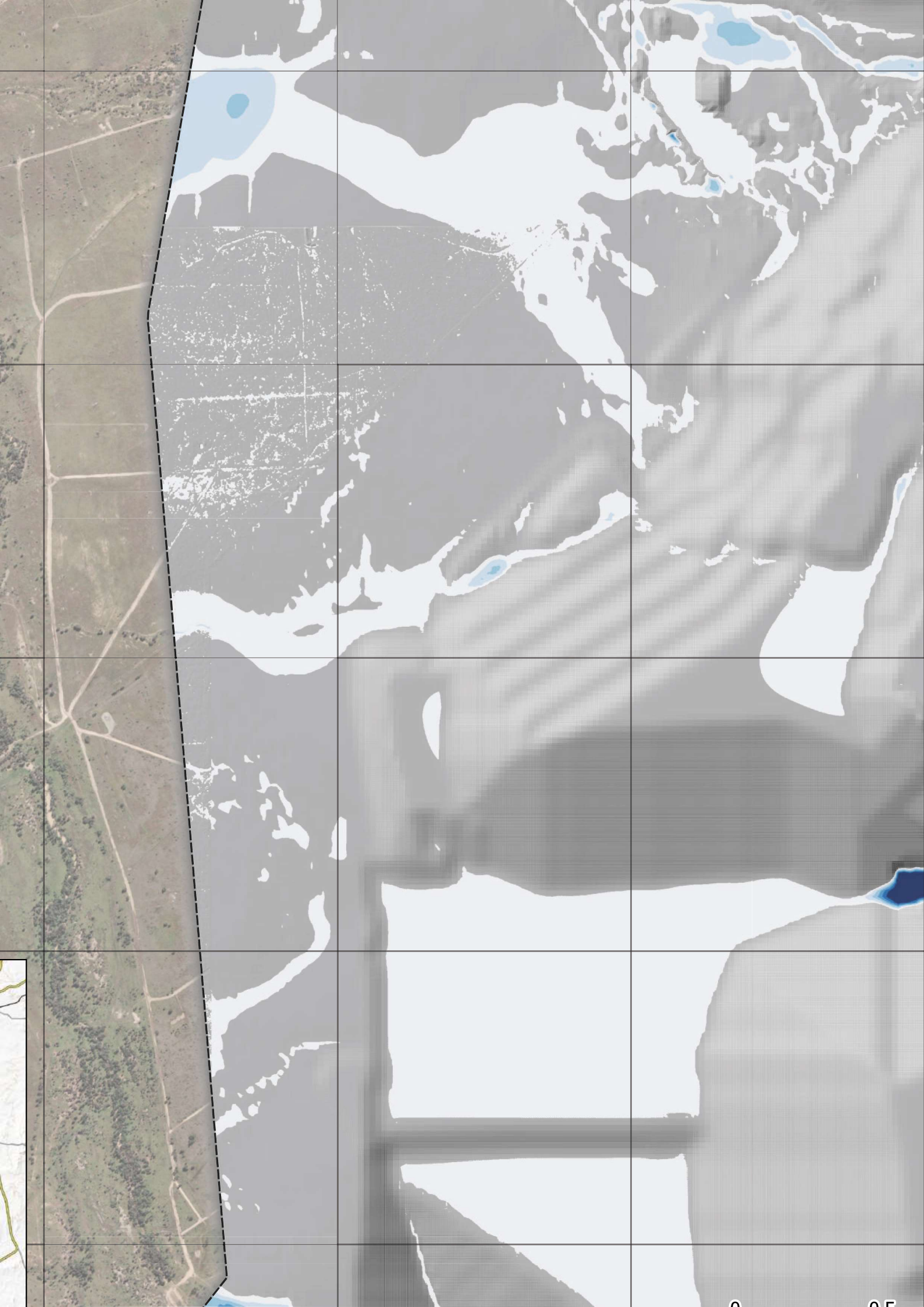


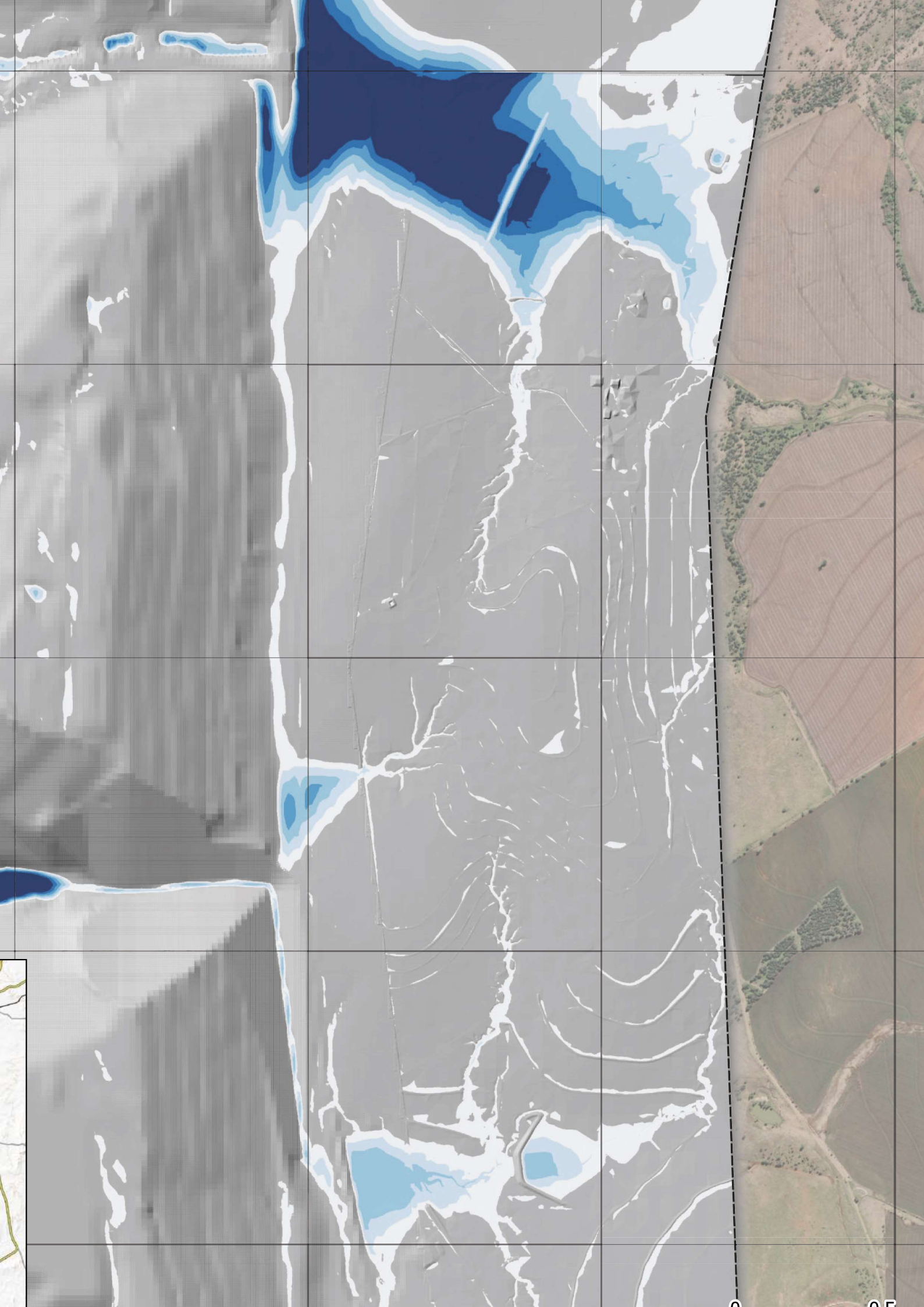


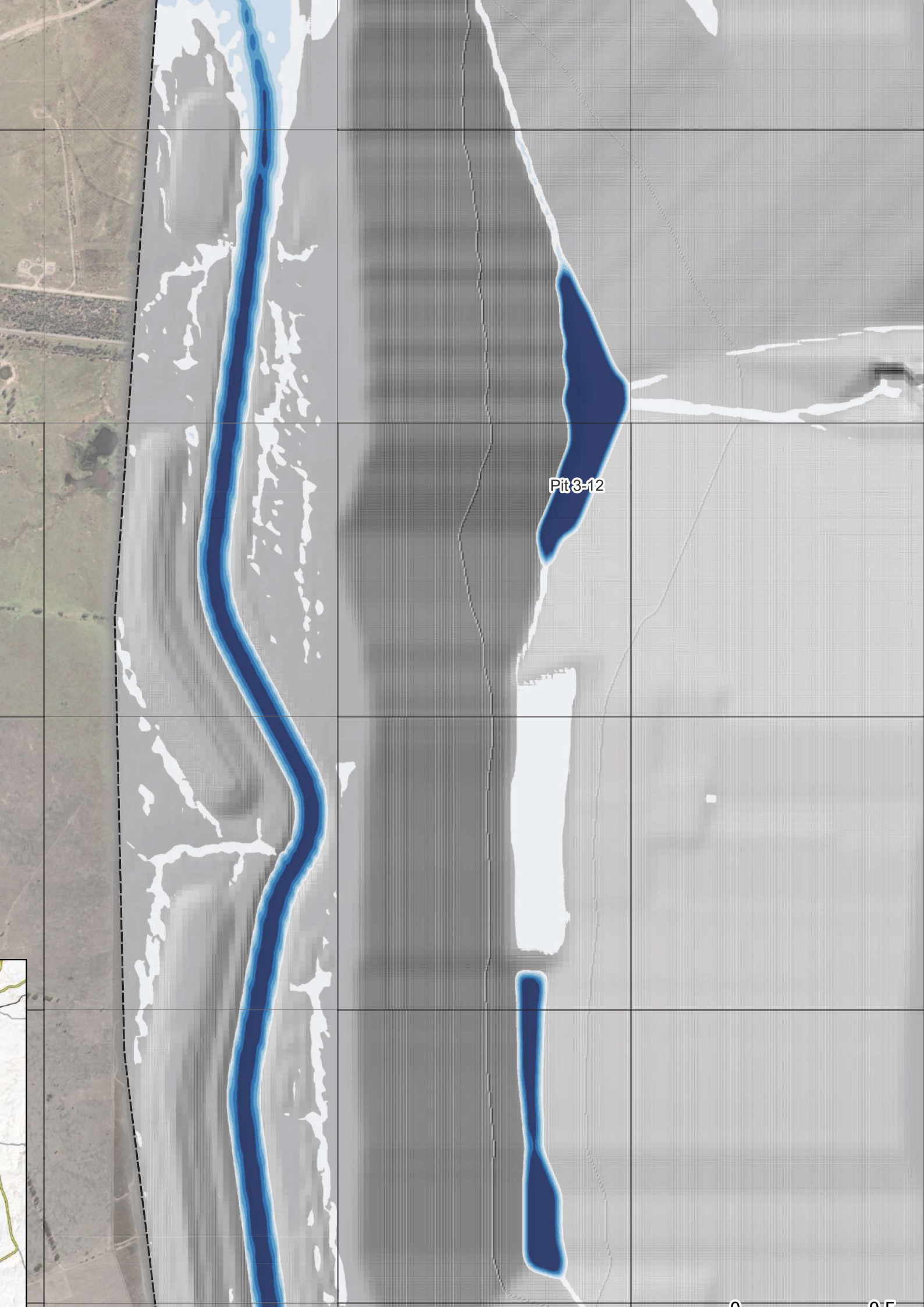


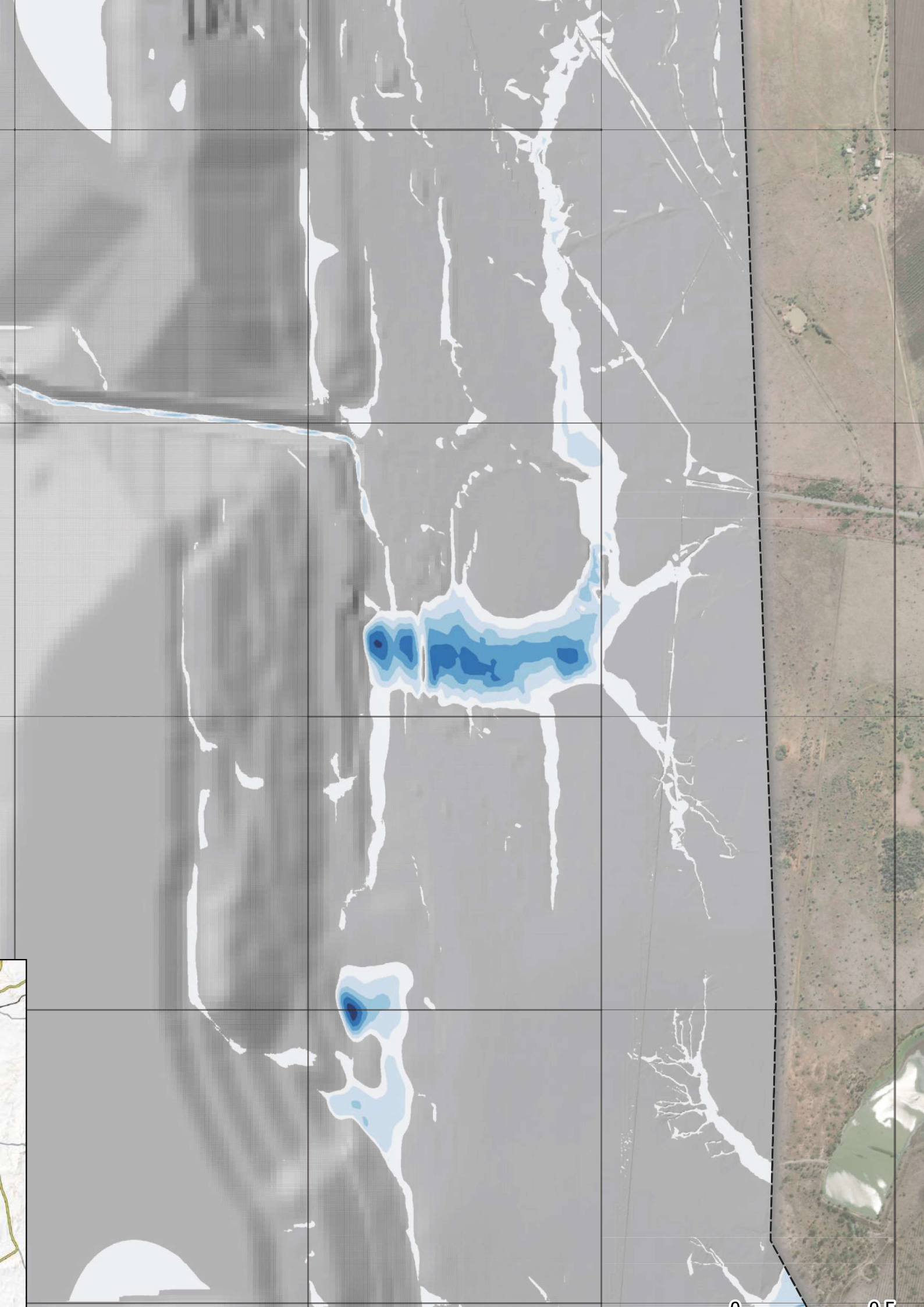

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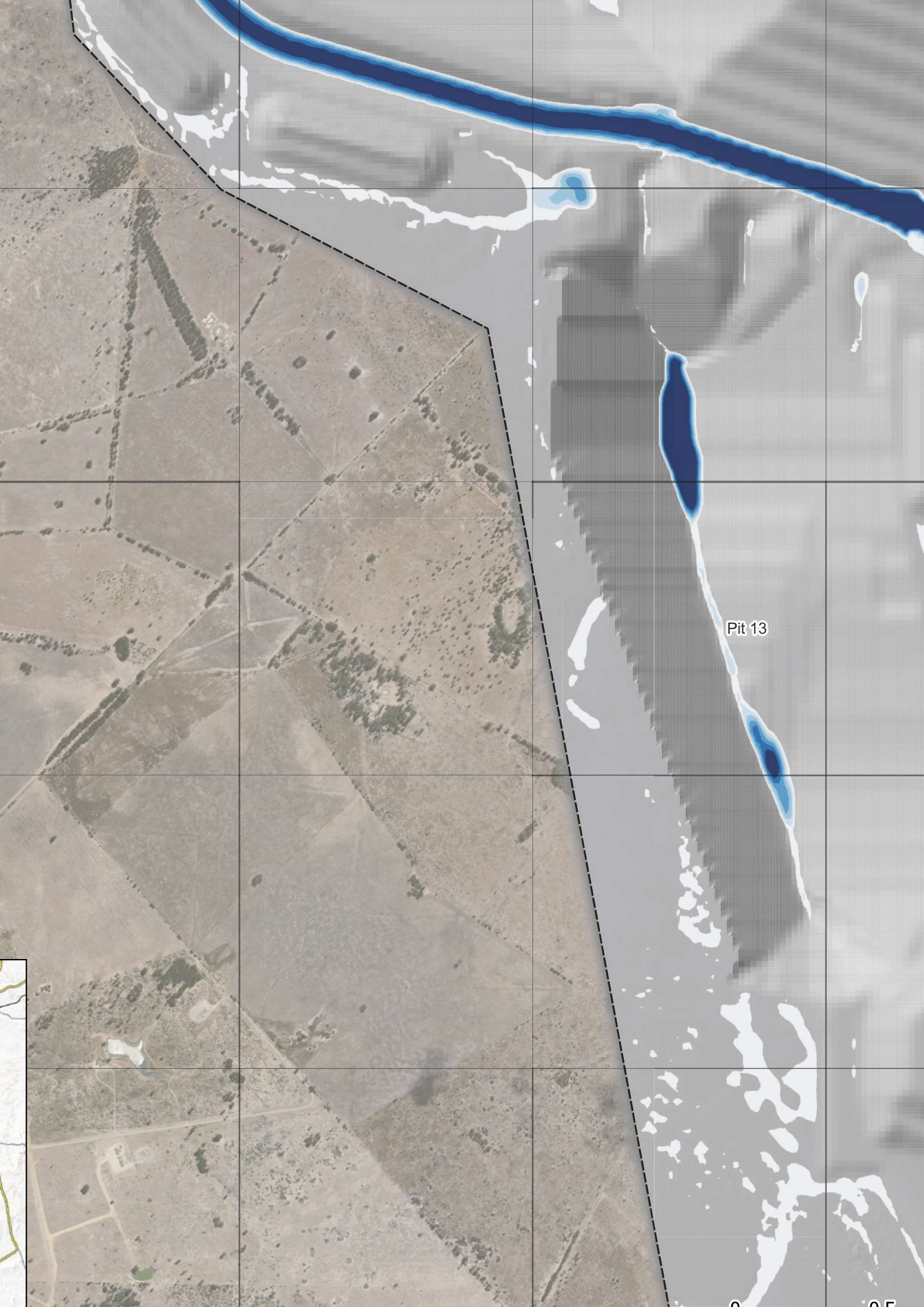


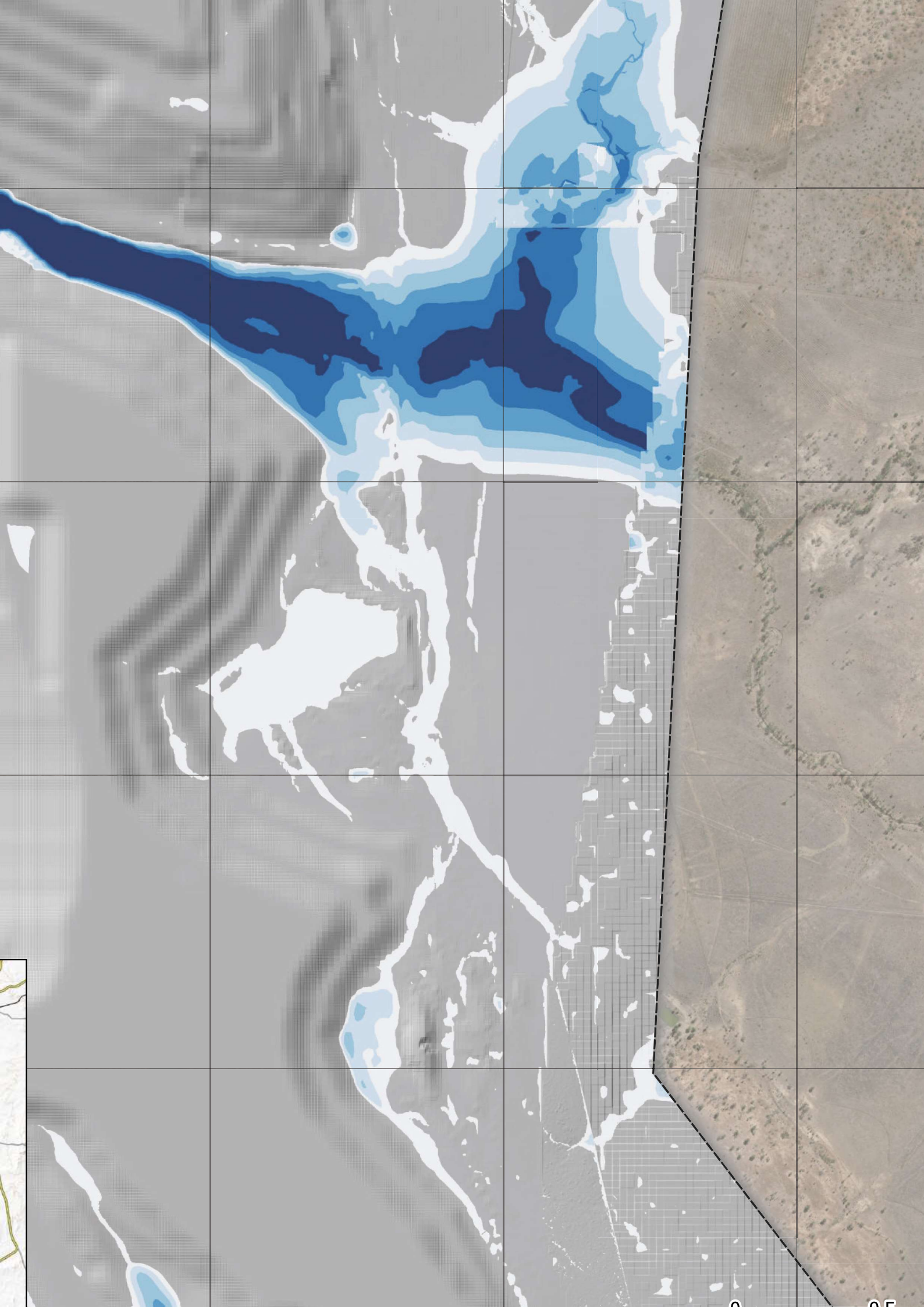


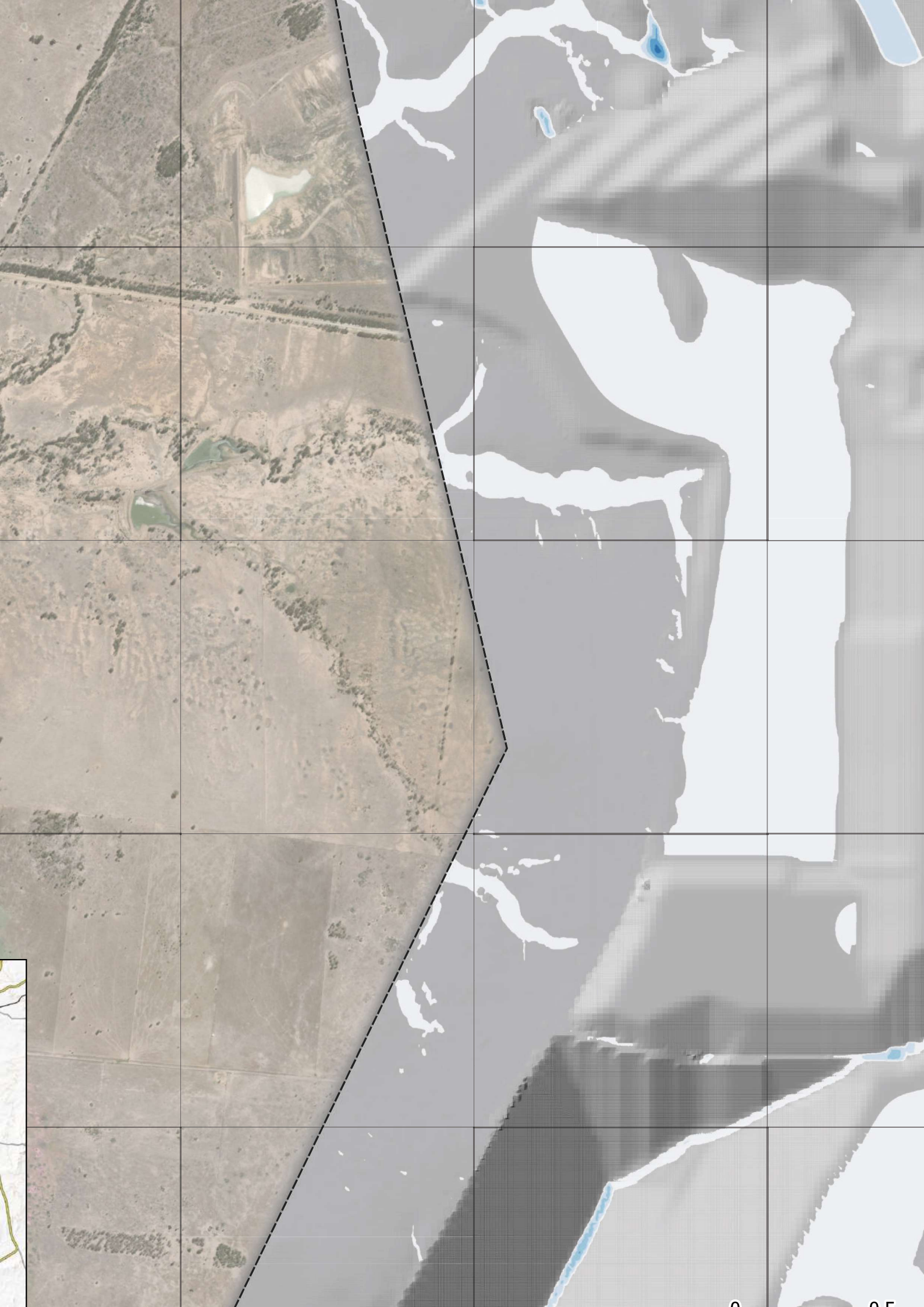


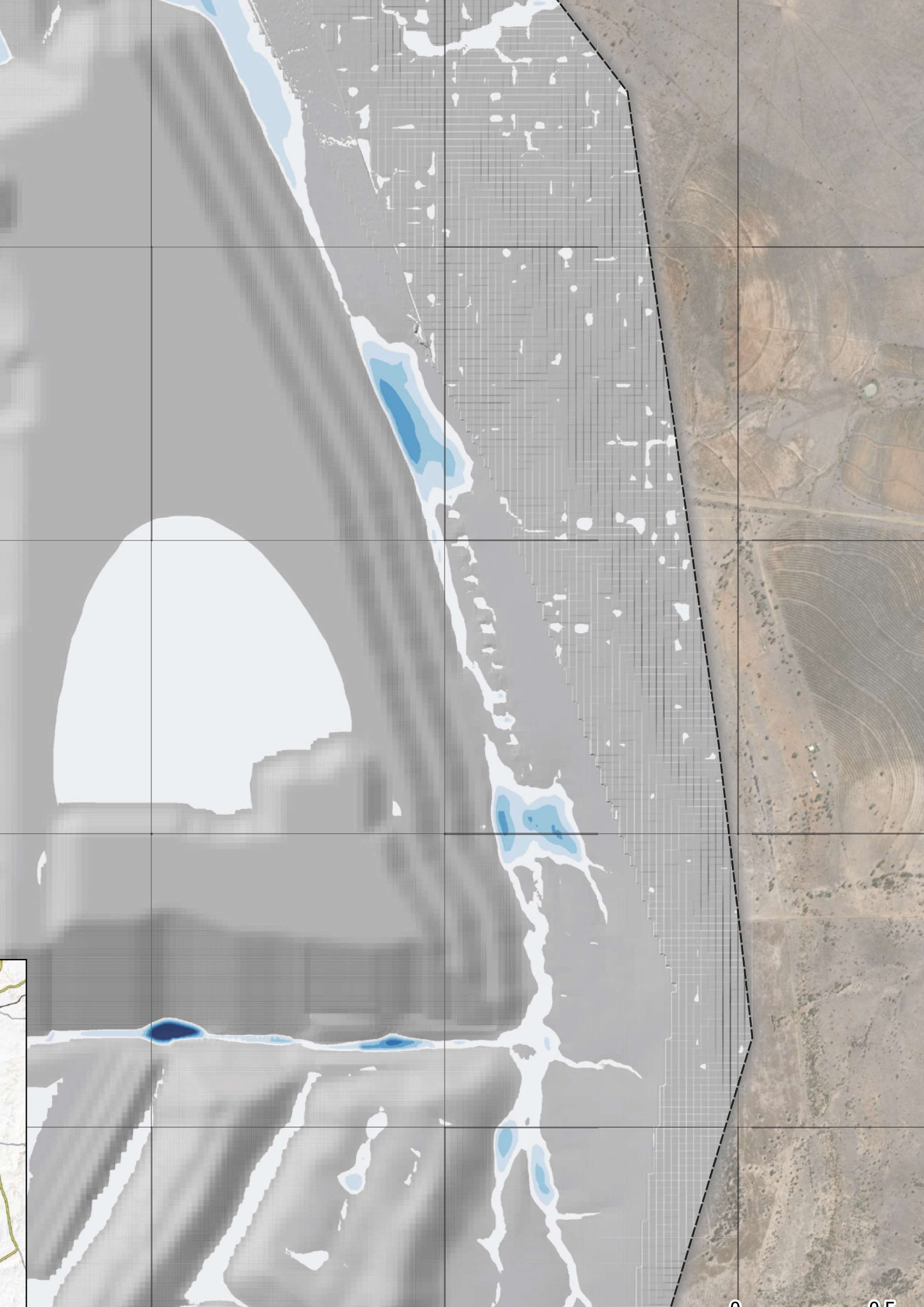

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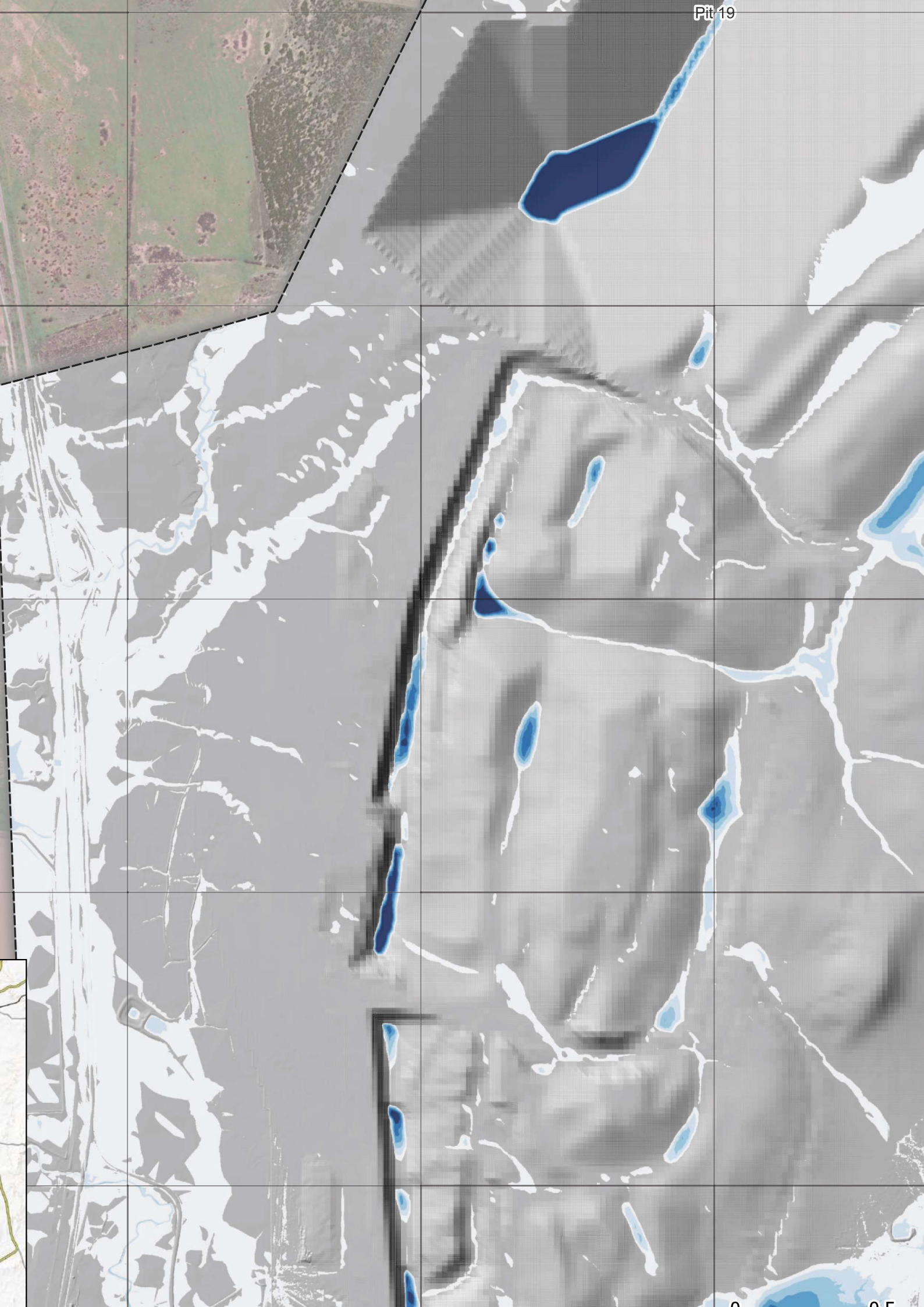


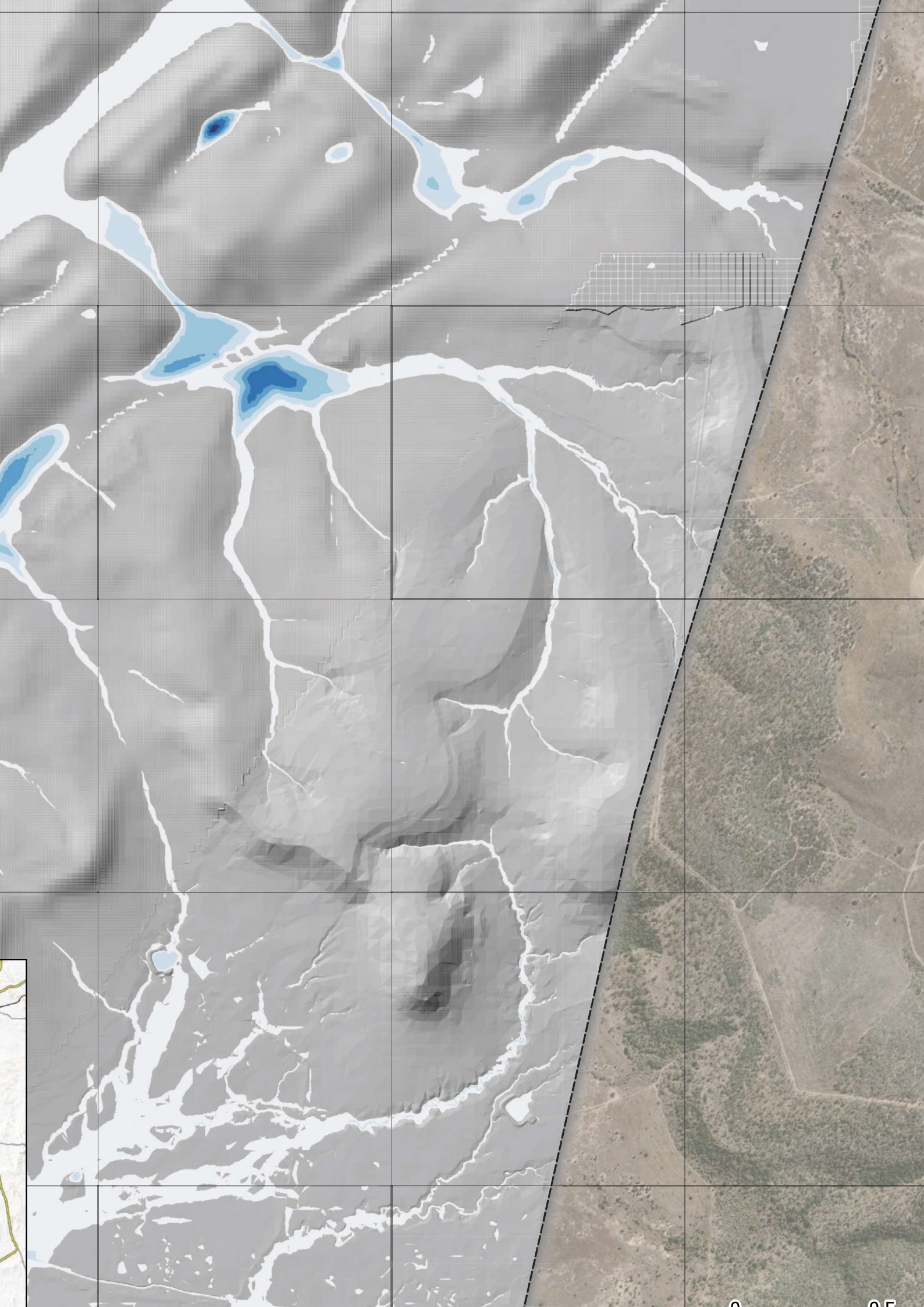

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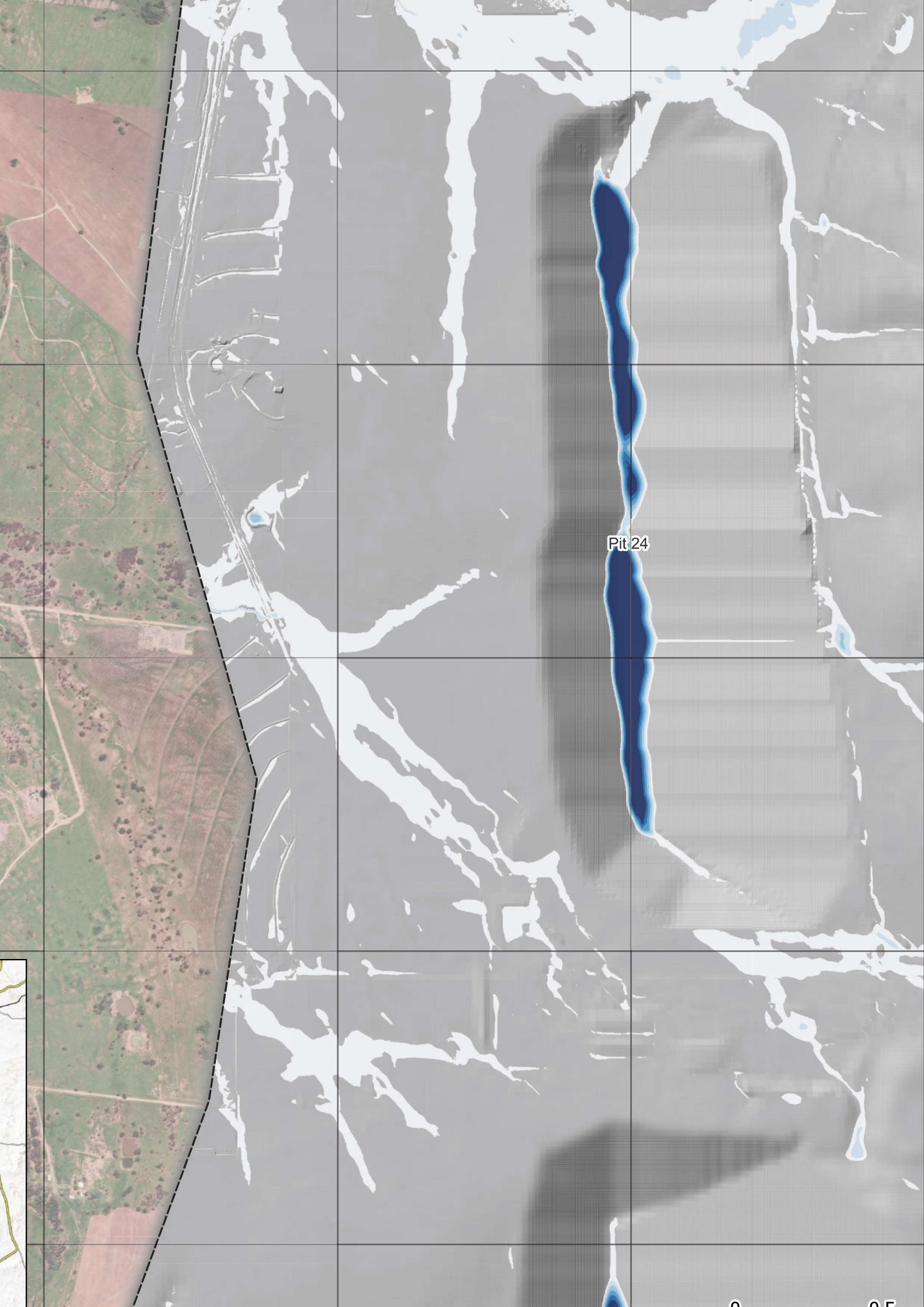


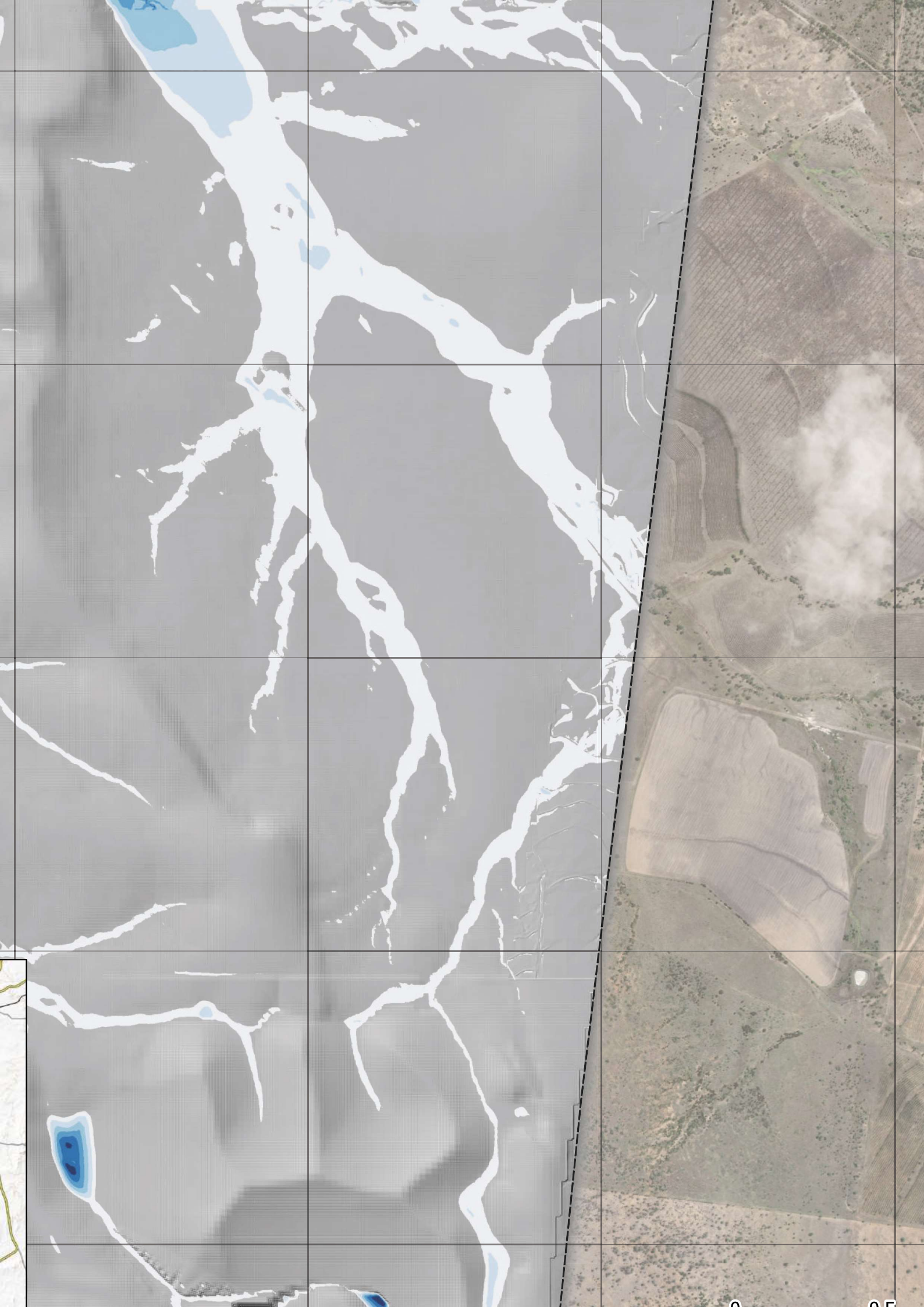


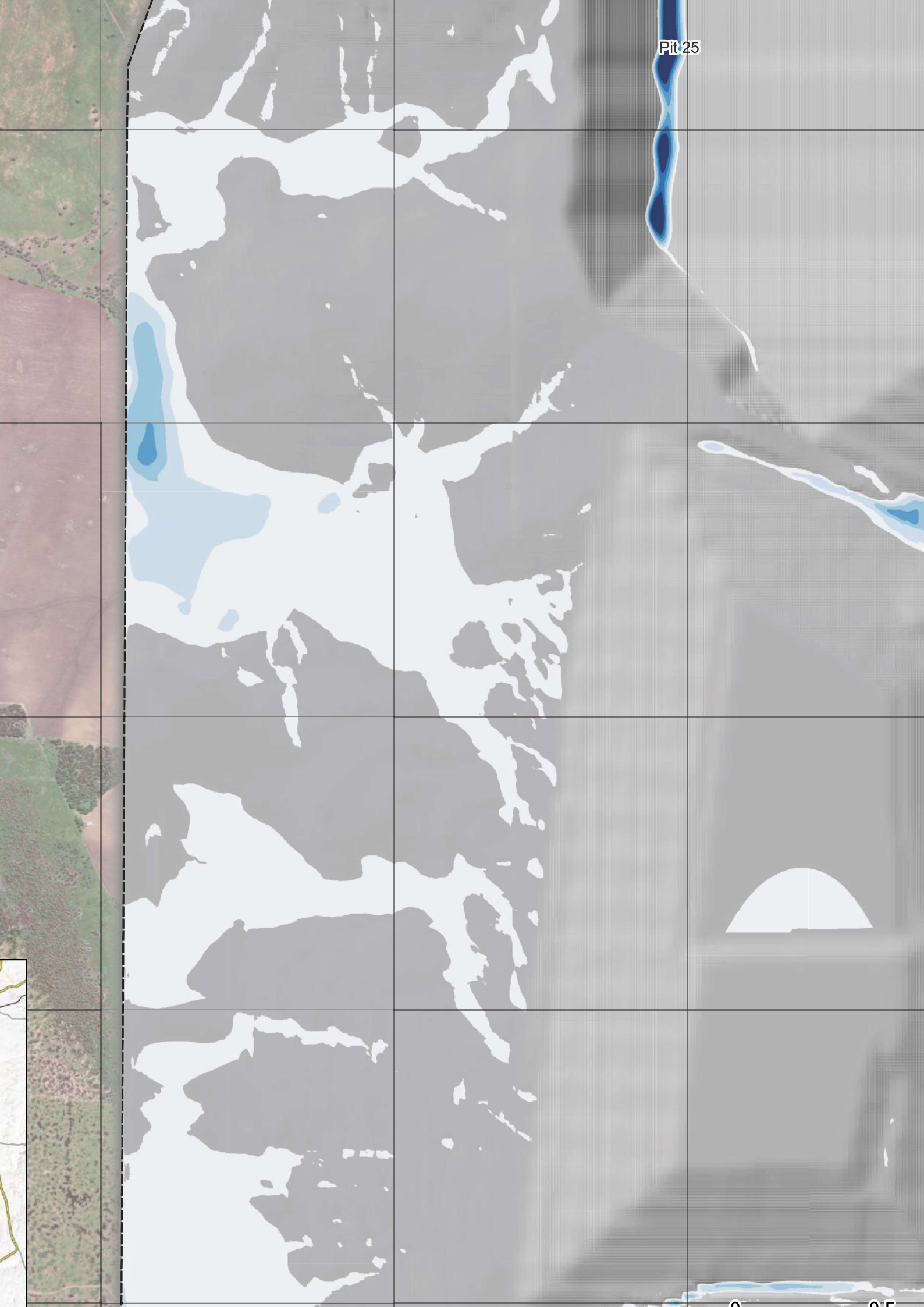


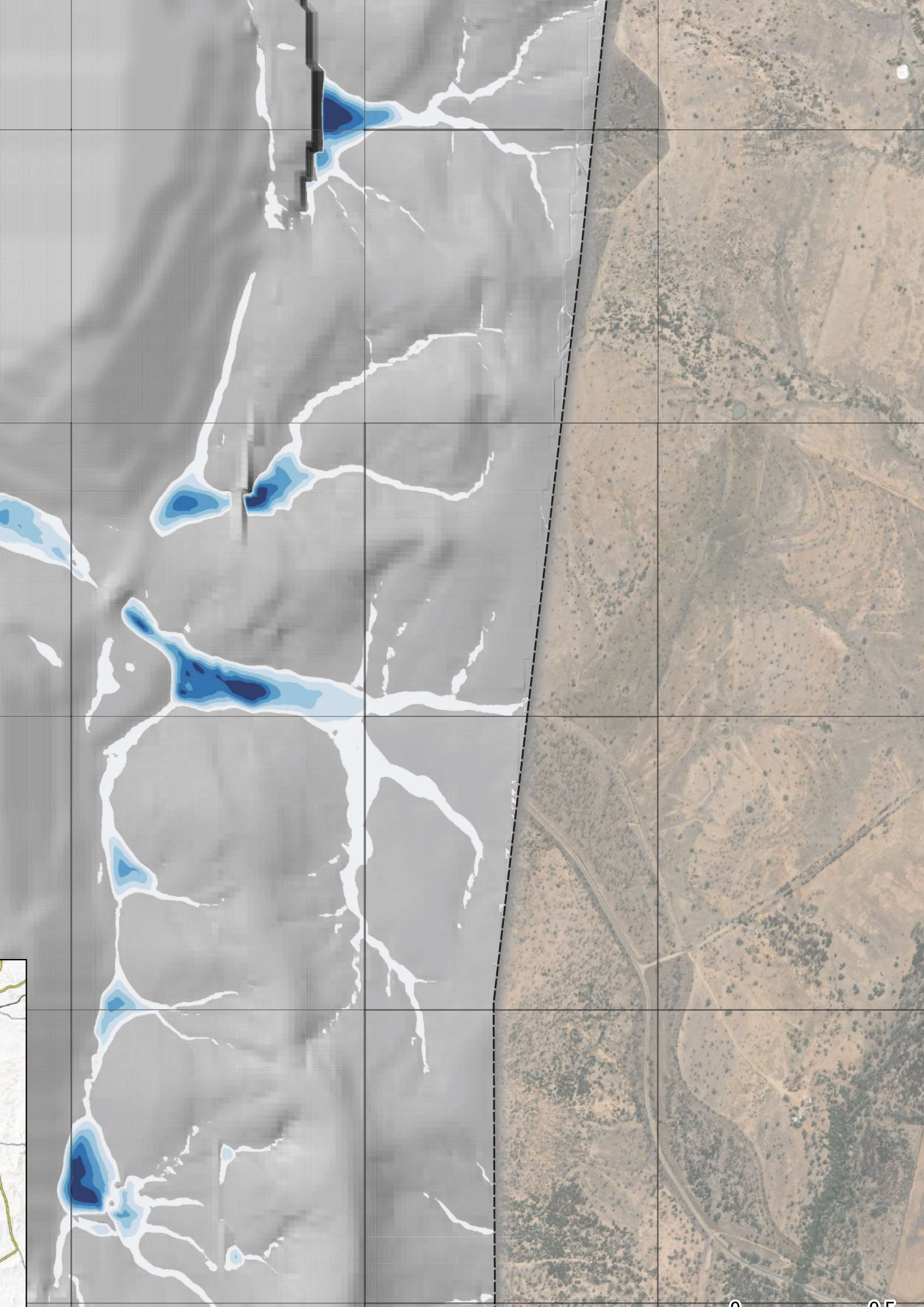

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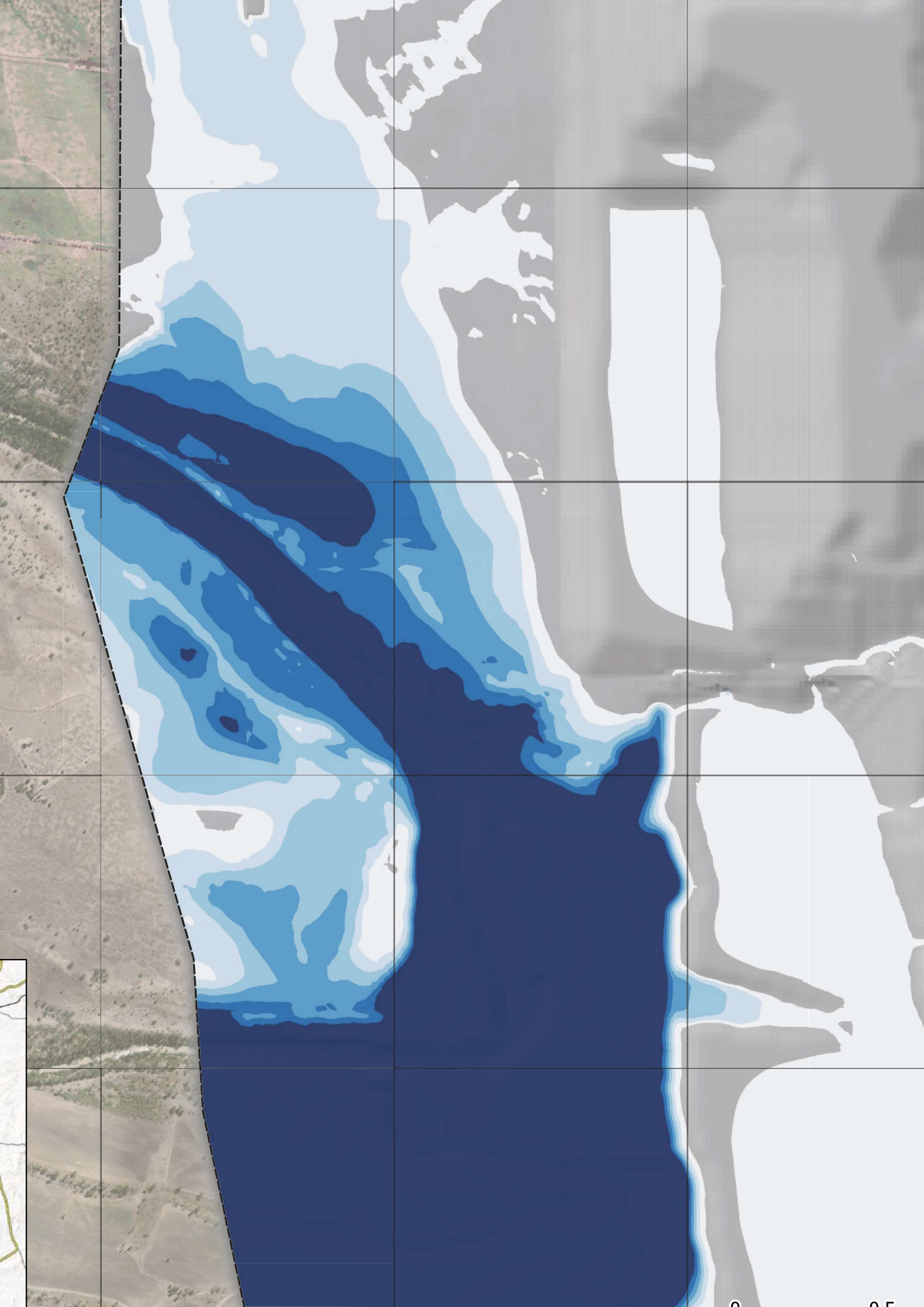


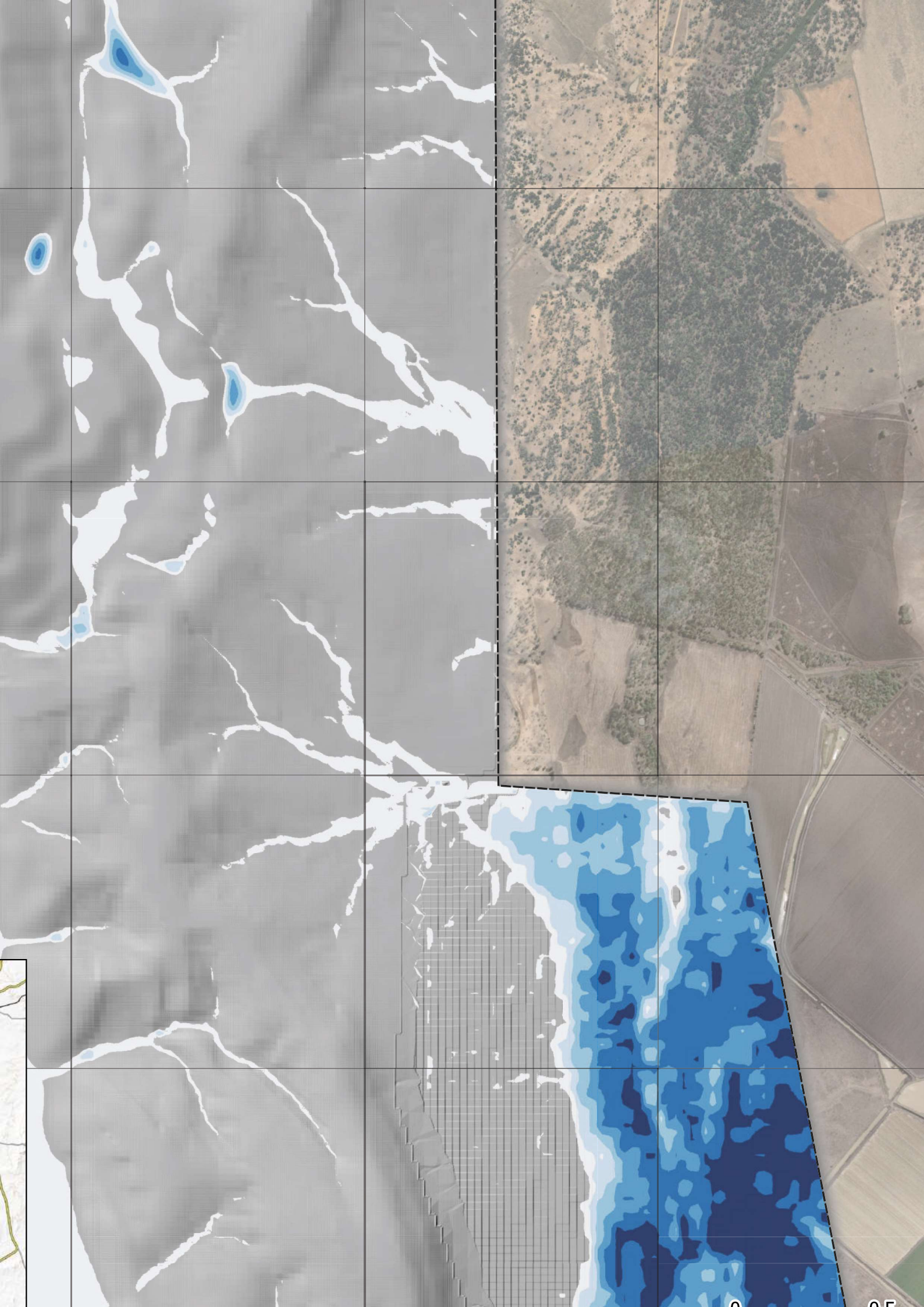

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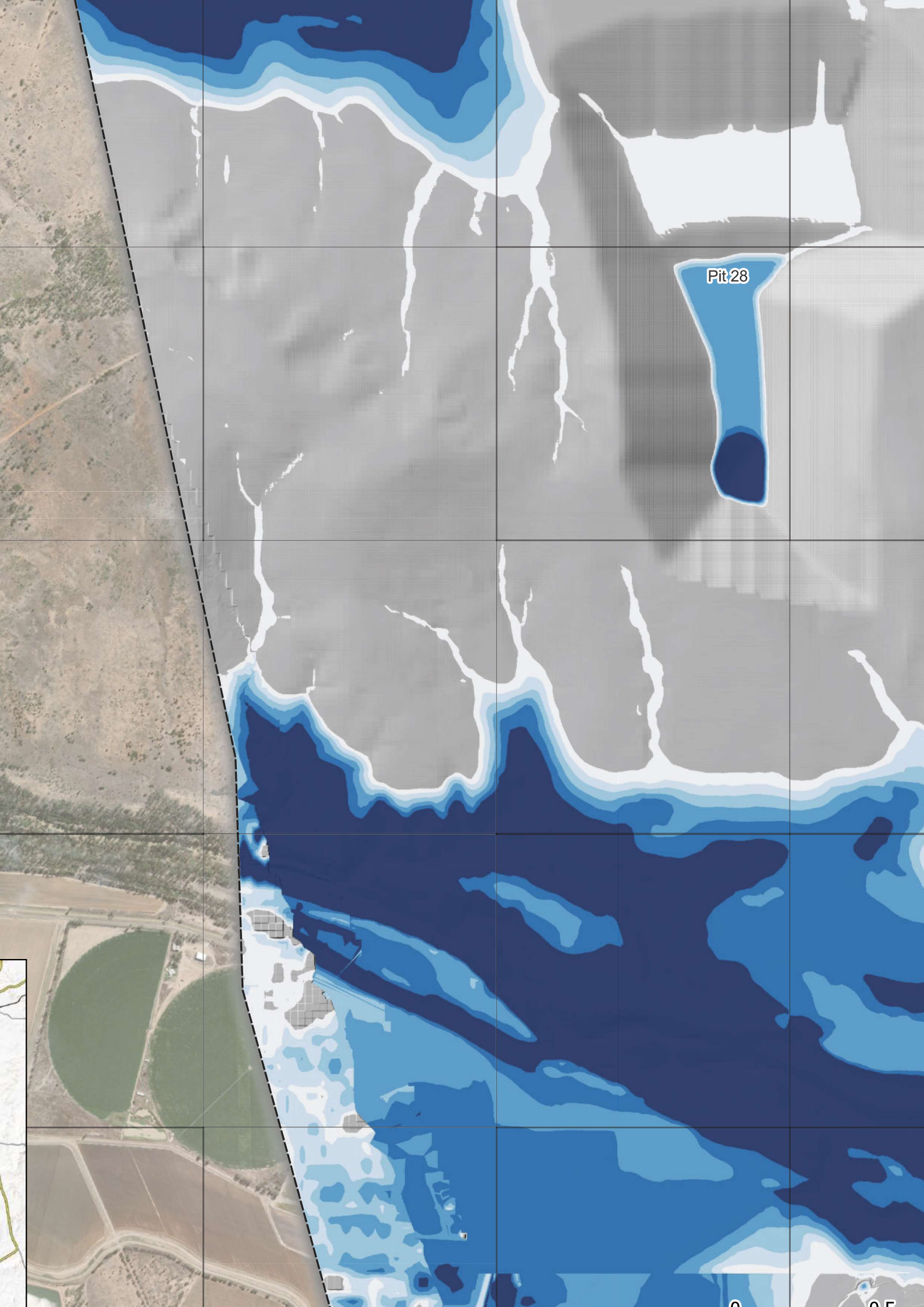


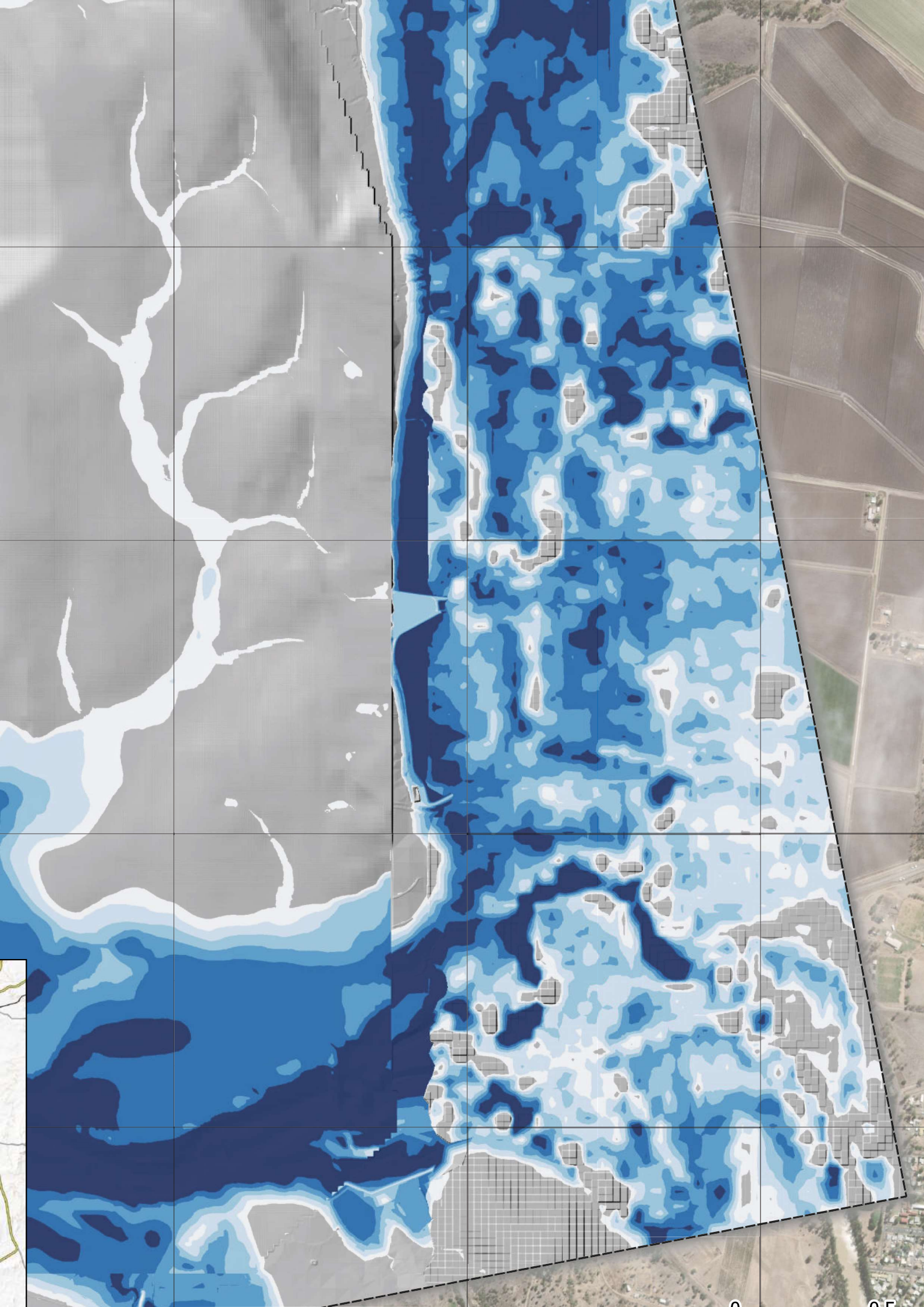

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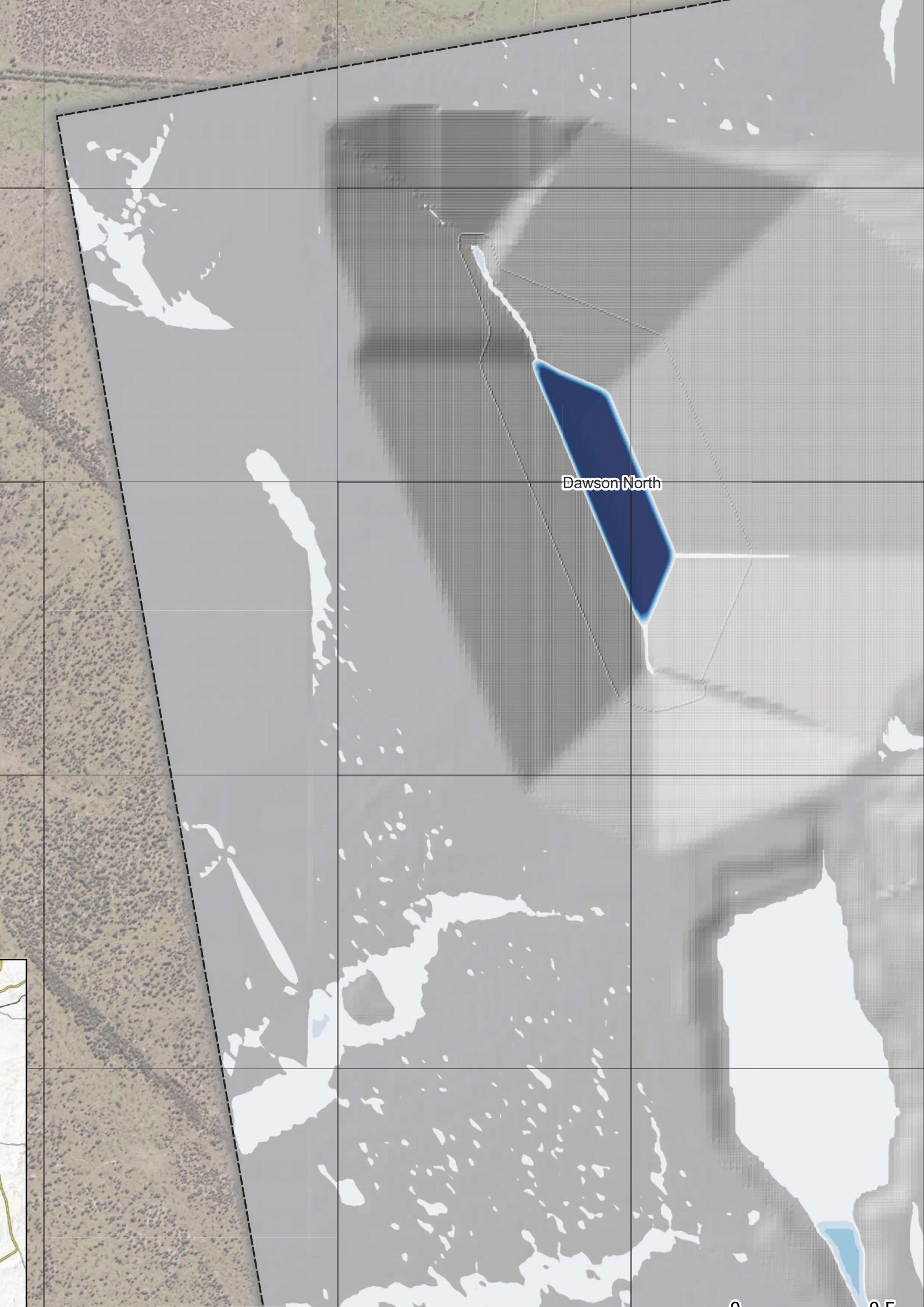


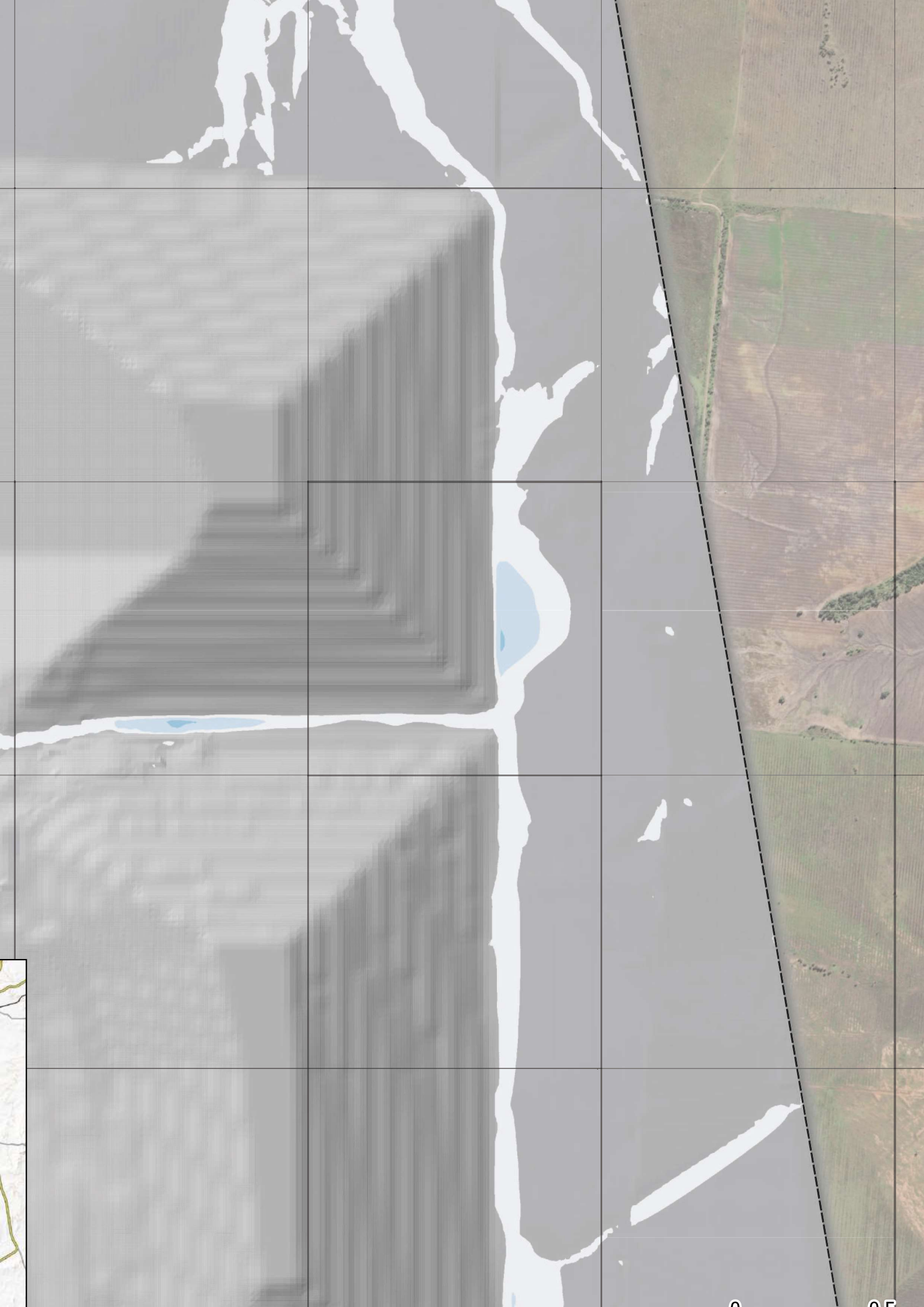


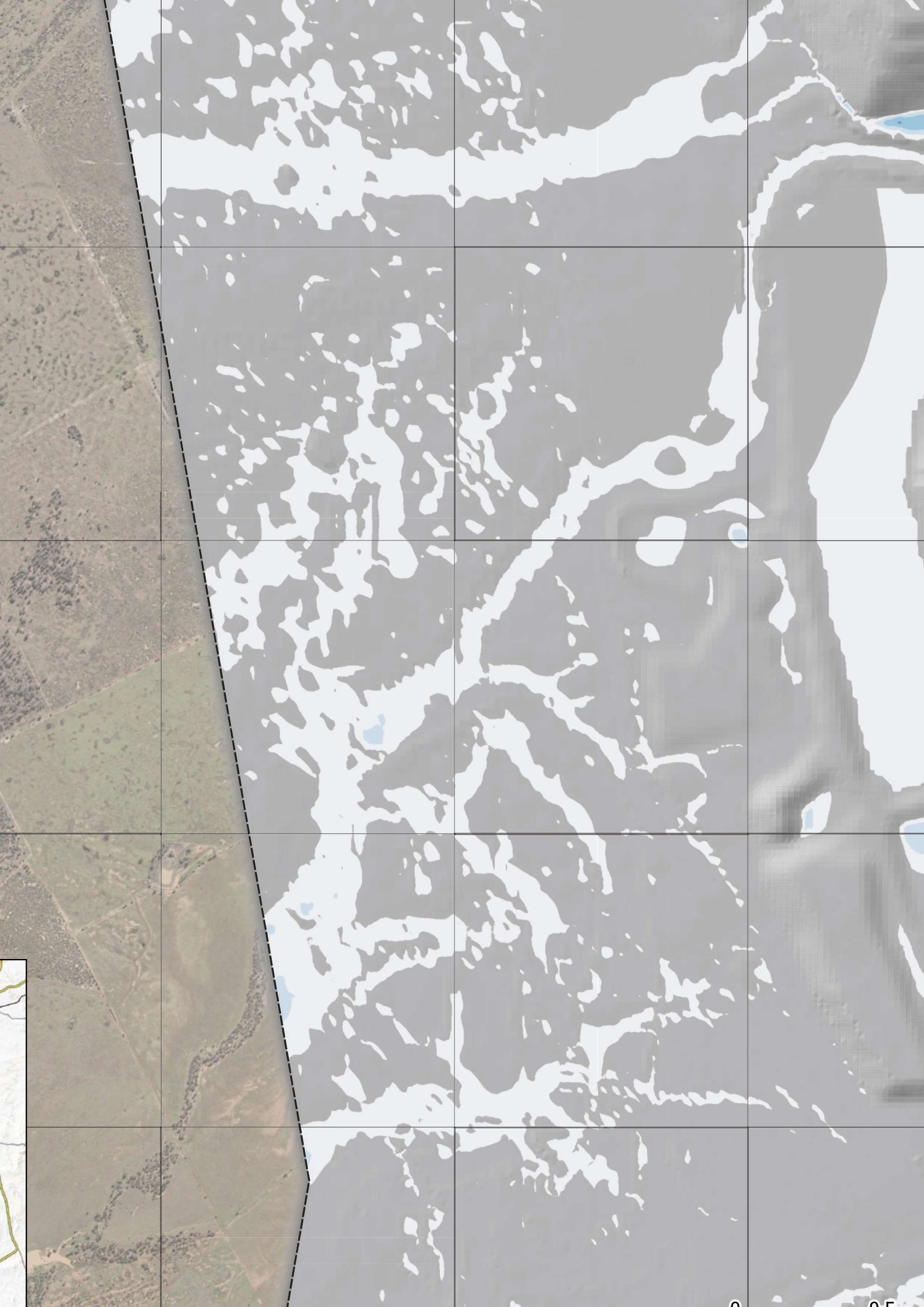


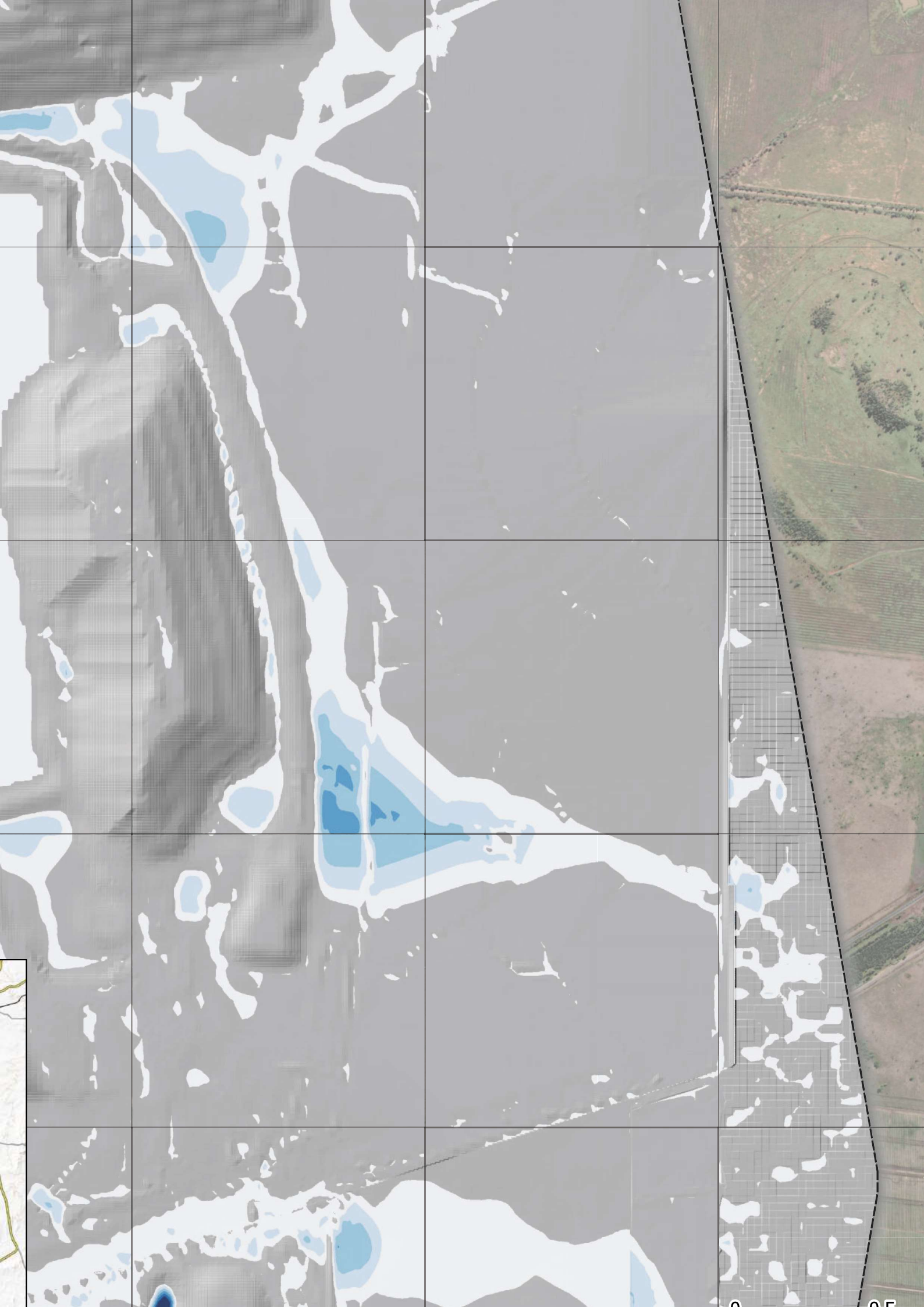

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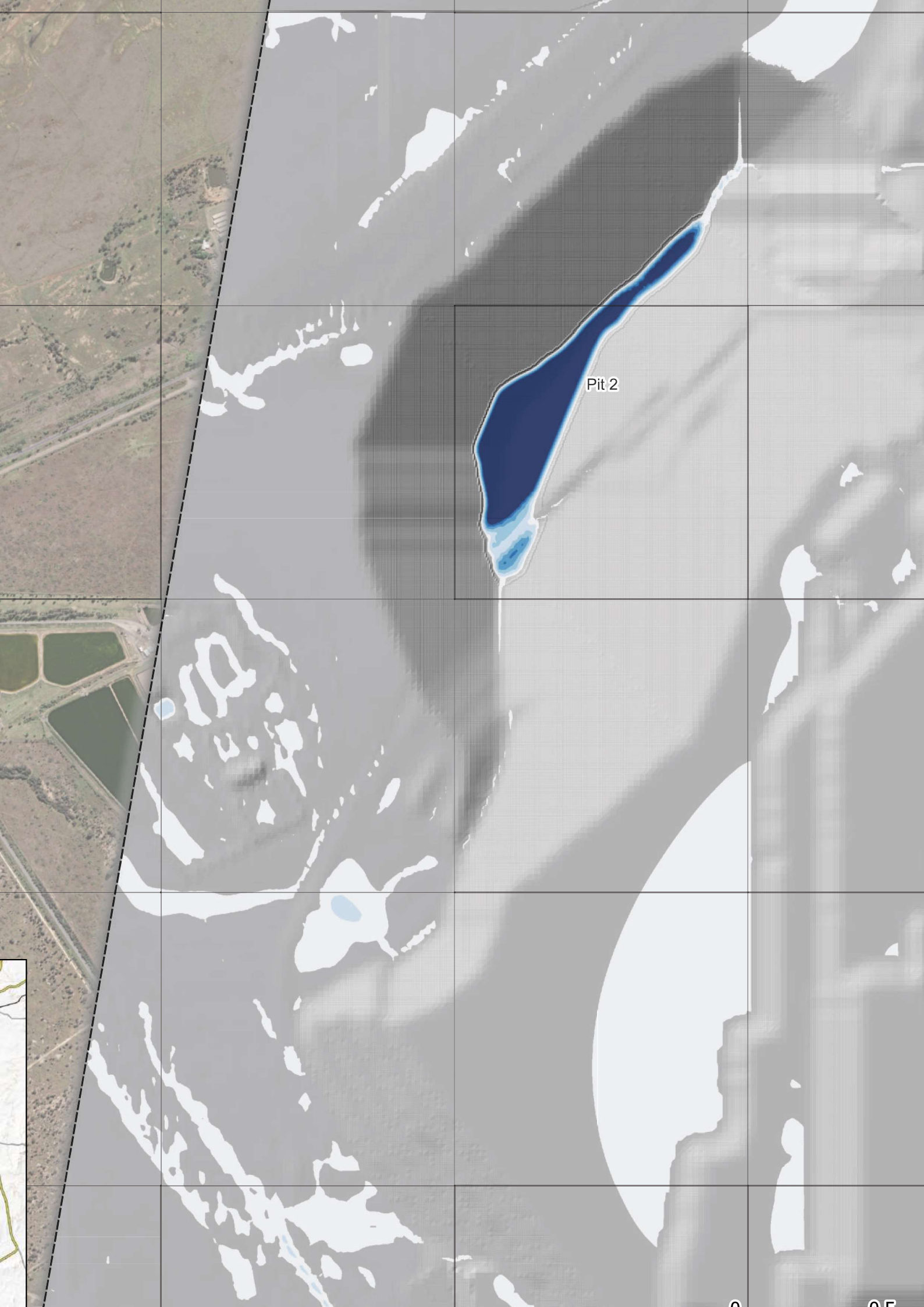


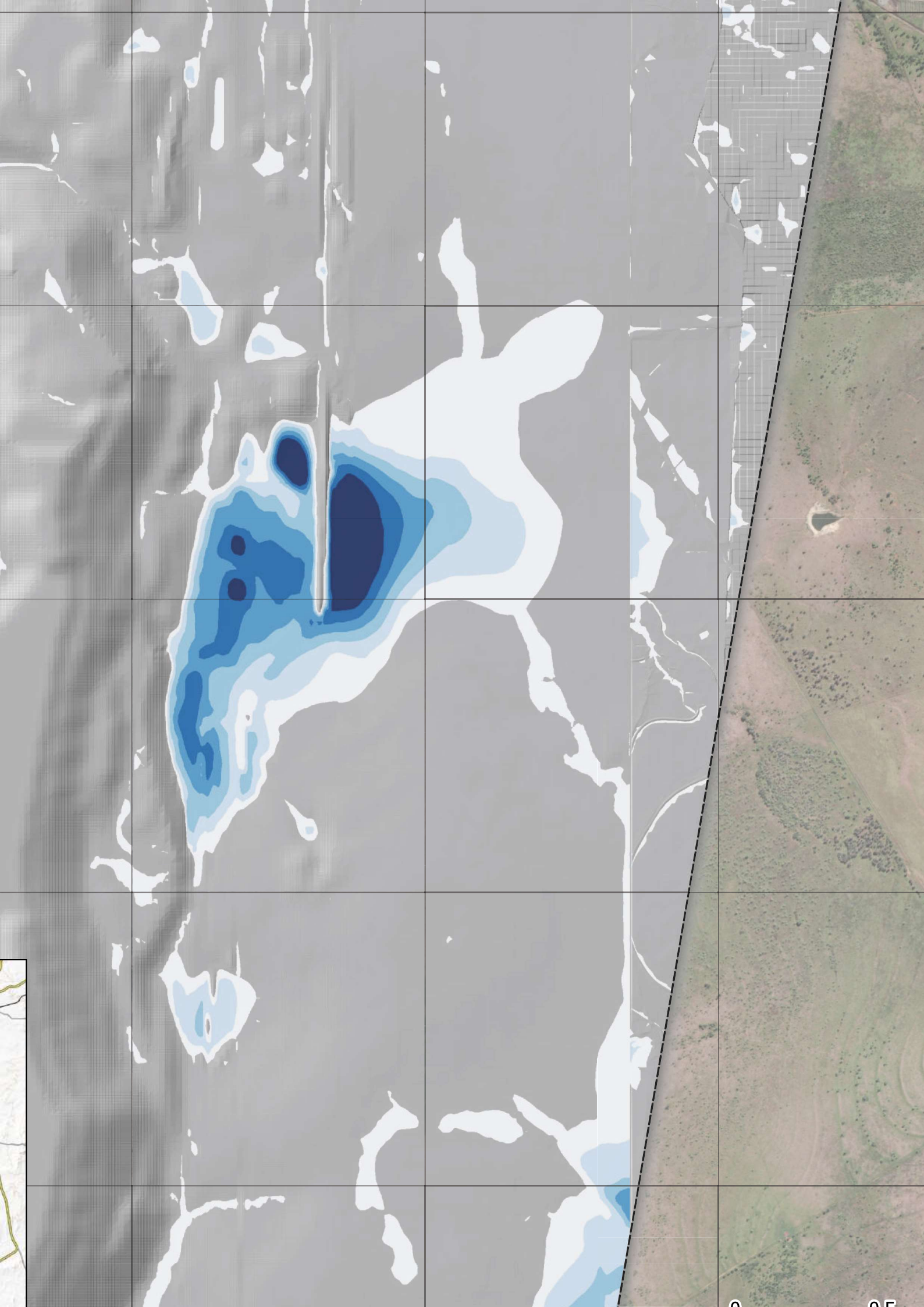

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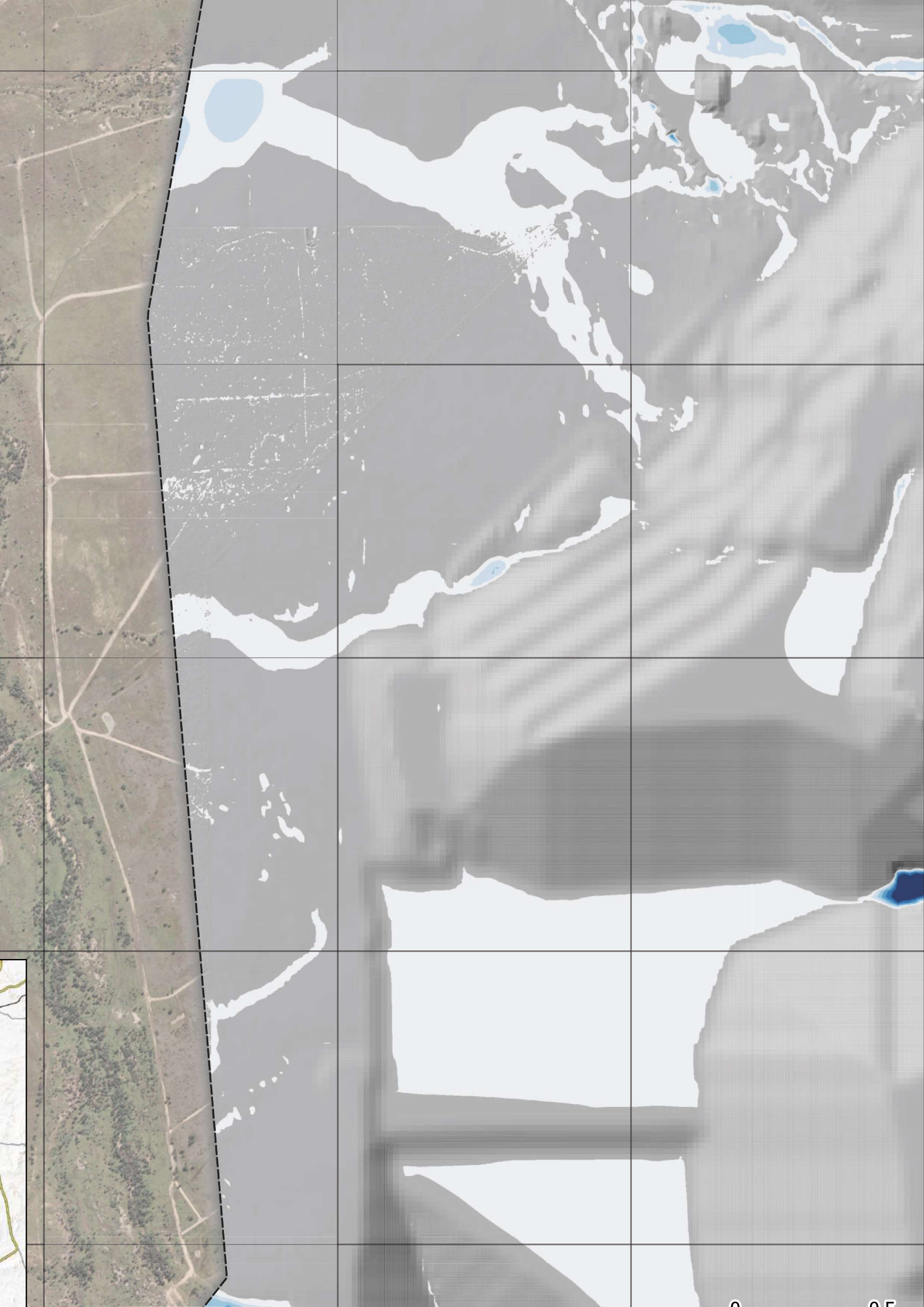


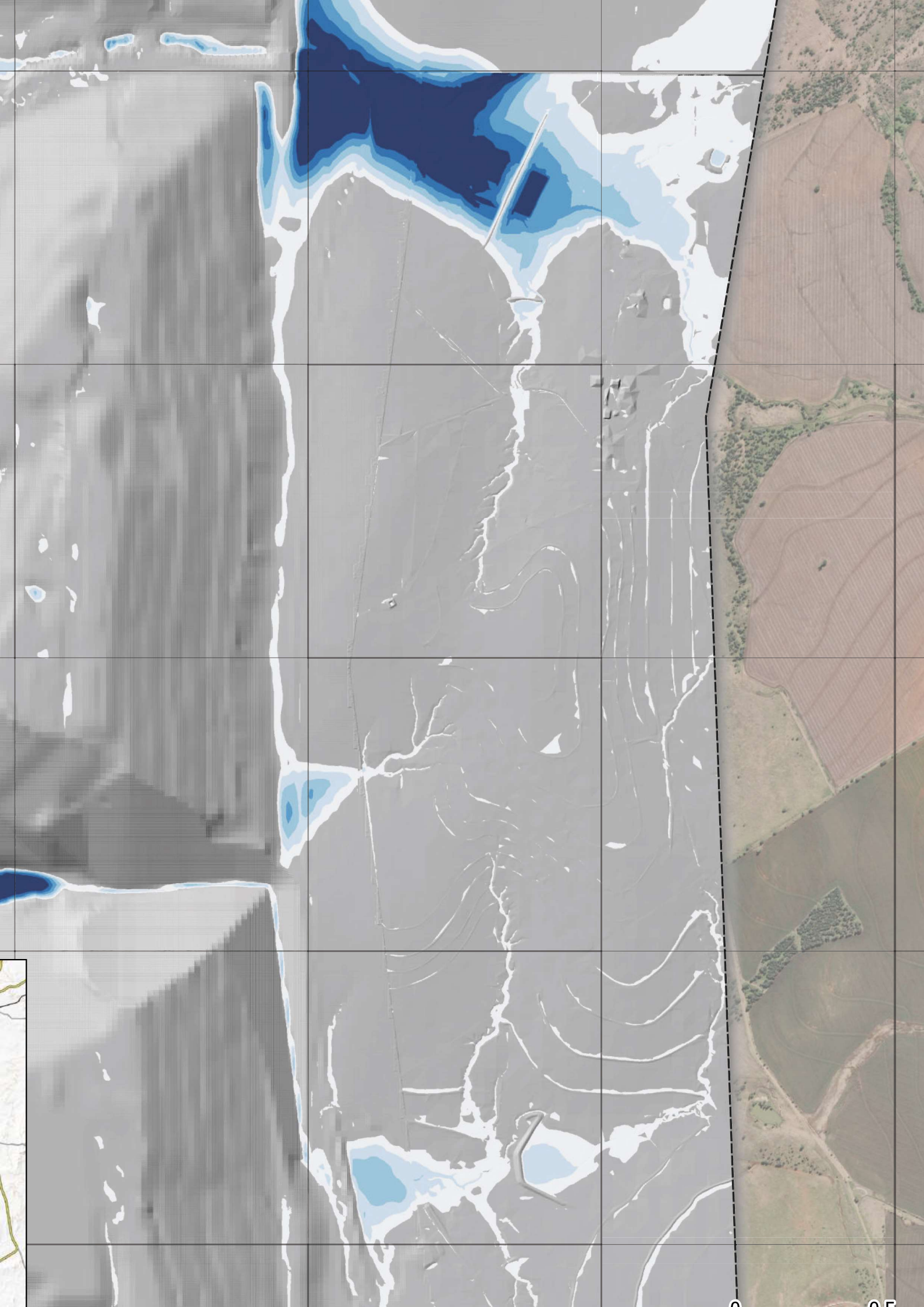




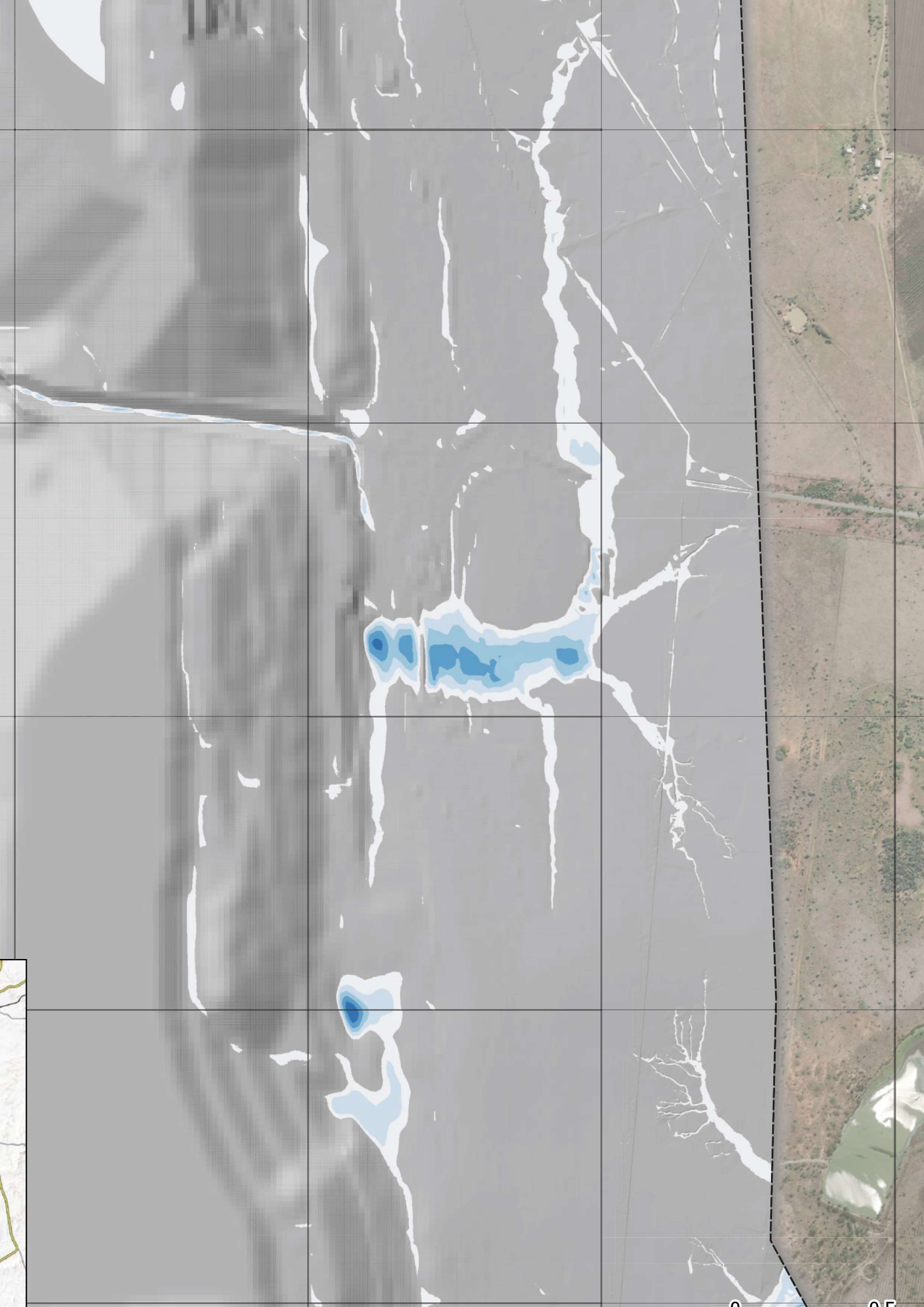

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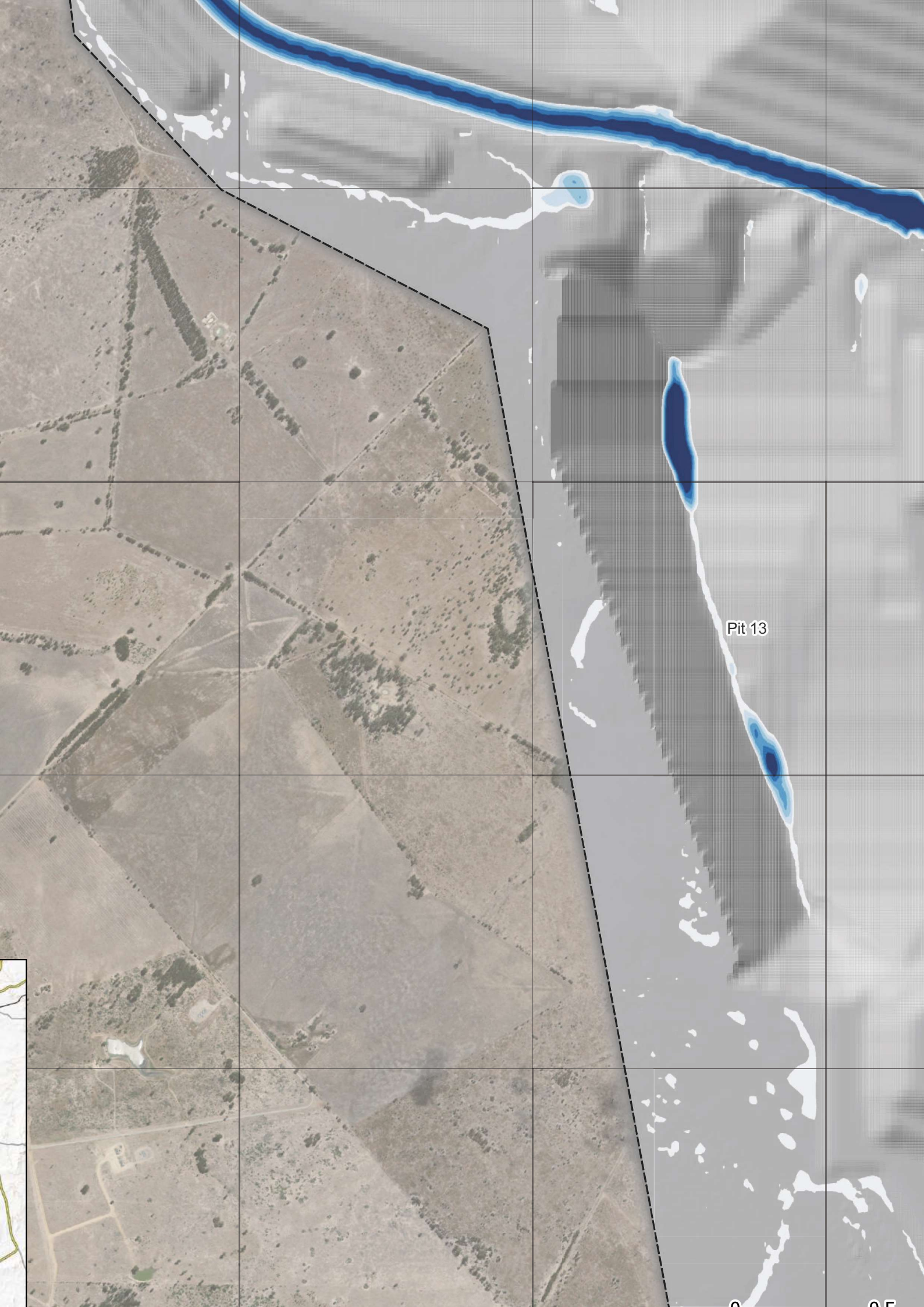


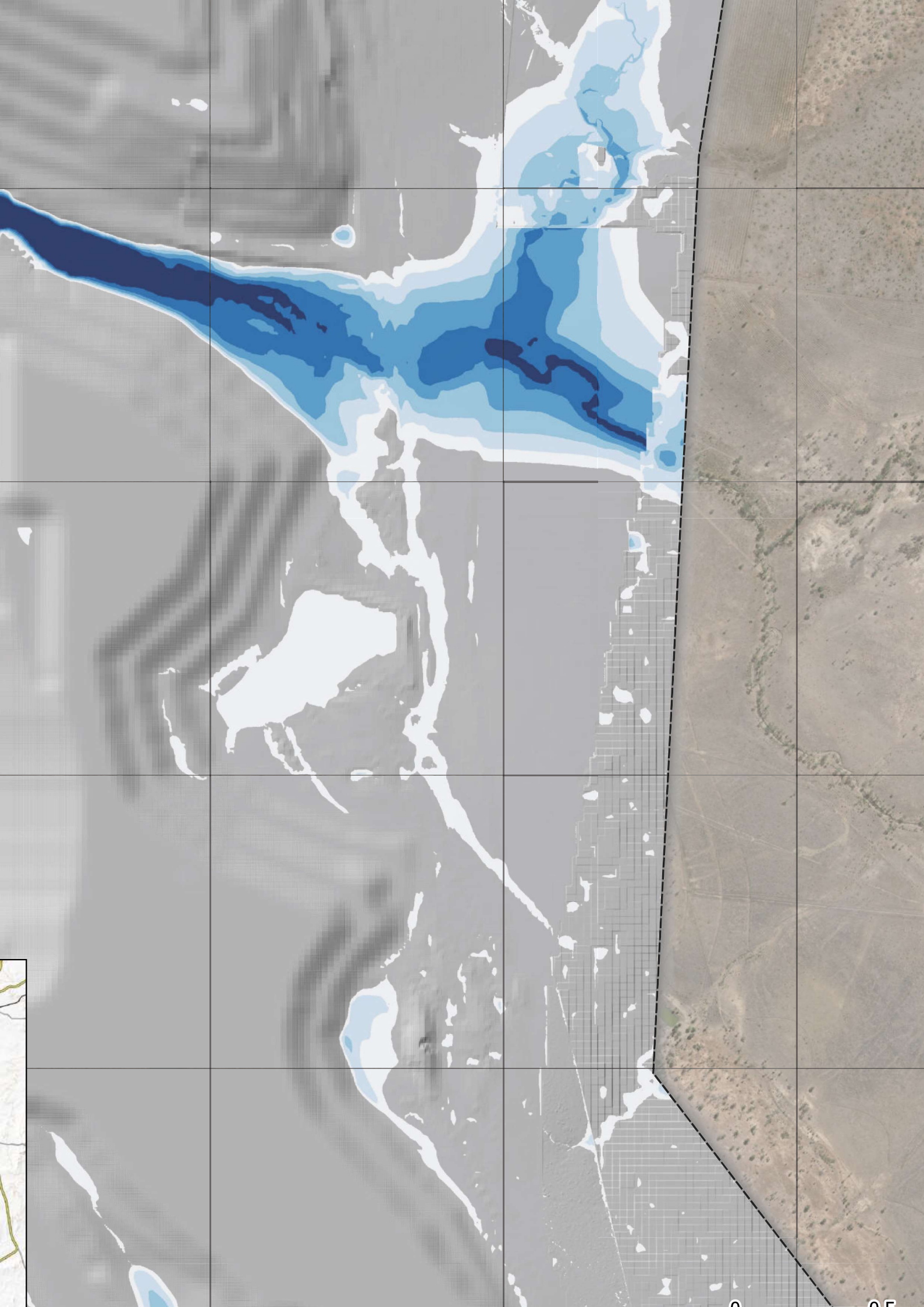


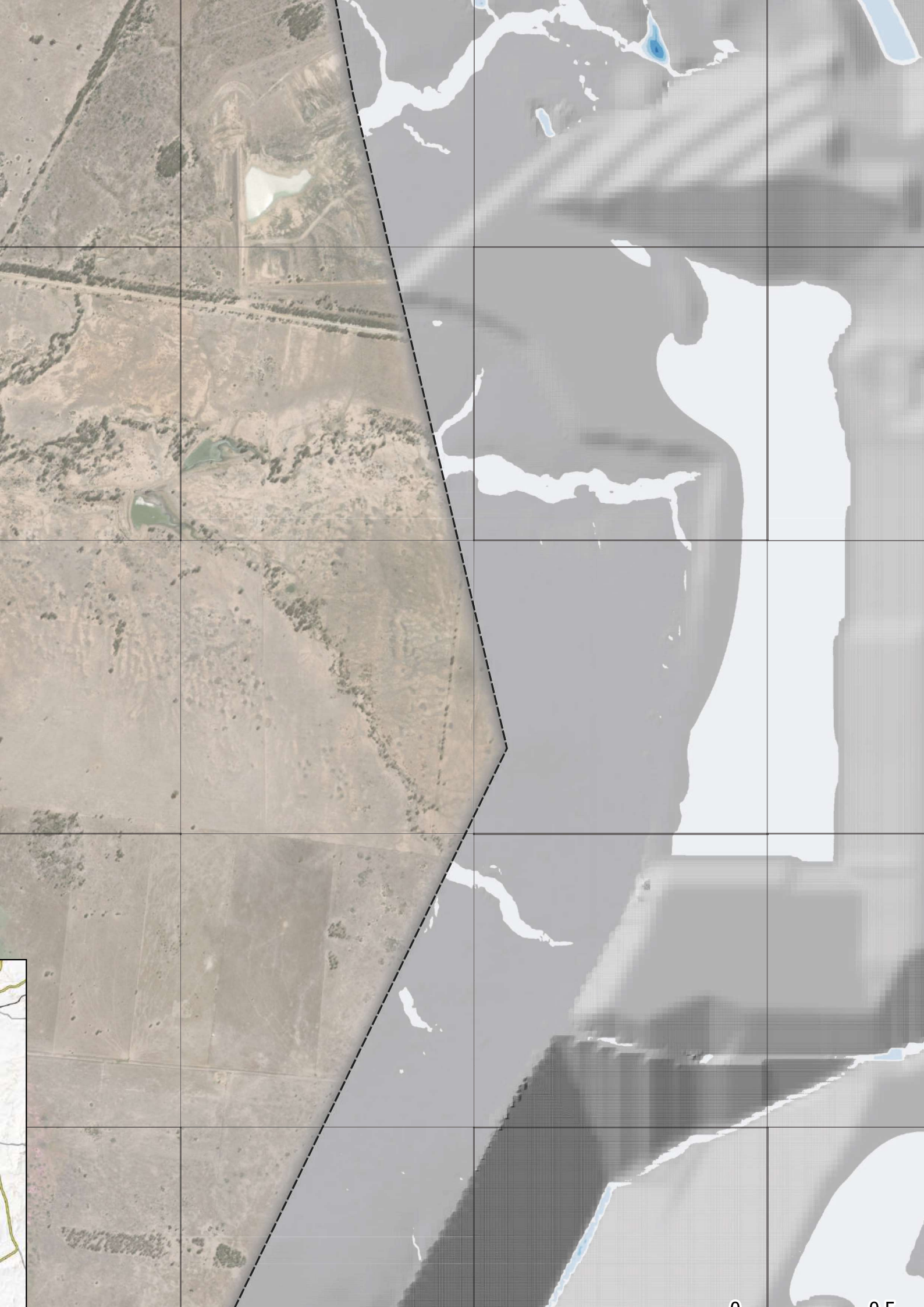


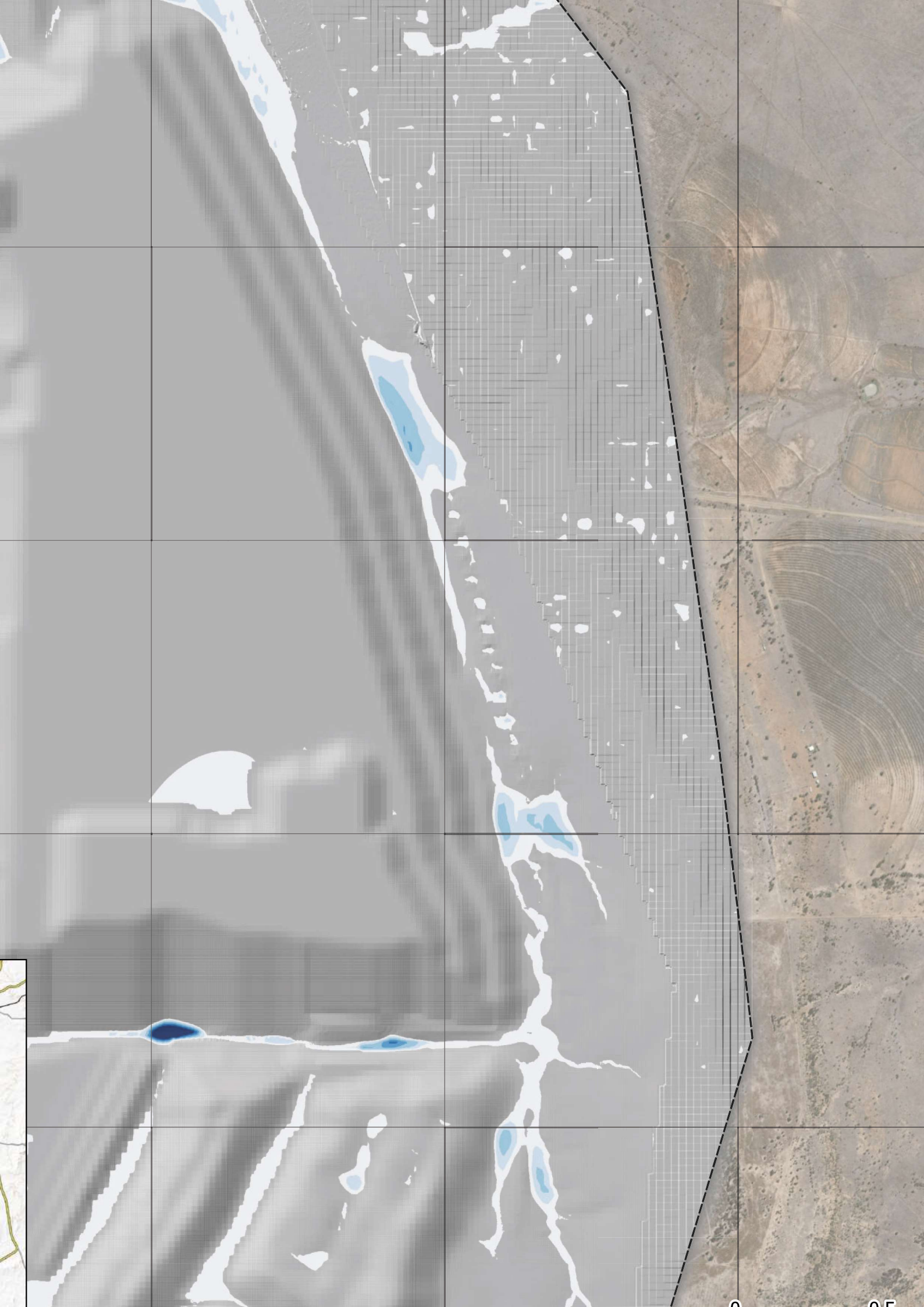

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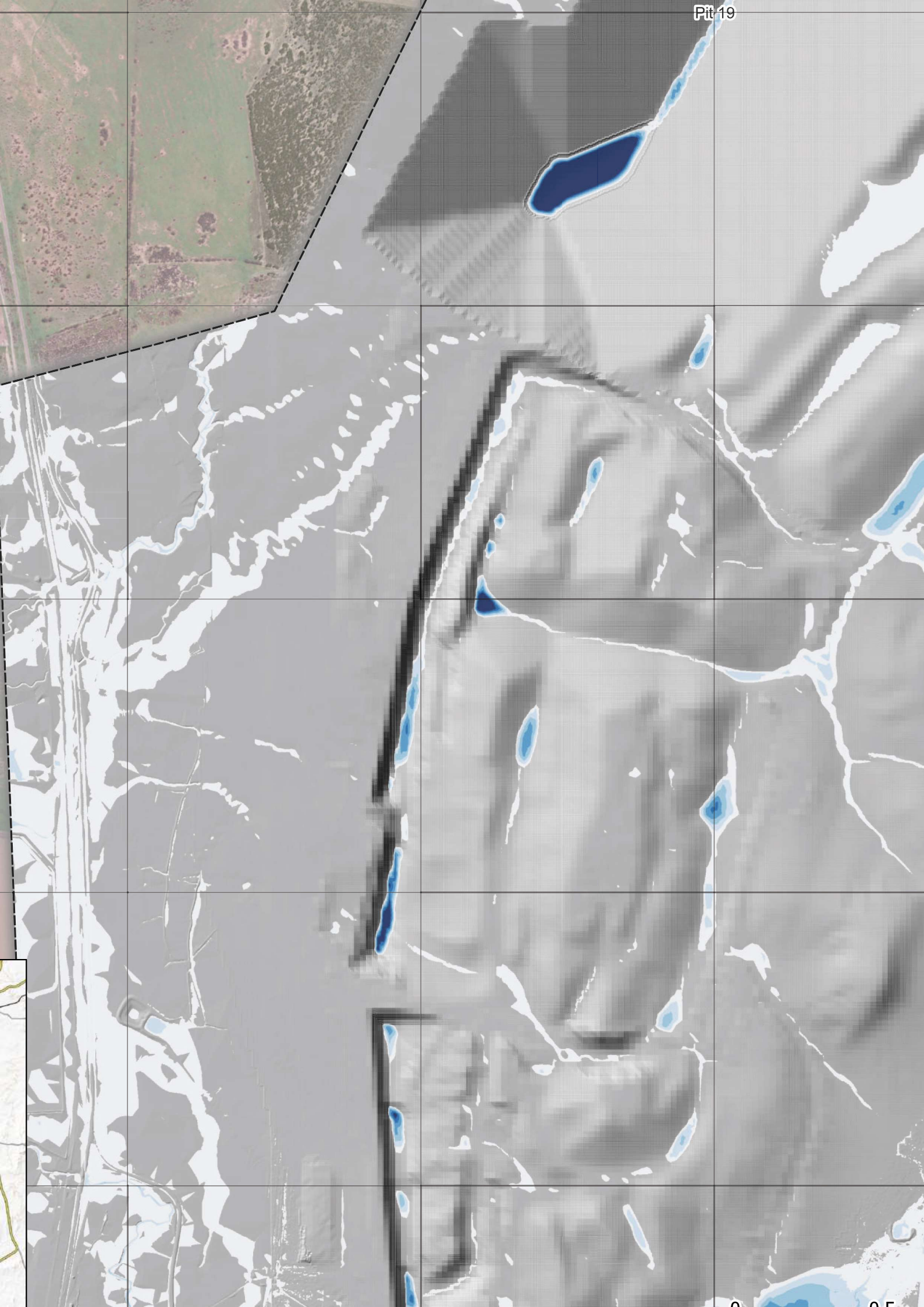


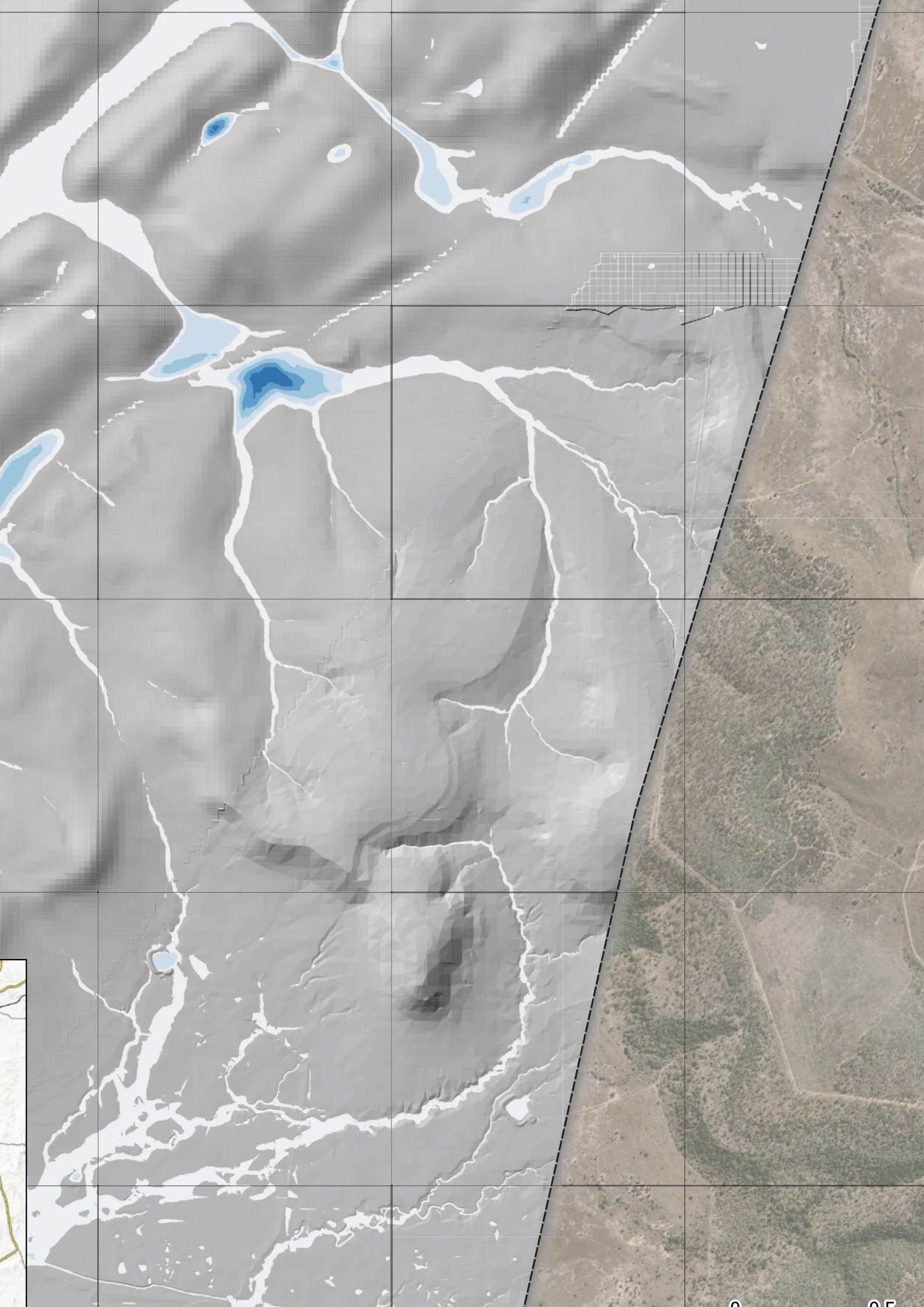

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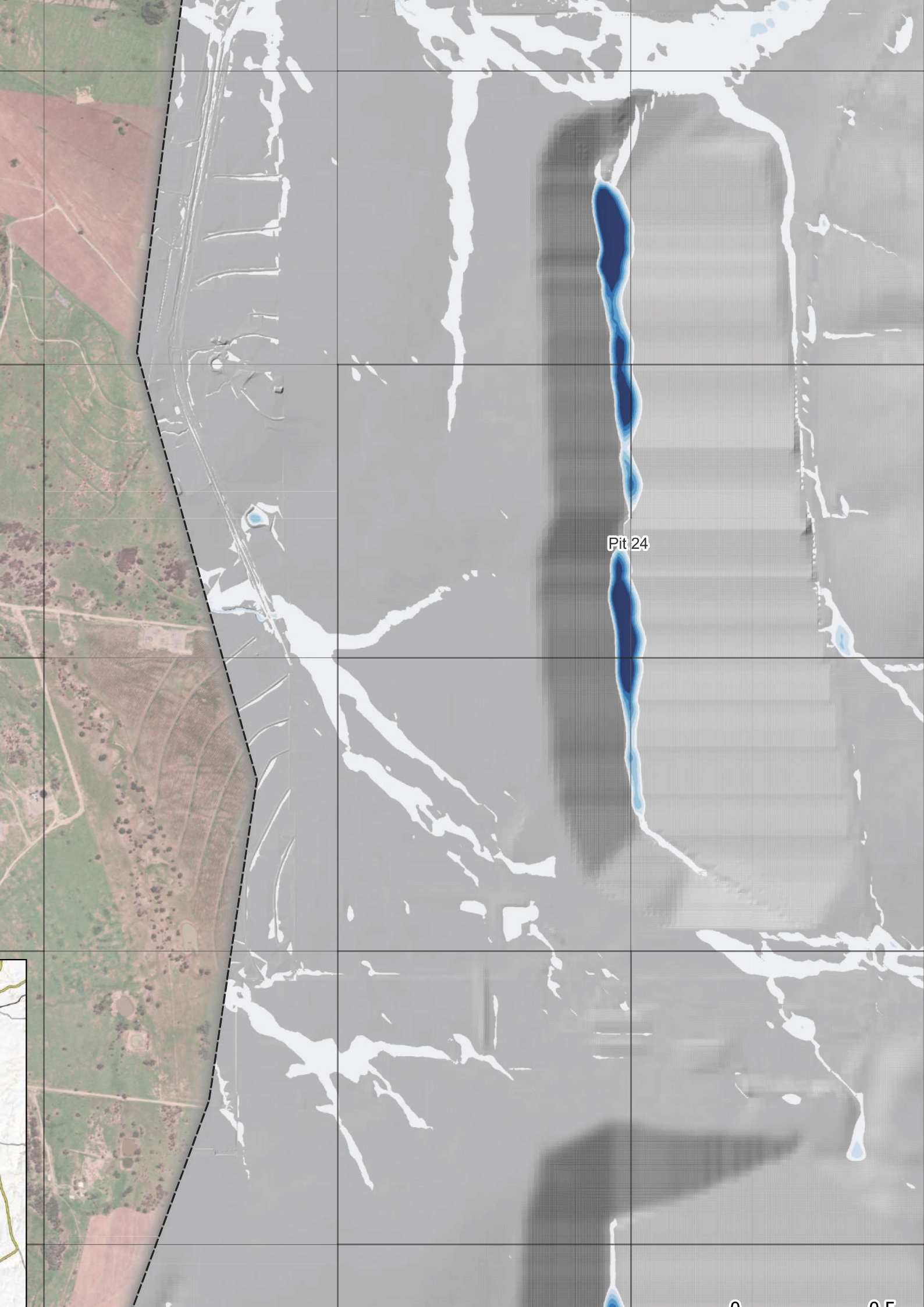


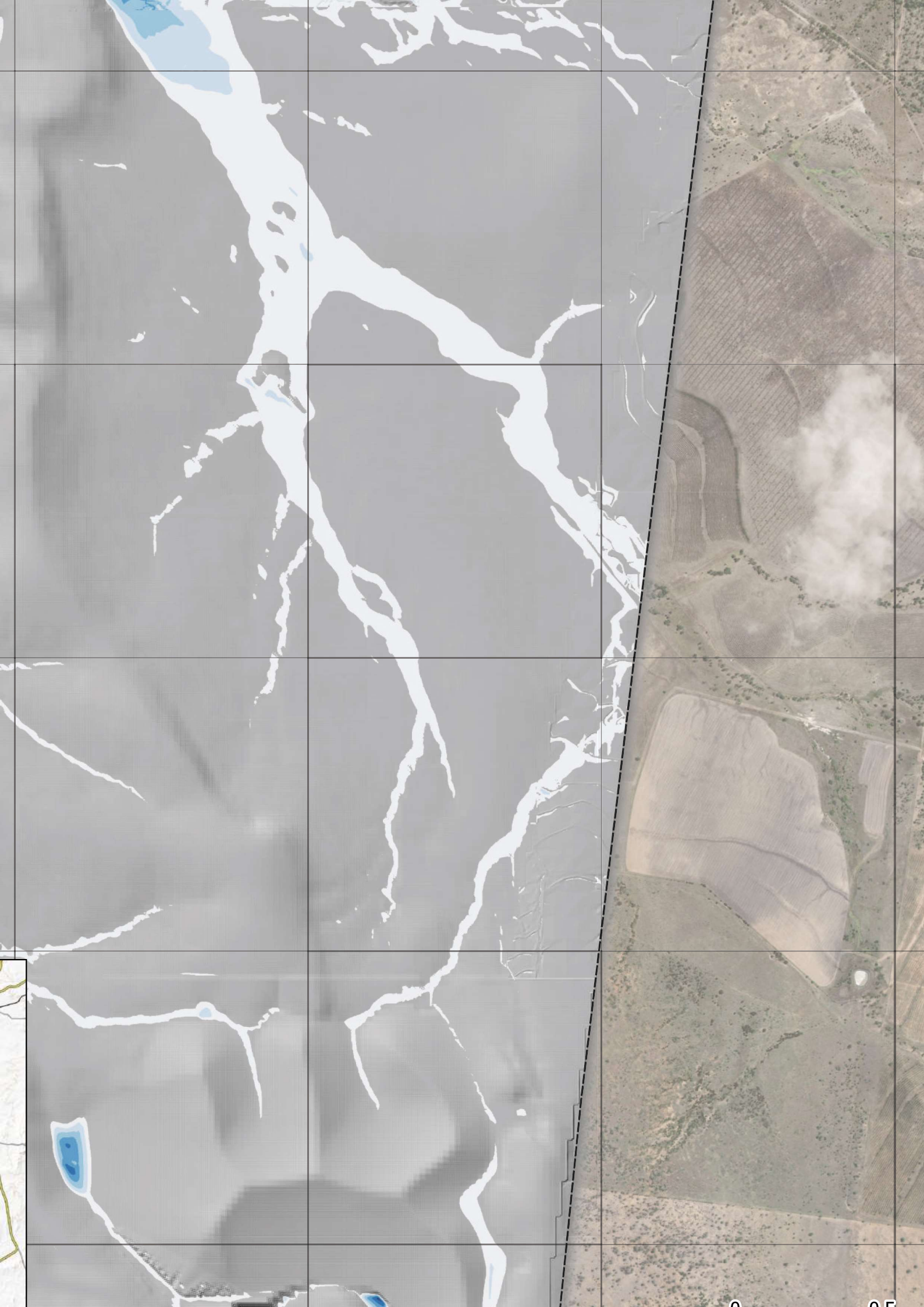


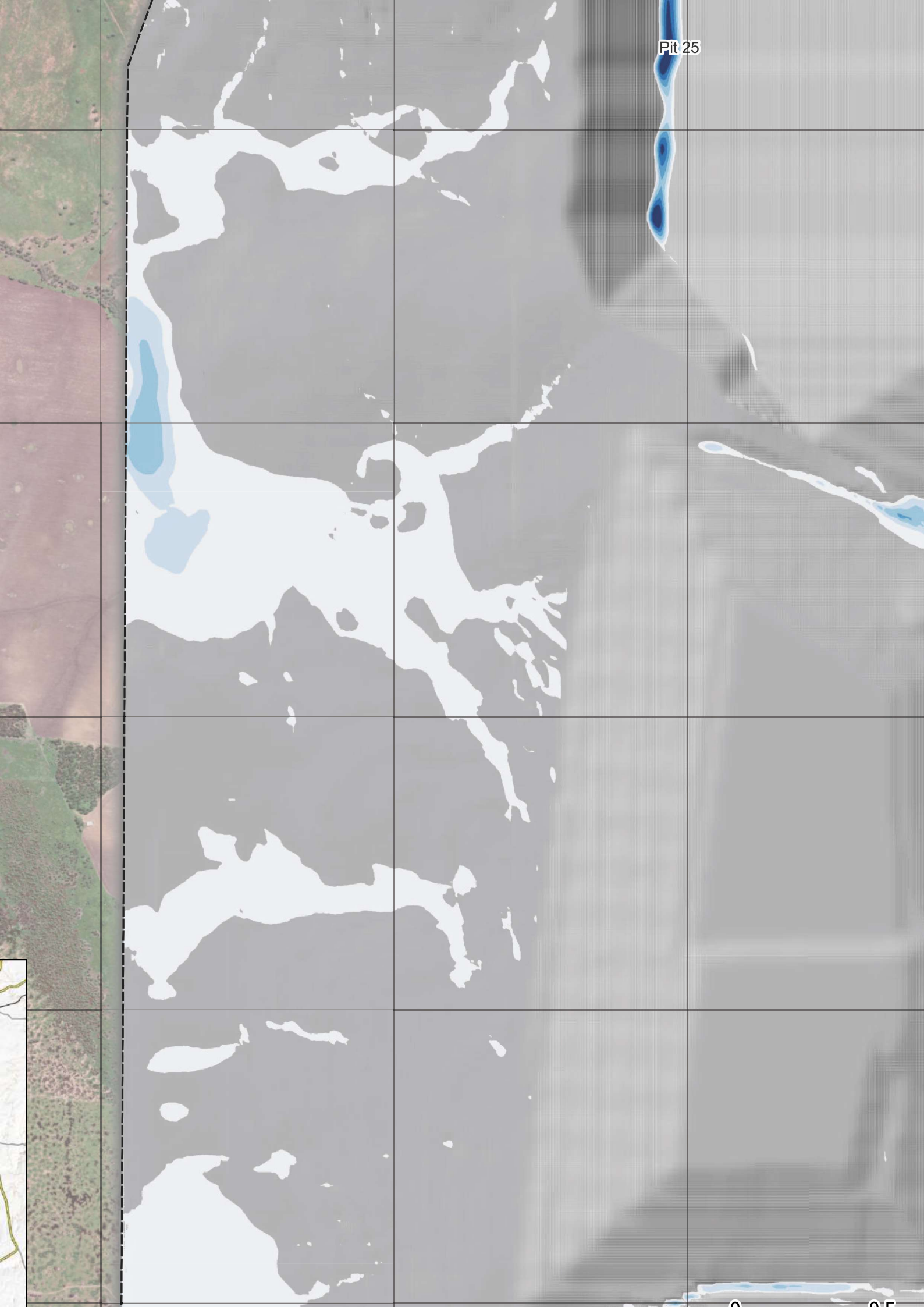


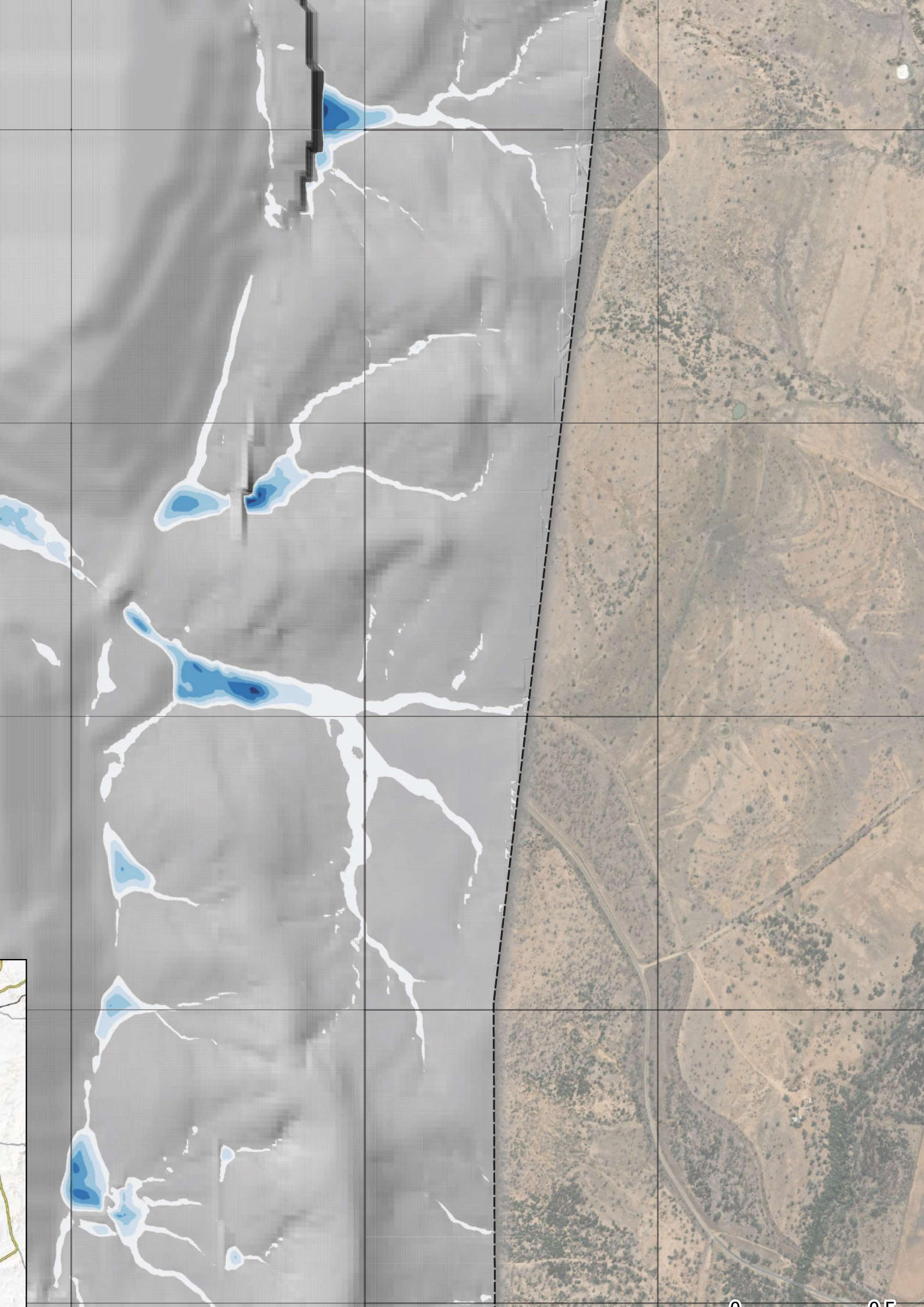

Pit 19

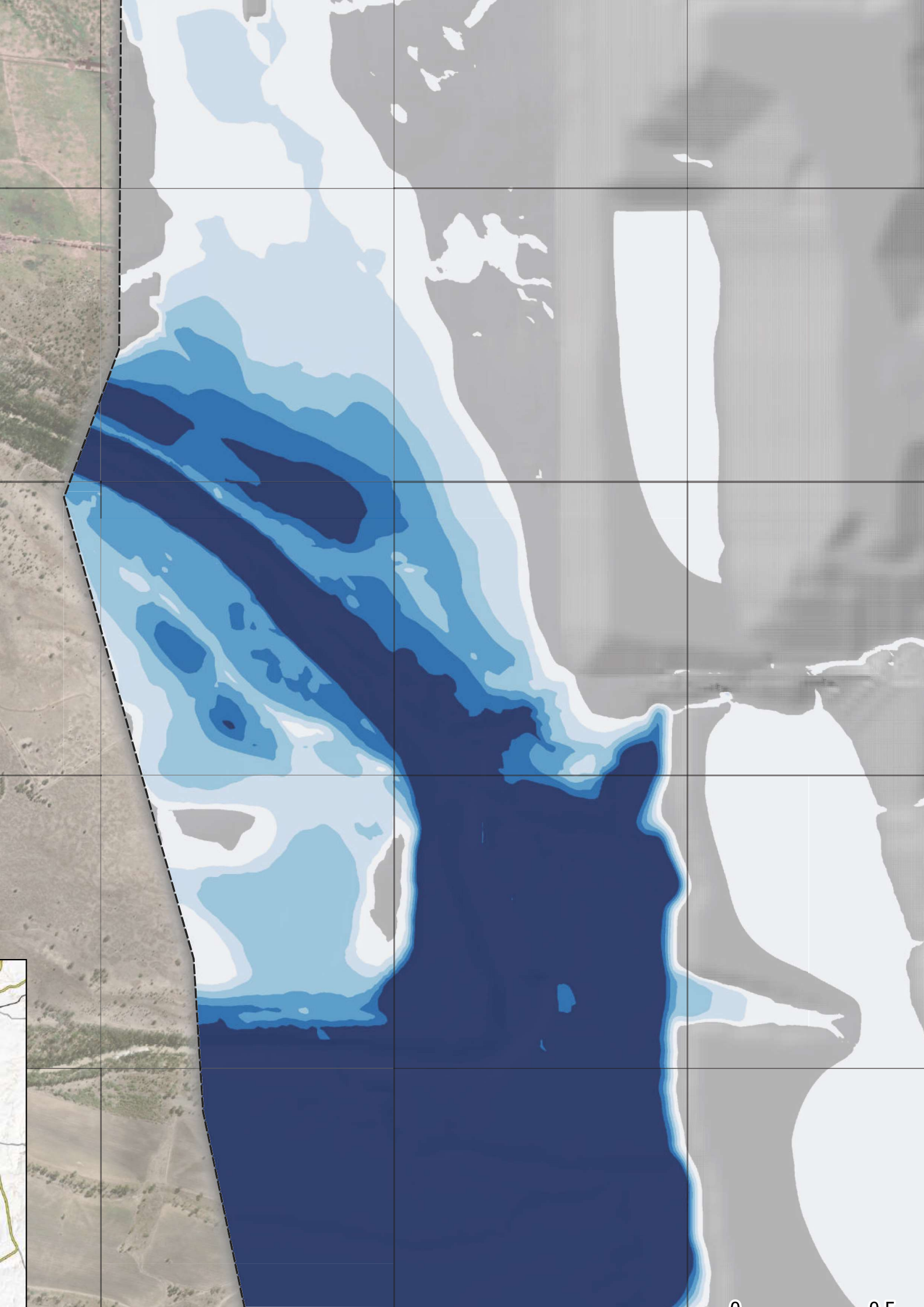


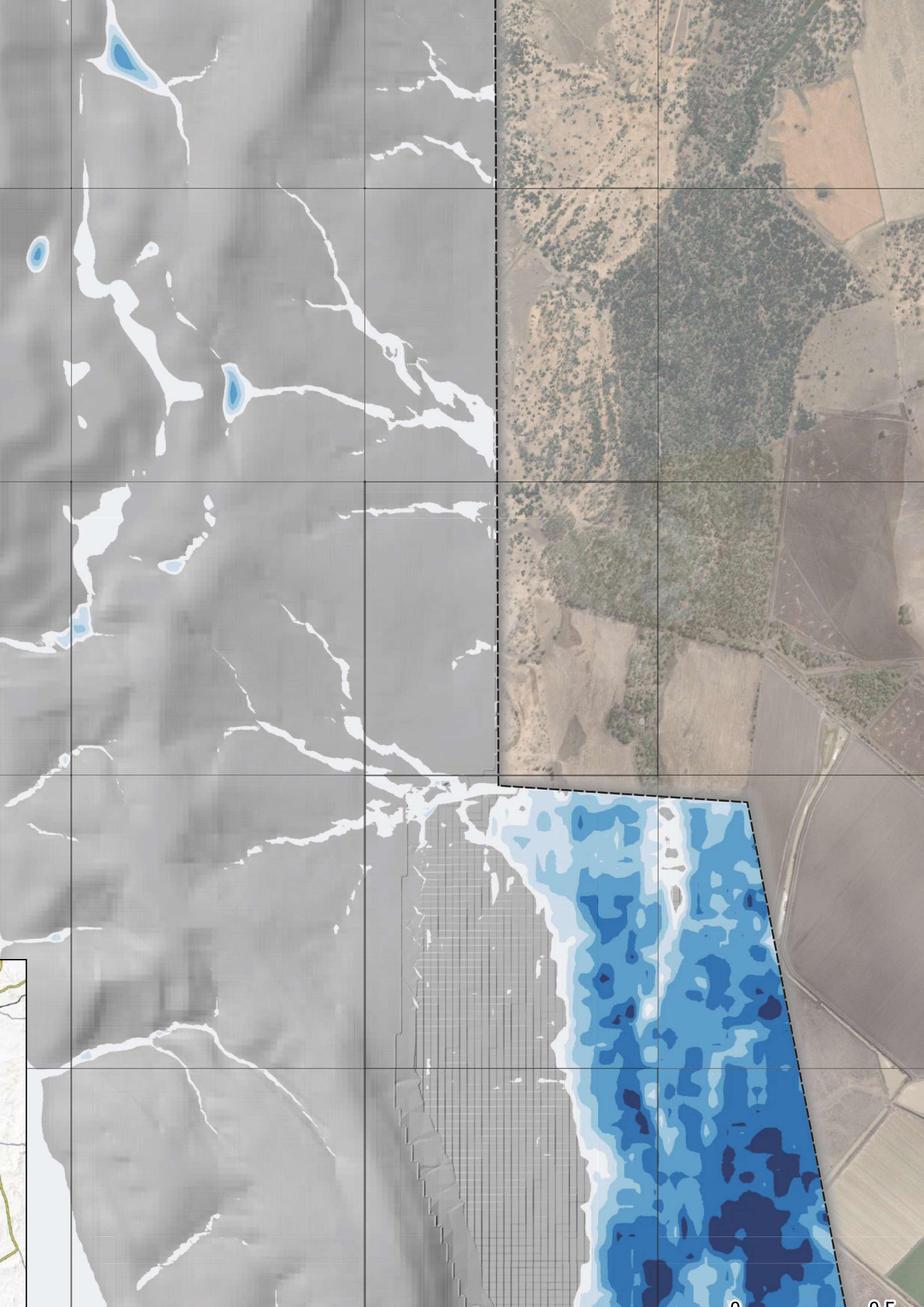

Pit 24

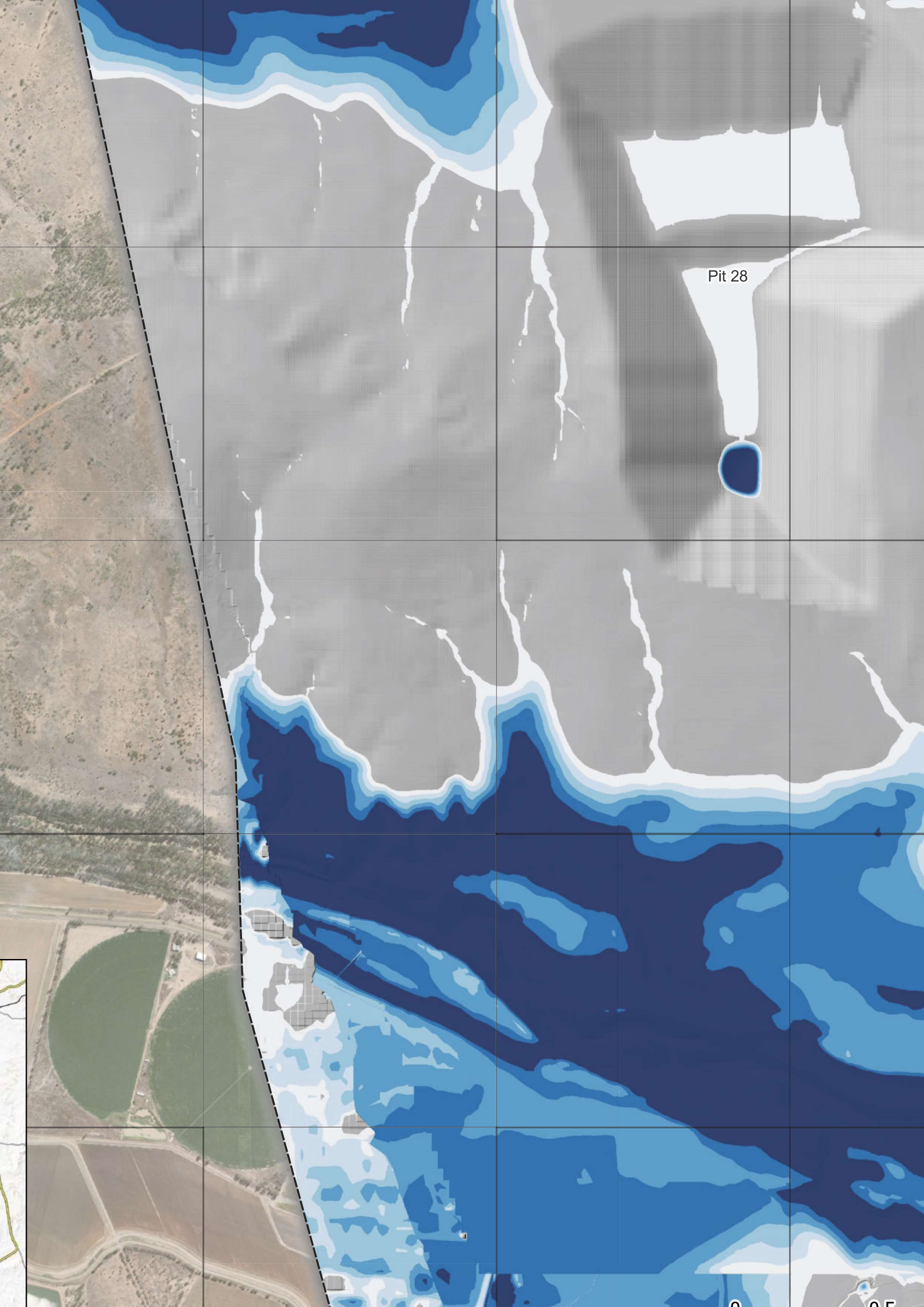


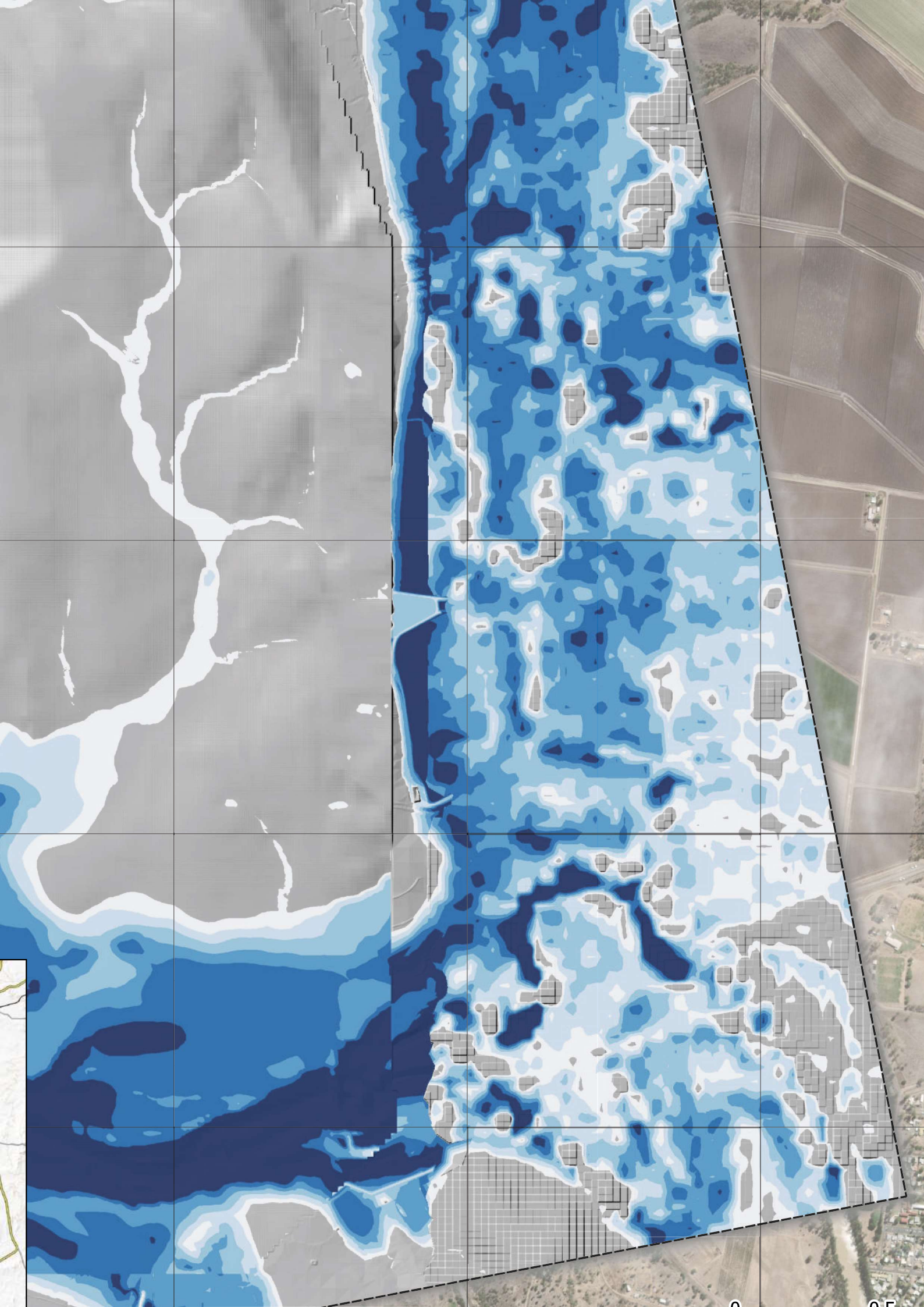

Pit 25








Pit 28



Appendix 4.5 Groundwater Technical Report

Klohn Crippen Berger

Anglo American

Dawson South EA Amendment

Groundwater Impact Assessment Report

Final

ISO 9001 14001 45001

DX7008A01

February 2025

10 February 2025

Anglo American
11/201 Charlotte St
Brisbane, QLD
4000

Katy Steele
Environmental Approvals Manager

Dear Ms. Steele:

Dawson South EA Amendment
Groundwater Impact Assessment Report
Final

KCB Australia Pty Ltd (KCB) is pleased to provide this final technical report on the groundwater impact assessment related to the Dawson South EIS update to support Anglo America's Dawson South Operation. This document has been updated in response to the request for information from the Department of Environment, Science and Innovation.

Yours truly,

KCB AUSTRALIA PTY LTD.



Brent Usher, PhD, RPGeo
Senior Hydrogeochemist, Principal
Project Manager

AC:BU:JJ

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CLARIFICATIONS REGARDING THIS REPORT

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the exclusive use of Anglo American (Client) for the specific application to Dawson South groundwater, and it may not be relied upon by any other party without KCB's written consent.

KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

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2. The Executive Summary is a selection of key elements of the report. It does not include details needed for the proper application of the findings and recommendations in the report.
3. The observations, findings and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.
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5. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.
6. This report is electronically signed and sealed, and its electronic form is considered the original. A printed version of the original can be relied upon as a true copy when supplied by the author or when printed from its original electronic file.

EXECUTIVE SUMMARY

KCB Australia Pty Ltd (KCB) was commissioned by Anglo American Steelmaking Coal (Anglo) to undertake an assessment of potential groundwater-related impacts as a result of proposed final landform changes to the Existing (already existing mine plan) open pit mining activities associated with Dawson South (the Project).

Description of the Project

The Dawson South mining area is located within the Mining Lease (ML) ML5657 and ML80160 boundary and is operated by Anglo Steelmaking Coal in accordance with the Dawson South Environmental Authority (EA) EPML00657413. Anglo commenced open cut mining in the Dawson South mining area in 2003. Coal is currently mined in three open cut pits (Pit 25, Pit 26 and Pit 27) located in the northern part of the Dawson South mining area. These pits are located along the strike of the coal seams. A fourth open cut pit (Pit 28) is existing mine plan in the southern part of the Dawson South mining area. The proposed Project involves:

i. Reconfiguration/relocation and extension of the existing mine plan Pit 28 final void; and
ii. Alterations to the existing final landform, including addition of a new final void in Pit 25.

The Project will use the same open cut mining methods currently used in the Dawson South mining area and will utilise the existing Dawson Mine infrastructure and mining equipment. Existing mining activities (that are existing mine plan) include several open pits including an existing mine plan final void in Pit 28.

Hydrogeology Context

The Project is located in the Dawson River catchment. Surface water flow across the Project area is from north to south, and south of the project the Dawson flows west to east. Local creeks drain toward the Dawson River.

Hydrostratigraphic units in the vicinity of the Project area include Quaternary alluvium, associated with surface water courses; Tertiary sediments; Tertiary basalt; the Triassic Rewan Group; and Permian coal measures. Saturated conditions are observed in the Rewan Group and Permian coal measures; while within the Project area, limited groundwater is observed within the Quaternary alluvium, Tertiary sediments and Tertiary basalt.

Groundwater use by third parties, within a 5 km radius of the Project area, has not been identified. All registered bores on the Department of Regional Development, Manufacturing and Water (DRDMW) groundwater bore database within a 5 km radius of the Project area are used for mine monitoring purposes and are screened across various hydrostratigraphic units.

Groundwater Dependent Ecosystem (GDE) mapping of the Fitzroy basin indicates that there is low confidence terrestrial GDEs located adjacent to the Dawson River which is within 5 km of the Project area.

Impact Assessment

A numerical groundwater model was developed for the Project area, and surrounds, to simulate the groundwater level drawdown associated with the proposed landform changes. The numerical groundwater model was constructed using data provided by Anglo and sourced from public domain sources. Model calibration was completed using groundwater levels, recorded over time, from bores within and surrounding the study area. Prediction of groundwater level drawdown was conducted based on the Proposed open pit mining schedule provided by Anglo. The updated groundwater model was able to achieve a good calibration between the measured/observed water levels and the model-predicted water levels for the transient calibration period. The model calibration metrics are acceptable and within the requirements of the Australian Groundwater Modelling Guidelines. The transient hydrograph comparisons between simulated and measured water levels show that the model is able to match the general trends and responses observed in the data record, including the shallower hydrostratigraphic units which could be potentially impacted by mining activities. Results from the predictive simulation were used to consider potential drawdown impacts to the groundwater environment.

Potential operational impacts to water-dependent assets were considered based on groundwater levels and drawdown assessments (See Figure A below the text in this summary for reference). A summary of the potential impacts to water-dependent assets are:

- Modelling results show that the greatest dewatering occurs at the end of mining operations (largest absolute impact on the groundwater system). This period is when the actively mined coal seams would have resulted in the lowest groundwater elevations in the final active pit and coincides with the period when the cumulative dewatering impact from the interaction between the pits is at its highest. Since the groundwater system is very slowly recovering outside of the active mining area, the end of the mining period shows the greatest overall groundwater drawdown at Dawson South.
- Observed changes to the potential impact on the groundwater system from the Project arise after operations have ceased, as result of the presence of the additional pit lake in the final void of Pit 25 and due to the increased size of the post-mining void in Pit 28.
- No additional third-party groundwater users are impacted by the Project. While the Project does result in additional post-closure drawdown the area impacted after closure and distance from the mining voids is less than at the end of mining. The maximum extent of groundwater level drawdown occurs during the final operational stages of the existing mining activities. The impact of the Proposed change in landform after closure is not predicted to extend beyond the end of existing mining activities. Therefore, no impacts to third-party groundwater users are predicted as result of the Proposed Project.
- Following the cessation of mining, groundwater levels will be allowed to recover, which will ultimately result in the development of two post-closure voids located in the north (Pit 25) and south (Pit 28) of the Proposed Project landform. Post-closure steady-state void levels, indicate that the voids will remain groundwater sinks.
- It should be noted that for the Project landform equilibrated water level elevation in the Pit 28 void is higher than in the existing mine plan landform. As result, the groundwater impact from the Proposed Pit 28 void will be reduced compared to the existing case.

- Although the existing mine plan landform equilibrated void water levels lie at a lower elevation for Pit 25, in comparison to the elevated void in the Proposed landform, the overall zone of influence (extent) will be smaller after closure than at the end of operations (confirming that end of operations represents the period of greatest impact to groundwater, irrespective of the Project).
- The largest difference observed in terms of the impact on surface water resources will occur once the pit voids have equilibrated (reached steady state). The predictions indicate under conservative modelled scenario conditions across the entire Dawson South area, that surface water bodies (creeks and the Dawson River) will lose water to the groundwater environment but at a similar magnitude to the Existing mine plan.
- The Project related groundwater level elevations across the study area, resulting from the Proposed post-closure landform, is not predicted to cause any additional discernible impacts to the groundwater resource already existing mine plan.

Conclusion

A groundwater impact assessment of the Project has been undertaken to consider potential impacts to groundwater resources and groundwater-dependent assets as a result of Proposed landform changes.

It is concluded that the Proposed development changes of the Project will not have a discernible impact on water resources already existing mine plan.

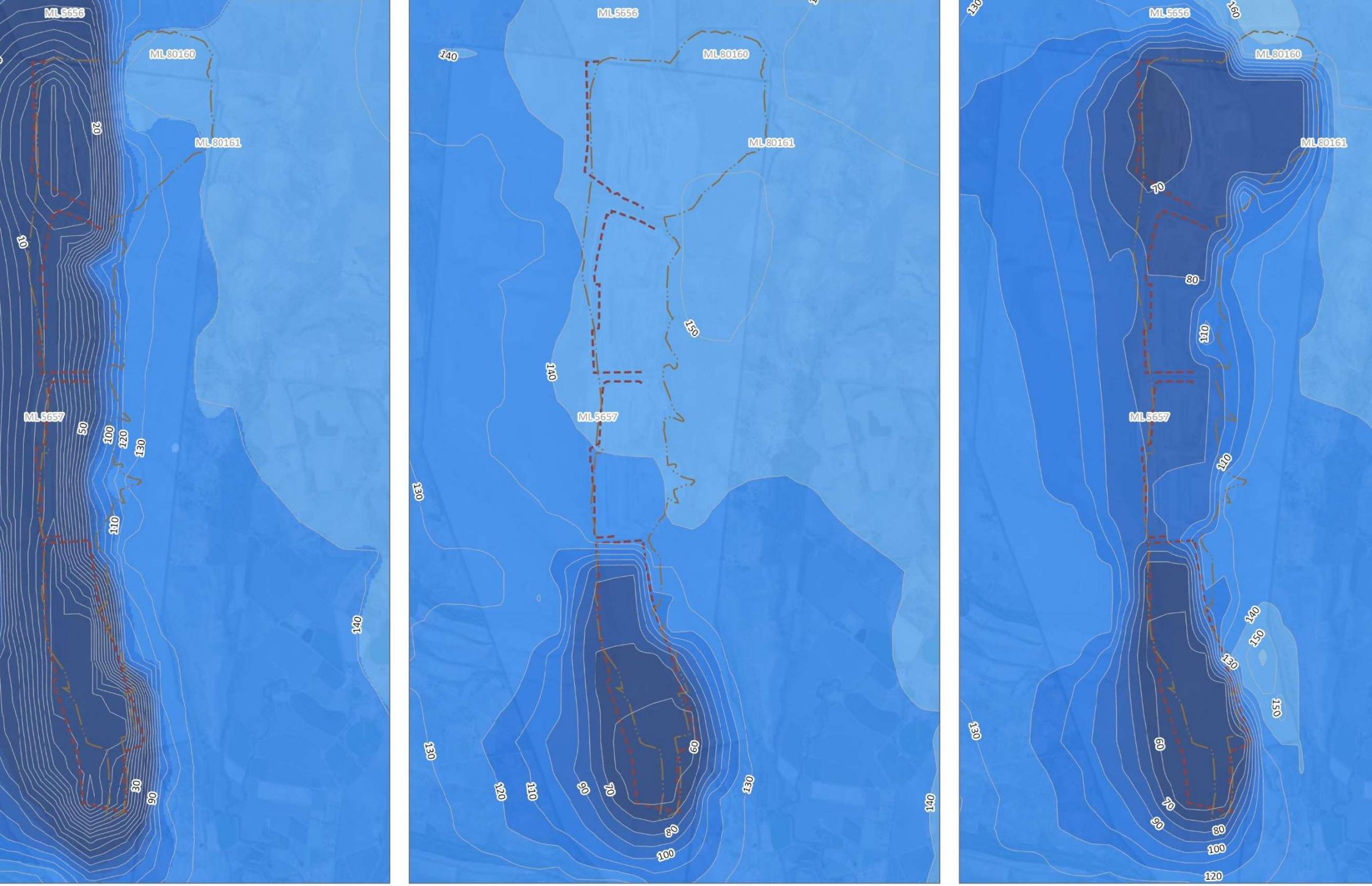

ML5656
ML80160
ML80161
ML5657
Groundwater Elevation (mAHD)
60 - 70
70 - 80
80 - 90
90 - 100
100 - 120
120 - 140
140 - 160
160 - 180
180 - 200
> 200
0 500 1,000 1,500 2,000
Meters
Scale: 1:75,000
Notes
1. Topographic fea
250K map series
2. Model bounda
3. Imagery courte

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Appendix I Groundwater Model Technical Report (with associated appendices)

1 INTRODUCTION

KCB Australia Pty Ltd (KCB) was commissioned by Anglo American Steelmaking Coal (SMC) to undertake the groundwater impact assessment (GIA) to support the application for amendment of the Dawson South Environmental Authority (EA) EPML00657413, in accordance with the Environmental Protection Act 1994 (EP Act).

The objective of this report is to assess the potential impact on groundwater resources and groundwater-dependent assets under the *Environment Protection Act 1994* (EP Act) (State of Queensland 2021) as a result of the proposed activities associated with the Project and other relevant guidelines.

1.1 Project Background

The Dawson Mining Complex is located within Queensland's Bowen Basin, ~175 km southwest of Gladstone. Dawson South comprises the southern extent of the complex, ~8 km north of Theodore.

The mining complex extends over 50 km (north-south) and comprises three distinct operating areas; Dawson North, Dawson Central, and Dawson South. Mining activity in the complex targets the Permian Baralaba Coal Measures.

Production of a mixture of coking, soft coking, and thermal coal is processed at the site, then transported by rail to the Barney Point Terminal and RG Tanna Coal Terminal for export.

The Dawson South mining area is located within the Mining Lease (ML) 5657 and ML 80160 boundary and is operated by Anglo American Steelmaking Coal in accordance with the Dawson South Environmental Authority (EA) EPML00657413. Open cut mining in the Dawson South mining area commenced in 2003. Coal is currently mined in three open cut pits (Pit 25, Pit 26 and Pit 27) located in the northern part of the Dawson South mining area. These pits are located along the strike of the coal seams. A fourth open cut pit (Pit 28) is existing mine plan in the southern part of the Dawson South mining area. The Proposed Project involves:

i. Reconfiguration/relocation and extension of the existing mine plan Pit 28 final void; and
ii. Alterations to the existing mine plan final landform, including addition of a new final void in Pit 25.

The Project will use the same open cut mining methods currently used in the Dawson South mining area and will utilise the existing Dawson Mine infrastructure and mining equipment.

The Project location (centred at Dawson South) is presented in Figure 1.1. Dawson South comprises three existing open pits (Pits 25 – 27) which will be backfilled in the future, and one proposed open pit (Pit 28). The Project will require an amendment to the Dawson South EA in accordance with the Environmental Protection Act 1994 (EP Act).

The environmental impact assessment (undertaken by others) will support the EA amendment application for approval from the Queensland Department of Environment and Science and Innovation (DESI) under the EP Act.



Figure 1.1 Dawson South Location

1.2 Report Structure

This report is structured as follows:

Section 1: Introduction – provides an overview of the Proposed Project, report purpose and structure.

Section 2: Regulatory Framework Context – describes the regulatory setting, for both Queensland and Commonwealth legislation, relating to groundwater and the project.

Section 3: Detailed Description – describes project location, project approval status and Proposed Project components.

Section 4: Assessment Methodology – describes the assessment method including the collection of relevant data and numerical groundwater modelling.

Section 5: Existing Environment – describes the relevant land uses, local topography, drainage and climate.

Section 6: Conceptualisation Hydrogeological Model – details the regional and local hydrogeological characteristics.

Section 7: Numerical Groundwater Modelling – provides a summary of the numerical groundwater modelling approach, design, calibration process, predictions and uncertainty analysis.

Section 8: Impact Assessment – provides a detailed description and the predicted effects of the Proposed mining on the local groundwater regime. This section also presents an assessment of the potential impacts on groundwater users and the sensitive environmental features. A summary of the potential risks to water resources and water-related assets, and the application of management controls for risk reduction, is also provided in this section in the form of a Risk Assessment.

Appendix I: Groundwater Modelling Report

2 REGULATORY FRAMEWORK

This report has been prepared with consideration of key guidelines, policies and legislation from the State of Queensland. This section provides an overview of key legislation/policies relevant to this assessment. The reporting and assessment have considered the requirements of applicable Commonwealth legislation relating to impacts on groundwater resources from mining. In this regard consideration of aspects such as flow regimes, recharge rates, inter-aquifer interaction, changes to groundwater and surface water interactions and groundwater table changes have been considered. Changes to the hydrological/hydrogeological characteristics of the proposed activities have been assessed as part of this study for the identification of potential impacts.

2.1 Queensland Legislation

2.1.1 Queensland Mineral Resources Act 1989

The Queensland *Mineral Resources Act 1989* (MR Act) entitles the holder of a mining lease to take or interfere with underground water (i.e. groundwater) as part of existing mine plan mining operations. This entitlement is termed the mining lease holder's 'underground water rights'.

Groundwater that is taken or interfered with while exercising the underground water rights is termed 'associated water'. The holder of the mining lease is entitled to use associated water for any purpose. To exercise the underground water rights for existing mine plan mining operations on mining leases that were in existence when the legislation came into force (i.e. 6 December 2016), the lease holder must:

- Comply with the notification requirements under Section 334ZP(6) of the MR Act by notifying the administering authority for Chapter 3 of the Queensland Water Act 2000 (Water Act) of the exercise of its underground water rights. The administering authority for Chapter 3 of the Water Act is the Department of Environment and Science (DES); and
- Comply with its monitoring and reporting obligations under Section 334ZP(5) of the MR Act and Chapter 3 of the Water Act. Section 334ZP(5) of the MR Act requires that the volume of associated water taken is measured and reported. Obligations under Chapter 3 of the Water Act include undertaking baseline assessments of the groundwater regime and water supply bores, providing ongoing assessment and reporting of groundwater take and (where necessary) entering into make good agreements with owners of affected water supply bores.

Under the requirements of the MR Act, the proponent notified DES of its intention to continue to exercise its underground water rights as part of the existing mine plan Dawson South mining operations. Existing mine plan mining is referred to the "Existing" mine plan throughout this document.

2.1.2 Environmental Protection Act 1994

The Queensland *Environmental Protection Act 1994* (EP Act) was amended in December 2016 to align the EP Act with the requirements of Chapter 3 of the Water Act.

Section 227AA of the EP Act requires that an EA amendment application that involves a change to the exercise of underground water rights must be supported by the following information:

- A description of each aquifer and the movement of water within each aquifer affected by the proposed activities;
- A description of the impacts of the proposed activities on environmental values;
- A description of the effects of the proposed activities on groundwater quality; and
- A description of any strategies to manage or mitigate the impacts of the proposed activities.

The supporting information required under the EP Act and as instructed in *requirements for site-specific and amendment applications – underground water rights* (DES 2021) is provided in this report. The conceptual groundwater regime, including relevant aquifers and the movement of groundwater is discussed in Section 5. The predicted effects of the Project changes in groundwater levels and quality are discussed in Section 7 and Section 8. The predicted impacts of the Proposed Project on groundwater users and sensitive environmental features are also addressed in Section 8**.**

The proponent will not require a separate approval (e.g. an associated water licence under the parallel provisions of the Water Act) in order to exercise its water rights.

2.1.3 Trigger Thresholds

Under Section 362 of the Water Act 2000, a bore trigger threshold for a consolidated aquifer of 5 m applies (2 m for an unconsolidated aquifer). The 5 m threshold represents the maximum allowable groundwater level decline in a groundwater bore, due to tenure holders' activities, prior to triggering an investigation into the water level decline and an assessment to establish whether a bore has, or is likely to have, an impaired capacity because of a tenure holder exercising their underground water rights. The presence of Groundwater-Dependent Ecosystems that may be impacted further by the Proposed Project is also a consideration and 1 m or incremental 0.2 m additional drawdown impacts may play a role in defining additional impact from the Proposed Project.

2.1.4 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The Environmental Protection (Water) Policy, the EPP (Water and Wetland biodiversity) provides a framework to protect and/or enhance the suitability of Queensland waters for various beneficial uses.

Groundwater resources within the Project area lie within the Dawson River catchment as listed in Schedule 1 of the EPP (Water and Wetland Biodiversity). The EPP states that the environmental values for groundwaters within the Lower Dawson River catchment may include aquatic ecosystems, irrigation, farm supply, stock water, aquaculture, primary recreation, drinking water and cultural and spiritual values.

2.1.4.1 Water Quality Objectives – Groundwater

The EPP provides water quality objectives (WQOs) to support and protect the various environmental values identified for waters within the Dawson River catchment. The groundwater WQOs for the Dawson River catchment are provided in the *Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment* (DES 2011) according to their chemistry zone and

depth category. Groundwater within the vicinity of the Dawson Mine (Northern area) is classified as ‘shallow’ and ‘deep’ under chemistry zone 34, a brackish (Na-Cl) type water. Groundwater within the Dawson Mine (southern area) within the project area is classified as ‘shallow’, under chemistry zone 21, an alluvial sequence with moderate salinity (Na-Mg-Ca, Cl) type water.

Section 6.8 presents the groundwater quality data relevant to the Project setting.

2.1.5 Water Resource and Resource Operations Plans

The water resource planning process under the Water Act provides a framework for the development of catchment-specific Water Plans. A Water Plan, along with Water Management Protocols, Resource Operations Licences and associated operations manuals, provides a management framework for water resources in a plan area, and includes outcomes, objectives and strategies for maintaining balanced and sustainable water use in that area.

The project area is outside of any groundwater management areas in the Water Plan (Fitzroy Basin) 2011. The Project site is located adjacent to, however, does not impact the Dawson Valley Water Management Area (Dawson H) under Schedule 3B of the Water Plan (Fitzroy Basin) 2011 area (Figure 3).

3 DETAIL OF PROJECT DESCRIPTION FOR GROUNDWATER

The Dawson mining complex lies over the Baralaba Coal Measures and coal resources are primarily produced from the Permian-age reserves contained in five major seams (Seams A to F). The mining complex extends over 25 mining leases and comprises three distinct operating areas; Dawson North (DN), Dawson Central (DC) and Dawson South (DS); which are aligned in a north south orientation along the strike of the coal seams and extend over a distance of approximately 50 km (JBT 2018).

Underground mining activities started in 1963 and ceased in 1994. The mine currently produces a mixture of coking, soft coking and thermal coal which is processed and then transported 150 km by rail to the Barney Point Terminal and RG Tanna Coal Terminal for export (JBT 2018).

Coal is currently mined in three open cut pits (Pit 25, Pit 26 and Pit 27) located in the northern part of the Dawson South mining area. These pits are located along the strike of the coal seams. A fourth open cut pit (Pit 28) is an existing mine plan in the southern part of the Dawson South mining area.

The Project involves:

- Reconfiguration and extension of the existing mine plan Pit 28 final landform; and
- Alterations to the existing mine plan final landform, including addition of new final void in Pit 25 and relocation and enlargement of the existing mine plan Pit 28 final void.

The Project will use the same open cut mining methods currently used in the Dawson South mining area and will utilise the existing Dawson Mine infrastructure and mining equipment. Figure 1.1 shows infrastructure and layout of the Dawson South mining complex including Pits 25, 26, 27 and 28.

3.1 Project Setting

A summary of the regional project setting is provided below, with further details included in the remainder of the report:

- The target coal seam for the Project is within the Baralaba Coal Measures, of the Permo-Triassic Bowen Basin.
- The Project is located adjacent to the Dawson Valley Water Management Area which forms part of the larger Fitzroy Basin.
- Groundwater in the Project area comprises three systems:
  - 1) shallow alluvial aquifers which generally follow water drainage systems and are thickest next to rivers and creeks;
  - 2) a deeper low permeability system associated with the Triassic Rewan Formation which is recognised as an aquitard; and
  - 3) The Baralaba Coal Measures which are recognised regionally as an interbedded aquitard (Section 6.5).

3.2 Project Approval Status

The Project's approval status within the legislative / regulatory framework is summarised by:

- Anglo is currently preparing to apply for an EA amendment for (ML) 5657 and ML 80160 under the Environmental Protection Act 1994 to authorise changes to mining landforms.
- An Environmental Assessment Report (EAR) is currently being prepared for the project. This will support the EA amendment application for the project approval from the Queensland Department of Environment and Science and Innovation (DESI) under the Environment Protection (EP) Act.
- The project must be supported by specific information on the take and/or interference with groundwater. Therefore, this Groundwater Impact Assessment Report has been prepared to support the EA amendment application.

3.3 Project Activities

The Project proposes to alter the final landform of Pit 25 to maintain a final void in the reconfigured Pit 25 final landform. Pit 28 will also undergo reconfiguration and extension of the final void.

The Project will continue to employ open cut methods which include dragline, truck and shovel methods. A summary of the Proposed mining activity is provided in the following section.

3.4 Mining Schedule

The Dawson mining complex consists of several mining areas spread over a strike-length of 50 km plus a coal handling and processing plant (CHPP) and train loading facilities. There are up to five separate coal mining horizons (seam groups) and associated splits are extracted in each mining area using shovel and truck operations for pre-strip and draglines for uncovering the lower coal seams (Anglo 2022). The mined coal is transported via overland conveyor to the CHPP where it is washed and then loaded into rail wagons and transported to the Port of Gladstone for export.

For Dawson South, the mining and extraction of coal occurs within existing surface rights areas from four pits (Pit 25, Pit 26 and Pit 27 and Pit 28) (see Table 3.1). The Proposed Project involves alterations to the final landform with a final void being maintained in Pit 25 as well as the reconfiguration and extension of the existing mine plan Pit 28 final void, with progressive rehabilitation conducted when Pits 26 and 27 are fully extracted. The approximate mine stages and timeframes are provided in Table 3.1.

Table 3.1 Mining activities and Timeframes

Mining Stage	Description	Timeframe
Pit 25	Recovering resource using extractive methods	2024-2030
Pit 26	Recovering resource using extractive methods	2024-2025
Pit 27	Recovering resource using extractive methods	2024-2027
Pit 28	Recovering resource using extractive methods	2027-2048

4 ASSESSMENT METHODOLOGY

4.1 Methodology and Data Sources

4.1.1 Assessment Area

The existing environment within the vicinity of the Project area was considered through a desktop assessment to establish the baseline groundwater conditions, environmental values and potential receptors.

The assessment area, for the purposes of this report, includes hydrogeological units underlying the Project within the Bowen Basin, Baralaba Coal Measures (Permian-aged strata). The Baralaba Coal Measures are overlain by the Rewan Formation (Triassic sedimentary rocks) which are in turn juxtaposed by Tertiary Sediments and Quaternary units (Alluvium deposits).

For the identification of groundwater receptors relevant to this Project, a nominal 5 km buffer around the Project area was established to capture potential adjacent groundwater receptors that may be impacted by the Proposed mining activity. Based on the assessment of drawdown for the Proposed mining activity compared to the Approved project (see groundwater modelling results in Appendix 1), a 5 km buffer is considered a sufficient distance beyond which potential drawdown will be low.

4.1.2 Database Searches and Government Mapping

A search of relevant Australian and Queensland databases was undertaken. The purpose of this search was to identify the presence of current and historical groundwater bores and collate drilling records and groundwater level, yield and quality data from relevant bores. The database search area included the Project area and its surrounds within a 5 km radius. The search radius was also considered representative of the geological and hydrogeological setting of the area.

The following databases and mapping were searched:

- The Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Database of registered water bore data from private water bores and Queensland Government groundwater investigation and monitoring bores. Sourced data includes bore location, groundwater levels, construction details, stratigraphic logs, available hydrogeological testing and available groundwater quality.
- The Queensland Spatial Catalogue (QSpatial), via Queensland Globe. Records of petroleum and coal seam gas (CSG) exploration, production and monitoring wells are contained within this database.
- Queensland Spring Register, published by the Queensland Herbarium (Queensland Herbarium 2018).
- Potential Groundwater Dependent Ecosystem (GDE) mapping published by the DES (DES 2018).
- Bureau of Meteorology (BoM), National Atlas of Groundwater Dependent Ecosystems (GDEs).
- Groundwater monitoring network within the Project area of Dawson South, including groundwater level and quality data.

4.1.3 Literature Review and Previous Groundwater Studies

A number of relevant studies have been conducted at, and within the vicinity of, the Project. These studies have supported the conceptual hydrogeological understanding of the Project area, as summarised in Table 4.1.

Table 4.1 Summary of Previous Reports

Document Name	Year	Author
Assessment of Hydrogeological Environment and Pit Inflow Estimates - Dawson South Stage 2 Coal Project	2004	Parsons Brinckerhoff
Whole Of Mine Groundwater Regime and Monitoring Program Dawson (Moura) Mine	2004	AGE
Whole of Mine Groundwater Regime and Monitoring Program Dawson (Moura) Mine	2004	AGE
Dawson (Moura) mine whole of mine groundwater regime & monitoring program mine layout - infrastructure	2004	AGE
Dawson (Moura) mine whole of mine groundwater regime & monitoring program water levels of coal seam gas bores (august 2004)	2004	AGE
Dawson (Moura) mine whole of mine groundwater regime & monitoring program locations of NRM registered bores	2004	AGE
Dawson (Moura) mine whole of mine groundwater regime & monitoring program mine layout - infrastructure	2004	AGE
Dawson South EIS appendices 10-14	2006	Anglo Coal
Dawson South environmental impact statement and environmental management plan	2006	EH&S Systems Pty Ltd
Assessment Report under the EP Act 1994 on the EIS for the Dawson South Stage 2 Coal Project	2007	Queensland Government EPA
Groundwater impact assessment Dawson central coal mine water supply/dewatering of underground mines	2007	AGE
Groundwater Impact Assessment Dawson Central Coal Mine Water Supply/dewatering of underground mines	2007	AGE
Moura no. 1 underground mine water resource	2010	AGE
Re: Moura no. 1 underground mine water resource	2010	AGE
Groundwater assessment report - Dawson mine South ml 5657	2012	EGC Pty Ltd
Groundwater Interaction with Dawson Final Voids	2018	JBT
Groundwater interaction with Dawson final voids	2018	Hatch/JBT
Dawson Mining Complex Water balance update - 1427-01-H1	2019	WRM
Dawson mine 2c west pit lake desktop review	2020	Stantec
Dawson South EIS GW Update	2023	KCB
Dawson South Extension Field Investigation Report	2023	Hydrogeologist.com.au

4.1.4 Dawson Mine Groundwater Monitoring Network

Table 4.2 summarises the groundwater monitoring network for Dawson South, including (where available) screened intervals or sensor depths, and hydrostratigraphic unit. Additional detail on available groundwater level data and groundwater quality data are provided in Table 4.3 and Table 4.4 respectively[1]. Bores are manually dipped and sampled on an ad-hoc basis with the majority of bores being part of the automated water level monitoring system. The monitoring network will be reviewed following the findings of this investigation.

[1] Only monitoring bores and vibrating wire piezometers with available data are included in the table.

Table 4.2 Groundwater Monitoring Network

ID	Easting[1]	Northing[1]	Type[2]	Drilled Date	Hydrostratigraphic Unit	Monitoring depths (mbgl)	Groundwater Level Data Available?	Groundwater Quality Data Available?
BH1	199360	7249750	MB	2011	Permian Coal Measures		Yes	Yes
BH2	199192	7249616	MB	2011	Permian Interburden (assumed)		Yes	Yes
BH3	199670	7246721	MB	2011	Permian Coal Measures		Yes	Yes
GW1	200118	7252308	MB	2005	Permian Coal Measures (D seam)		Yes	Yes
GW1A	200121	7252326	MB		Permian Coal Measures (DU seam)		Yes	Yes
GW2	199819	7259768	MB	2005	Permian Coal Measures (D seam)		Yes	Yes
GW2A	199933	7251406	MB	2005	Permian Coal Measures (E seam)		Yes	Yes
GW2B	199933	7251406	MB	2005			No	No
GW3	200817	7249737	MB				Yes	Yes
GW4	199909	7249574	MB	2005	Permian Coal Measures (D seam)		Yes	Yes
GW4A	199919	7249690	MB	2005	Fault		Yes	Yes
DSMB05	199958	7242428	MB	2022	Alluvium	14.0 - 17.0	Yes	Yes
DSMB06	199743	7243192	MB	2022	Alluvium	16.0 - 19.0	Yes	Yes
DSMB07	199158	7244361	MB	2022	Alluvium	16.5 - 19.5	Yes	Yes
DSMB08	200776	7241911	MB	2021	Permian Coal Measures (A seam)	69.0 - 78.0	Yes	Yes
DSMB10	201663	7241544	MB	2021	Permian Coal Measures (Underburden)	50.0 - 56.0	Yes	No
DSMB13	197538	7246445	MB	2022	Alluvium	17.0 - 20.0	Yes	Yes
DSMB14	197363	7248966	MB		Alluvium (dry)	13.0 - 16.0	No	No
DSMB15	199710	7245593	MB	2021	Permian Coal Measures (assumed interburden)	6.0 - 10.0	Yes	No
DSMB16	198609	7247568	MB		Alluvium (dry)	10.5 - 13.5	No	No
DSVWP01-1	199569	7245792	VWP		Permian Coal Measures (DU seam)	257.5	No	No
DSVWP01-2	199569	7245792	VWP		Permian Coal Measures (C seam)	243	No	No
DSVWP01-3	199569	7245792	VWP		Permian Coal Measures (B seam)	187	No	No
DSVWP02-1	200389	7243371	VWP	2021	Permian Coal Measures (DL seam)	138	No	No
DSVWP02-2	200389	7243371	VWP	2021	Permian Coal Measures (DU seam)	110	No	No
DSVWP02-3	200389	7243371	VWP	2021	Permian Coal Measures (C seam)	76	No	No
DSVWP03-1	201020	7240526	VWP	2021	Permian Coal Measures (C seam)	150	No	No
DSVWP03-2	201020	7240526	VWP	2021	Permian Coal Measures (DU seam)	190	No	No

ID	Easting[1]	Northing[1]	Type[2]	Drilled Date	Hydrostratigraphic Unit	Monitoring depths (mbgl)	Groundwater Level Data Available?	Groundwater Quality Data Available?
DSVWP03-3	201020	7240526	VWP	2021	Permian Coal Measures (DL seam)	230	No	No
DSVWP05-1	199740	7243193	VWP	2021	Rewan Group	140	No	No
DSVWP05-2	199740	7243193	VWP	2021	Rewan Group	87	No	No
DSVWP05-3	199740	7243193	VWP	2021	Rewan Group	45	No	No
DSVWP11-1	199785	7253142	VWP	2021	Permian Coal Measures (A seam)	103	No	No
DSVWP11-2	199785	7253142	VWP	2021	Permian Coal Measures (B seam)	165.5	No	No
DSVWP11-3	199785	7253142	VWP	2021	Permian Coal Measures (C seam)	225	No	No
28588	201239	7251989	MB				Yes	No
28589	201259	7251989	MB				No	No
28624	201230	7249876	MB				Yes	No
28627	201087	7249788	MB				Yes	No
28639	201186	7252065	MB				Yes	No

Notes:
1 = Easting and Northing coordinates have been compiled from various sources and are in AGD66, Zone 56
2 = MB: monitoring bore; VWP: vibrating wire piezometer
Blank cell = information not available or unknown

Table 4.3 Available Groundwater Level Data

ID	Number of Groundwater Level Measurements Available														
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 to 2021	2022
BH1	-	-	-	-	-	-	-	-	-	1	4	2	-	-	-
BH2	-	-	-	-	-	-	-	-	-	4	4	2	-	-	-
BH3	-	-	-	-	-	-	-	-	-	1	4	2	-	-	-
GW1	4	10	-	7	4	5	5	5	4	5	3	2	-	-	-
GW1A	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
GW2	4	10	-	7	4	5	6	3	-	-	-	-	-	-	-
GW2A	-	-	-	-	-	-	-	-	3	5	4	1	-	-	-
GW3	4	10	-	4	-	-	-	-	-	-	-	-	-	-	-
GW4	1	10	-	7	5	5	6	5	4	6	3	2	-	-	-
GW4A	-	-	-	-	-	-	-	-	3	6	4	-	-	-	-
DSMB05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
DSMB06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
DSMB07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
DSMB08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
DSMB10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
DSMB13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
DSMB15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1*
28588	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
28624	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
28627	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
28639	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
* = Water level measured following airlift development

Table 4.4 Available Groundwater Quality Data

ID	Number of Groundwater Quality Measurements Available														
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 to 2021	2022
BH1	-	-	-	-	-	-	-	-	-	-	3	2	1	1 (2018)	-
BH2	-	-	-	-	-	-	-	-	-	-	3	2	1	-	-
BH3	-	-	-	-	-	-	-	-	-	-	3	2	1	-	-
GW1	-	1	-	7	5	4	5	7	3	1	-	-	-	-	-
GW1A	-	-	-	-	-	1	-	-	-	-	2	2	-	-	-
GW2	-	1	-	7	5	5	6	5	-	-	1	-	-	-	-
GW2A	-	-	-	7	5	5	6	6	3	2	2	1	-	-	-
GW3	-	1	-	4	-	-	-	-	-	-	1	-	-	-	-
GW4	-	1	-	7	5	5	5	7	3	2	3	2	-	-	-
GW4A	-	-	-	4	-	5	6	6	3	2	3	-	-	-	-
DSMB05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
DSMB06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
DSMB07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
DSMB08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
DSMB13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

4.2 Data Analysis and Conceptualisation

Information compiled as part of the review of relevant data sets and previously completed assessments (Section 4.1) was analysed in detail to develop a conceptual understanding of the hydrogeological system. This included the key geology, groundwater flow and groundwater quality characteristics. The conceptualised groundwater regime is discussed in Section 5. The collated local groundwater dataset is considered fit for purpose for this Project and data that was used to develop the conceptual understanding included:

- Geological data collected from the proponent's current Geological Model (Vulcan). The Geological model was informed by data compiled by the geological logs collected from drilling across the Dawson Mining Leases, regional geological mapping and mapped structural geology.
- Groundwater level data collected from nineteen (19) bores screening the Permian Coal Measures and the Alluvium from within the Project area and its surrounds. Fifteen bores were used to monitor and record water levels in the Permian coal measures. This includes manual and automated logger groundwater level data from the Dawson groundwater monitoring bores and surrounding mine monitoring bores.
- Eight (8) Monitoring bores have been installed to monitor the shallower hydrostratigraphy (i.e. alluvium, Tertiary sediments, Tertiary basalt), however, groundwater was only recorded in four of these bores and has not been observed in these bores since installation.
- Hydraulic testing results collected from eight (8) rising/falling head tests conducted on eight Dawson South groundwater monitoring bores screened across the Alluvium and Permian Coal Measures.
- Groundwater quality data collected from 15 bores including detailed field measurements and laboratory results for key hydrostratigraphic units within and surrounding the Project area.

4.2.1 Geology

The geological setting has been compiled based on the following data sources:

- Geological logs and data compiled from drilling across the Project site, Dawson North, Central and Southern Mining leases;
- Geological data from registered bores within the vicinity of the project site held on DNRME's groundwater database;
- Publicly available geological mapping and reports; and
- Regional geological mapping included in the Bowen Basin Supermodel (CSIRO 2002). The geological setting forms the basis for the conceptual hydrogeological model described in Section 7 and provides the structural framework for developing a MODFLOW numerical groundwater model.

4.2.2 Groundwater Levels and Flow

Spatially distributed groundwater level data were used to characterise groundwater flow directions, gradients and velocities. The groundwater monitoring network at Dawson South includes 25 monitoring bores and 15 VWPs, screened or installed in four hydrostratigraphic units (Alluvium, Rewan, Permian Coal Measures, and a Fault Zone) at varying depths (Table 4.1, Table 4.2, and Figure 4.1). Groundwater levels from these bores in November 2024 provided on Figure 4.2 with the inferred groundwater levels (using the data and the last output from the transient calibrated model).

Hydrographs of available data are included in Appendix III of model report with further discussion in Section 6.7

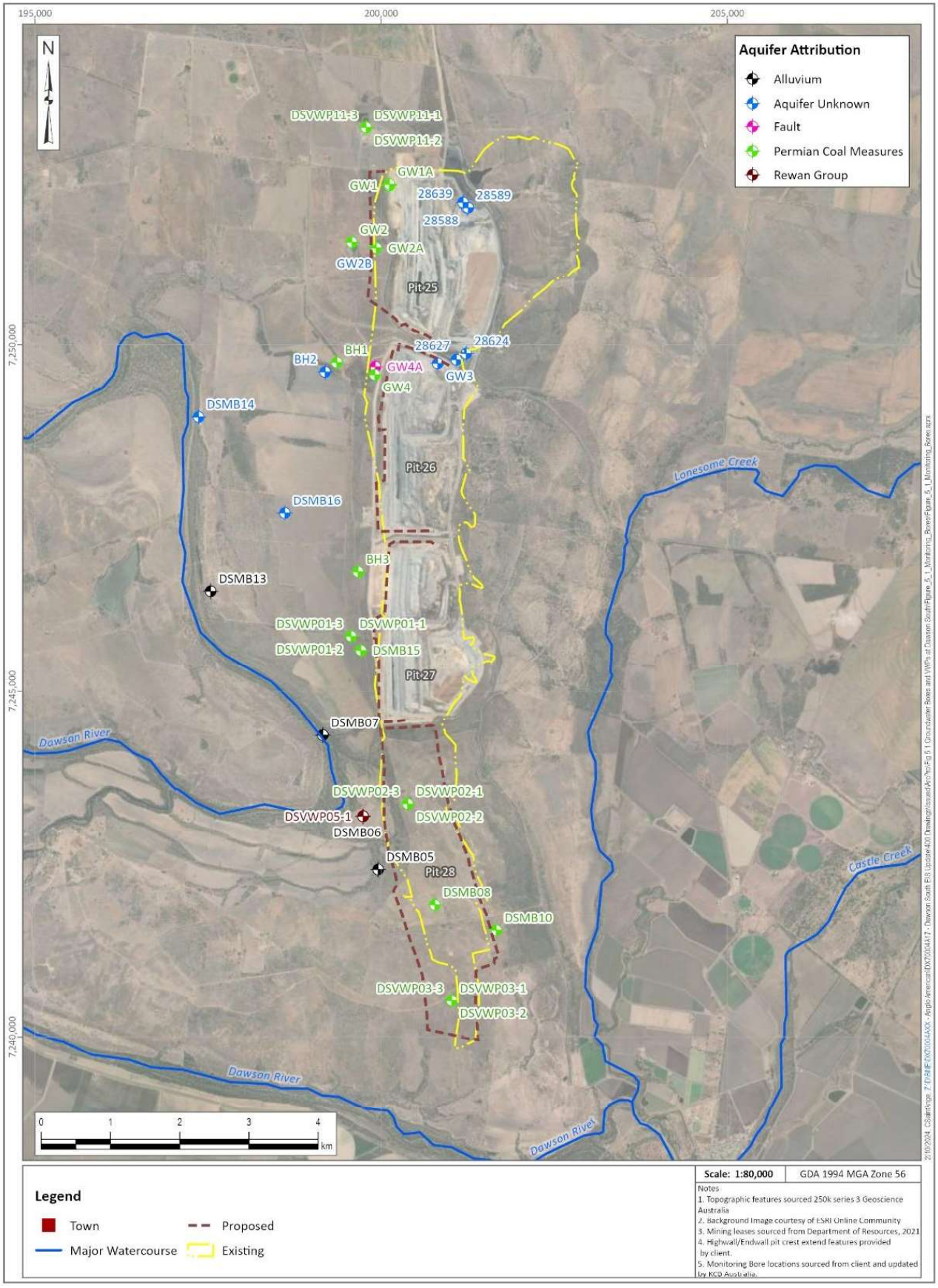


Figure 4.1 Dawson South Groundwater Monitoring Bore Network



Figure 4.2 Dawson South Groundwater Levels (Q4 2024)

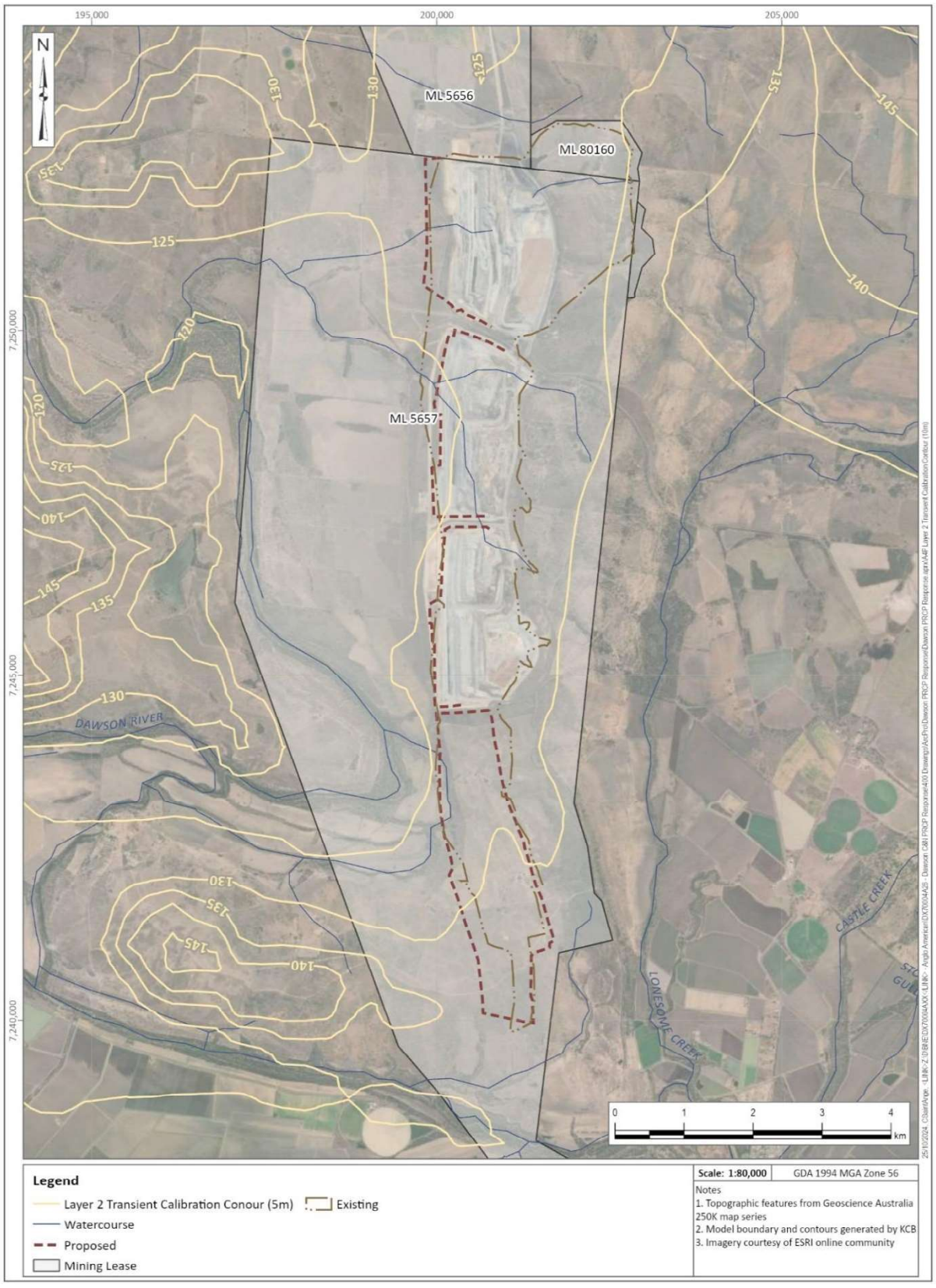


Figure 4.3 Inferred Dawson South Groundwater Levels (water table interpolated from transient model calibration results)

4.2.3 Groundwater Quality

Groundwater quality data provides useful information on the hydrogeological regime, as it is influenced by interaction with the aquifer matrix, and groundwater recharge/discharge processes.

Salinity is a key constraint to the usability of groundwater resources for productive applications such as potable supply, irrigation, stock watering and industrial applications. If groundwater with elevated salinity levels is used for incompatible purposes or applications it may result in impacts to agricultural productivity, health and the environment.

A categorisation scheme for salinity proposed by (FAO 2013) is presented in Table 4.5 and compared compiled results from laboratory analysis of groundwater samples collected from the current and historical Dawson groundwater monitoring bores. The dataset collected from these bores represents the most relevant and comprehensive, long-term record of groundwater quality within the vicinity of the Project. The groundwater monitoring bores on the Dawson Mine site indicate that the groundwater is moderately saline.

Table 4.5 Available Groundwater Quality Data

Salinity	Range (TDS md/L)	Groundwater salinity in Monitoring Bores (Average TDS (mg/L))
Fresh	<500	NIL
Brackish	500-1,500	-
Moderately Saline	1,500-7,000	GW1, GW2, GW3, GW4, DSMB05, DSMB06, DSMB07, DSMB08, DSMB13
Saline	7,000-15,000	-
Highly Saline	15,000-35,000	-
Brine	>35,000	-

4.3 Numerical Groundwater Modelling

A numerical groundwater model was developed from the conceptual groundwater regime and supported by the collated dataset. The numerical model was used to predict the effects of the Project on the groundwater regime during and post-mining. The modelling results were used to inform the assessment of the Project impacts on groundwater users and the surrounding environment, and the cumulative groundwater impacts of the Project. Numerical groundwater modelling was undertaken to represent the conceptual groundwater regime described in Section 6 and predict the effects of the Proposed Project activities on the groundwater regime (discussed in Section 8). A detailed description of the groundwater modelling methodology is provided in Appendix I.

5 EXISTING ENVIRONMENT

5.1 Topography and Drainage

The Dawson Mine Complex is located within the Dawson River Catchment (in the Fitzroy Basin), between the Dawson River to the west and the Malakoff Range (a prominent north south trending ridge) to the east. Westerly flowing creeks across the mine complex have been significantly altered by mining activities (AGE 2004).

Topography at the Dawson Mining Complex is generally flat to gently undulating, rising immediately east of the seam sub-crops with light brush and pasture covering the majority of the undisturbed watershed catchment. The Dawson Range (a northwest-southeast trending topographic high) is located to the west of Dawson River with elevations reaching 360 mAHD.

Topography and drainage across Dawson South are presented in Figure 5.1. Topography ranges from low-lying alluvial flood plains adjacent to the Dawson River, to undulating hills associated with the Malakoff Range. Kianga Creek, Castle Creek, and Lonesome Creek are located near the Project site, and all drain west into the Dawson River. Kianga Creek's course has been diverted due to mining activities further north of Dawson South (Figure 5.1).

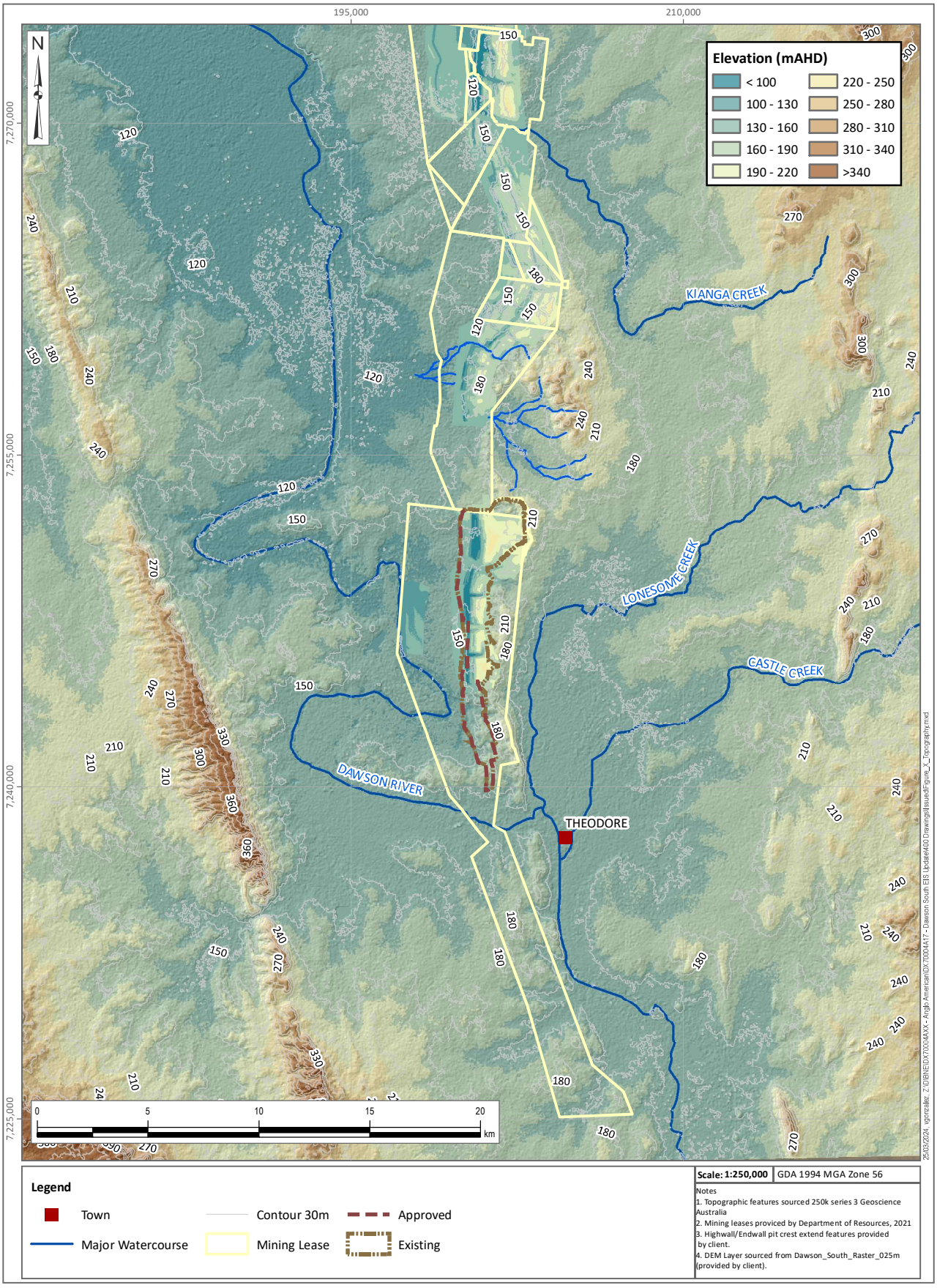


Figure 5.1 Regional Topography and Drainage at Dawson South

5.2 Climate

Dawson South mine is located in eastern Central Queensland which experiences a subtropical climate with moderately dry winters (modified Köppen classification system) (BOM. 2005). Climate summary statistics for the area including average annual rainfall and precipitation are presented in Table 5.1 rates are presented on Figure 5.2. Data from 1960 to present were analysed for this report.

Table 5.1 Climate Summary Statistics for Dawson South (SILO Grid lat, long: -24.85, 150.05), 1960 – 2024

Month	Mean Max. Temp	Mean Min. Temp	Mean Rainfall (mm)	Mean Evaporation (mm)
	1960-2024	*1960-2024*	*1960-2024*	*1960-2024*
January	33.8	20.6	85.1	231.1
February	33.4	20.6	90.4	187.8
March	31.9	18.6	54.9	187.8
April	29.3	14.7	34.6	146.0
May	25.6	10.7	33.9	109.0
June	22.6	7.5	28.1	84.3
July	22.3	6.0	28.0	92.2
August	24.3	7.1	23.8	123.0
September	27.7	10.7	28.9	164.4
October	30.5	14.6	61.0	206.2
November	32.1	17.5	75.4	219.3
December	33.4	19.5	87.6	237.1
Annual	-	-	**631.6**	**1988.3**

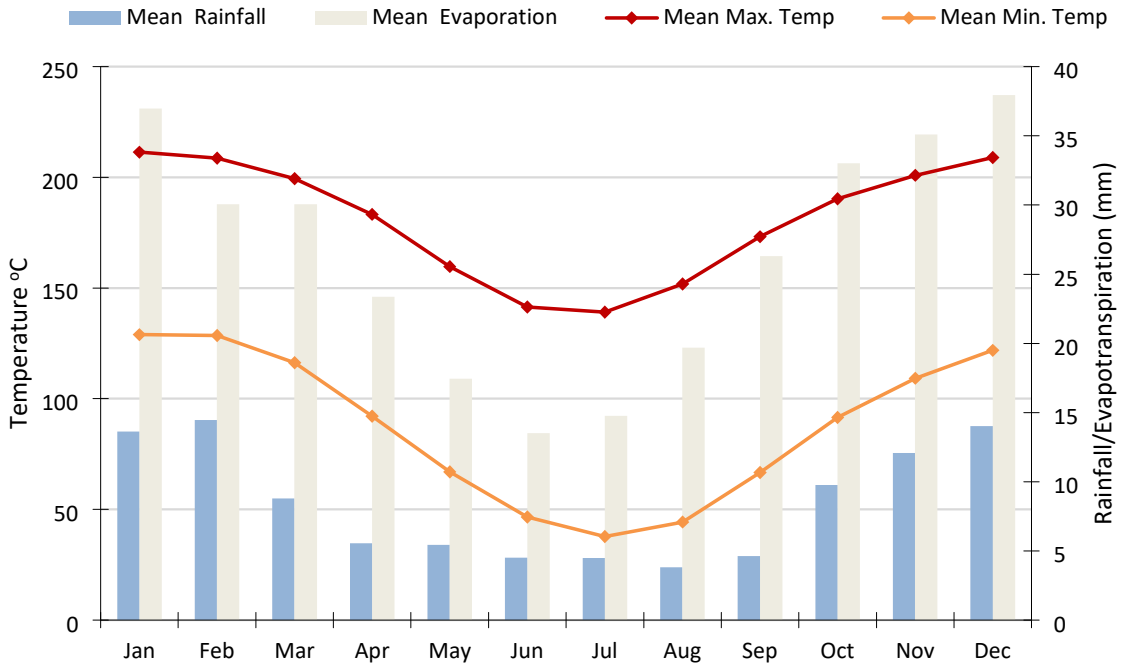


Figure 5.2 Average Monthly Climate at Dawson South (SILO Grid lat, long: -24.90, 150.03), 1960 – 2024

Maximum temperatures range between 33.8°C and 22.3°C during summer. Minimum temperatures range between 20.6°C and 6.0°C during winter. Daily evaporation rates are generally high and exceed rainfall throughout the year. Highest rainfall occurs December to February and lowest rainfall occurs April to September.

Synthetic rainfall data were used to analyse rainfall trends due to incomplete rainfall data for the Project area (State of Queensland 2022). SILO is an enhanced synthetic climate database that provides daily timeseries data for point locations and comprises observed weather station data augmented by interpolated estimates where observed data were absent.

Figure 5.3 presents daily rainfall between 1960 and 2024, alongside a cumulative rainfall departure (CRD) trend for the same period. CRD trends represent a running deviation of long-term actual rainfall against the overall average. This method provides season-scale identification of trends (wet / dry) and longer term (e.g., decadal) deviation from average conditions. CRDs are useful for correlating rainfall events with aquifer responses.

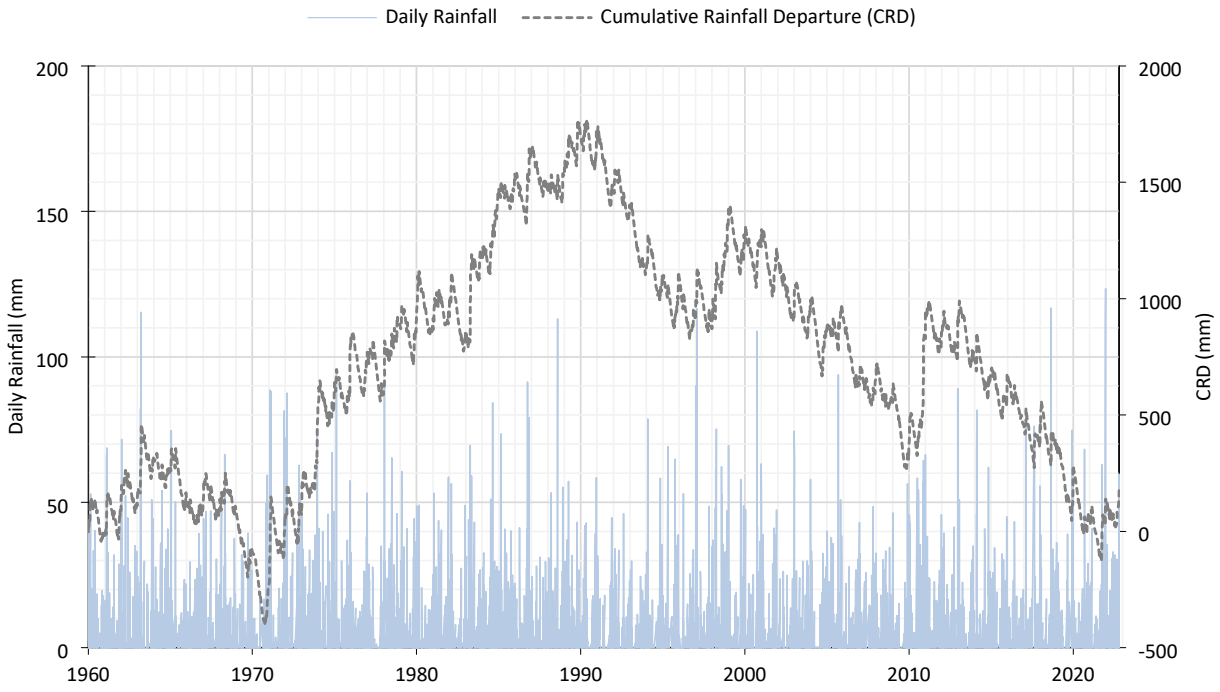


Figure 5.3 Historical Daily Rainfall and CRD Trend at Dawson South (SILO Grid lat, long: -24.90, 150.03), 1960 – 2024

Observations from the rainfall record and CRD trend include:

- The overall rainfall trend is characterised by wet / dry season cyclicity, with annual fluctuations of approximately 200 mm evident across the record.
- A period of increasing rainfall between 1971 and 1990 and an overall declining rainfall trend between ~2000 and 2024 (interrupted by the 2011 extreme wet season).
- High rainfall associated with the 2011 wet season is followed by a period of decline to below average rainfall conditions at present.

6 CONCEPTUAL HYDROGEOLOGICAL MODEL

6.1 Regional Geology

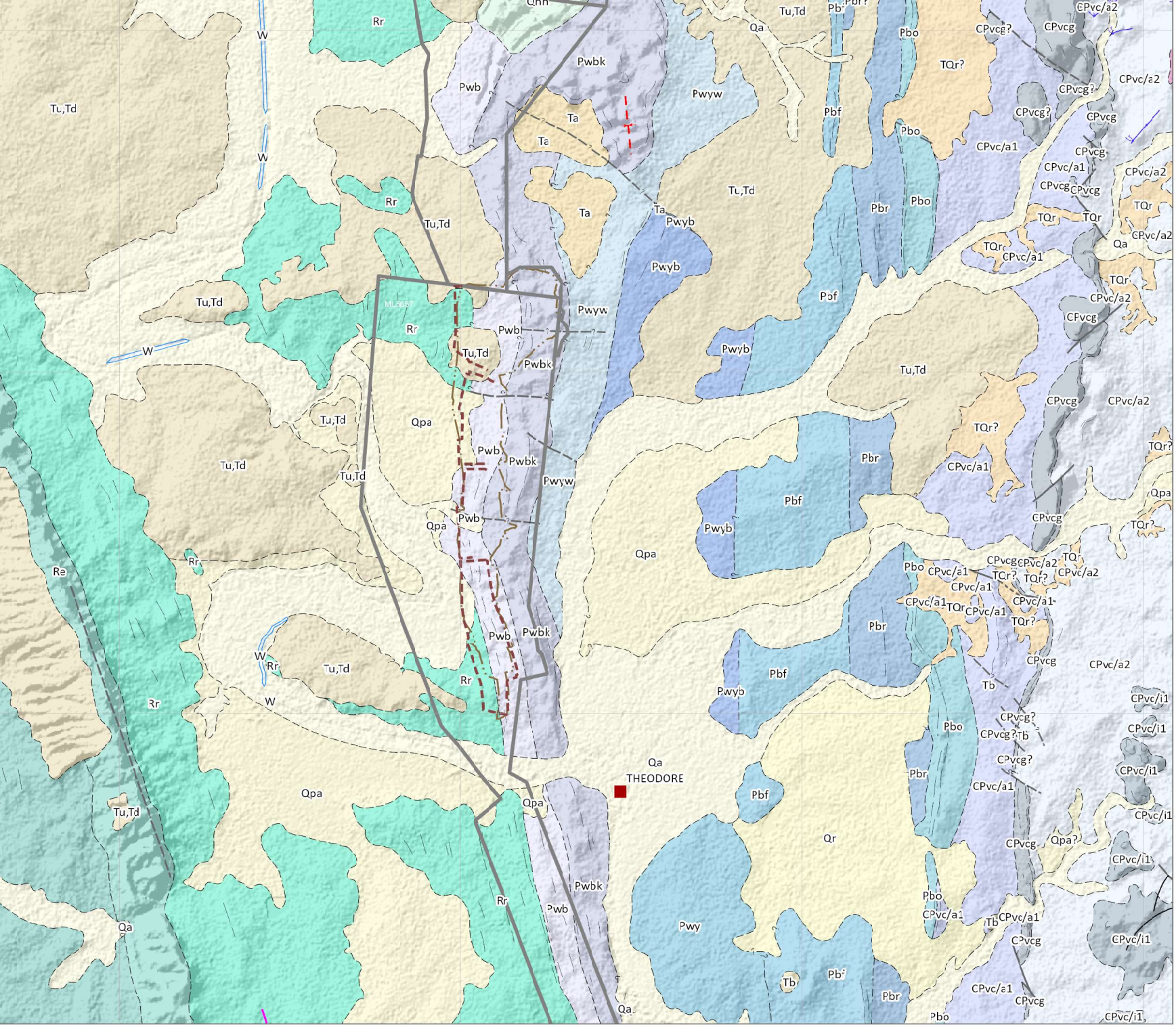
The Dawson Mining Complex is located within the Bowen Basin, an Early-Permian to Middle-Triassic foreland basin containing thick successions of shallow marine and non-marine sediments, volcanics, and productive Permian Coal Measures (Table 6.1, Figure 6.1 and Figure 6.2). Dawson South is overlain by Quaternary Alluvium associated with the Dawson River and associated creeks (JBT 2018).

General stratigraphy of the Dawson Mining Complex is presented Table 6.1. Permian coal-bearing strata generally strike north-south and dip 5° to 16° west. They are exposed to the east of the mining complex where isolated Tertiary or Quaternary watercourse sediments occur. Tertiary cover is relatively thin, thickening west where the unit becomes increasingly pervasive (JBT 2018). A series of minor roughly west-to-east striking faults are inferred to the east of the open pits that are part of the Project. The most prominent of these are located between pits and act to separate Pit 25 from Pit 26 and Pit 27 from Pit 28. These occur most in the deeper Permian units and are not indicated to extend to surface.

Information in this section comprises previously known geological information, augmented by geological data from bores drilled since 2004.

Table 6.1 Regional Stratigraphy at The Dawson Mining Complex

<table>
<tr><th colspan="2">Age</th><th colspan="2">Formation</th><th>Hydrostratigraphic Description (OGIA 2019b)</th><th>Relevance to Project area</th></tr>
<tr><td rowspan="2">Cenozoic</td><td>Quaternary</td><td colspan="2">Alluvium</td><td>Aquifer</td><td>Associated with watercourses</td></tr>
<tr><td colspan="2">Tertiary Sediments (includes residual Tertiary aged cover, Colluvium (Qr) and Duaringa Formation)</td><td>-</td><td>Deposits across the Project area</td></tr>
<tr><td rowspan="3">Jurassic</td><td rowspan="3">Early</td><td>Boxvale Sandstone Member</td><td>Evergreen Formation</td><td>-</td><td rowspan="3">Outcrops 25 km south of the Project area</td></tr>
<tr><td colspan="2">Precipice Sandstone</td><td>Aquifer</td></tr>
<tr><td rowspan="4">Triassic</td><td rowspan="2">Middle</td><td colspan="2">Moolayember Formation</td><td>Tight Aquitard</td><td rowspan="4">Predominantly located to the west of the Project area. However, the Rewan Group is also present within the Project area</td></tr>
<tr><td colspan="2">Clematis Group</td><td>Major Aquifer</td></tr>
<tr><td rowspan="2">Early</td><td colspan="2" rowspan="2">Rewan Group</td><td rowspan="2">Tight Aquitard</td></tr>
<tr><td rowspan="2">Permian</td></tr>
<tr><td>Late</td><td colspan="2">Baralaba Coal Measure</td><td>Interbedded Aquitard</td><td>Target CSG formation</td></tr>
<tr><td>Middle</td><td colspan="2">Back Creek Group</td><td>-</td><td rowspan="2">Located east of the Project area</td></tr>
<tr><td colspan="2">Pre-Permian Basement</td><td colspan="2">Basement Rocks</td><td>-</td></tr>
</table>



Quaternary Alluvium, Qa
Qhh-QLD
Qpa-QLD
Qpa?-QLD
Qr-QLD
TQr-QLD
TQr?-QLD
Ta-YARROL/SCAG
Tb-QLD
Duaringa Formation,Td-QLD

Solid Geology

Moolayember Formation, TRm
Clematis Group, Tre
Rewan Group, Rr
Baralaba Coal Measures, Pwb
Kaloola Member, Pulk
Gyranda Subgroup, Puy
Banana Formation, Pwy
Wiseman Formation
Flat Top Formation, Pbf
Barfield Formation, Pbr
Barfield Formation?, Pbr?
Oxtrack Formation, Puo
Camboon Volcanics/a1, CPvc/a1
Camboon Volcanics/a2, CPvc/a2
Camboon Volcanics/i1, CPvc/i1
Gonyelinka Ignimbrite Member
Gonyelinka Ignimbrite Member?
Waterhole, W

Fault accurate
Fault approximate
Fault concealed
Fault inferred
Fault interpreted f
Geological bounda
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Lake, lagoon or wa
Lineament
Sedimentary facies
Syncline inferred
Trend line
Trend line showing

0 2

Scale
Notes
1 Top

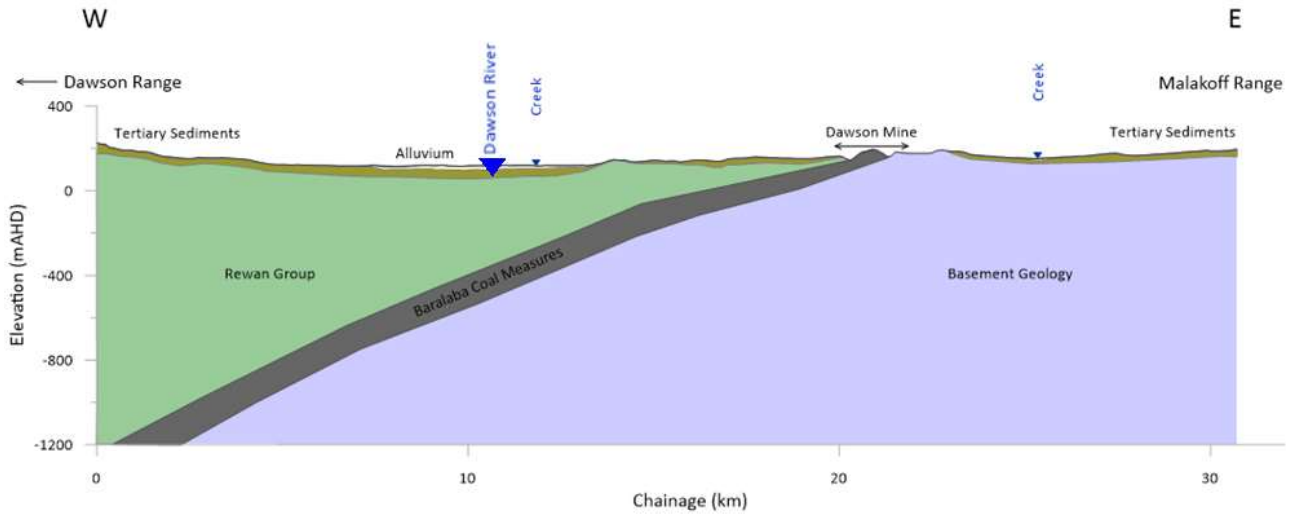


Figure 6.2 Schematic Geological Cross-section for the Dawson Mining Complex

6.2 Geological Units

6.2.1 Alluvium (Recent)

Regional Quaternary deposits comprise a sequence of unconsolidated alluvium deposited by the Dawson River and associated creeks. Primary alluvial deposits associated with the Dawson River occur within the Project area. Lesser alluvial deposits associated with Kianga Creek and Lonesome Creek occur in the north and east. Alluvium is composed of fine to coarse grained gravels and channel sands interbedded with silt and clay lenses. The formation overlies Tertiary deposits and Triassic to Permian units. Alluvium thickness ranges from 17 – 21 m and distribution are variable.

6.2.2 Tertiary Sediments

Tertiary Sediments (clay, silt, sands, and gravel) occur beneath Quaternary Alluvium in some areas (DNRME 2018). The unit is not exposed within the Project area; however, it is exposed beyond the Dawson Ranges. Exposures of limited extent also occur west of the Project area.

The Duaringa Formation unconformably overlies Permian units of the Bowen Basin and is the most exposed geological unit in the area. The unit is composed of mudstone, sandstone, conglomerate, siltstone, shale, lignite and basalt (Murray and Cranfield 1989).

Geological contacts between Tertiary-Quaternary colluvium and the Duaringa Formation are often indistinguishable due to lithological similarities between the two units. The units are therefore considered to be a single unit, hereafter referred to as the ‘Tertiary Sediments’.

6.2.3 Rewan Formation (Triassic)

The Rewan Group comprises reddish-brown to greenish-grey siltstones and mudstones, and thick-bedded, fine to medium-grained, micaceous and feldspathic sandstones. Thin, medium-coarse grained, poorly sorted sandstones occur near the top of the unit (Olgers et. al. 1966).

6.2.4 Baralaba Coal Measures (Permian)

The Late-Permian Baralaba Coal Measures underlies the Rewan Group and forms the upper parts of a larger group known as the Blackwater Group. The Baralaba Coal Measures comprises economical coal seams interbedded with calcareous mudstone, siltstone, and shale overburden/interburden (CDM Smith 2016). The Baralaba Coal Measures were deposited in predominantly paludal and lacustrine environments. The lower section comprises carbonaceous shale, limestones, coal, and sandstone deposited during base level fluctuation sedimentation.

Baralaba Coal Measures strike north south and dip 5° to 16° west (AGE 2011); the lower range is likely more representative within the Project area. Upper coal seams of the target Baralaba Coal Measures occur ~40 m below ground level in the eastern area of PL 94, to >1,500 m below ground level in the western section.

6.2.5 Kaloola Member (Permian)

The Kaloola Member (equivalent to the Burngrove Formation) comprises mudstone, siltstone, sandstone, conglomerate, and minor coal (Geoscience Australia 2022) and is the basal sub-unit of the Baralaba Coal Measures.

The Kaloola Member outcrops to the east of the Project area, immediately east of the Dawson Mine. The unit is recognised as an interbedded aquitard.

6.2.6 Gyranda Formation (Permian)

The Late-Permian Gyranda Formation is part of the Blackwater Group and comprises siltstone and shale with minor tuff, sandstone, and coal (rare).

6.3 Structural Features

The Bowen Basin contains a variety of thrust faults, volcanics, extensional fault systems, and reactivated faults resulting in a structurally complex basin (OGIA 2021).

The main structural feature (located in the southern part of the Bowen Basin) is the Mimosa Syncline, located ~45 km west of the Dawson Mining Complex. The syncline axis follows the Taroom Trough and basin development occurred during the Triassic (Dickins and Malone 1973).

Discontinuous northwest-southeast trending faults occur to the northeast of the Dawson Mining Complex. Multiple phases of deformation resulted in reactivation of older structures. A compressional event during the Middle Cretaceous caused uplift and erosion of the Bowen and Surat Basins and their associated volcanic arcs (Green 1997).

Regional faulting is summarised below (JBT 2018):

- Reverse faults occur throughout the Moura area;
- Reverse faults generally strike north-west and dip 30° to 70° northeast;
- Fault displacement is variable along strike, and it is assumed that larger faults (with vertical displacements >2 to 3 m) will disrupt all coal seams;
- Structural movement occurs along faults following weaker zones in strata, which may occur within the seam or along lithological boundaries;

- Some faults are less than 1 m wide, however, others may comprise fractured zones which can be 20 - 30 m wide; and
- Dominant joint set trend is north south to northwest/southeast with 2 to 4 m joint spacing (Figure 6.1). Iron oxide staining is present in some fracture surfaces, indicating water movement along joints.

6.4 Existing Hydrogeology

6.4.1 Groundwater Bores

The groundwater monitoring network at Dawson South includes 25 monitoring bores and 15 VWPs, screened or installed in four hydrostratigraphic units (Alluvium, Rewan, Permian Coal Measures, and a Fault Zone) at varying depths (Figure 4.1). All monitoring bores with available data were installed post-2004.

6.5 Hydrostratigraphy

Three main aquifer types occur at Dawson South: a shallow alluvial aquifer; a weathered basement aquifer; and a sequence of deeper sedimentary rock aquifers (schematically on Figure 6.2).

The alluvial aquifer occurs within unconsolidated sediments deposited on land by rivers, creeks, and flood events. Alluvial aquifers generally follow surface water drainage systems and are thickest next to rivers and creeks, thinning laterally with distance. Alluvial aquifers directly overlie weathered basement and competent rock aquifers. Bore logs indicate alluvial thickness at Dawson is between 17 and 21 m.

Weathered basement aquifers occur directly beneath alluvium or outcrop at the surface and consist of a weathered zone of basement rock typically 2 m to 25 m thick (AGE 2004). Monitoring bores DSMB06 and DSMB13 (drilled during 2022) indicate a weathered zone of 1.5 m to 15 m thick (Hydrogeologist.com.au 2022). Primary porosity occurs within intergranular space and secondary porosity within fractures. These aquifers may have moderate to high hydraulic conductivity and storage capacity.

Competent rock aquifers underlie weathered basement aquifers and consist of competent, un-weathered rock. Groundwater storage in these aquifers may be within intergranular space where rock porosity and permeability are high (e.g., sandstone), or in fractures where rock porosity and permeability are low (e.g., mudstone). These units are described in detail in the subsection that follow, and indicative idealisation of the units across the region and closer to Dawson South are shown on Figure 6.3 to Figure 6.5.

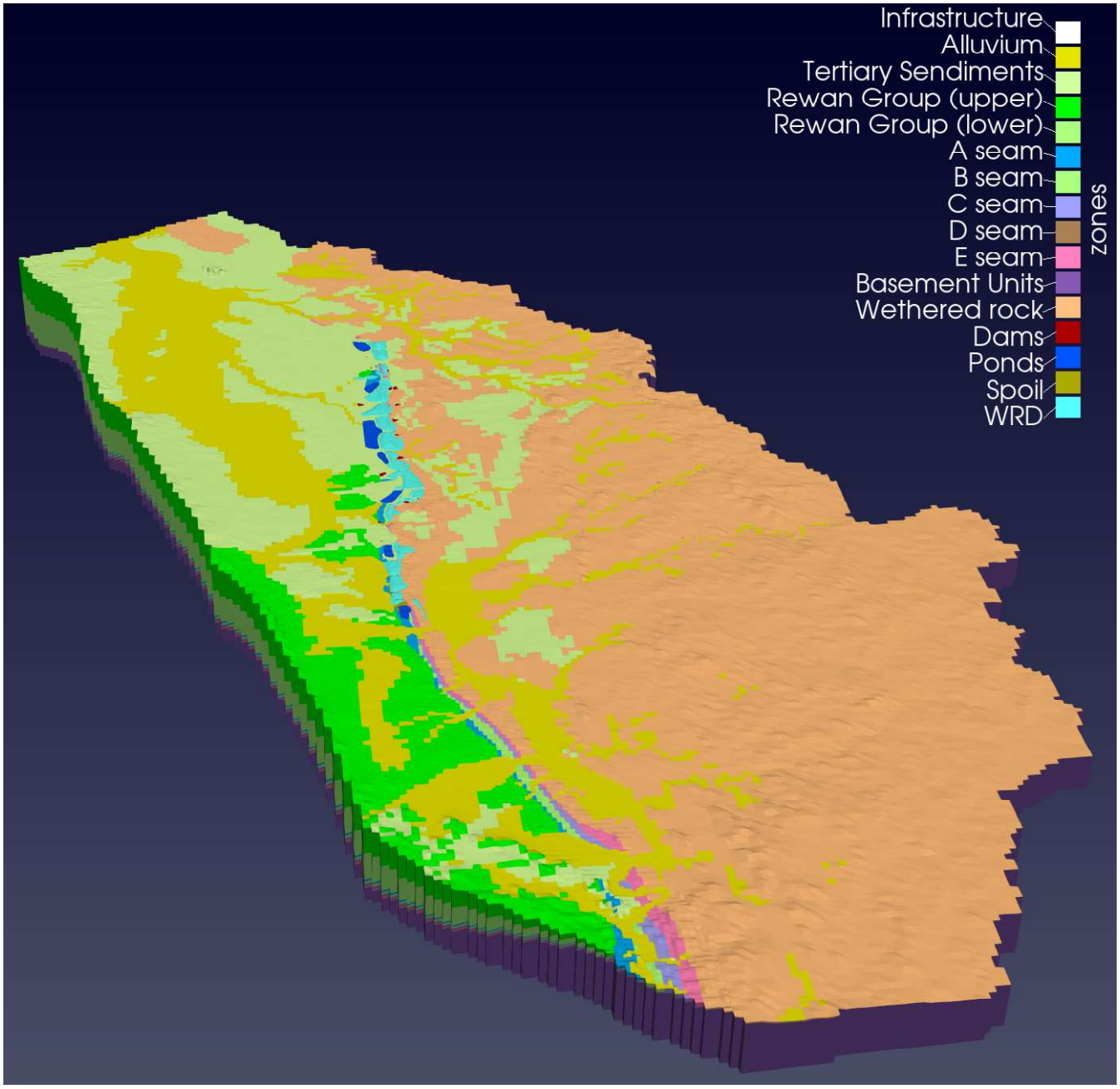


Figure 6.3 **Hydrostratigraphic variation across the region as represented by the numerical model domain**

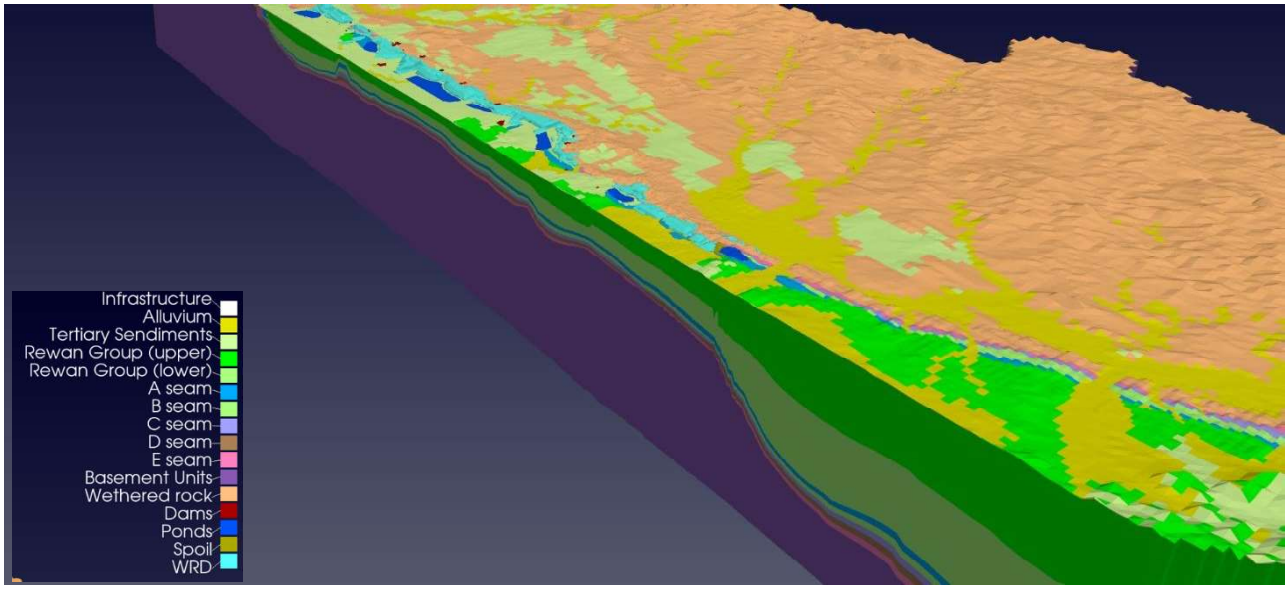


Figure 6.4 North -South Cut through the Dawson Area showing hydrostratigraphic variation

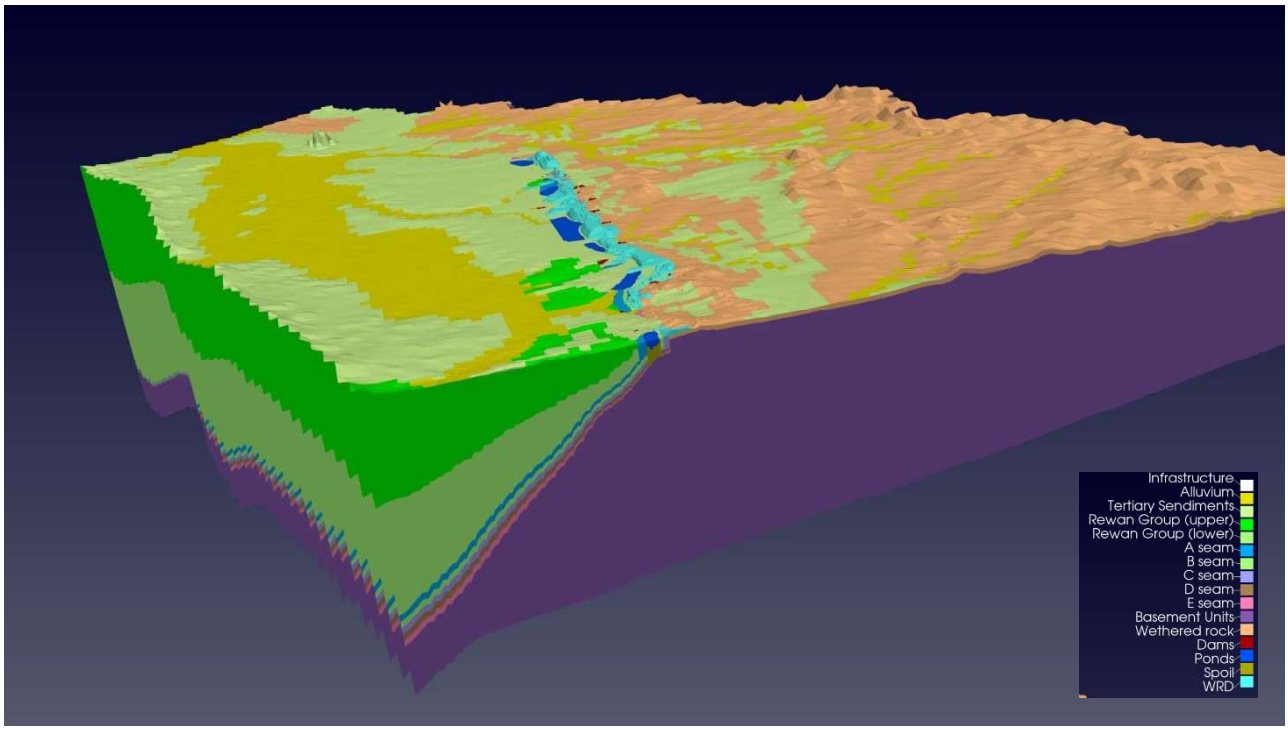


Figure 6.5 West -East Cut approximately along Dawson Central/Dawson South boundary showing hydrostratigraphic variation

Additional detail on the hydrogeological properties of each aquifer type is provided below:

6.5.1 Alluvium/Tertiary Sediments *Aquifer*

Quaternary Alluvium comprises unconsolidated sediments with relatively high hydraulic conductivity and storage which form a complex sequence of productive confined and semi-confined aquifers (of variable thickness and lateral extent) and interbedded aquitards. Stratigraphic complexity occurs where grain size and cementation are variable: interbedded mud/clay lenses and sands/gravels.

Tertiary Sediments comprise a sequence of weathered, weakly consolidated or unconsolidated sands, silts, and clays.

6.5.2 Rewan Formation *Tight Aquitard*

The Rewan Formation is a thinly interbedded sequence of siltstone, claystone, and minor fine-grained sandstone that overlies the Permian Coal Measures. It is recognised as a regional aquitard and forms a confining unit which overlies the Permian Coal Measures. This unit is characterised by low primary porosity; therefore, groundwater movement is controlled by secondary porosity (local fracture sets). This unit exhibits slightly higher permeability where fractures intersect; where fracture intersections are absent lower permeability (associated with primary porosity) occurs (KCB 2022).

6.5.3 Baralaba Coal Measures *Interbedded Aquitard*

The Baralaba Coal Measures outcrops to the east of the Project area (CDM Smith 2019) and are recognised regionally as an interbedded aquitard (OGIA 2021). The unit's coal seams are the primary regional-scale conduits for groundwater flow within Permian units.

Interbedded fine-grained shales and siltstones exhibit low permeability and form local aquitards; however, target coal seams often exhibit higher permeability and form confined aquifers.

6.5.4 Transmissive Fault Zones

Faults and fractures influence both regional and local groundwater movement by providing preferential flow paths or creating compartmentalisation across the hanging wall and foot wall of faults. Initially high yields in those zones decrease over relatively short timeframes (weeks or months), indicating that faulted rock zones represent high-yielding aquifer systems with low storage.

When faulted rock units are drained of groundwater, recharge will occur from adjacent groundwater storage units (spoils, surface water-recharged dilated zones close to mined voids) along fractures.

6.6 Hydraulic Conductivity

Hydraulic conductivity values for Dawson aquifers from various sources are summarised in Table 6.2. Hydraulic conductivity values from six pumping tests in the alluvium range from 1.27 to 12.7 m/day (KCB 2022). The Rewan Formation is characterised by generally low hydraulic conductivity (ECG 2012). Hydraulic conductivity within the coal seams is generally low despite them being the main conduits for groundwater flow in that unit.

Table 6.2 Hydraulic conductivity values for Dawson South

Source Reference	Source Type	Hydraulic Conductivity, K (m/day)		
		Alluvium and Tertiary Sediments	Rewan Formation	Permian Coal Measures
KCB 2023	Test pumping	1.27 to 12.7	-	-
Hydrogeologist.com.au 2022	Packer tests	-	5.8×10^{-5} to 1.3×10^{-3}	1.1×10^{-4} to 9.8×10^{-2}
EGC 2012	Literature Review	-	1.2×10^{-3} to 6.1×10^{-4}	2.4×10^{-6} to 1.1×10^{-2}
AGE 2004	Packer tests	-	-	8.6×10^{-3} to 1.7×10^{-2} (*Moura North*) 4.3 to 1.7×10^{-2} (*Dawson South Stage 1*) 4.3×10^{-4} to 1.1×10^{-2} (*Dawson South Stage 2*)

6.7 Groundwater Levels, Flow, Recharge and Discharge

Baseline groundwater flow (pre-mining) is from east to west with a hydraulic gradient of 0.01 in the Dawson South Stage 2 area (PB 2004). Mining at Dawson South (Pit 25) commenced in August 2003.

Groundwater levels in the Permian Coal Measures are shown in Figure 6.6 from 2003 to 2023. A steady decline can be seen from 2003 to 2011 in response to dewatering of the mine pits. Groundwater levels then show a notable stabilisation/recovery during 2011 following a major recharge event (see CRD in Figure 5.3), indicating a resilient groundwater system which is responsive to recharge during high rainfall years. There is a data gap from 2013 to mid-2022 after which monitoring commenced at DSMB08 and at DSMB10 located near Pit 28. The data at DSMB10 is erroneous and has not been included. Groundwater levels range from 90 to 160 mAHD across all bores and there seems to be a general north-westward decline in groundwater elevations. There is a single bore in the Rewan which has consistently reported no water levels since installation.

Groundwater level monitoring in alluvium bores commenced mid-2022 and the data is shown in Figure 6.7. The bores are screened at depth and groundwater elevations do not show any significant response to rainfall recharge or response the rainfall patterns and flow changes in the adjacent surface water. This is likely due to the complex (and discontinuous) layering of clays, sands and gravels which have formed aquifers that are capped by aquitards preventing direct connection to the runoff within the river. Results suggest that the water levels in the alluvial are fairly stable and likely not well connected to river systems. At the time of reporting (October 2024), the site was in the process of installing automated loggers to provide a more reliable and continuous data set for the alluvial bores.

More complete hydrographs for the site monitoring and surrounding bores is included in Appendix III of the model report.

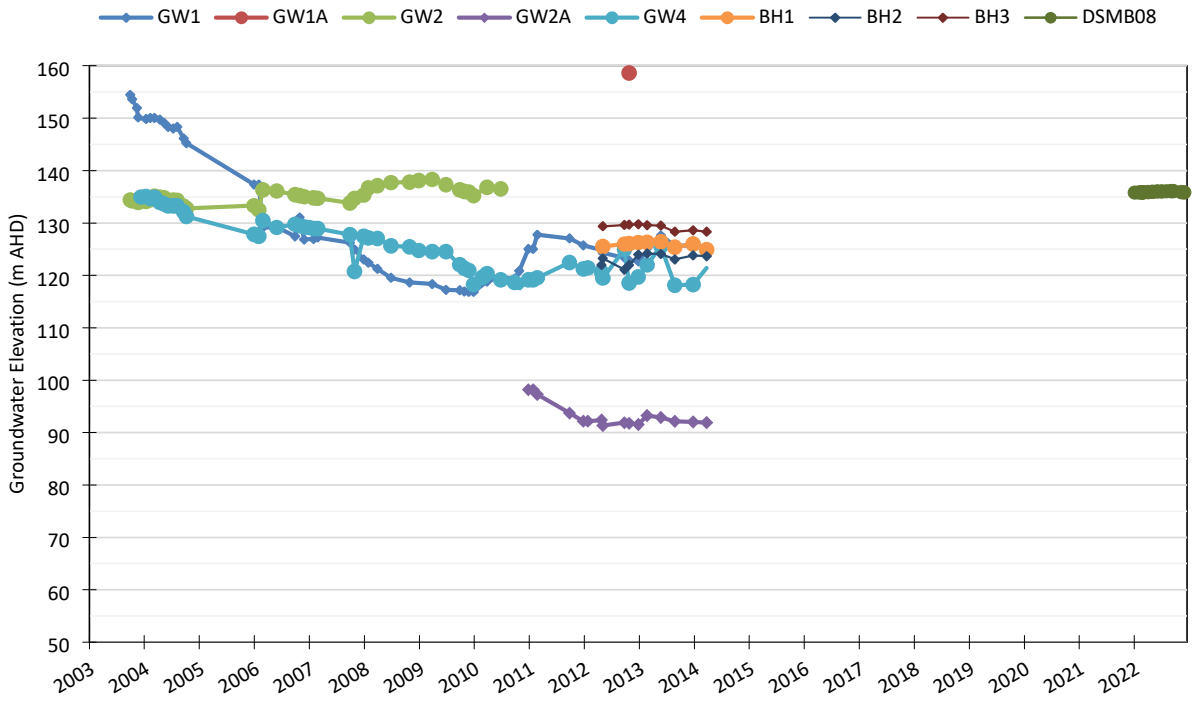


Figure 6.6 Groundwater Elevations, Permian Coal Measures

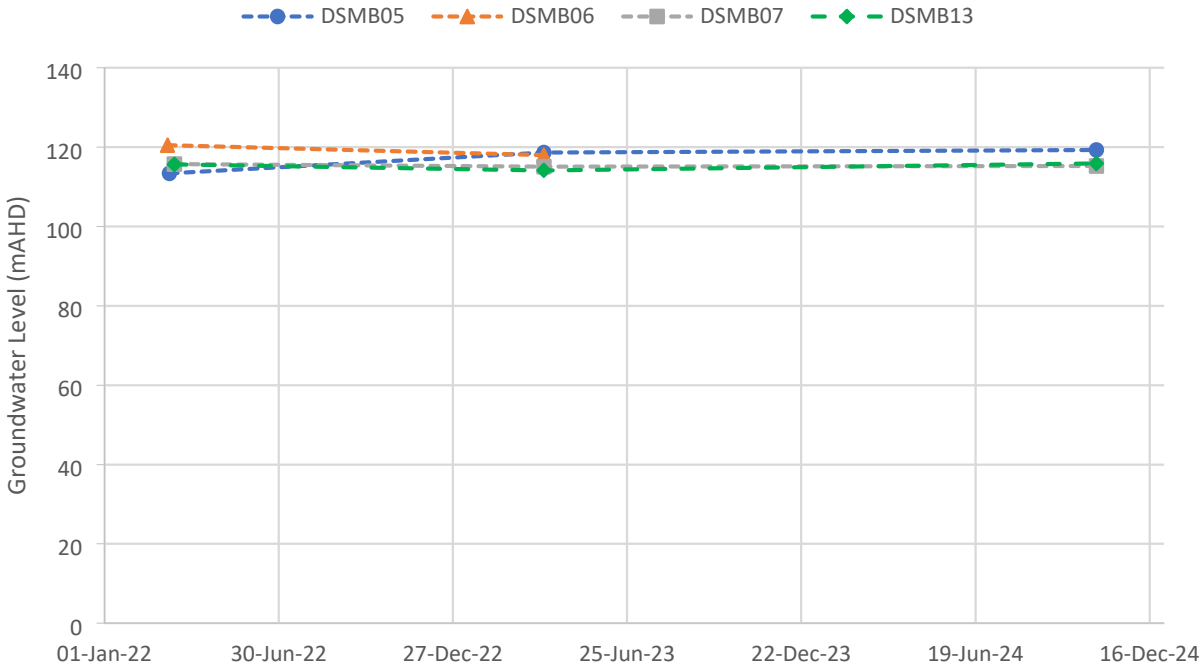


Figure 6.7 Current groundwater elevations in bores screened in the Alluvium

6.8 Groundwater Chemistry

Groundwater quality records were analysed for Alluvium and the Permian Coal Measures within Dawson South.

This section provides groundwater monitoring results from data collected in 2022 for the Alluvium, from 2004 to 2012 and 2022 for the Permian Coal Measures.

Timeseries plots for key parameters (pH, EC, sulfate, chloride) are presented in subsequent sections. Those parameters were selected as representative water quality indicators because changes in those parameters provide indication of changing groundwater quality or hydrogeochemical conditions (Table 6.3).

Table 6.3 Water Quality Summary Data for Dawson South

Parameter		Alluvium	Permian Coal Measures
pH (pH units)	Min.	8.0	6.3
	Max.	8.3	9.2
	Mean.	8.1	7.5
Electrical Conductivity (µS/cm)	Min.	3660	210
	Max.	8460	11830
	Mean.	5013	4049
Sulfate (mg/L)	Min.	108	2.1
	Max.	687	886
	Mean.	442	93
Chloride (mg/L)	Min.	892	1320
	Max.	1010	1320
	Mean.	933	1320

It should be noted that higher EC is expected in the Permian Coal Measures (which is more saline) relative to the alluvium (which may have variable but generally lower salinity) as a consequence of depositional setting. Anomalous minimum and mean EC in alluvium is a function of a smaller sample size (n = 4) relative to the Permian Coal Measures (n = 140).

6.8.1 Alluvium

Water quality data were not available for bores screened in alluvium pre-2022. A summary of 2022 data is provided below:

- pH values range from 8.01 to 8.27, indicating slightly alkaline groundwater.
- Electrical Conductivity (EC) values range from 3660 to 8460 uS/cm. Highest EC was observed in DSMB05.
- Chloride concentrations range from 892 to 2240 mg/L. Highest chloride concentration observed in DSMB05.
- Sulfate concentrations range from 108 to 687 mg/L.

6.8.2 Permian Coal Measures

Figure 6.8 to Figure 6.10 present timeseries plots for pH, EC, and sulfate for bores screened within the Permian Coal Measures. Data are summarised below:

- pH values generally range from 6.0 to 9.0. Three sampling periods in 2009 and 2010 recorded alkaline pH at 8.5 to 9.0. Most bores during these periods fluctuated in a similar pattern, indicating possible response to a common groundwater influence.

- Electrical Conductivity for most bores screened within the Permian Coal Measures declined from the start of the monitoring in 2004 and remained stable until 2012. GW2 exhibited declining EC levels before slightly increasing from 2009 to 2010.
- Stable sulfate concentrations were observed for all bores screened within the Permian Coal Measures. Maximum sulfate concentrations were recorded at the start of the monitoring period in 2004 and have since declined and remained stable at less than 250 mg/L until 2012. DSMB08 recorded 521 mg/L in January 2022.
- No pre-2022 data were available for chloride.

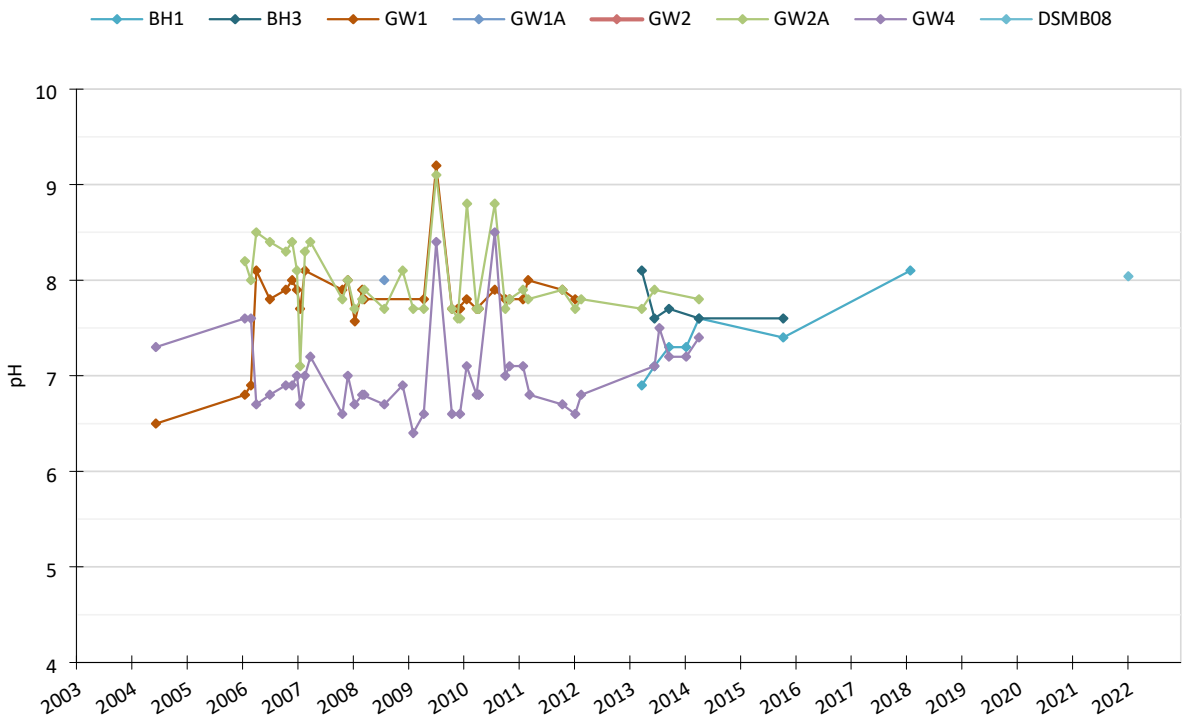


Figure 6.8 pH of Groundwater in the Permian Coal Measures

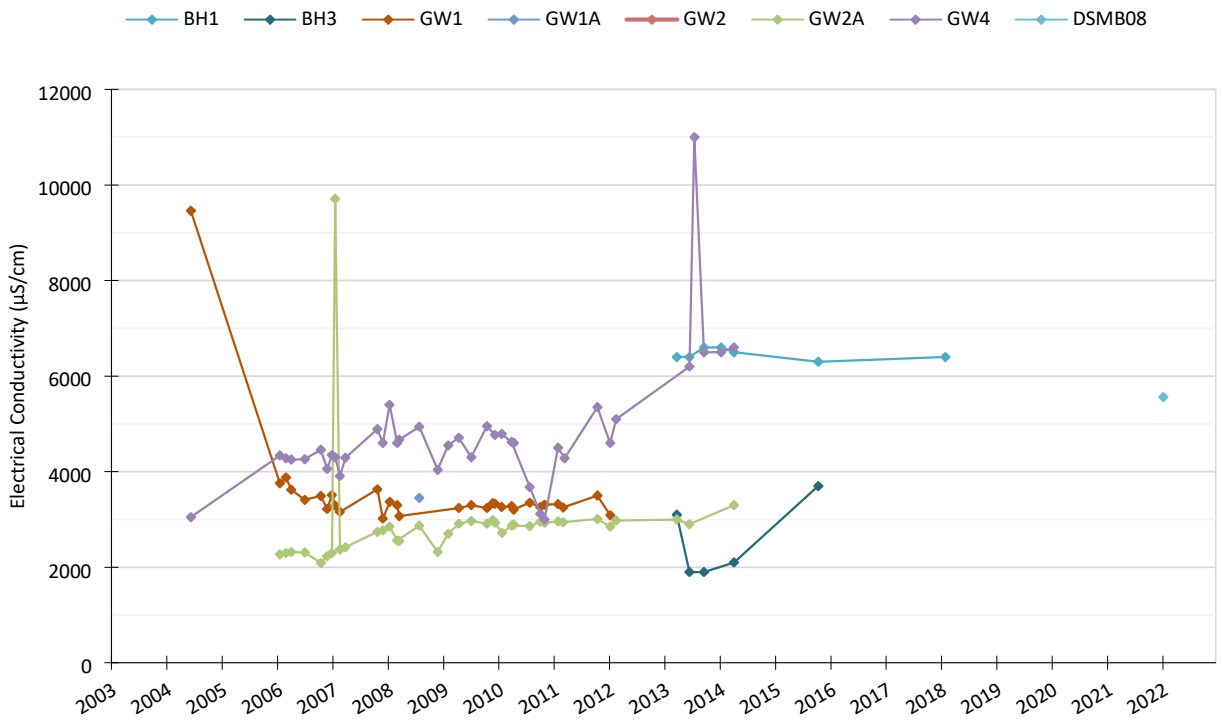


Figure 6.9 EC of Groundwater in the Permian Coal Measures

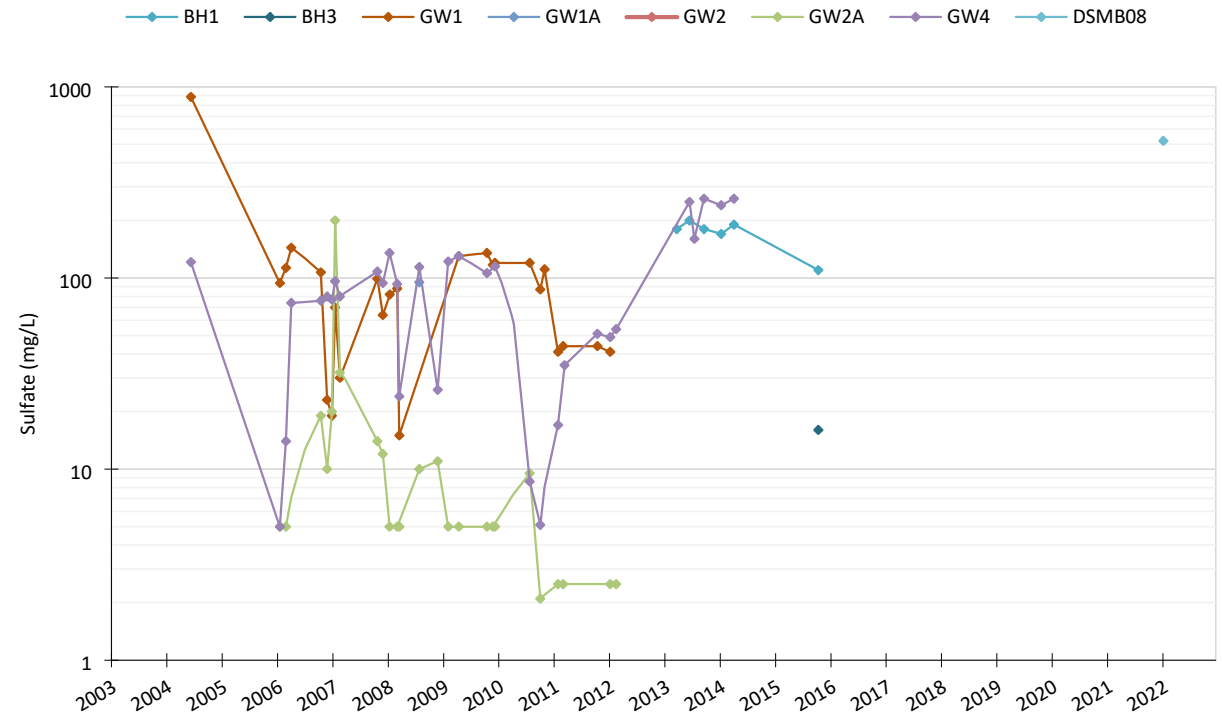


Figure 6.10 Sulfate of Groundwater in the Permian Coal Measures

6.9 Groundwater-Surface Water Interactions

Groundwater-surface water interaction within the Project area may occur from two key processes, where surface water systems are either gaining or losing, or both along the length of the drainage systems:

- Discharge of groundwater to watercourses as baseflow; and
- Recharge to aquifers as leakage from watercourses.

Recharge to groundwater systems from watercourses (like the Dawson River) may occur across the Project area.

6.10 Springs and Groundwater Dependent Ecosystems

GDEs are defined as 'Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes and ecosystem services' (Richardson et al. 2011). There are three categories of GDEs:

- Aquatic GDEs, which are ecological communities dependent on the surface expression of groundwater, including springs other than EPBC-listed springs, river baseflow systems (watercourse springs), riparian ecosystems and wetlands.
- Terrestrial GDEs, which are surface ecosystems dependent on the subsurface presence of water (i.e., terrestrial vegetation accessing the water table below ground), including ecosystems that are intermittently and permanently dependent on groundwater; and
- Subterranean GDEs, which are subterranean ecosystems dependent on the permanent presence of subsurface water.

6.10.1 Potential Aquatic GDEs

Public domain information of mapped springs and wetlands (DNRME 2018), indicates that there are no known springs within 5 km of the Project area. Based on the GDE mapping, there are no potential surface expression GDEs located within 5 km of the Project site.

6.10.2 Potential Terrestrial GDEs

GDE mapping of the Fitzroy basin indicates that there is low confidence terrestrial GDEs located along the course of the Dawson River and Lonesome Creek which comes within 5 km of the Project area (Figure 6.11). These terrestrial GDEs are characterised by treed ecosystems on which intermittently access fluctuating groundwater in alluvial deposits. The groundwater within the shallow alluvium fluctuates with wet-dry seasonal runoff in the river system as water infiltrates and becomes perched on shallow clay layers, allowing it to be accessed by the vegetation.

To the east and west of Dawson South are areas marked as nature refuge, namely the Willawa Nature Refuge (these lie to immediate east of Pit 26 and Pit 27 and adjacent to Dawson River to the west of these pits). A nature refuge is "a voluntary agreement between a landholder and the Queensland Government to protect the significant natural and cultural values of privately managed land" as declared in the Nature Conservation Act 1992. The nature refuge hosts a

Brigalow ecological community (dominated by *Acacia harpophylla*) which is listed as endangered but not a wetland and it occurs mostly on gently undulating slopes (DCCEEW 2013).

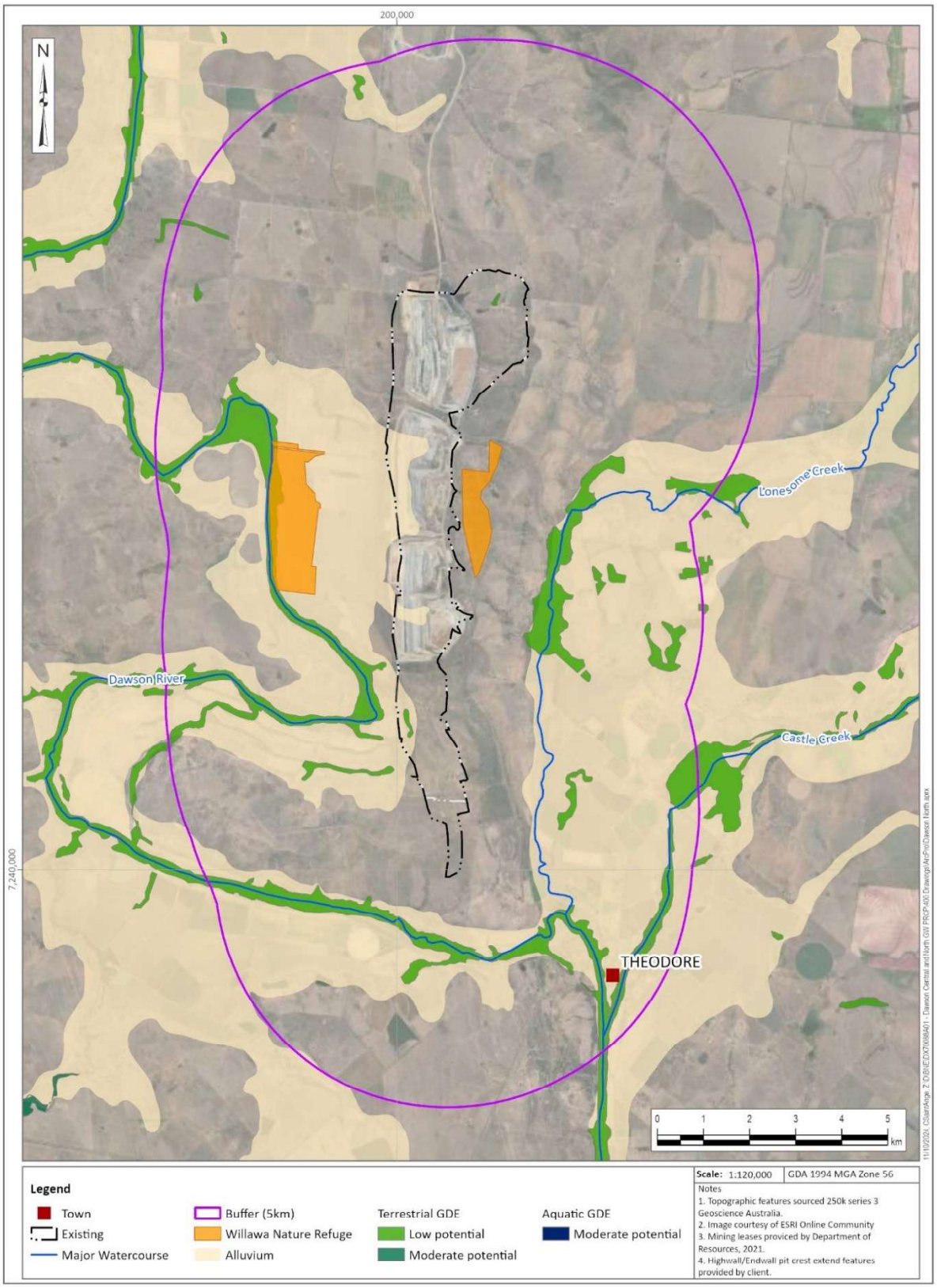


Figure 6.11 Potential Terrestrial and Aquatic GDEs from Desktop Review

6.11 Third-Party Groundwater Users

Table 6.4 summarises the current registered bores from the DRDMW groundwater bore database that occur within a 5 km buffer of the Project area. A total of 49 registered bores are located within the 5 km buffer of the Project area. Note that the groundwater database is not considered a complete record of bores in the area and that there may be unregistered bores present.

Figure 6.12 presents the location of these registered bores; which comprise:

- 36 bores screened in the Quaternary Alluvium;
- 7 bores screened in the Baralaba Coal Measures;
- 1 bore screened in the Gyandra Subgroup; and
- 5 bores where the screened lithology is not stated.

There are 83 listed abandoned bores which include past exploration bores and groundwater monitoring bores within 5 km of the Project area. These bores comprise:

- 15 petroleum gas exploration bores screened in the Baralaba Coal Measures; and
- 68 water monitoring and investigation bores screened in the Dawson River Alluvium.

The majority of the bores screened in the Quaternary Alluvium are for water supply purposes. Seven bores screened in the Quaternary Alluvium are listed as monitoring bores. All of the bores screened in the Baralaba Coal Measures are mine monitoring bores. This information has been used to inform the conceptual understanding of the groundwater regime and the numerical groundwater model discussed in Sections 7 and 8, respectively.

Table 6.4 Summary of Registered Groundwater bores within 5 km of Project Area

Bore	Screened Lithology (Bore Card)	Screened Interval	Recorded Use
38975	Dawson River Alluvium	18.6-21.4	Water Supply
47549	Dawson River Alluvium	10.7-13.7	Water Supply
62918	Castle Creek Alluvium	16.7-19.2	Water Supply
68103	Lonesome Creek Alluvium	16.4-19.0	Water Supply
68104	Lonesome Creek Alluvium	17.8-21.4	Water Supply
68105	Lonesome Creek Alluvium	15.5-21.8	Water Supply
68337	Lonesome Creek Alluvium	16.6-19.4	Water Supply
68338	Lonesome Creek Alluvium	17.5-20.2	Water Supply
89508	Castle Creek Alluvium	15.5-17.5	Water Supply
89546	Dawson River Alluvium	19.3-21.0	Water Supply
89563	Castle Creek Alluvium	21.0-23.2	Water Supply
89591	Lonesome Creek Alluvium	14.1-16.2	Water Supply
89619	-	-	Water Supply
111712	-	6.00-24.0	Water Supply
128096	-	-	Water Supply
128151	Castle Creek Alluvium	17.5-19.00	Water Supply
128192	Gyranda Subgroup	23.4-25.8	Water Supply
128193	Cattle Creek Alluvium	20.5-23.5	Water Supply
128298	Dawson River Alluvium	16.0-22.0	Water Supply
128647	-	25.5-37.5	Water Supply

Bore	Screened Lithology (Bore Card)	Screened Interval	Recorded Use
128831	Castle Creek Alluvium	14.0-20.0	Water Supply
128957	Quaternary Alluvium	18.4-20.6	Water Supply
128958	Lonesome Creek Alluvium	16.31-18.14	Water Supply
128965	Castle Creek Alluvium	20.34-23.59	Water Supply
170009	Quaternary Alluvium	16.15-18.59	Water Supply
170221	Dawson River Alluvium	19.20-21.34	Water Supply
170259	Castle Creek Alluvium	21.64-23.47	Water Supply
170358	Dawson River Alluvium	7.0-10.0	Monitoring Bore
170367	Baralaba Coal Measures	26-29	Monitoring Bore
170368	Baralaba Coal Measures	69.0-78.0	Monitoring Bore
170369	Baralaba Coal Measures	50.0-56.0	Monitoring Bore
170406	Quaternary Alluvium	17.36-19.34	Water Supply
170423	Quaternary Alluvium	14.5-18.5	Monitoring Bore
170446	Castle Creek Alluvium	16.64-18.14	
170447	Dawson River Alluvium	19.49-21.49	
170448	Dawson River Alluvium	17.66-19.96	
170449	Quaternary Alluvium		
170464	Quaternary Alluvium	11.0-14.0	
170465	Quaternary Alluvium		Monitoring Bore
170466	Quaternary Alluvium	10.5-13.5	Monitoring Bore
170467	Quaternary Alluvium	27.31-39.31	
170470	Quaternary Alluvium	10.5-13.5	Monitoring Bore
170471	Quaternary Alluvium	11.0-14.0	Monitoring Bore
170472	Quaternary Alluvium		Monitoring Bore
170495	-		Water Supply
196314	Quaternary Alluvium	16.5-19.5	Monitoring Bore
196315	Baralaba Coal Measures	17.0-20.0	Monitoring Bore
196316	Baralaba Coal Measures	-	Monitoring Bore
196317	Baralaba Coal Measures	15.5-18.5	Monitoring Bore
196484	Baralaba Coal Measures	-	Monitoring Bore

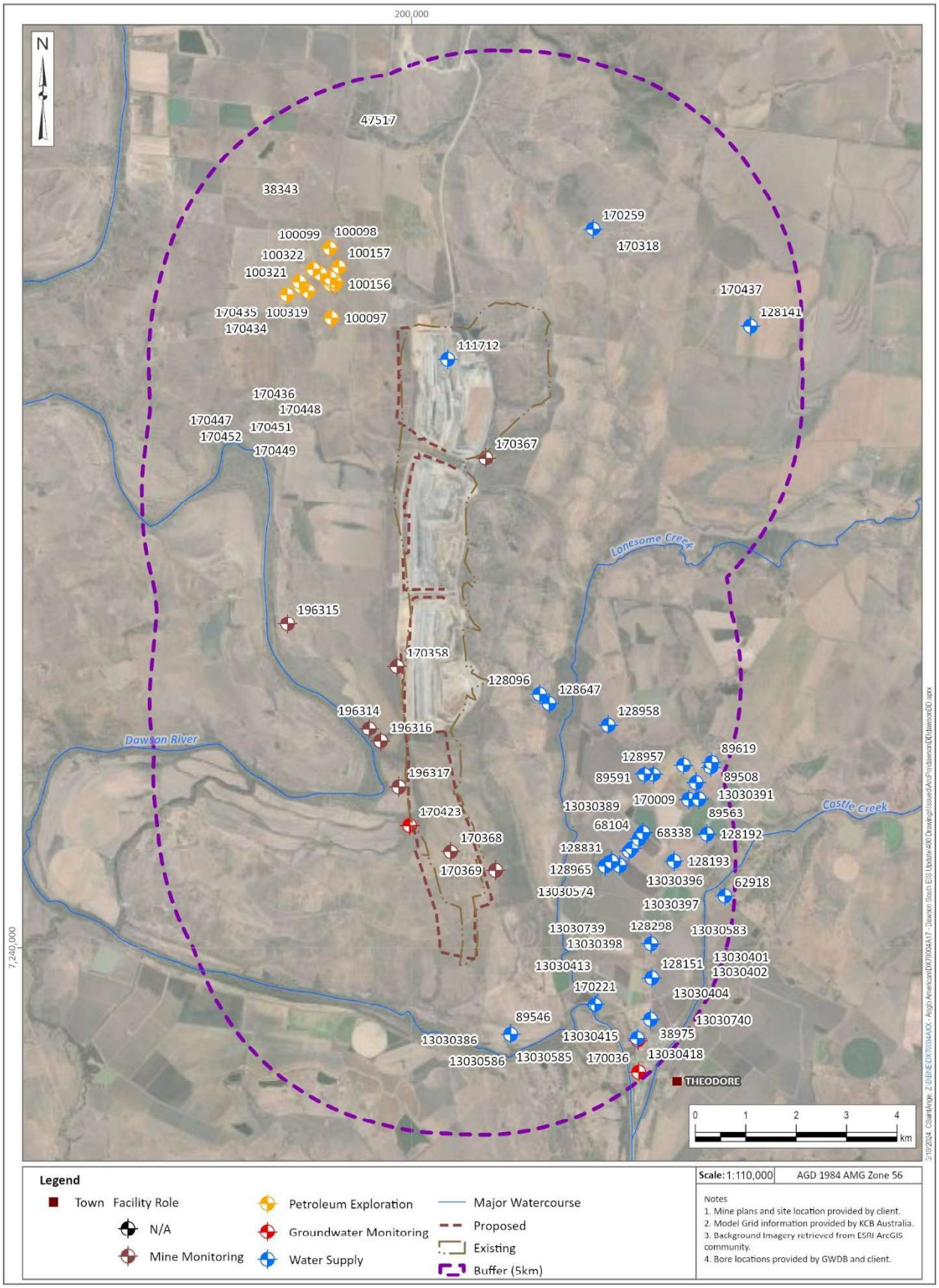


Figure 6.12 Location of Registered Groundwater Bores within 5 km of the Project Area

7 NUMERICAL GROUNDWATER MODELLING OVERVIEW

7.1 Model Development

A 3D numerical groundwater flow model was developed using MODFLOW-USG software to represent the conceptual hydrogeological model described in Section 6. A detailed description of the modelling methodology is provided in Appendix I. KCB has modified the existing groundwater model that KCB has developed for the Dawson Central and North PRC plan and the associated data and assessment that has been completed to date on that project.

The model represents the key hydrostratigraphic units using multiple layers and the full model extent is ~7,110 km^2. The model extent is as follows:

- North – a distance far enough away from the Project such that the model boundary does not influence the model results in the vicinity of the Project area.
- East – aligned with the surface water catchment.
- South – Surat Basin extent and surface water catchment.
- West – Dawson Range.

A total of eleven were used in the model to represent the Baralaba Coal Measures. Additional interburden layering was used to assist with the representation of the A, B, C, D and E coal seams. Model layers are presented in Table 7.1.

Table 7.1 Layers applied to the model domain

	Model Layer	Hydrostratigraphic Unit	Geological Age
Shallow aquifers	1	N/A - boundary layer to set up boundaries for spoils and inpit tailings (for extended Central/North Area)	N/A
	2	Alluvium, tailings, rehabilitation and backfill material	Quaternary
	3	Tertiary sediments/Duaringa formation	Tertiary
Deeper units	4	Rewan Group - Upper	Triassic
	5	Rewan Group - Lower	
	6	Baralaba Coal Measures - A seam	Permian
	7	Baralaba Coal Measures - B seam	
	8	Baralaba Coal Measures - C seam	
	9	Baralaba Coal Measures - D seam	
	10	Baralaba Coal Measures - E seam	
	11	Undivided Basement unit	Permian and older units

This model uses the calibrated model developed by KCB (2023) to support the Dawson Central and North PRCP as a starting point. Additional data provided by Anglo from ongoing monitoring and activities in the Dawson South area were included to amend the existing model. This model was refined to include details of current and historical mining and the Proposed expansion of Dawson South.

The regional groundwater model previously developed by KCB for the Westside Coal Seam Gas (CSG) fields was also used as reference (where needed) to amend the existing model built to support the Dawson North and Central PRCP (KCB 2023). This report details the design basis for the groundwater modelling, including the purpose of the model, assumptions, and limitations.

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) were used to frame the calibration process. A detailed description of the calibration method is provided in Appendix I. The groundwater model was initially calibrated using groundwater levels from 88 monitoring bores screened across a variety of aquifers and aquitards, which included the monitoring of groundwater levels between October 1990 and March 2023.

The calibration process included steady-state and transient calibration. The results of the steady-state calibration were used to define starting conditions for the transient calibration. The transient (time variant) calibration considered the change in groundwater levels as a result of mining activities and/or residual landforms. The transient calibration achieved a 3.68% scaled RMS error which is an acceptable calibration metric as recommended by the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). Furthermore, the calibrated groundwater levels, vertical gradients and flow patterns replicate measured data and groundwater trends.

The model calibration is therefore considered robust. The calibrated groundwater model was used to predict groundwater inflows, changes in groundwater levels and the associated groundwater level drawdown extent in response to the Proposed mine closure design.

7.2 Model Predictions

The calibrated groundwater model was used to predict groundwater inflows, changes in groundwater levels and the associated groundwater level drawdown extent in response to the Project development, including the simulation of the open pits in accordance with the proposed and existing Dawson South mine closure plan. Both sensitivity analyses and an alternate more conservative closure scenario for the Proposed Project was simulated (for the conservative case a lower post-closure void water level elevation was maintained; see associated model report for further details).

8 POTENTIAL CUMULATIVE IMPACTS

This section describes the operational and post-closure impact of the Project on:

- Groundwater resources;
- Groundwater users; and
- Surface water features.

The predicted impacts are related to the cumulative groundwater drawdown resulting from proposed mining activity. The drawdown has been calculated as the difference in the groundwater level between the calibrated pre-mining levels (nominally 1963) and the results for each mining time period. These results indicated that during 2052 (end of operational period) the largest associated groundwater drawdown may be expected.

At five years post mine closure the drawdown in the southern area of the mine lease is between 150 m and 170 m. There is little difference between the modelled groundwater drawdown between the existing and the Proposed mine closure landforms.

At 50 years post mine closure, existing mine plan groundwater drawdown in the northern area of the study is 80 m and 140 m in the southern area. At 50 years post mine closure for the Proposed Project, the groundwater drawdown in the northern area of the study is 85 m and 135 m in the southern area. The associated Project related cumulative groundwater drawdown in the southern area decreases from 170 m, 5 years post-mining to 135 m after 50 years post-mining.

8.1 Potential Impacts on Groundwater Resources

The impacts on the groundwater system are presented in the Dawson South Amendment Report in Appendix I. Groundwater resources within the study area and its surrounds are located within the Fitzroy Basin. The project area is outside of any Groundwater management areas in the Water Plan (Fitzroy Basin) 2011. The Project site is located adjacent to, however does not lie within the Dawson Valley Water Management Area (Dawson H), under Schedule 3B of the Water Plan (Fitzroy Basin) 2011 area.

The highest impact on potential groundwater resources occurs at the end of mining. This is indicated by the comparison of the predicted heads for end of existing mine plan mining, 1,000 years after closure, with the representative head from the same period of the proposed Project (Figure 8.1). The maximum cumulative Project impacts (i.e. the incremental change between the current and proposed landform) manifest at closure. A comparative figure shows the difference between the cases and indicates the end of mining as the period of greatest influence on water levels, as well as the comparative difference between the Existing mine plan and the Proposed Project plan at 1, 000 years (Figure 8.1).

A comparison of the post-closure progression of groundwater levels in each of the units is provided as a comparison, along with indicative cross-sections of Pit 25 and Pit 28 for the post-closure period when the proposed changes are implemented in Pit 25. For Pit 25, a cross-section through the approved case (with a backfilled pit) is shown in Figure 8.2, with the proposed case (pit lake) shown on Figure 8.3. For Pit 28, the two cases are illustrated on Figure 8.4 (both cases have a pit lake so the minor change is from the proposed change small change in pit shell.

ML80160
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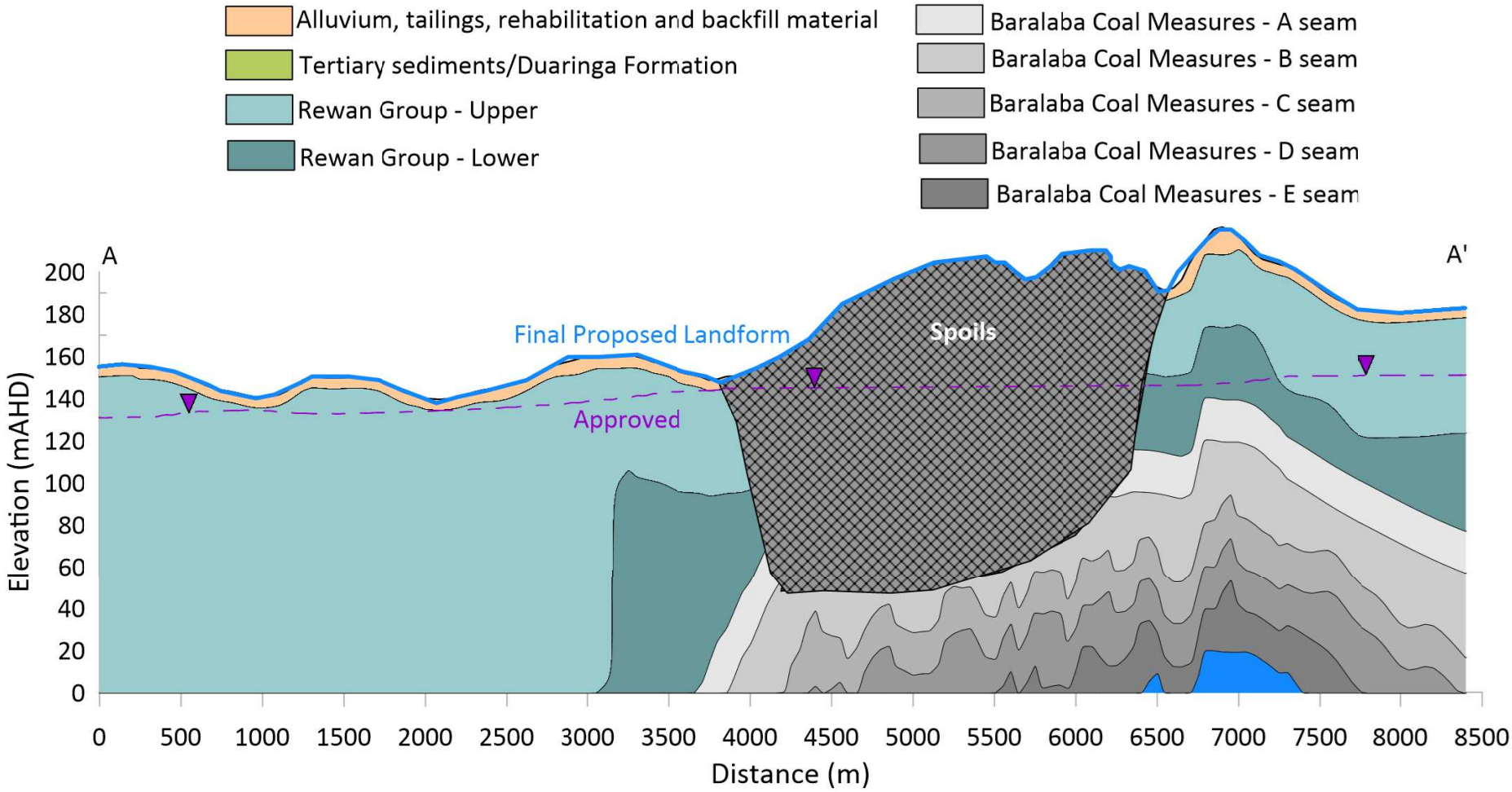


Figure 8.2 Cross-Section through Pit 25 (Approved Case): Water table at 1,000 years post-closure.

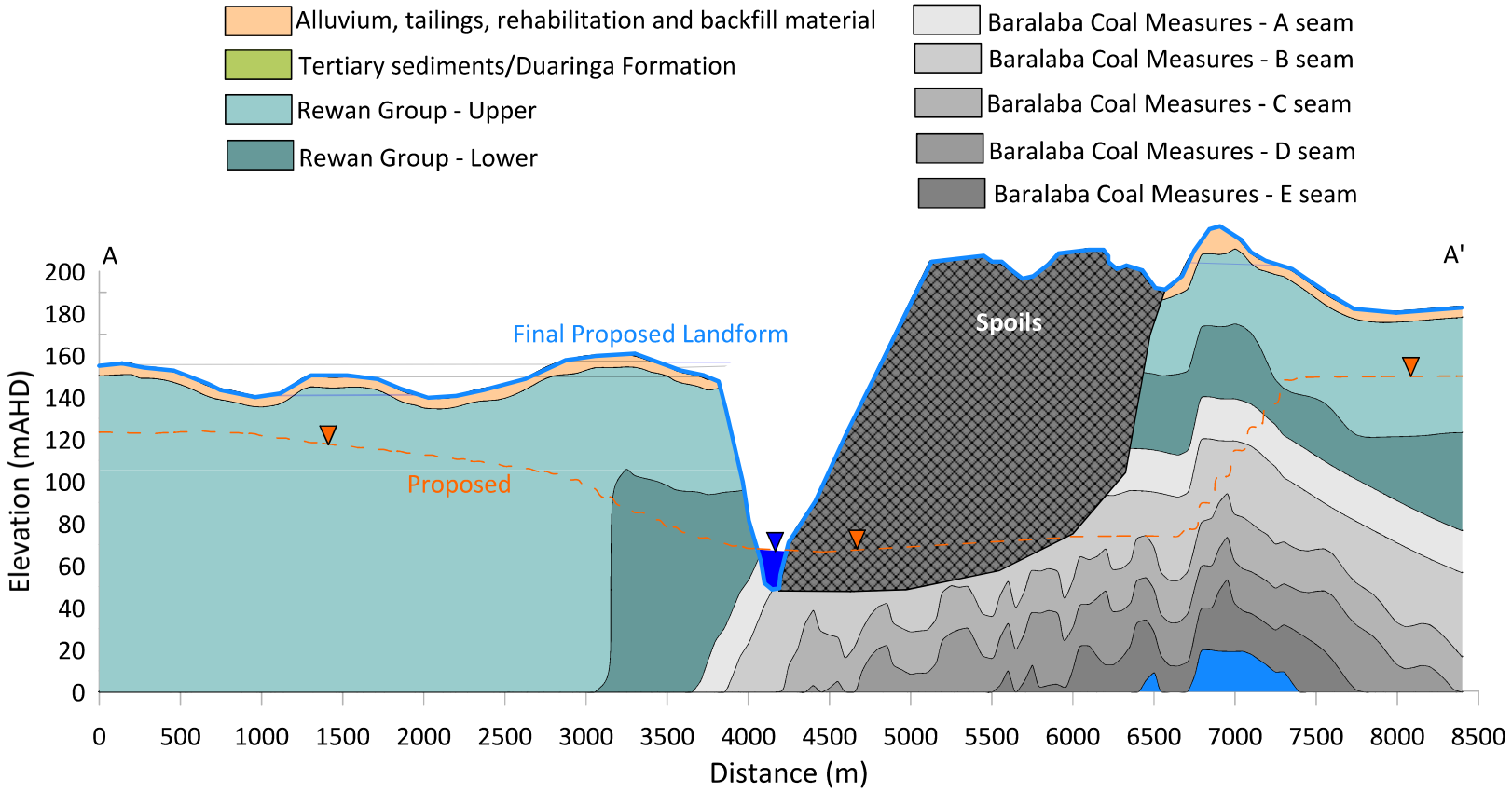


Figure 8.3 Cross-Section through Pit 25 (Proposed Case): Water table at 1,000 years post-closure.

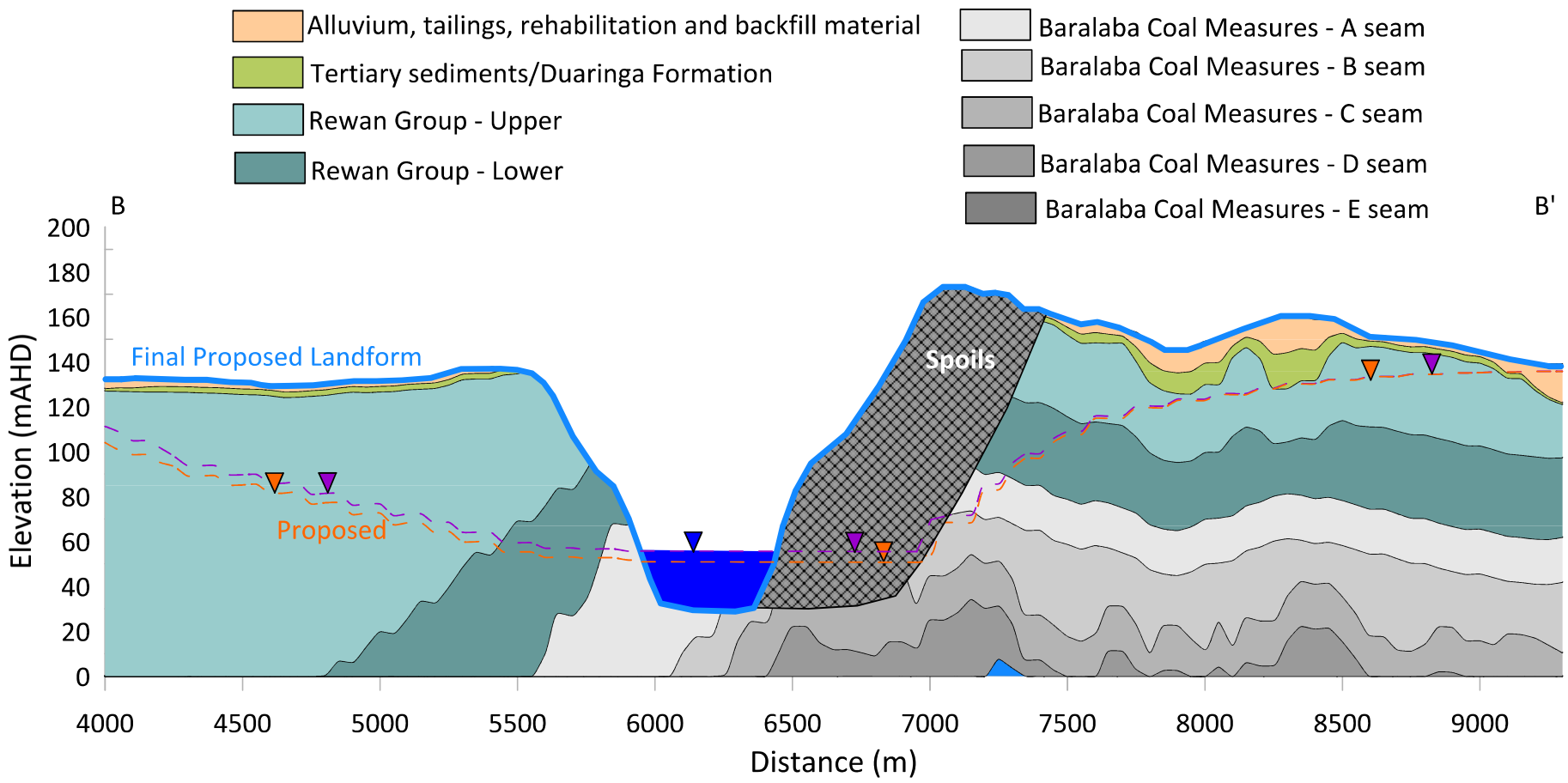


Figure 8.4 Cross-Section through Pit 28 (Approved and Proposed Case): Water table at 1,000 years post-closure.

8.2 Potential Impacts to Third-Party Groundwater Users

A desktop assessment was used to identify water supply bores surrounding the project site that could potentially be impacted by the Project. The bore census drew upon information gathered from a search of the DNRME groundwater database. The bore census was targeted towards bores and properties that could potentially be impacted by the project due to their proximity to proposed mining activities. It included a conservative search radius of 5 km beyond the boundary of the project site. Although the DNRME groundwater database is comprehensive and regularly updated, it may not be a complete record of all bores in the area. The bore census found that groundwater use is typically for monitoring and water supply for agricultural purposes.

The groundwater drawdown at the end of operations and the mine closure were assessed against the location of the water supply bores present in the groundwater database. The 5 m groundwater drawdown for the existing mine plan Pit 28 landform is identical to the proposed landform. Therefore, no impacts to third-party groundwater users are predicted due to the Project.

8.3 Impacts on Surface Drainage

The Project site is located adjacent to Dawson River. The Dawson River and its tributary drainage lines are ephemeral and are characterised by short duration, surface water flows that are typically restricted to periods after rainfall events.

Two groundwater monitoring bores (DSMB05 and DSMB13) are located adjacent to the Dawson River, which monitor the groundwater elevations in the alluvial aquifer. The groundwater elevation in the alluvium did not show any significant response to rainfall recharge. This suggests that there is no direct interconnection between runoff and the alluvial aquifer.

Groundwater monitoring bore DSBM05 is located adjacent to Pit 27 and monitors the groundwater level in the alluvium. There is no response (drawdown) to the groundwater level in the alluvium at this location from the current mining of the Permian coal seams in Pit 27. This suggests that the alluvium aquifer is not well connected to the Permian Coal Seam aquifer. These observations suggests that the Project will unlikely have any cumulative impact on the surface water environment.

During operations, the existing mine plan and proposed scenarios have very similar impacts on groundwater and consequently there is a negligible difference in river interaction with the aquifers. For the 1,000-year post-closure scenario (i.e. the greatest incremental impact), the River Boundary water balance across the entire extent of the Dawson South was extracted as comparison (Table 8.1).

The results indicate that for all layers (i.e. considering all the fluxes that may occur from the River Boundary condition), that an additional ~ 46 m^3/day (~0.5 L/s) may be taken from the Dawson River as result of the proposed Project. Overall, the total river boundary outflows (loss to groundwater) are 11.9% and 11.5% respectively for the existing mine plan and proposed scenarios.

Table 8.1 Comparison of the River Boundary condition flux across the Dawson South Mine Lease (1,000-year post closure)

		Influx (m^3/d)	Outflux (m^3/d)
Existing mine plan	River	1416.7	-700.8
Proposed	River	1403.8	-678.5

8.4 Impacts on Groundwater Quality

During operations, no additional impacts to water quality are anticipated. The mining process will result in drawdown effects toward the voids for both the existing mine plan landform and the proposed landform, which should limit migration of salinity away from the mining area (i.e., remaining mine voids will act as groundwater sinks).

Groundwater levels will slowly recover after each pit is completed and the spoils are progressively rehabilitated, and Pit 26 and Pit 27 are fully back filled. With Pit 25 and Pit 28 being maintained as final voids, the proposed landform will maintain lower water elevations (i.e. encourage flows toward the final voids), with the result, that provided the final void elevations remain below the regional water table (which is expected based on the negative climatic water balance), risks to regional groundwater qualities are reduced for the proposed landform compared to the existing mine plan landform.

The impacts on the water quality for Pit 28 were addressed in the Dawson South Groundwater EIS update investigation for Pit 28 (KCB 2023). This assessment reviewed the water quality of the void water and the spoil water and its potential impact on the groundwater. The water quality data was sourced from the void salinity modelling (WRM 2019), the spoils water quality results and site-specific groundwater monitoring data. These water quality inputs were used in the KCB 2023 groundwater model for the existing mine plan mine closure design.

The water quality assessment data was included in the 2023 and indicate that although the water quality in the void would progressively deteriorate due to the effects of evapo-concentration (more evaporation than freshwater dilution), the water quality risks to surrounding water resources remain low.

Using the Office of the Queensland Mine Rehabilitation Commissioner's leading practice guidance it is considered:

- Very unlikely that the voids would discharge to surface water or shallow aquifers;
- Likely that the salinity in the void would exceed relevant water quality thresholds in the very long-term; and
- Very unlikely that the voids will represent a source to the surrounding groundwater environment.

Details are contained in the Pit 28 Final Void and groundwater assessment report (KCB 2023).

In terms of post-closure risks, consideration of the particle tracking assessment confirms that that Pit 25 and Pit 28 will remain as long-term sinks. The forward projections (i.e. indications of flow paths from the final voids) for both North/Central and Dawson South are shown to assess the potential cumulative impact of the post-mining recovery. The results show that some inter-void flow will occur as the voids fill but that the successive voids act to limit flow away from the mining complex and that the void complex remain a sink after closure (Figure 8.5).

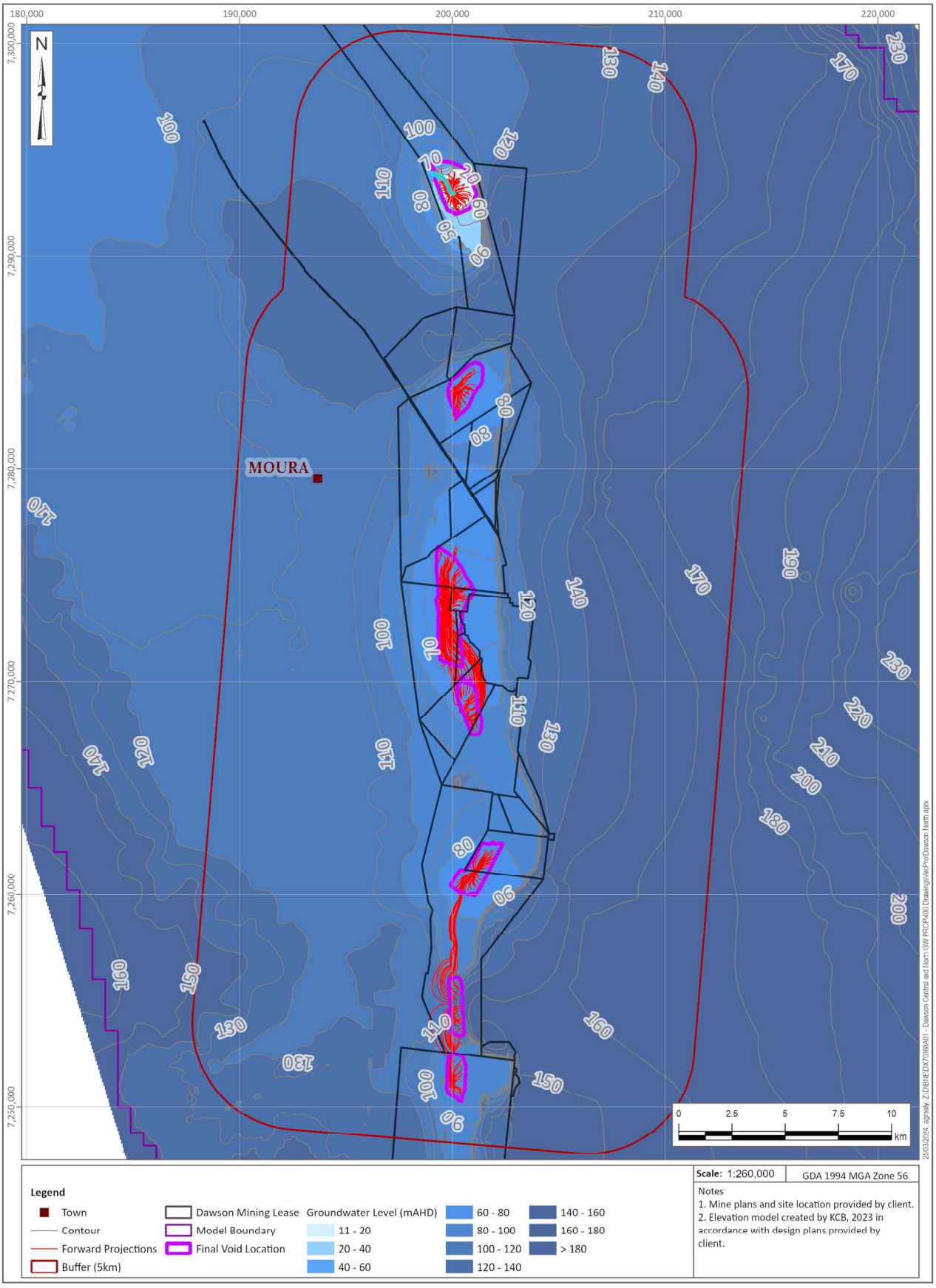


Figure 8.5 Particle tracking assessment from final voids (forward projections)

8.5 Potential Impacts to Spring Complexes

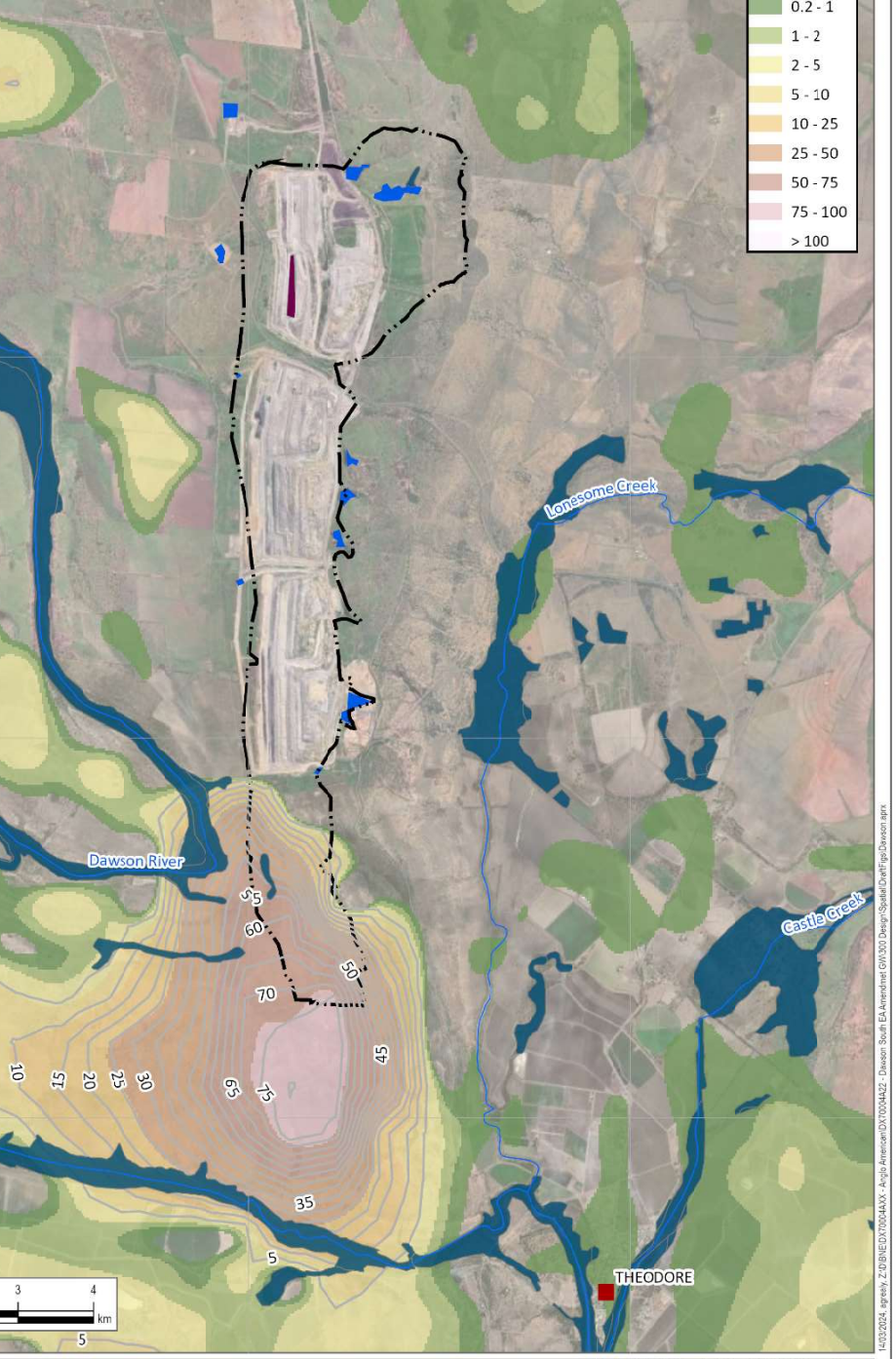
Section 6.6 has identified that there are no springs or wetlands within a 5 km buffer of the Project area. Therefore, there will be no impacts to springs or wetlands as a result of the proposed Project development.

8.6 Potential Impacts to Groundwater Dependant Ecosystems

Low potential terrestrial GDEs (identified from GDE mapping datasets) are located along the Dawson River and Lonesome Creek and vegetation managed wetland located near the town of Theodore which are within 5 km of the Project.

The low potential terrestrial GDEs located along the Dawson River, to the west of the Project area are within the predicted 0.2 m drawdown extent at the end of operations. The low potential terrestrial GDEs (i.e. an area where the likelihood of groundwater supporting the ecosystem is regarded as low) adjacent to Lonesome Creek to the east of the project site are within >0.2 m drawdown extent at the end of operations. Importantly, since the proposed final pit lakes are located in the northern-most pit (Pit 25) and southern-most pit (Pit 28), no additional post-closure impacts arise to the Willawa Nature Refuge area (see Figure 6.11) adjacent to the Dawson River.

The maximum groundwater drawdown at 1,000 years post-mine closure with the existing mine plan landform design is 40 m at the Dawson River. This drawdown extends to the Dawson River directly west of Pit 25 where the mapped low potential terrestrial GDEs are present. The maximum drawdown at 1,000 years post-mine closure for the proposed landform design is 30 m at the Dawson River. Therefore, the proposed landform design will not have as a significant impact to the potential terrestrial GDE's than the existing mine plan landform design (Figure 8.6 and Figure 8.7).



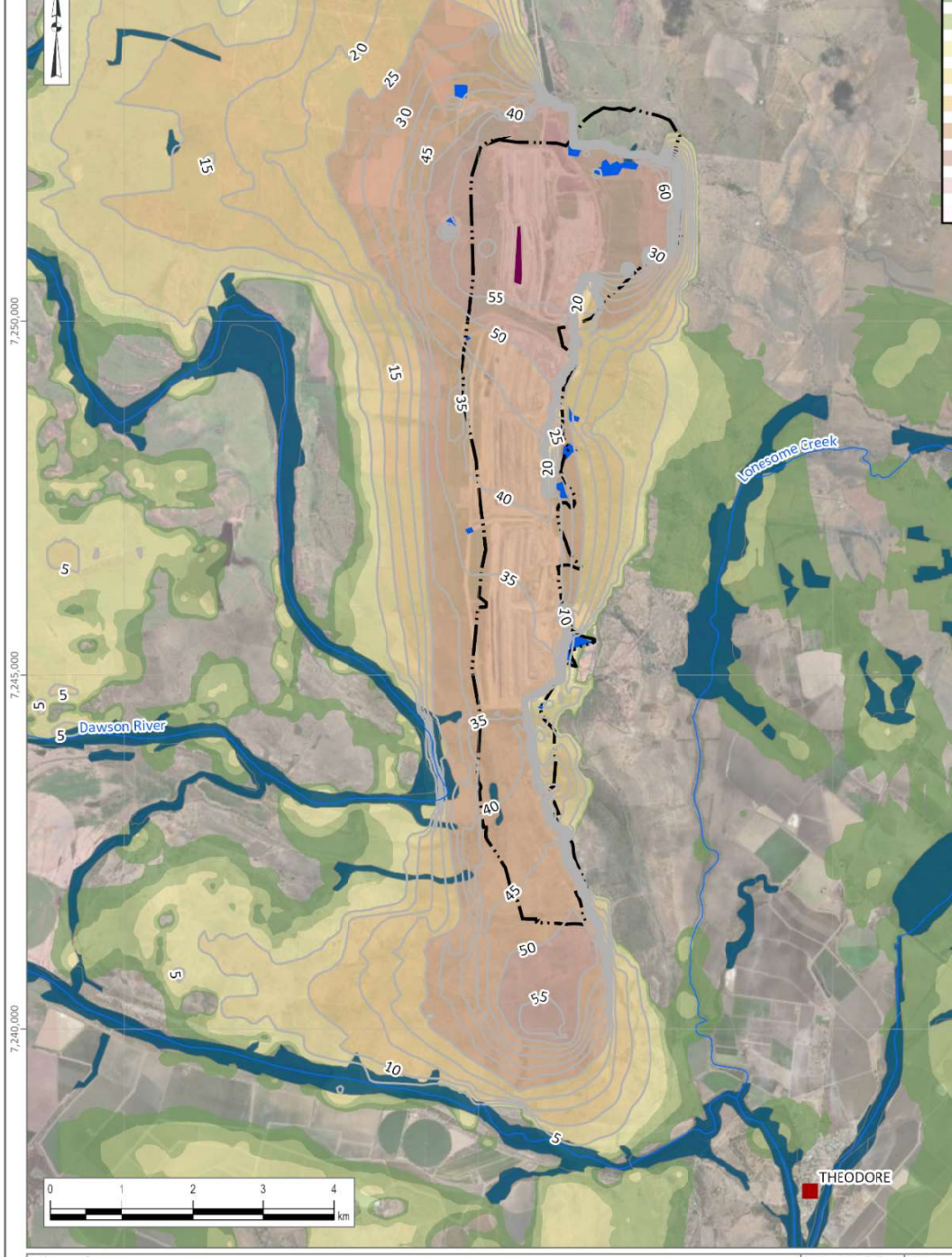
Dam Terrestrial GDE

Pit lake Low potential GDE

Scale: 1:90,000	GDA 1994 MGA Zone 56

Notes
1. Topographic features sourced 250k series 3 Geoscience Australia
2. Image courtesy of ESRI Online Community
3. Mining leases provided by Department of Resources, 2021
4. Highwall/Endwall pit crest extend features provided by client.

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Legend

Town Dam Terrestrial GDE

Major Watercourse Pit lake Low potential GDE

Contour (5m)

EIS Final Pit Shell

Scale: 1:90,000	GDA 199

Notes
1. Topographic features sourced 250
Australia
2. Image courtesy of ESRI Online Co
3. Mining leases provided by Depart
4. Highwall/Endwall pit crest extend
by client.

9 CONCLUSIONS

An assessment has been completed to compare the existing mine plan final landform design at Dawson South against the proposed final landform design (extension of Pit 28 and maintaining Pit 25 as a final void).

The assessment updated an existing numerical groundwater model that included both Dawson Central and North as well as Dawson South and refined this model to account for the potential predicted cumulative changes associated with the proposed Project.

From the observations, the following aspects are worth highlighting:

- The updated groundwater model was able to achieve a good calibration between the measured/observed water levels and the model-predicted water levels for the transient calibration period. The model calibration metrics are acceptable and within the requirements of the Australian Groundwater Modelling Guidelines. The transient hydrograph comparisons between simulated and measured water levels show that the model is able to match the general trends and responses observed in the data record, including the shallower hydrostratigraphic units which may potentially be impacted by mining activities.
- Modelling results show that the greatest dewatering occurs at the end of mining operations. This period is when the actively mined coal seams would have resulted in the lowest groundwater elevations in the final active pit and coincide with the period when the cumulative dewatering impact from the interaction between the pits is at its highest. Since the groundwater system is very slowly recovering outside of the active mining, the end of mining period shows the greatest overall groundwater drawdown at Dawson South.
- The modelling results indicate that during operations there is negligible change between the existing mine plan final landform and proposed final landform, because of the overall drawdown that would have resulted from the related mining activity and the slow recovery in the system. For Pit 25, a conservative end of mining scenario was assumed where the pit void was allowed to fill naturally rather than storing additional water which would result in a higher void water level, than the modelled value. Should additional mine water be stored in this void, this will reduce the drawdown extent (i.e. a decreased overall impact on the groundwater system can be expected, then has been modelled – representing a worst-case scenario).
- Due to the proposed scenario maintaining a final void in Pit 25 and the larger pit void in Pit 28, the difference between water in the existing mine plan and the proposed landform scenarios becomes progressively more pronounced after closure. Under both conditions, the groundwater slowly recovers, however, due to excess evaporation (compared to inflows) in the final voids, water levels recover more slowly in the proposed scenario, until the system has stabilised (i.e. the final voids reach their equilibrated elevations). The largest difference between the existing mine plan scenario and the proposed Project in terms of groundwater conditions occurs at this point.
- Although the equilibrated pit lake water levels for Pit 25 lie at a lower elevation in the proposed scenario than in the existing mine plan scenario (due the presence of the pit

lake rather than a backfilled void), the overall zone of influence for the equilibrated post-closure case is less than the water level impact at the end of operations (confirming that end of operations represents the period of greatest impact to groundwater irrespective of the proposed change in landform).

- For the proposed Project, the equilibrated water level elevation in Pit 28 is higher than in the planned landform for the Approved Pit 28. As a result, the proposed impact from Pit 28 is reduced compared to the existing mine plan landform in the southern part of Dawson South.
- The maximum difference in terms of the impact on surface water resources will occur once the pit voids have reached equilibrium (a steady state). The results indicate that under the conservative scenario modelled, the surface water (creeks and Dawson River) will likely provide additional flows to the groundwater system (lose water), but for the Project final landform, the recovery of the water levels in Pit 25 above 75 mRL and in Pit 28 just below 80 mRL, there is negligible difference in surface water impacts estimated in the south. The exchange between surface water and the alluvial aquifer may be marginally reduced for the proposed Project landform.
- The results suggest that there is no cumulative change to impacted water uses and that no additional registered groundwater users are likely to be impacted by the proposed Project.
- Post-closure voids water levels reduce the risk associated with impact to groundwater quality on the surrounding environment. Pit void water elevations will likely remain lower than the local groundwater elevation, meaning the pit voids will permanently act as a ‘groundwater sink’ and reduce the potential migration of saline water from these final voids.

10 CLOSING

We thank you for the opportunity to work on this assignment. Should you have any queries please do not hesitate to contact the undersigned.

KCB AUSTRALIA PTY LTD.



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Senior Hydrogeochemist, Principal
Project Manager

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APPENDIX I

Dawson South Model Report

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1 INTRODUCTION

KCB Australia Pty Ltd (KCB) has developed a 3D numerical groundwater flow model for the Dawson South area (the Project) to support Anglo American Steelmaking Coal's (Anglo) application for an amendment of the Dawson South Environmental Authority (EA) EPML00657413, in accordance with the Environmental Protection Act 1994 (EP Act).

The modelling results presented in this Model Appendix have been used to assess the potential impact to water resources as a result of the Proposed activities associated with the Project.

This model used the calibrated model developed by KCB (2023) to support the Dawson Central and North PRCP as a starting point. Additional data provided by Anglo from ongoing monitoring and activities in the Dawson South area was included (as needed) to amend the existing model. This model was refined to include details of current and historical mining and the Proposed expansion of Dawson South.

The regional groundwater model previously developed by KCB for the Westside Coal Seam Gas (CSG) fields was also used as reference (where needed) to amend the existing model built to support the Dawson North and Central PRCP. This report also details the design basis for the groundwater modelling, including the purpose of the model, assumptions, and limitations.

1.1 Model Objectives

The objectives of the Dawson South Model were to develop a groundwater flow model that reasonably represents the groundwater system, and that predicts changes in the groundwater levels and flows that may be the result of the changes to the Dawson South operations. The current model was updated and refined to incorporate the data related to the proposed mine progression.

The objectives of the refined groundwater model were to predict changes in groundwater levels and flows that may be a result of all operations (e.g. Open pit operations, surface water infrastructure, and tailings – historical and Proposed), which can be used to inform the application of the EA amendment, in accordance with the Environmental Protection Act 1994 (EP Act) which includes the existing (i.e. currently approved) Dawson South mine plan. This mine plan involves:

- Reconfiguration and extension of the approved Pit 28 final void; and
- Alterations to the approved final landform, including addition of a new final void in Pit 25 and southward extension of the approved Pit 28 final void.

The extent and area of influence of groundwater level drawdown associated with the Proposed mine plan including the final voids have been assessed (change in groundwater flow pattern and potential for increased drawdown are considered to be quantities of greatest interest in terms of comparing the current Dawson South final landform with the Proposed final landform). The project location is shown in Figure 1.1 below.

The current and proposed mine plans are not expected to meaningfully differ during the operational period since the mining footprint and sequence have not materially changed and the same coal seams are targeted. The post-closure period with an altered Pit 28 and new Pit 25 final void pit lake represents the most likely period for differences in groundwater drawdown to occur.

1.2 Application of the Conceptual Model

The groundwater flow model is based on the hydrogeological conceptual model. This conceptual model is described in the Dawson South EA Amendment Report. A hydrogeological conceptual model is a descriptive representation of the groundwater flow system and stresses. The closer the conceptual model approximates the field situation, the more accurate the numerical model predictions (Anderson and Woessner, 1991). A conceptual model defines the current understanding of the key processes of the groundwater system with consideration of the influence of stresses (Barnett et al., 2012). The application of the conceptual model to the groundwater flow model required synthesis and description of the geology framework and consideration of the groundwater flow systems that are present within the vicinity of the Project.

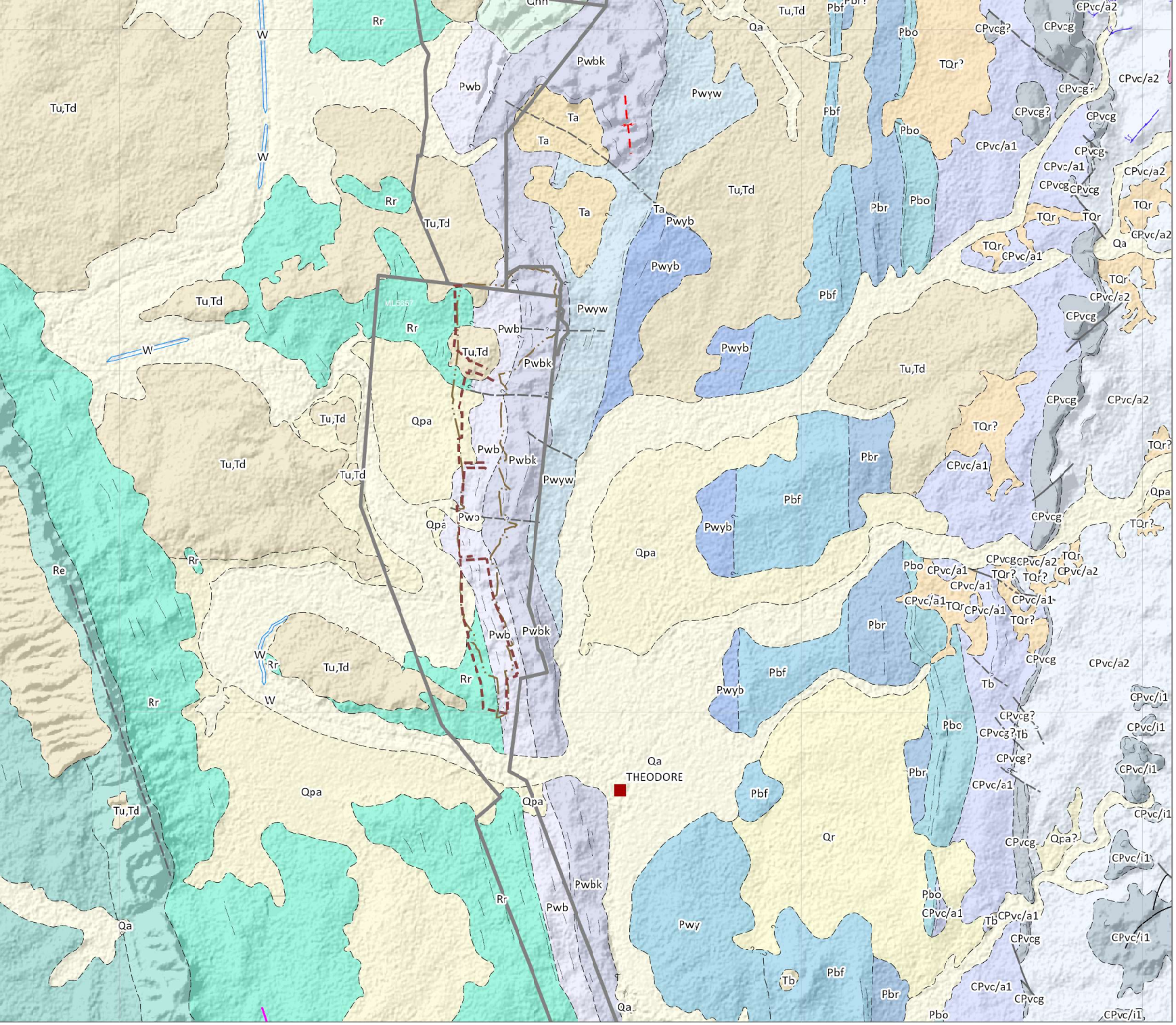
The Dawson Mining Complex is located within the Bowen Basin, an Early Permian to Middle Triassic foreland basin that contains thick successions of shallow marine and non-marine sediments and volcanics as well as extensive Permian coal measures. The geological setting of the Project area is shown in Figure 1.2. The topography at the Dawson Mine Complex is flat and gently undulating as shown in Figure 1.3. The area generally slopes to the west.

Under natural conditions, groundwater flow rates are low, partly from the alluvial deposits adjacent to the surface water systems (Dawson River and ephemeral creeks such as the Lonesome Creek to the west of the mining area). Under natural conditions, rainfall recharge is low over the Tertiary and Permian outcrop areas, while the alluvial has higher recharge and may be fed by surface water in high flow periods along the Dawson River.

The average annual rainfall in the Dawson Mining Complex area is approximately 654 mm with rainfall during the summer months occurring on an average of 63 days per year. Long-term average annual evaporation (Morton Lake evaporation) is around 1,752 mm (Silo data).



Figure 1.1 Project Location and Proposed Mine Design



Quaternary Alluvium, Qa
Qhh-QLD
Qpa-QLD
Qpa?-QLD
Qr-QLD
TQr-QLD
TQr?-QLD
Ta-YARROL/SCAG
Tb-QLD
Duaringa Formation,Td-QLD

Solid Geology

Moclayember Formation, TRm
Clematis Group, Tre
Rewan Group, Rr
Baralaba Coal Measures, Pwb
Kaloola Member, Pulk
Gyranda Subgroup, Puy
Banana Formation, Pwy
Wiseman Formation
Flat Top Formation, Pbf
Barfield Formation, Pbr
Barfield Formation?, Pbr?
Oxtrack Formation, Puo
Camboon Volcanics/a1, CPvc/a1
Camboon Volcanics/a2, CPvc/a2
Camboon Volcanics/i1, CPvc/i1
Gonyelinka Ignimbrite Member
Gonyelinka Ignimbrite Member?
Waterhole, W

Fault accurate
Fault approximate
Fault concealed
Fault inferred
Fault interpreted
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Geological boundary
Lake, lagoon or wa
Lineament
Sedimentary facies
Syncline inferred
Trend line
Trend line showing

0 2

Scale
Note
1 Top

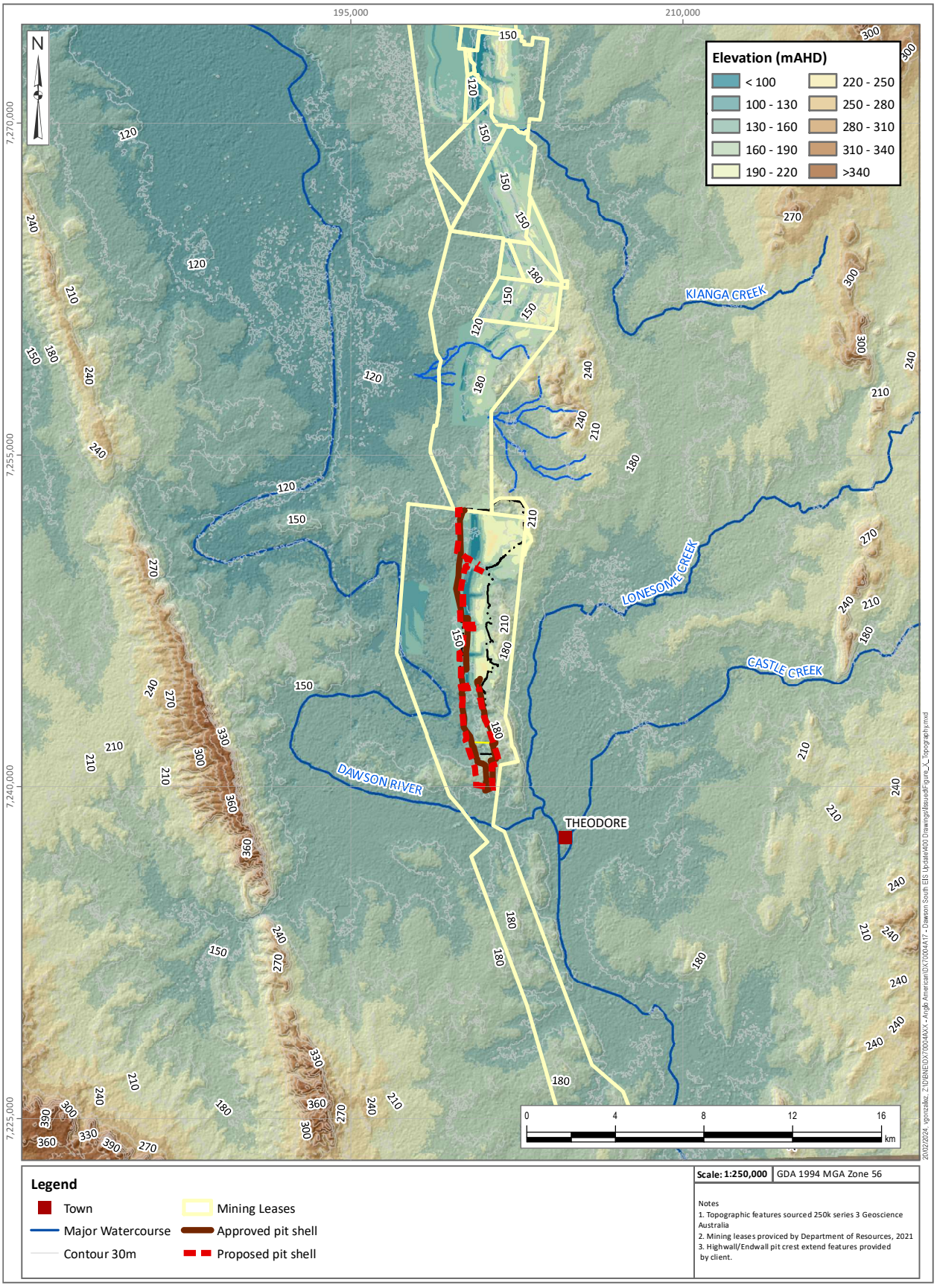


Figure 1.3 Regional Topography and Drainage at Dawson South

2 MODEL DESIGN

2.1 Model Code Selection

The existing groundwater model developed by KCB for the Dawson central and north PCRP report was developed using MODFLOW-USG. This model was used as a starting point and amended to include the changes to the mining sequence in Dawson South.

MODFLOW-USG is an "unstructured grid" version of MODFLOW that can use an irregular grid structure with arbitrary cell/node connections. This enables focused grid refinement to occur in areas where detail is important, without the need for continuation of grid refinement to the extremes of the model domain. It also facilitates implementation of pinching-out layers and/or layer discontinuities within the modelled domain. This can greatly reduce the number of grid cells within the model domain and thus greatly reduce model runtimes. In addition, MODFLOW-USG implements an "upstream weighting" formulation of the groundwater flow equation that allows cells to dewater and re-saturate easily.

2.2 Units and Datum

The time unit for this model is day and the length unit is metre. In the horizontal plane, the model uses the GDA 1994 MGA Zone 55 projection, while the vertical datum is the Australian Height Datum (AHD) in metres. The Dawson mine reference system is at +2,000 m (2,000 metres above AHD). Conversions were made from the mine reference system to the Australian Height Datum.

2.3 Model Domain and Discretisation

The model domain was selected to adequately reflect the regional hydrostratigraphic units and prevailing surface water/groundwater interactions while also providing a platform for regional assessment of cumulative groundwater impacts from existing and operating projects in the area. The following hydrogeological elements were used as perimeter boundary conditions:

- North – "a distance far enough away from the mining area such that the model boundary does not influence the model results in the vicinity of the Project area";
- East – aligned with the surface water catchment;
- South – Surat Basin extent and surface water catchment; and
- West – Dawson Range.

The model domain has a total area of approximately 7,110 km^2 covered by 762,971 active cells.

A quadtree refinement was applied to generate an unstructured grid. The Dawson Mining Complex was represented with a fine grid, while areas distant from the project site were represented with a coarser grid. The model grid size ranges from 75 m to 600 m. The resulting mesh developed for the model is presented in Figure 2.1.

2.3.1 Dawson South Model

Using the Dawson Central and North PRCP model, the grid was refined to accommodate the operations and pits in the Dawson South area. Within the footprint of Pit 25, 26, 27, 28N and around a 1,000 m outward buffer, the grid cell size was refined to 75 m. Between the west border and the southern pits, the grid was refined to 150 m to cover the Dawson River and alluvium aquifer.

The local coal seam stratigraphy was updated based on the Dawson South local geology and the stratigraphy merged to the larger domain PRCP model for Dawson Central and North.

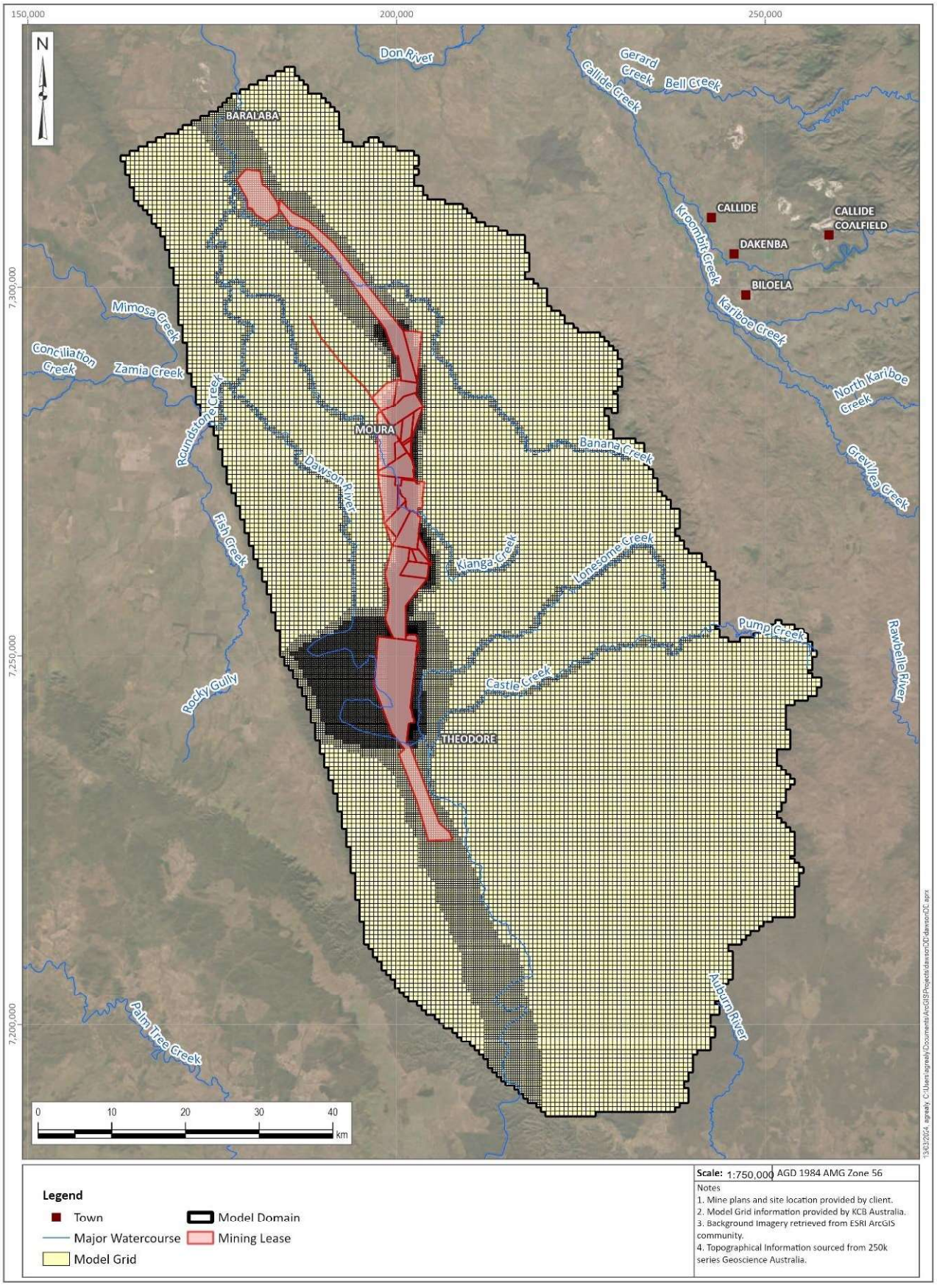


Figure 2.1 Numerical Model Domain and Mesh

2.4 Model Layers

The hydrostratigraphy of the study area was represented using eleven (11) model layers that are mainly discontinuous across the model domain. Multiple layers represent the Baralaba Coal Measures, with the interburden bulked into the relevant representations of the A, B, C, D and E coal seam hydrostratigraphic units. The model layers are outlined in Table 2.1.

Table 2.1 Model Layers Applied to the Model Domain

	Model Layer	Hydrostratigraphic Unit	Geological Age
Shallow aquifers	1	N/A - boundary layer to set up tailings heads	N/A
	2	Alluvium, tailings, rehabilitation and backfill material	Quaternary
	3	Tertiary sediments/Duaringa formation	Tertiary
Deeper units	4	Rewan Group - Upper	Triassic
	5	Rewan Group - Lower	
	6	Baralaba Coal Measures - A seam	Permian
	7	Baralaba Coal Measures - B seam	
	8	Baralaba Coal Measures - C seam	
	9	Baralaba Coal Measures - D seam	
	10	Baralaba Coal Measures - E seam	
	11	Undivided Basement unit	Permian and older units

2.5 Model Boundary Conditions

Boundary conditions are necessary for solution of the 3D groundwater flow equation that is implemented by MODFLOW-USG. They also provide a means by which auxiliary groundwater fluxes and stresses can be specified within the model. The following boundary conditions have been adopted in the model:

2.5.1 Recharge

Recharge was assumed to be effective recharge and was assigned to the uppermost layer of the model using the “MODFLOW Recharge package”.

Zones are defined by the extent/outcrops of different hydrostratigraphic units. The recharge zones and percentages calibrated in the model built for the Dawson Central and North Progressive Rehabilitation and Closure Plan (PRCP) were applied as initial values, as defined in Table 2.2 in areas shown on Figure 2.2. An extended recharge dataset, based on the inclusion of current and ongoing rainfall data was used for transient simulations.

Table 2.2 Model Recharge Rates

Modelled Recharge Zone	KCB (2021) Groundwater Model Percentage of Daily Rainfall %
Quaternary alluvium	0.6
Tertiary Sediments	0.2
Others	0.01

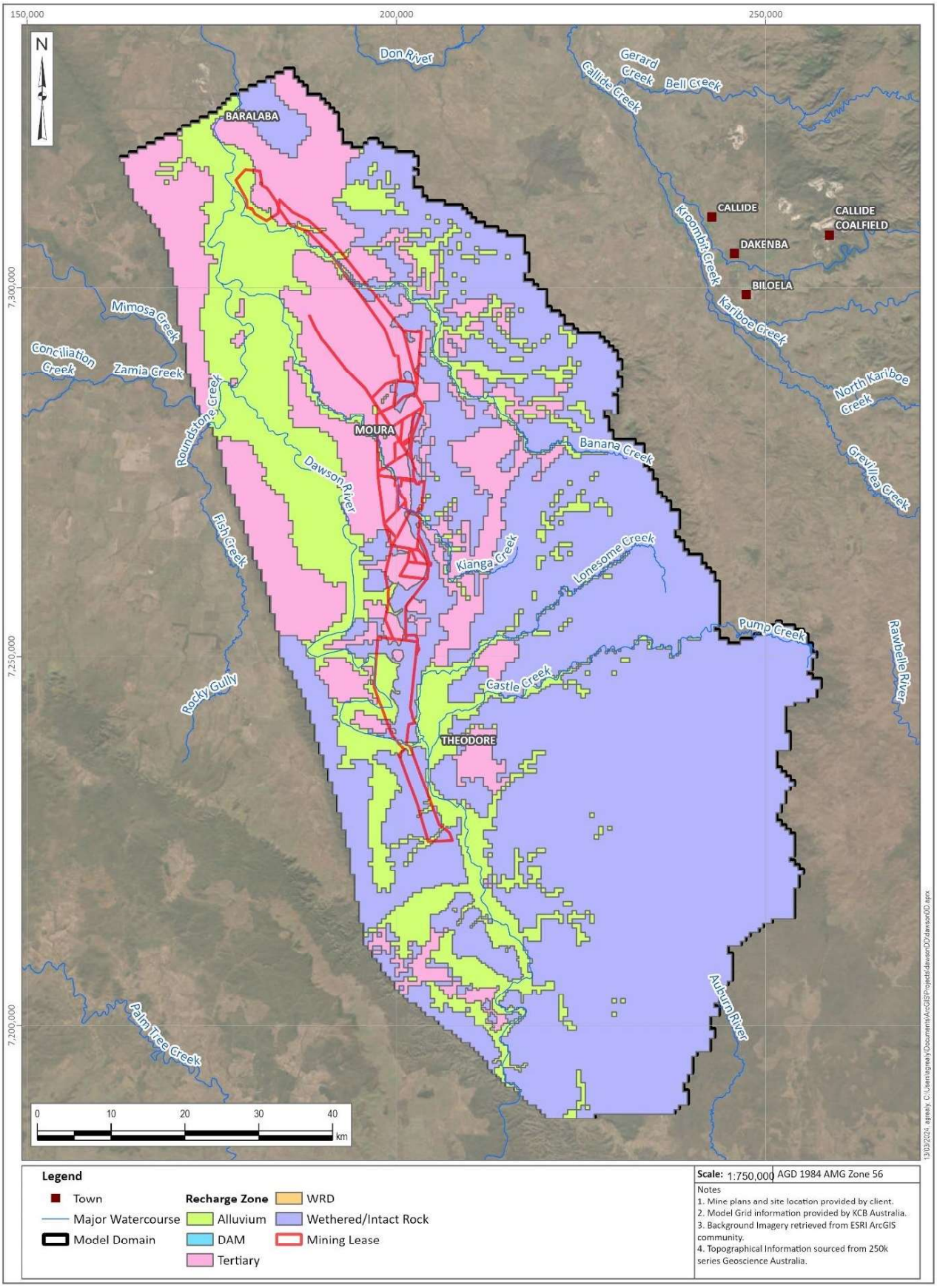


Figure 2.2 Location of Recharge Areas in the Model Domain

2.5.2 Evapotranspiration

The MODFLOW Evapotranspiration package (EVT) was used to simulate evapotranspiration. The evapotranspiration given by KCB (2021) was applied as initial values. A uniform extinction depth was applied across the domain and set at 1.5 m below the natural surface, below which evaporative losses from the groundwater surface are zero. Where the groundwater elevation is above this level, water is removed from the system at a maximum rate of 365 mm/annum.

2.5.3 Drains

The drain package was also used to simulate open cut mining. Drains were placed in all layers above and including the target extraction layer. They were progressively switched on/off to reflect the mining progress, and the Time-Variant Materials (TVM) package was used along with the DRN package to reflect the rehabilitation and backfill of voids. The bottom elevations of the target coal seams in each open cut mining area were used to represent the depths of the drains. The amended and additional, current and proposed mining operation areas represented by drain cells included each of the Proposed pits (Table 2.2).

Table 2.2 Drain Cells in Pits

Location	Existing operation area	Proposed operation area	Proposed operating Time
Dawson South	Pit 25	Pit 25	Y2022 – Y2030
	Pit 26	Pit 26	Y2022 – Y2025
	Pit 27	Pit 27	Y2022 – Y2027
	Pit 28	Pit 28	Y2027-2048

CSG extraction has been in operation near the project area for some time. CSG dewatering was implemented in the Dawson North and Central model using drain cells (DRN package). At the location of each CSG development well, drains were placed throughout the Baralaba Coal Measures. The starting reference head level for these drains was nominally 30 m above the top of the Baralaba Coal Measures at that location (KCB 2021). Drain conductance was refined during calibration.

2.5.4 River

For the Dawson River, MODFLOW's River Package was implemented to simulate interactions between the Dawson River and the alluvium during times of flow. Gauging station 130374A on the north boundary of the model was used, except where site-specific stage data was provided from Dawson upstream and downstream points.

Lonesome Creek and Castle Creek are located east of the South Dawson Project site and were represented as drain cells (DRN). Other ephemeral water courses in the vicinity of the project site were also represented using drain cells.

2.5.5 General Head Boundaries

The surface water storages (mine water storage and water dams) were represented using General Head Boundary conditions (GHB). The conductance and head of GHB boundaries were further calibrated with observed pit influx and piezometric data in the vicinity of Dawson South area.

Tailing dams were also represented by General Head Boundary (GHB package) passing through the tailing materials, which produces basal seepage to the foundation. The areas defined for the Central and North were also modelled as tailing dams before their closure (no tailings are stored at Dawson South).

MODFLOW's General Head Boundary (GHB package) was implemented around the perimeter of the model domain. GHB was applied to all model layers in contact with the model boundary. This boundary type allows for the regional groundwater flow system to be reliably replicated at a sub-regional scale and ultimately improves the predictive capability of the model. It should be noted that GHBs do not significantly influence the model predictions in the vicinity of the project site due to the significant distances separating operations from the perimeter of the model.

Underground longwall mining was included in the Dawson North and Central PRCP model and was retained for the Dawson South Model.

2.6 Initial Material Parameters

Hydraulic conductivity (K) and storage parameters that were calibrated in the model built to support the Dawson Central and North Progressive Rehabilitation and Closure Plan (PRCP) were used as starting values for the refinement of the model in the Dawson South area (Table 2.3).

Table 2.3 Hydraulic Conductivity Values

Unit	Kh, m/d	Kv, m/d	Calibrated Specific Yield (-)	Calibrated Specific Storage (m^{-1})
Alluvium	1	0.1	0.01	3.24E-06
Tertiary sediments	0.2	0.02	0.01	3.26E-05
Rewan Group – upper	1.65E-03	1.65E-04	2.24E-03	1.00E-07
Rewan Group – lower	1.65E-03	1.65E-04	2.24E-03	1.00E-07
A seam	2.25E-02	2.25E-03	2.92E-03	9.00E-08
B seam	1.48E-03	1.48E-04	2.92E-03	9.00E-08
C seam	9.36E-04	9.36E-05	2.92E-03	9.00E-08
D seam	1.04E-04	1.04E-05	2.92E-03	9.00E-08
E seam	2.35E-02	2.35E-03	2.92E-03	9.00E-08
Model basement	1.06E-04	1.06E-05	1.71E-03	9.00E-08
Underground mine	1	0.1	0.01	3.24E-06

The accumulation of coarse spoil dumps creates zones of high permeability, as indicated by Edraki et al. (2019). For this reason, hydraulic conductivity values found for spoils in the literature were applied to the spoil dumps areas at Dawson South. Tests conducted by Fityus and Buzzi (2022) showed that most estimates for the saturated hydraulic conductivity of spoil based on physical measurement lie between 0.01 to 25 m/day.

JBT (2018) estimated a K for spoils at Dawson in saturated/unsaturated conditions, which was equal to 7x 10^{-2} m/day. A starting value of specific storage (Ss) for spoils equal to 10^{-5} 1/m, and specific yield (S_y) equal to 0.2 was used.

3 MODEL CALIBRATION

3.1 Calibration Process and Metrics

Calibration was conducted with the adjustment of model parameter values to achieve better replication of historical observations of the groundwater system. The outcome of the calibration process provides the initial conditions for transient predictive simulations used to assess changes to the groundwater regime through the operations and closure phases of the Project.

The calibration process included steady-state and transient calibration. The results of the steady-state calibration were used to define starting conditions for the transient calibration. Different stress periods were used to reflect the historical mining operations, which include underground mining, open pit operation and CSG extractions.

The calibration sequence consists of:

- A steady-state calibration with boundary conditions applied to replicate known mining development.
- Quarterly stress period-based transient calibration using steady-state calibration model outputs as the initial heads.

The North and Central Dawson PRCP calibrated model was the basis for inclusion of additional data provided by Anglo for Dawson South (landforms that reflect mine progression during life of mine until closure phase). The Dawson South Model was updated to accommodate the resizing of the pits in the south and the updated model was subsequently verified and calibrated.

The same steady-state and transient calibration stress periods applied in the North and Central PRCP model, which were: steady-state (pre-1963 condition), and transient calibration (1963-2022) were applied to the South Dawson Model. The duration of stress periods in the transient calibration will be yearly between 1963 and 2002, quarterly between 2003 and 2020, and monthly between 2021 and 2022.

The following model approaches were used to assess the calibration performance, based on the Australian Modelling Guidelines (Barnett et al. 2012):

- Model convergence.
- Water balance error <1%.
- RMS error <10 m.
- Scaled RMS of <10%.

3.1.1 Calibration Approach

Calibration of this model aimed to fix parameter estimation on the prevailing conditions over the period of October 1990 to March 2023 as this is the most reliable sequence of observation data available in the vicinity of the project site. Recordings for the period after 2014 are limited, with only a limited number of bores having one record for each year. Historical groundwater level data extracted from 88 monitoring bores located in the project area were used in the calibration. Figure 3.1 shows the distribution of calibration targets in the model area.

The calibration model run was initiated in steady-state with boundary conditions applied to replicate known mining progression at Dawson South. Following this initial model conditioning period, the model transitioned to transient mode for the remainder of the calibration period in which the same steady-state and transient calibration stress periods applied in the North and Central PRCP model. This was represented by a steady-state (pre-1963) condition, and transient calibration (1963-2022) applied to the South Dawson Model. The duration of stress period in the transient calibration was yearly between 1963 and 2002, quarterly between 2003 and 2020, and monthly between 2021 and 2023 to align with the availability of data. This stress period length was sufficient to allow for seasonal climatic variations to be considered and to represent the associated mine development within the model.

Automatic parameter optimisation was implemented with the use of PEST. PEST is a powerful tool applied to provide rapid feedback on the adequacy of the conceptual model. PEST reports on where limits on particular parameters, or groups of parameters, are required to be reached to achieve a better model calibration and/or where increased scrutiny on the field(s) and model data supporting the parameter limit(s) is required.

3.1.2 Calibration Targets

A total of 88 monitoring bores located in the project area were used to assess the calibration dataset, which included the monitoring of groundwater levels between October 1990 and March 2023. Figure 3.1 shows the distribution of monitoring bores at Dawson South.

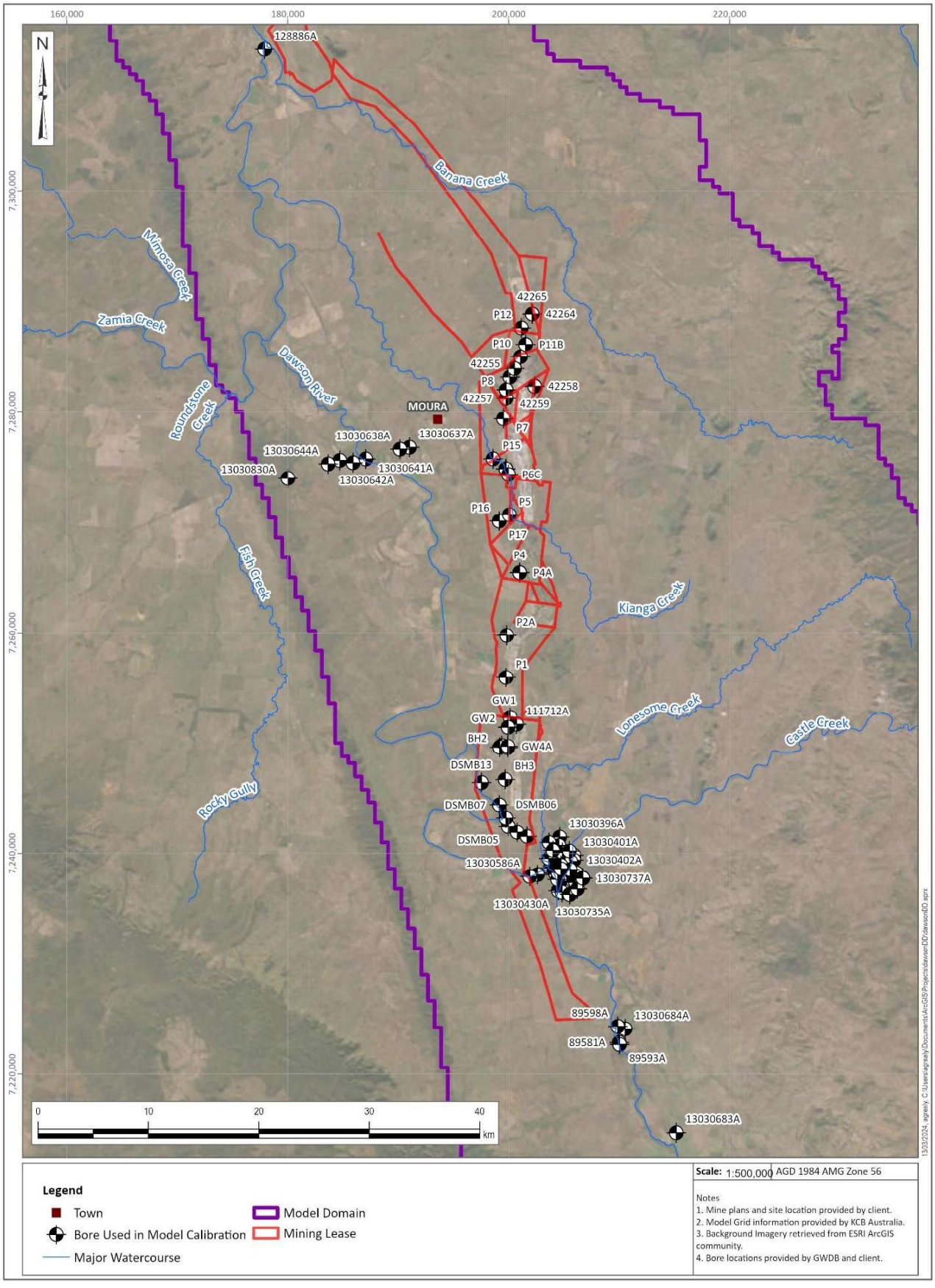
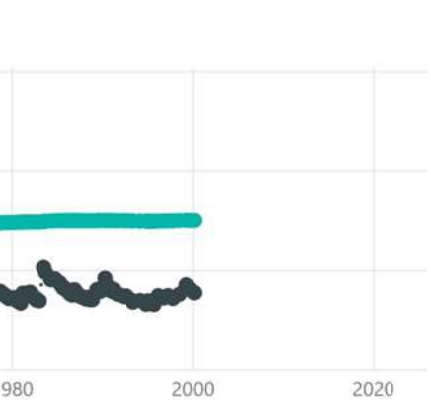
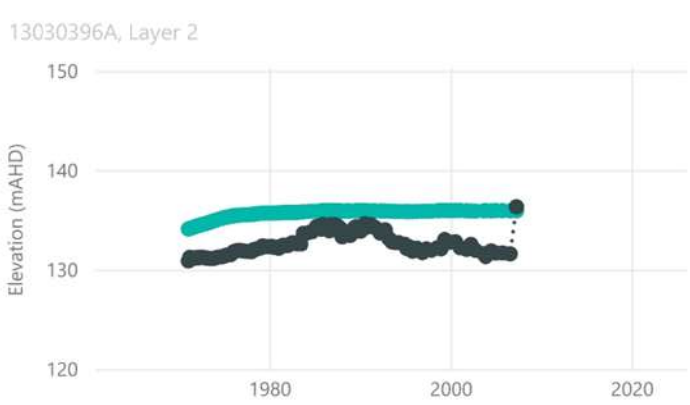


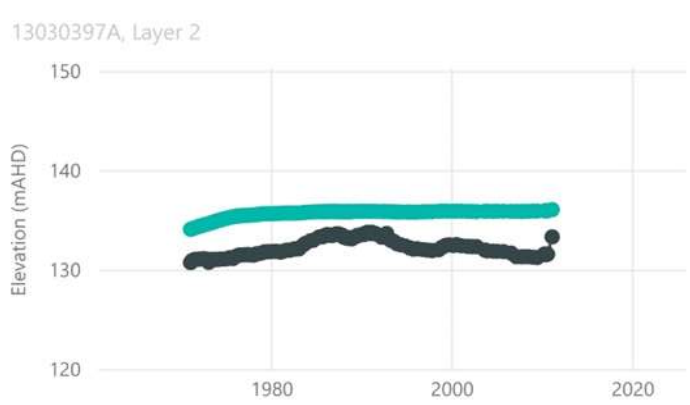
Figure 3.1 Transient Model Calibration Targets

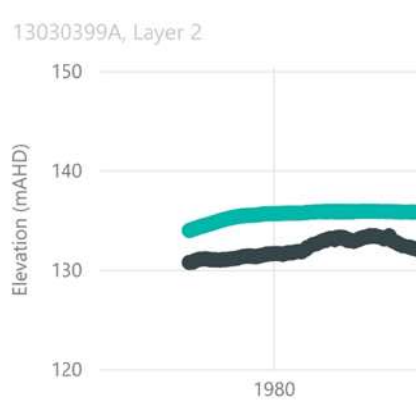
3.2 Calibration Hydrographs

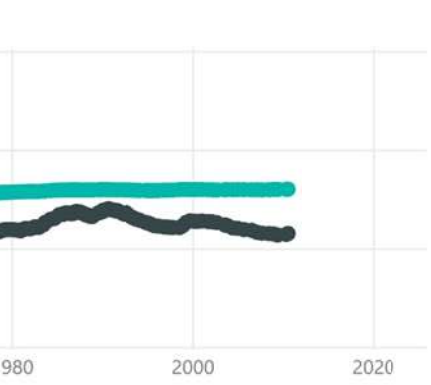
Selected calibration hydrographs, demonstrating the correlation between modelled and measured observations achieved through the calibration process, are shown in Figure 3.2 to Figure 3.7. The transient model simulation successfully matches observed groundwater level trends identified in the groundwater level monitoring records. The model calibration is considered robust and adequate for undertaking subsequent predictive simulations. Calibration in the shallow deposits (alluvium and Tertiary sediments) was considered important, as this formation is most likely to represent/reflect potential groundwater-related impacts. Detailed hydrographs of the raw data are provided in Appendix III.

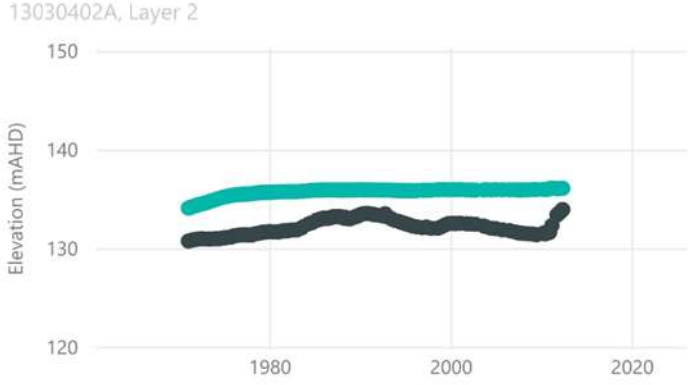

980
2000
2020

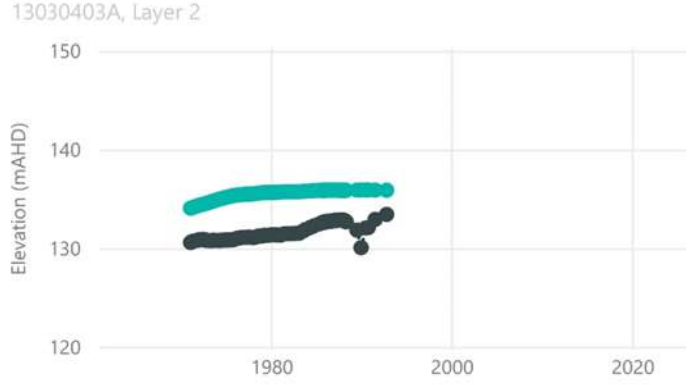

13030396A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

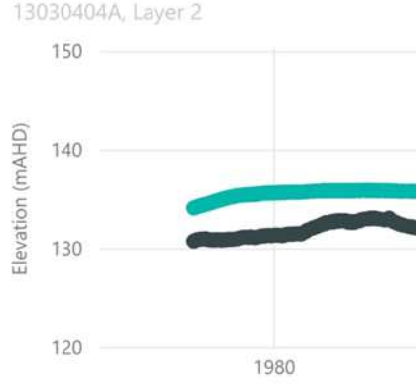

13030397A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

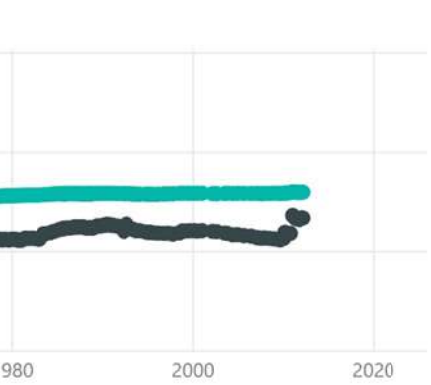

13030399A, Layer 2
Elevation (mAHD)
150
140
130
120
1980

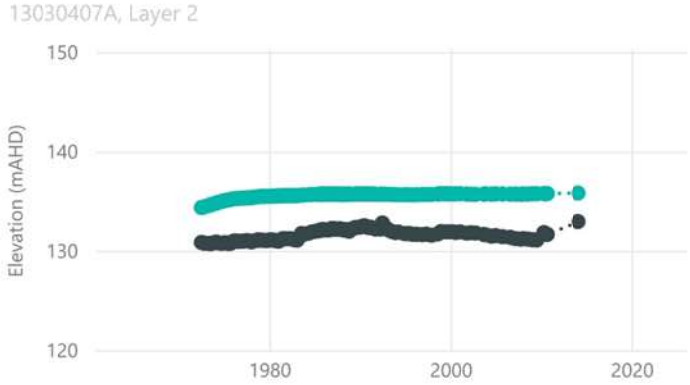

980
2000
2020

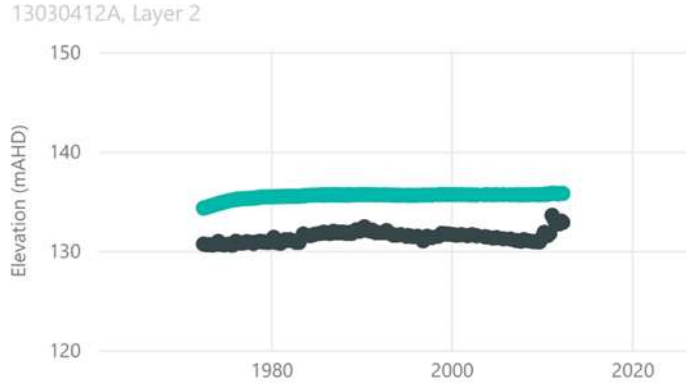

13030402A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

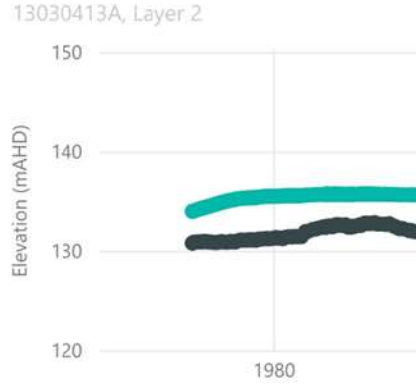

13030403A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020


13030404A, Layer 2
Elevation (mAHD)
150
140
130
120
1980


980
2000
2020


13030407A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020


13030412A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

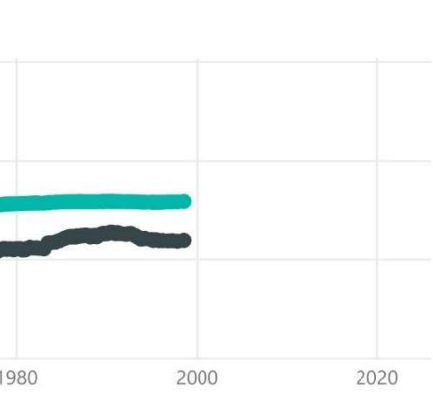

13030413A, Layer 2
Elevation (mAHD)
150
140
130
120
1980

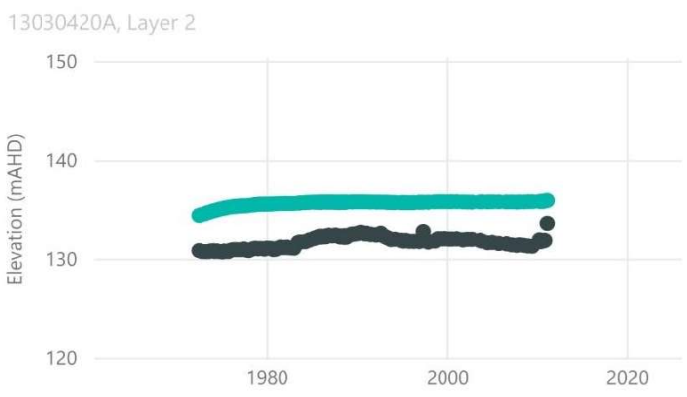


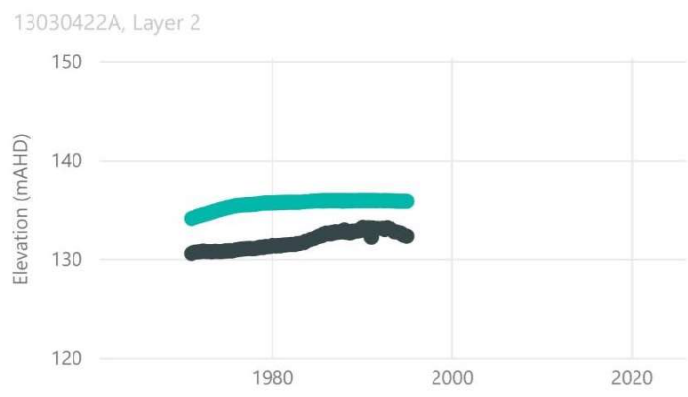

13030415A, Layer 2
Elevation (mAHD)
150
140
130

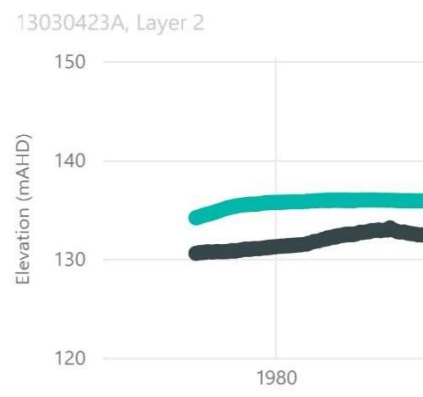

13030416A, Layer 2
Elevation (mAHD)
150
140
130

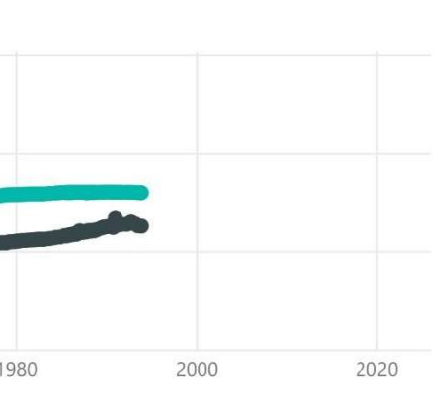

13030417A, Layer 2
Elevation (mAHD)
150
140
130


1980
2000
2020

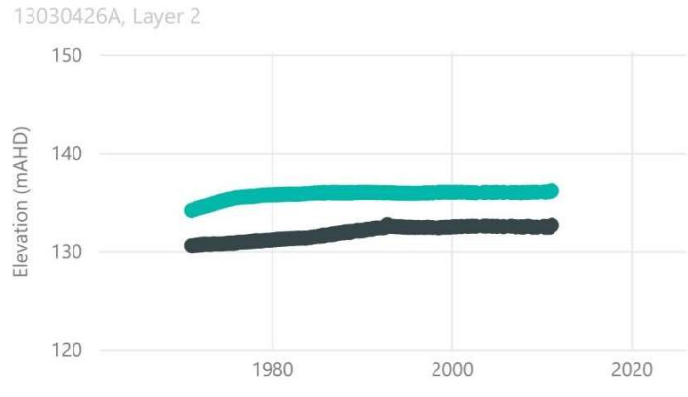

13030420A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

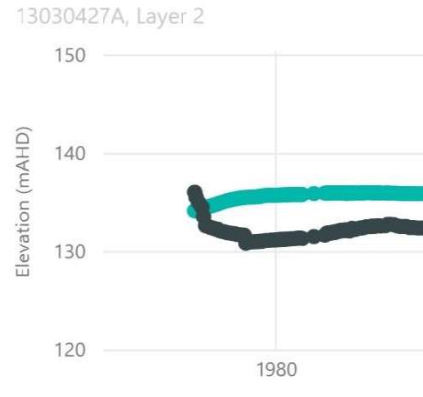

13030422A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

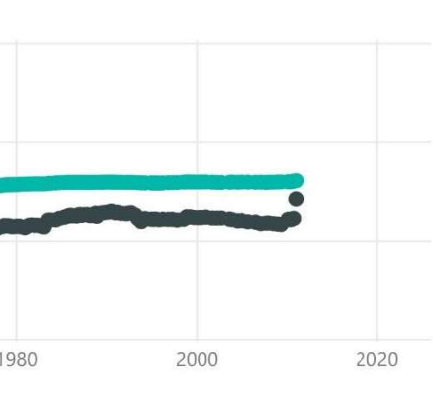

13030423A, Layer 2
Elevation (mAHD)
150
140
130
120
1980

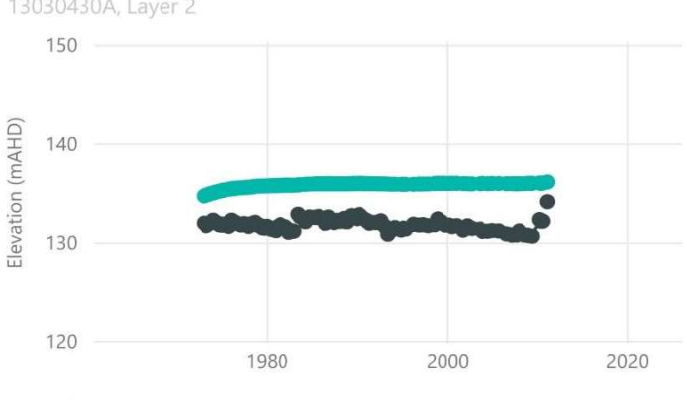

1980
2000
2020

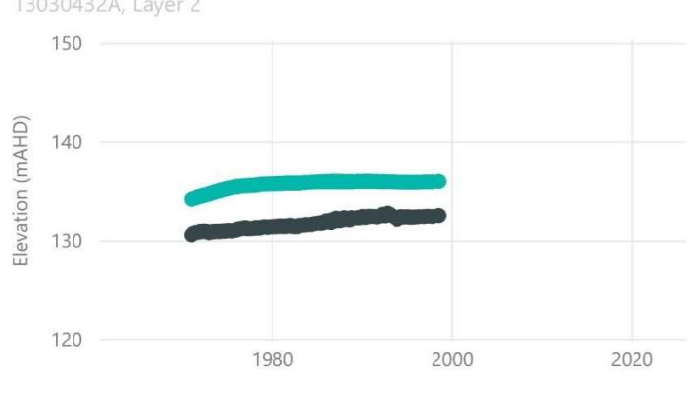

13030425A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020


13030426A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020


13030427A, Layer 2
Elevation (mAHD)
150
140
130
120
1980


1980
2000
2020

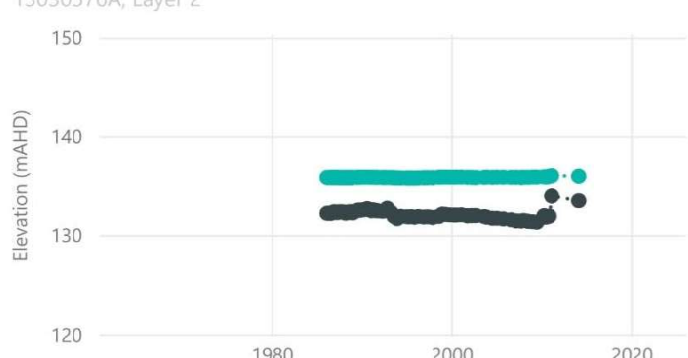

13030430A, Layer 2
Elevation (mAHD)
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140
130
120
1980
2000
2020


13030432A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

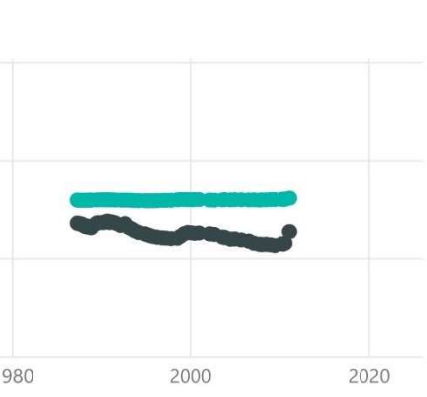

13030433A, Layer 2
Elevation (mAHD)
150
140
130
120
1980


1980
2000
2020

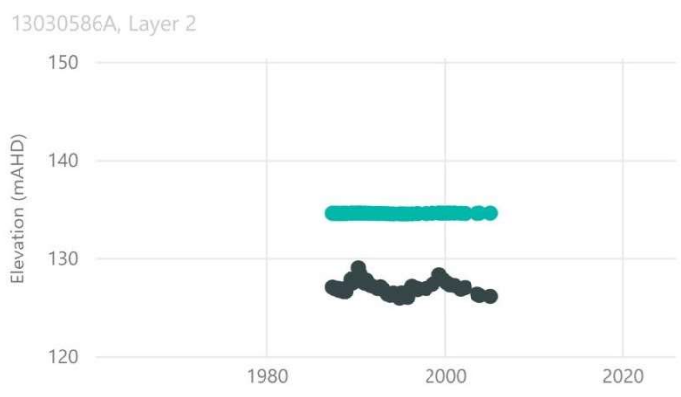

13030575A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020


13030576A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

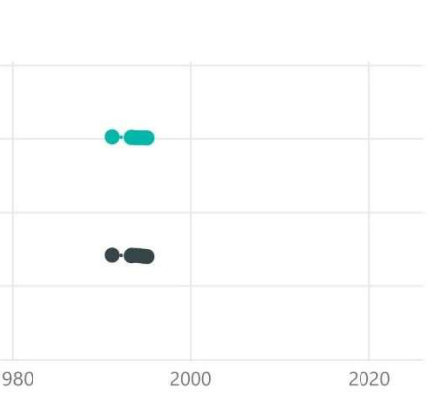

13030582A, Layer 2
Elevation (mAHD)
150
140
130
120
1980

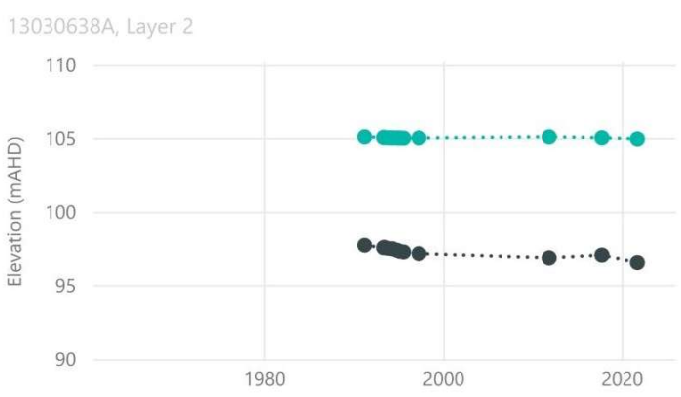


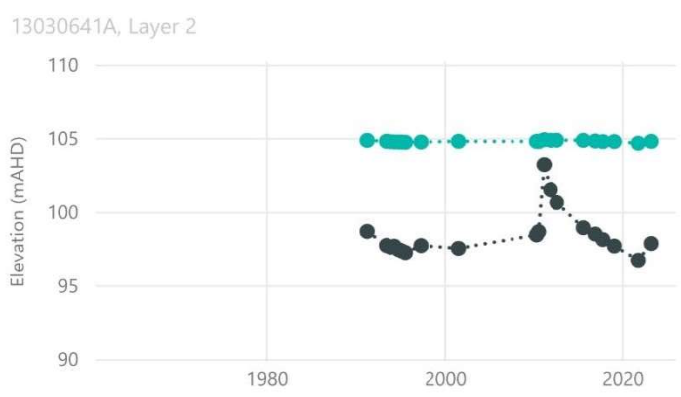

13030584A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

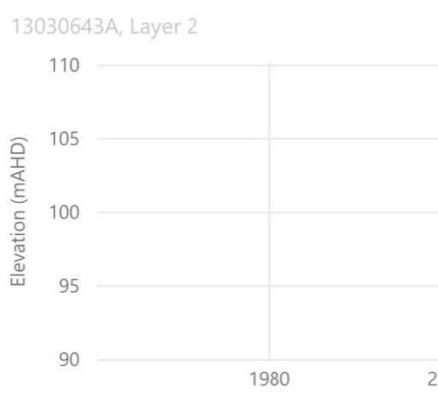

13030586A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

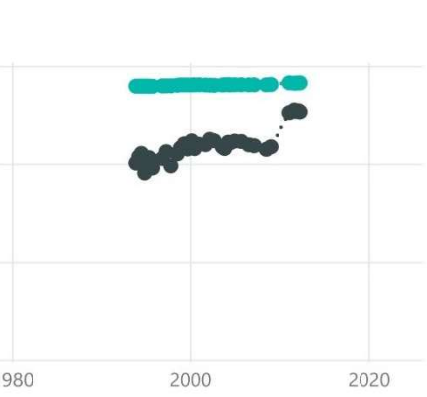

13030590A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2

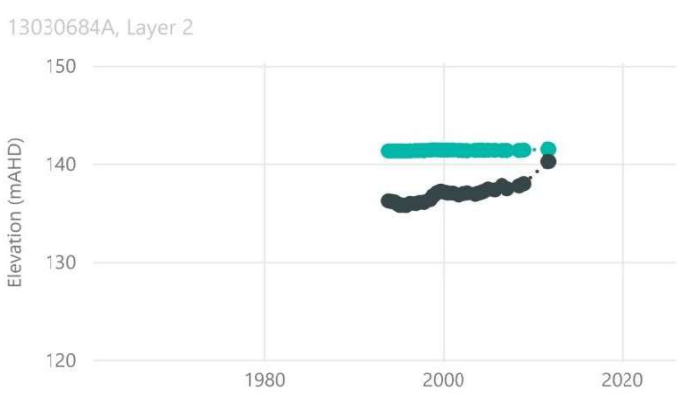



13030638A, Layer 2
Elevation (mAHD)
110
105
100
95
90
1980
2000
2020

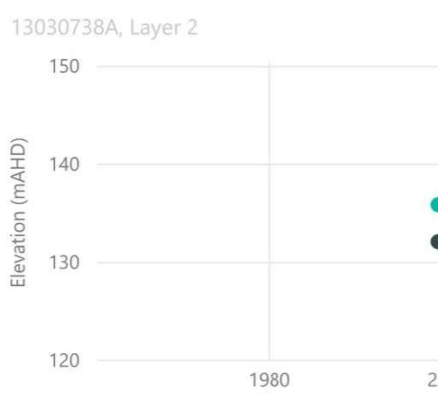

13030641A, Layer 2
Elevation (mAHD)
110
105
100
95
90
1980
2000
2020

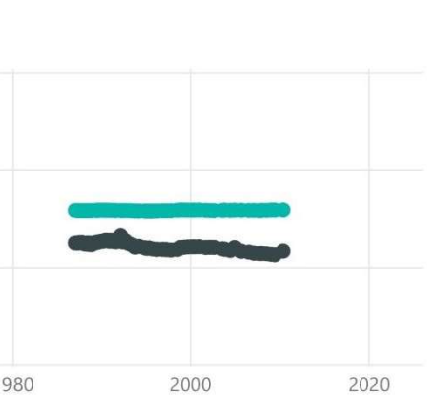

13030643A, Layer 2
Elevation (mAHD)
110
105
100
95
90
1980
2

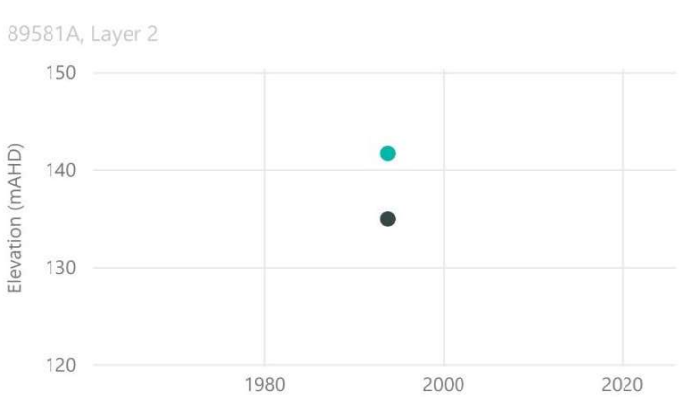


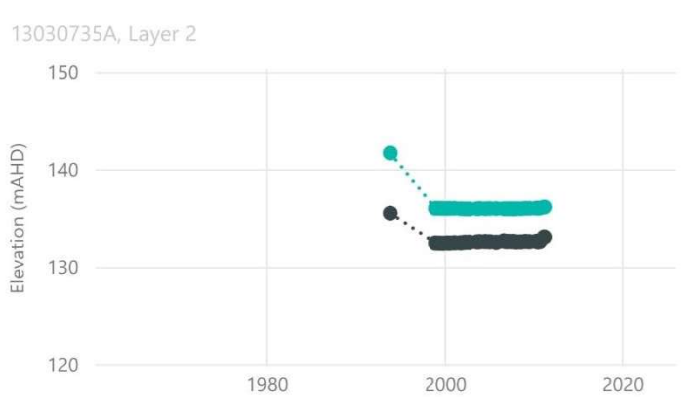

13030684A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

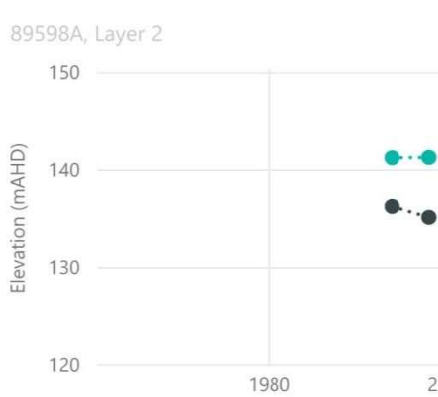

13030735A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

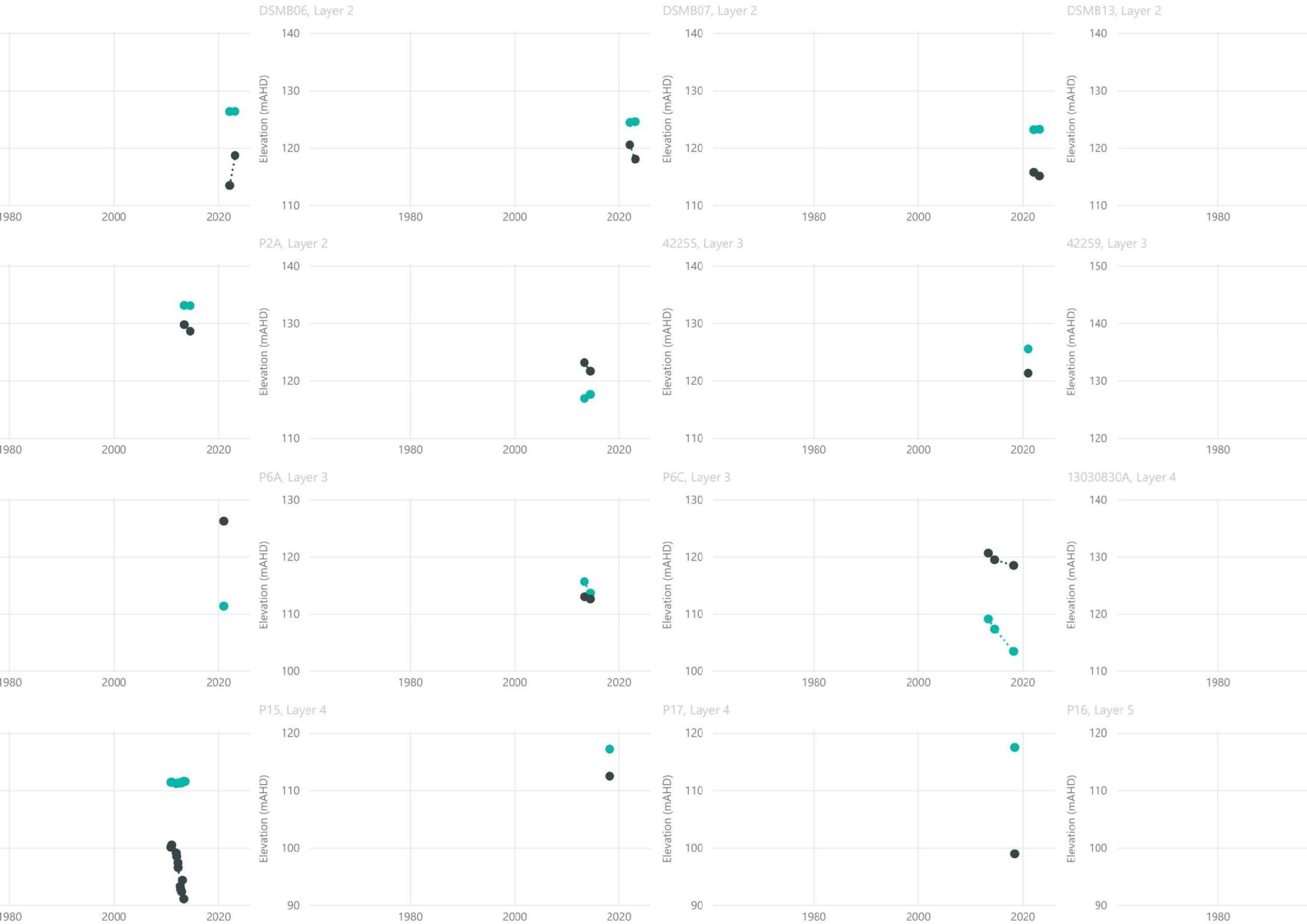

13030738A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2

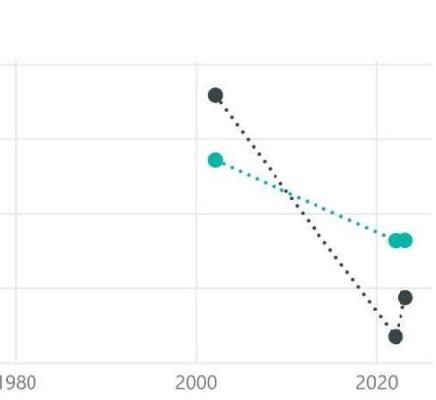


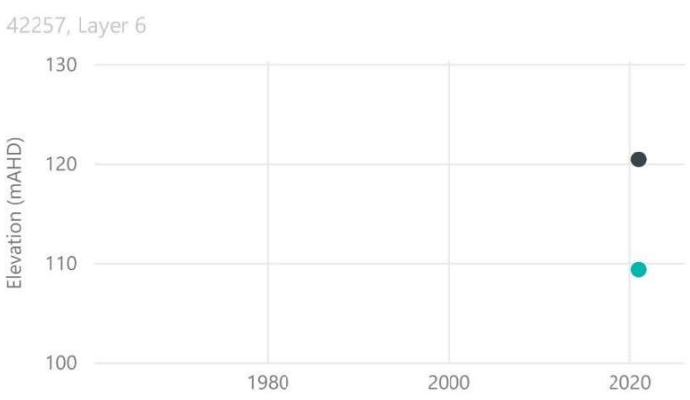

89581A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

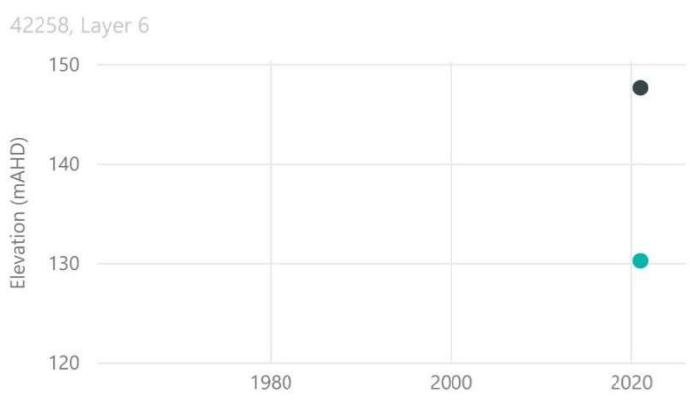

13030735A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2000
2020

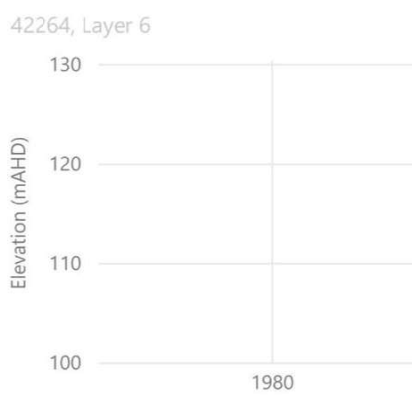

89598A, Layer 2
Elevation (mAHD)
150
140
130
120
1980
2

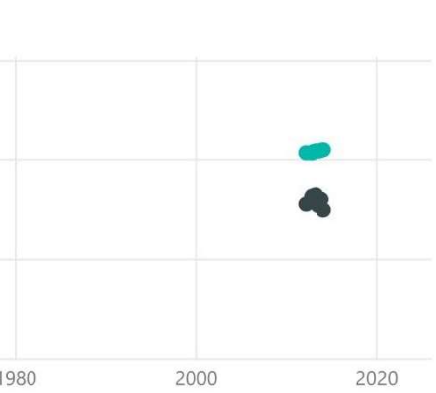

DSMB06, Layer 2
DSMB07, Layer 2
DSMB13, Layer 2
P2A, Layer 2
42255, Layer 3
42259, Layer 3
P6A, Layer 3
P6C, Layer 3
13030830A, Layer 4
P15, Layer 4
P17, Layer 4
P16, Layer 5
Elevation (mAHD)
1980
2000
2020

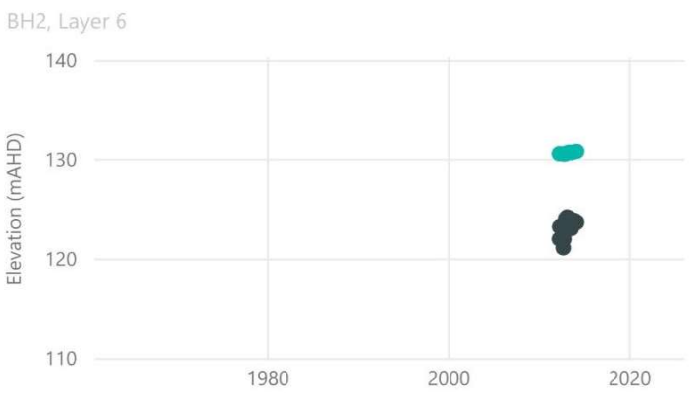

1980
2000
2020

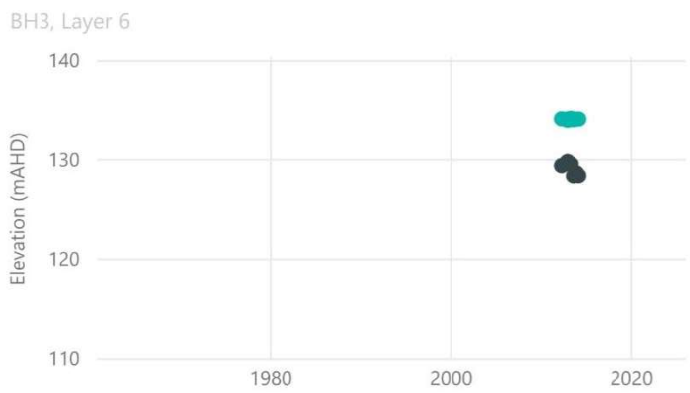

42257, Layer 6
Elevation (mAHD)
130
120
110
100
1980
2000
2020

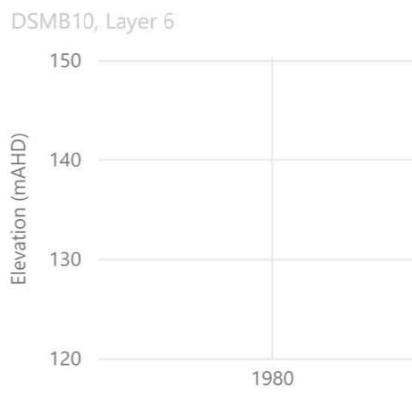

42258, Layer 6
Elevation (mAHD)
150
140
130
120
1980
2000
2020

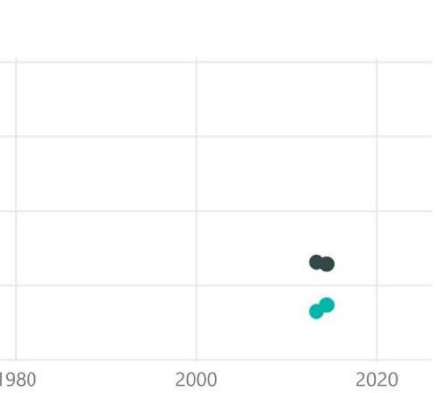

42264, Layer 6
Elevation (mAHD)
130
120
110
100
1980

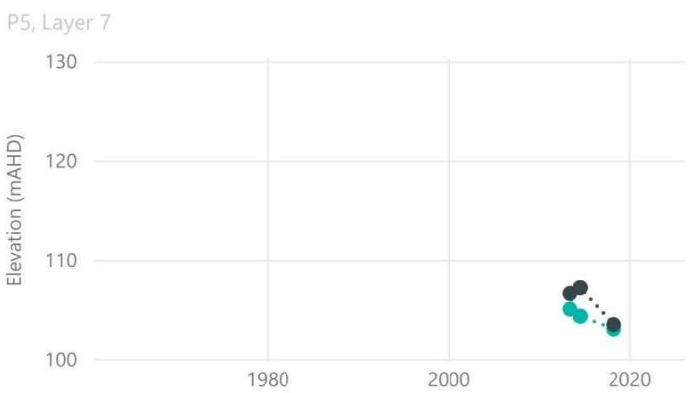

1980
2000
2020

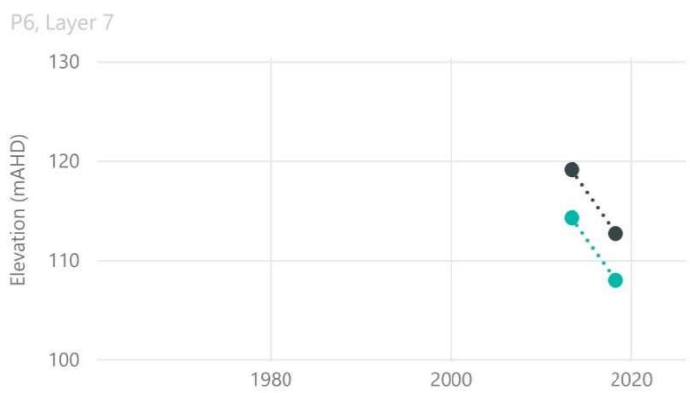

BH2, Layer 6
Elevation (mAHD)
140
130
120
110
1980
2000
2020

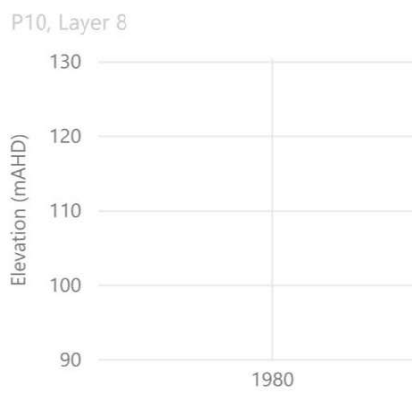

BH3, Layer 6
Elevation (mAHD)
140
130
120
110
1980
2000
2020

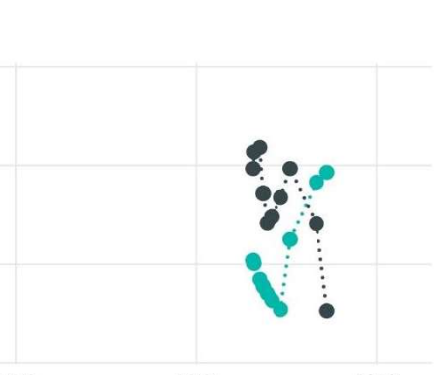

DSMB10, Layer 6
Elevation (mAHD)
150
140
130
120
1980

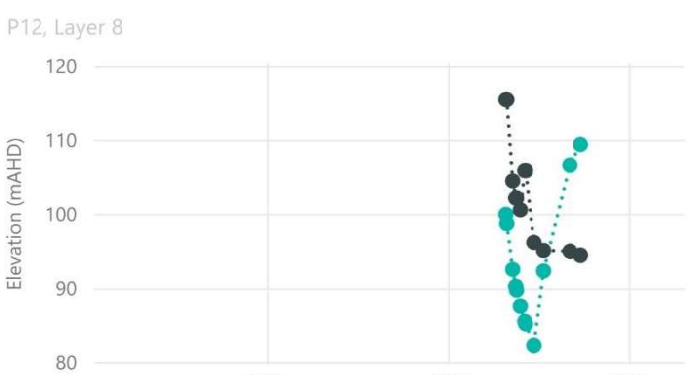

1980
2000
2020


P5, Layer 7
Elevation (mAHD)
130
120
110
100
1980
2000
2020

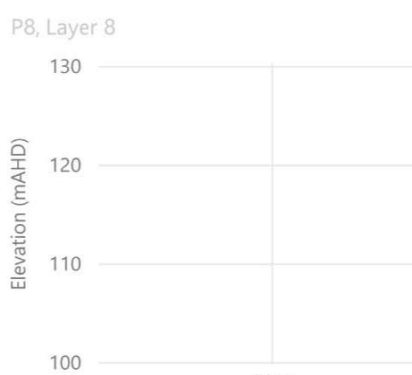

P6, Layer 7
Elevation (mAHD)
130
120
110
100
1980
2000
2020

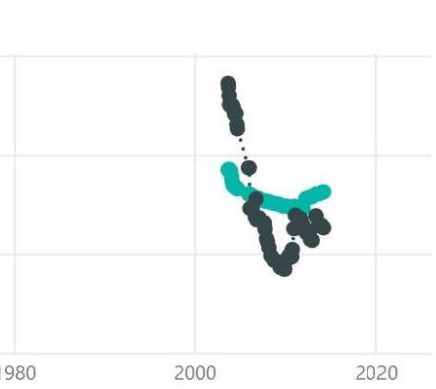

P10, Layer 8
Elevation (mAHD)
130
120
110
100
90
1980

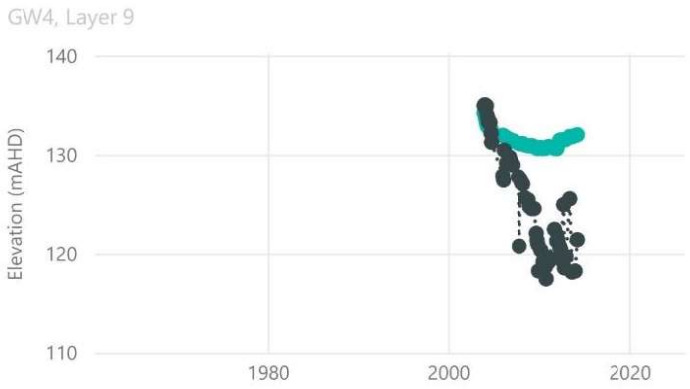


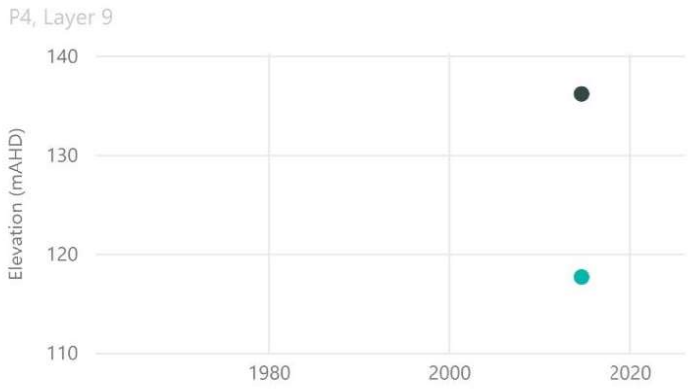

P12, Layer 8
Elevation (mAHD)
120
110
100
90
80

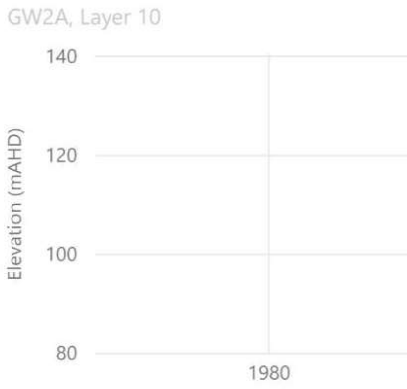

P7, Layer 8
Elevation (mAHD)
80
60
40
20

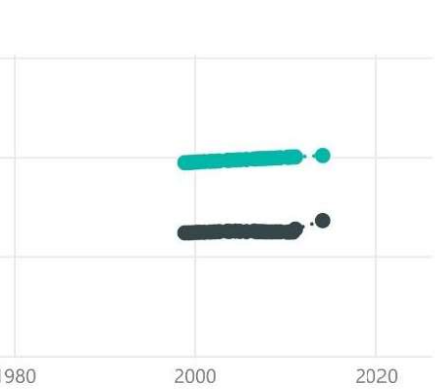

P8, Layer 8
Elevation (mAHD)
130
120
110
100

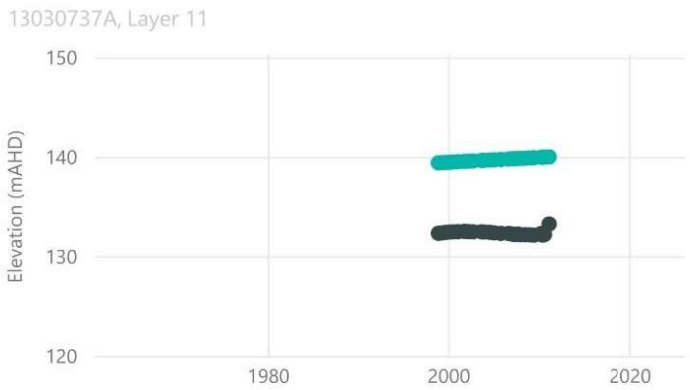














ent Calibration Hydrographs – Permian Coal Seams

3.2.1 Calibration Metrics

A good transient calibration was achieved, and this is reflected in the calibration metrics as summarised in Table 3.1.

The scaled RMS of the observed groundwater levels vs simulated groundwater levels is less than the 10% limit recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), which indicates that a good calibration has been achieved. It is also important to note that the calibrated model reproduces the groundwater flow processes in terms of matching recharge zones, discharge zones and balance in the system (replication of groundwater flow and vertical hydraulic gradients). The scatter plot of the observed vs the modelled hydraulic heads shows a good correlation with a recorded correlation coefficient of 0.85. The visual comparison of modelled against measured groundwater elevations is provided in Figure 3.8.

Table 3.1 Summary of Model Calibration Performance

Metric	Value
Number of Observations	4952
RMS Error (m)	5.01
Scaled RMS (%)	3.68 %
Mean Sum of Residuals	-3.80
Correlation coefficient	0.85

It should be noted that some divergence is noted in the calibration of selected bores in the deeper units. This appears to be related to a mismatch between the Proposed/scheduled timing of mining-associated dewatering and the field implementation. These discrepancies do not have a significant impact on the groundwater system above the shallowest mine seam (Layer 6 in the model).

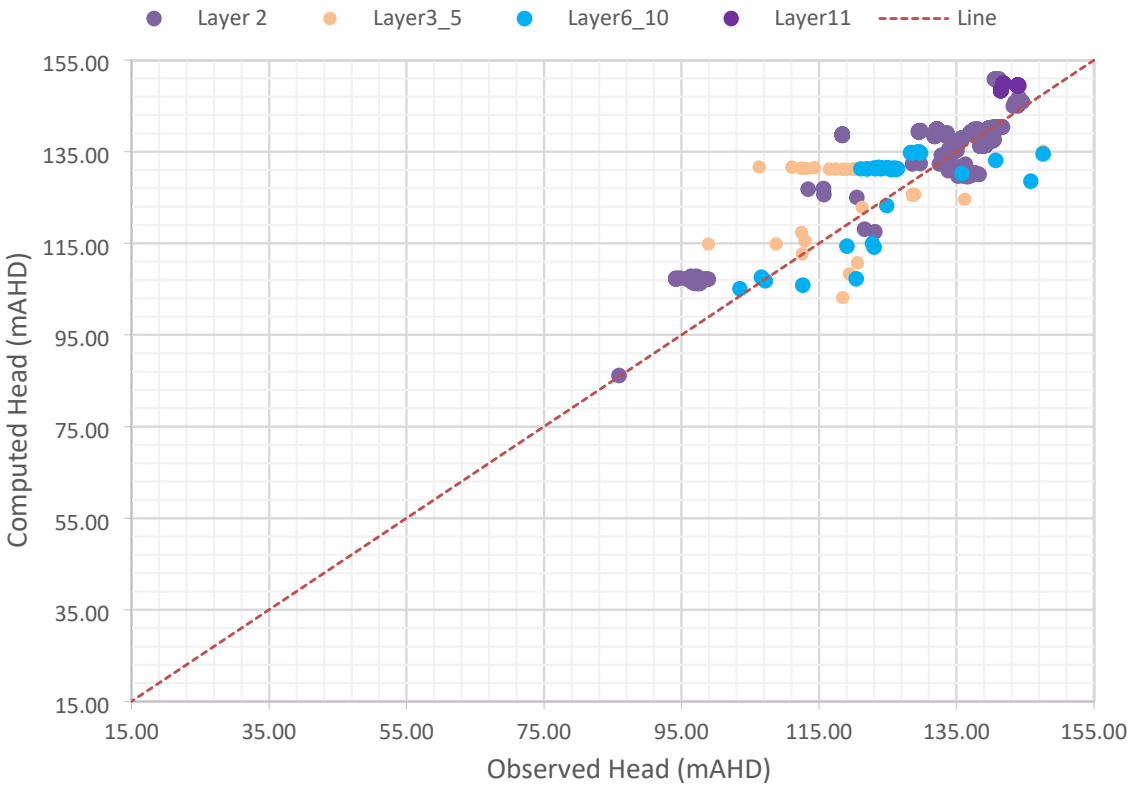


Figure 3.8 Scatter Plot of Observed vs Modelled Hydraulic Heads

3.3 Calibrated Hydraulic Parameters

The calibrated hydraulic conductivity values and the calibrated storage parameters for each layer are presented in Table 3.2 while the calibrated recharge is provided in Table 3.3. These are largely unchanged in the shallower units (Rewan and above) but have been refined for the spoils and coal layers (including a slight increase in hydraulic conductivity for B, C and D seams).

Table 3.2 Summary of Calibrated Hydraulic Properties

Layer (Zone)	Geological Unit	Calibrated Kh (m/d)	Calibrated Kh/Kv	Calibrated Specific Storage(-)	Calibrated Specific Yield (m^{-1})
1 (1)	N/A Boundary Layer to set up tailings heads	10	1	3.24E-06	0.1
2 (2)	Quaternary Alluvium	1	0.1	3.24E-06	0.01
3 (3)	Tertiary Sediments	0.2	1.00E-01	3.26E-05	0.01
4 (4)	Rewan Group (upper)	1.65E-03	1.00E-01	1.00E-07	0.00224
5 (5)	Rewan Group (lower)	1.65E-03	1.00E-01	1.00E-07	0.00224
6 (6)	A seam	2.25E-02	1.00E-01	9.00E-08	0.00292
7 (7)	B seam	1.48E-02	1.00E-01	9.00E-08	0.00292
8 (8)	C seam	9.36E-03	1.00E-01	9.00E-08	0.00292
9 (9)	D seam	1.04E-02	1.00E-01	9.00E-08	0.00292
10 (10)	E seam	2.35E-02	1.00E-01	9.00E-08	0.00292
11 (12)	Spoils	10	1	1.00E-05	0.1
12 (13)	Underground mining areas	1.00E+00	1.00E+00	1.00E-05	0.2
13 (11)	Model basement	1.06E-04	1.00E-01	9.00E-08	0.00171

Table 3.3 Calibrated Recharge Rates

Modelled Recharge Zone	Percentage
Quaternary Alluvium	0.6
Tertiary sediments	0.2
Others	0.001
Spoil	10

3.4 Calibrated Water Balance

The mass balance error of the transient calibration model is the difference between model inflows and model outflows calculated by the model. An error of 1% or less is typically considered acceptable for a regional groundwater aquifer system (Anderson and Woessner 1991).

The water budget and mass balance error for the steady-state and transient calibrations are presented in Table 3.4 and Table 3.5. The water balance error is less than 0.01%, which indicates that convergence of the numerical solution of the groundwater flow problem was achieved. Details are provided in Model Appendix II.

Table 3.4 Calibrated Water Balance – Steady-State

Steady-State	Inflow (m^3/d)	Outflow (m^3/d)
Drain	0.0	32.51
ET	0.0	25650.97
GHB	383.35	11.18
Recharge	24856.31	0.0
River	3257.63	2802.76
Mass balance error	<0.01%	

Table 3.5 Calibrated Water Balance – Transient Calibration

Transient State	Inflow (m^3/d)	Outflow (m^3/d)
Storage	594.63	25800.84
Drain	0.0	1439.36
ET	0.0	33434.36
GHB	365.35	10.87
Recharge	55483.92	0.0
River	4366.23	124.69
Mass balance error	<0.01%	

3.5 Model Classification

Barnett et al. (2012) developed a system to classify the confidence level of groundwater flow models based on the calibration process used and the predictive capability of the model. Three classes of model were developed: Class 1, Class 2 and Class 3. A Class 3 model has the greatest confidence level, and a Class 1 model has the least. Factors that are considered when determining model confidence level are:

- Data availability;
- Calibration procedures;

- Consistency between calibration and predictive analyses; and
- Stresses induced on the model.

The model outlined in this report is considered a Class 2 model because:

- A transient calibration was undertaken, and mining-induced groundwater trends have been replicated;
- Independent observations and calculations were used to support the calibration process; and
- The water balance error is less than 1%.

The model meets the criteria for a Class 2 model and exceeds the criteria for a Class 1 model. The model is therefore considered a suitable tool for assessing the potential groundwater impacts of the Project.

4 MODEL PREDICTIONS

4.1 Predictions Overview

The predictive scenarios considered groundwater response to existing mining (life of mine to closure) and Proposed mining (life of mine to closure) conditions. The duration of predictive simulations was from 2023 to 2052, as specified by the life of mine plan for Dawson South. The duration of stress periods was refined to assess wet and dry seasonal groundwater changes. For the mining periods, drain cells were activated to coincide with the mine plan (location and depth of mining) and turned off to allow recovery to correspond with the pit backfill and rehabilitation plan.

The post-closure simulations were modelled for a duration of 1,000 years to allow groundwater level to recover to a state of equilibrium. A conservative case was modelled for the Pit 25 and Pit 28 voids, maintaining the void water elevation at a minimum elevation as estimated through previous post-mining void scenarios (reported by WRM, 2019 and KCB 2023).

4.2 Predictions for Remaining Operating Period

The predicted groundwater drawdown is the difference in the groundwater level between the pre-mining water level and the water level at each mined interval (the end of the initial calibration period in 1963 was used as representative of the pre-mining groundwater level for consistency). The maximum observed drawdown occurs in 2052 (toward the end of the mining operational period). The estimated dewatering flow patterns for the existing Dawson South mining scenario are represented in Figure 4.1.

Groundwater predictions indicate that during operation there is negligible difference between the current and proposed mine scenarios. The reason for this similarity is the result of relatively low hydraulic conductivity of the overlying units, influencing the early stages of slower groundwater level recovery and the fact that both mining scenarios target the same coal seam, at the same depth and extent. The higher permeability though the coal and spoils layers mean that the dewatering influences from the various pits overlap and at the end of operations the depth of the operations is a main

In the vicinity of Dawson South (from Pit 25 to Pit 28) there is predicted a decrease in the groundwater level to -20m AHD. Due to these factors, the comparative groundwater drawdown at the end of operations for the Proposed mine design and the current mine design (Model Appendix are not significantly different).

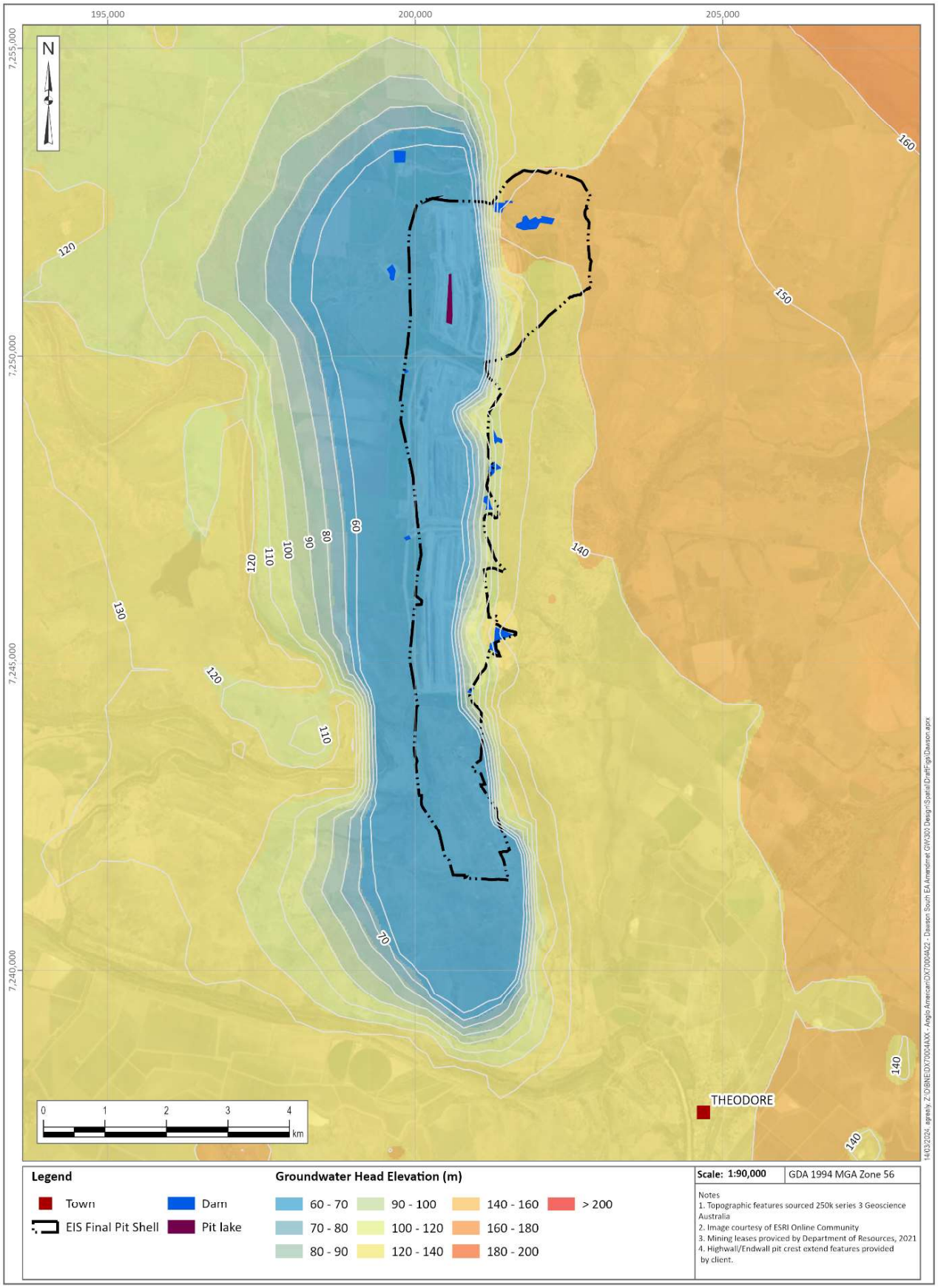


Figure 4.1 Water Table (Layer 2) at End of Mining (2052)

4.3 Post-Closure

An assessment of post-closure recovery of groundwater levels was performed to evaluate the response of the groundwater system following cessation of mining operations. The model considered the 1,000-year post-closure period, where all drain cells in Dawson South voids were deactivated/removed and recharge applied, in accordance with the long-term historical average. The other drain cells that represent mining in Dawson Central and North and for CSG were de-activated according to the mining/gas production schedules.

Predicted Post-Closure Groundwater Inflow and Void Elevation Estimates

The post-closure groundwater inflow flux was estimated for a range of void lake elevations, from the maximum inflow rate when groundwater levels are at the base of the pit (lowest), to the pre-mining groundwater level elevation where no groundwater inflow is observed (representing steady-state or equilibrium conditions). These fluxes (as a function of void head) were provided to ERM as inputs for the water balance model.

Final void elevations were simulated using the current Dawson water balance model (in GoldSIM), as part of ERM's the surface water assessment. This water balance incorporated all contributing fluxes to the voids, including the estimated groundwater inflow from this numerical model assessment.

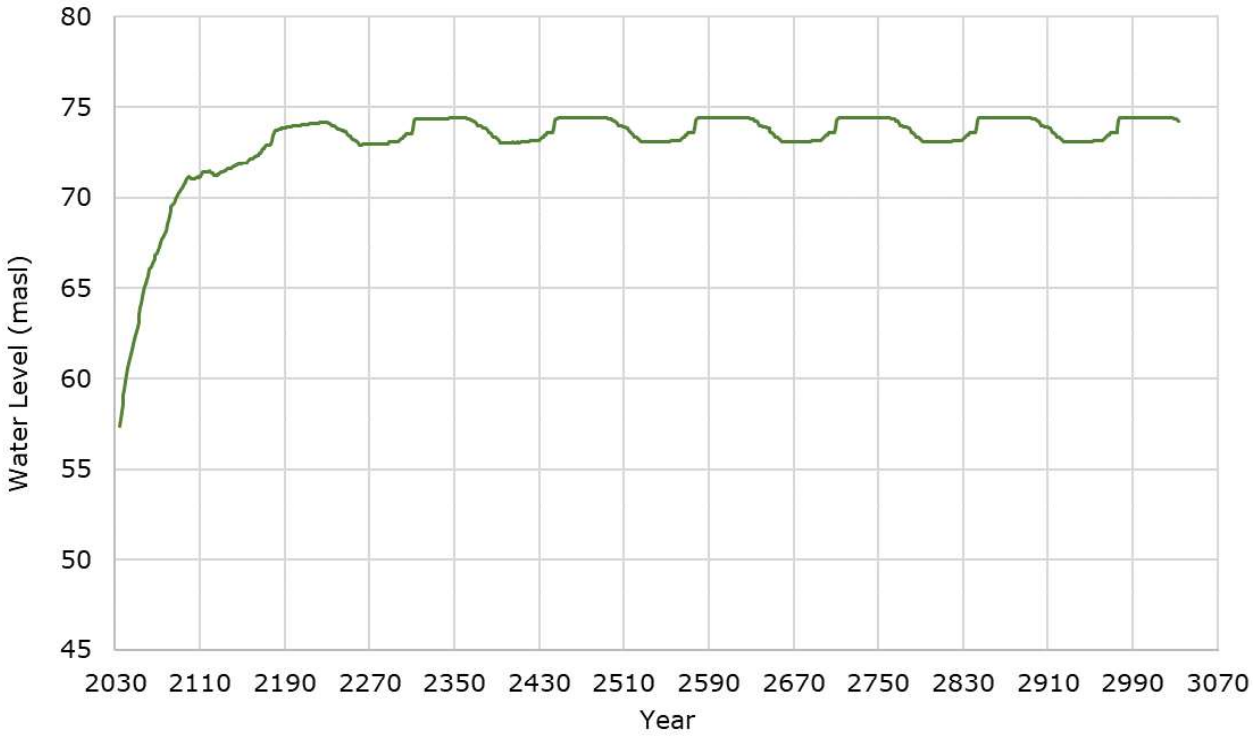


Figure 4.2 Pit 25 Predicted Void Water Levels

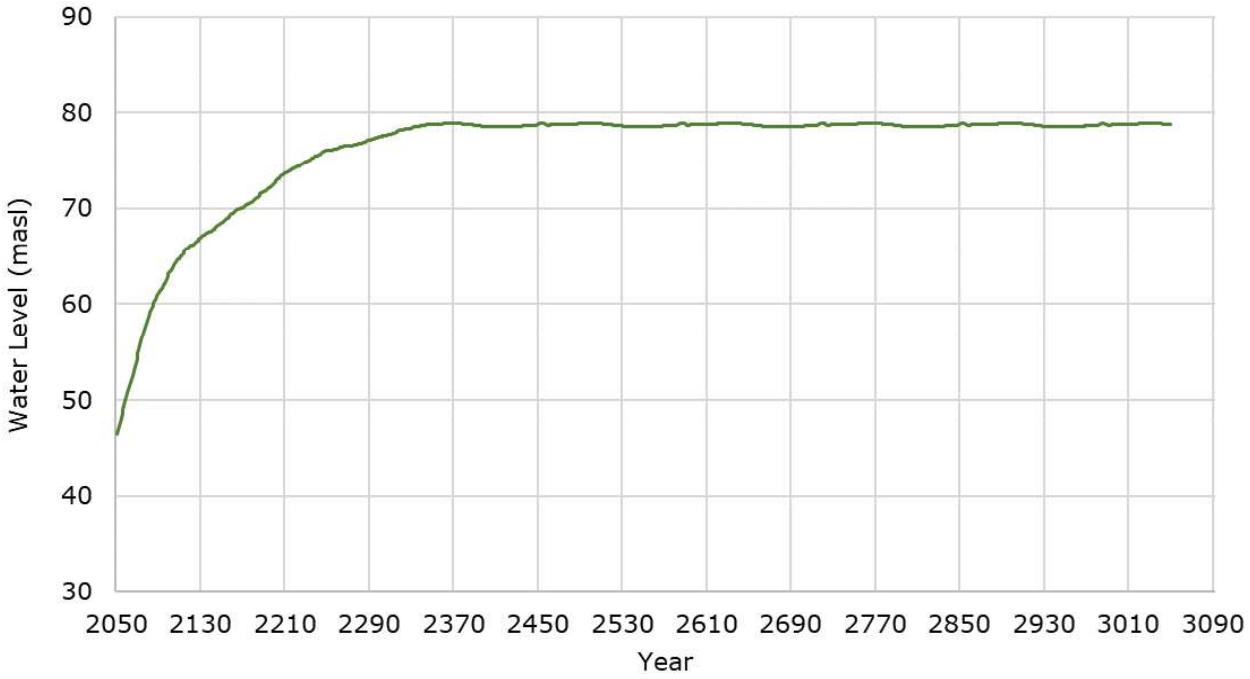


Figure 4.3 Pit 28 Predicted Void Water Levels

Predicted Post-Closure Groundwater Elevation

The post-closure predicted void rebounding water levels, using the groundwater model results integrated into the surface water model (as estimated by ERM) for Pit 25 and Pit 28 (Figure 4.2 and Figure 4.3 respectively), were re-applied to the groundwater model, using a time-variable General Head Boundary (GHB) to assess the post-closure groundwater conditions.

1,000 Year Post Mine Closure Elevation

Since the greatest difference in groundwater response is in the long-term at the cessation of mining, two cases were compared: a case where water levels in the pit lakes are allowed to recover and a second (conservative case) where the pit lake water levels are kept at a minimum.

The current 1,000-year post-closure design there is a remaining lake in Pit 28 and the groundwater elevation has recovered to ~75 mAHD. The Proposed 1,000-year post-closure design shows there are two remaining pit lakes, including one in the north of the project area around Pit 25, which both recover to around ~75 m (Figure 4.3Figure 4.4).

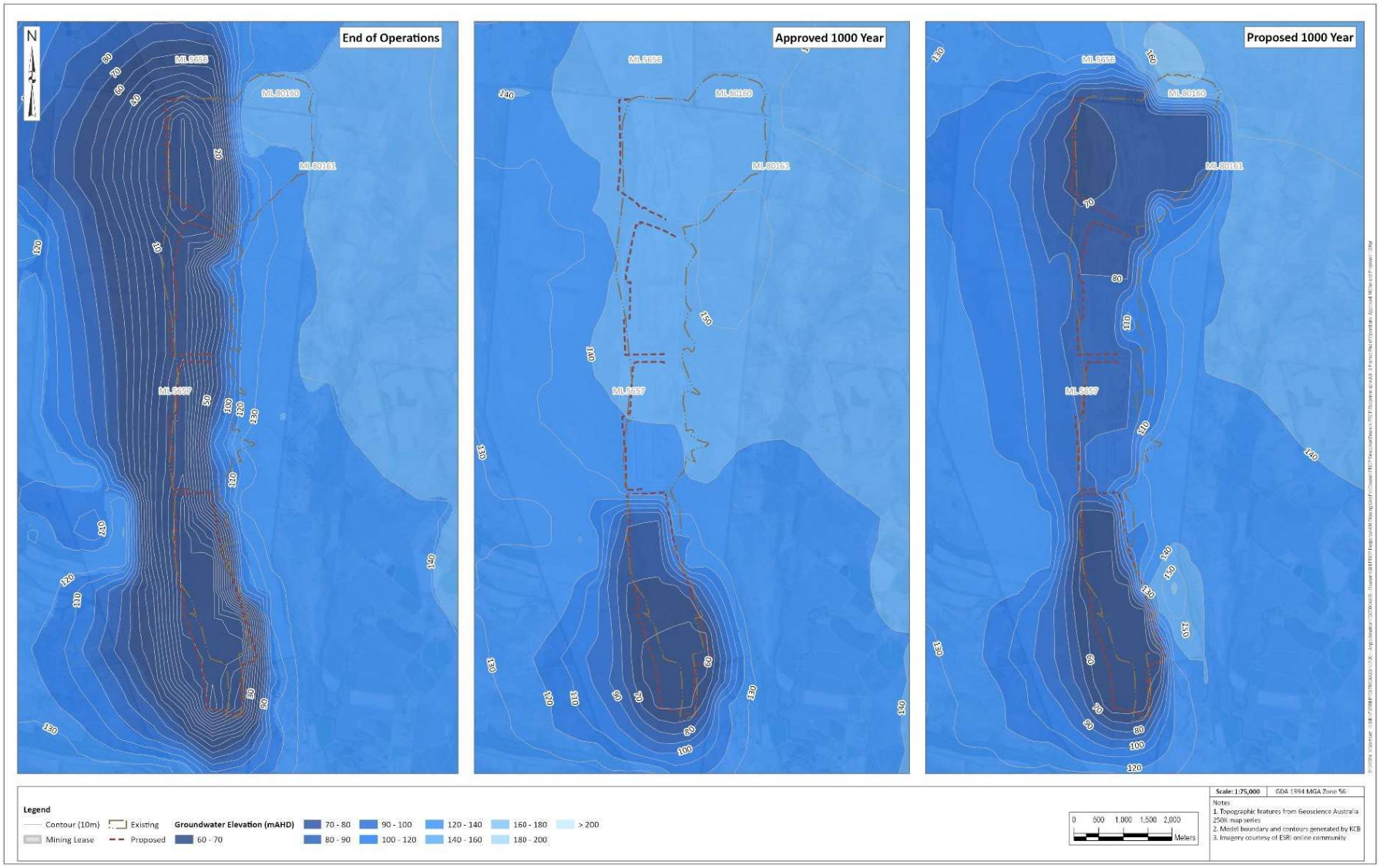


Figure 4.4 Water table contours at the end of operations and for 1,000 year post-closure.

Several important observations follow from these comparisons, where the presence of the Pit 25 void in the Proposed case results in a continued flow of groundwater toward the void in the north. Around Pit 28, the difference between current and proposed is noteworthy since the Proposed landform allows a final void water level to equilibrate to a higher elevation than in the existing mine plan. In the current landform, the equilibrated final void water elevation was around 50 m RL while the Proposed landform suggests that a final void water elevation of around 78 mRL is more likely.

A series of cross-sections has been prepared to illustrate the difference between the approved and proposed case. For Pit 25, a cross-section through the approved case (with a backfilled pit) is shown in Figure 4.6, with the proposed case (pit lake) shown on Figure 4.7. For Pit 28, the two cases are illustrated on Figure 4.8 (both cases have a pit lake so the minor change is from the proposed change small change in pit shell.

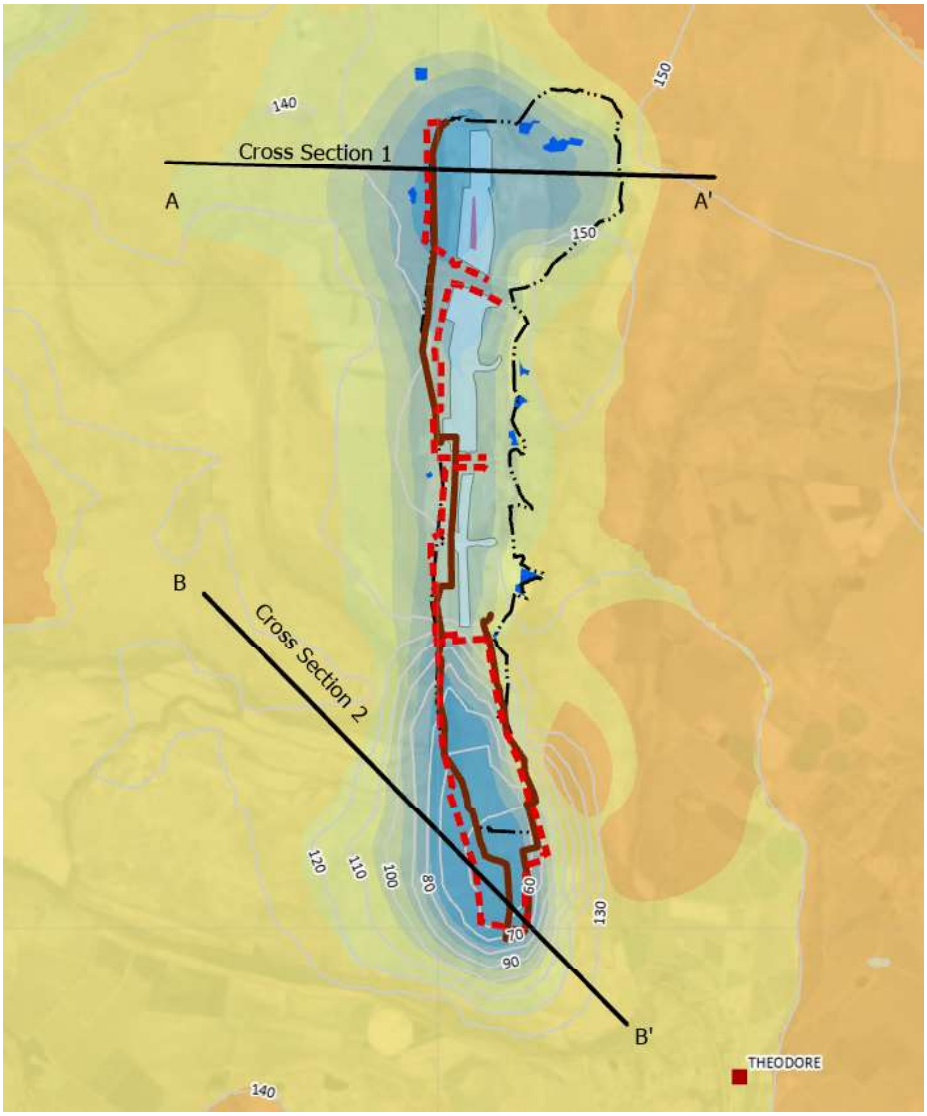


Figure 4.5 Cross-Section Lines through Pit 25 and Pit 28 (Cross-sections follow).

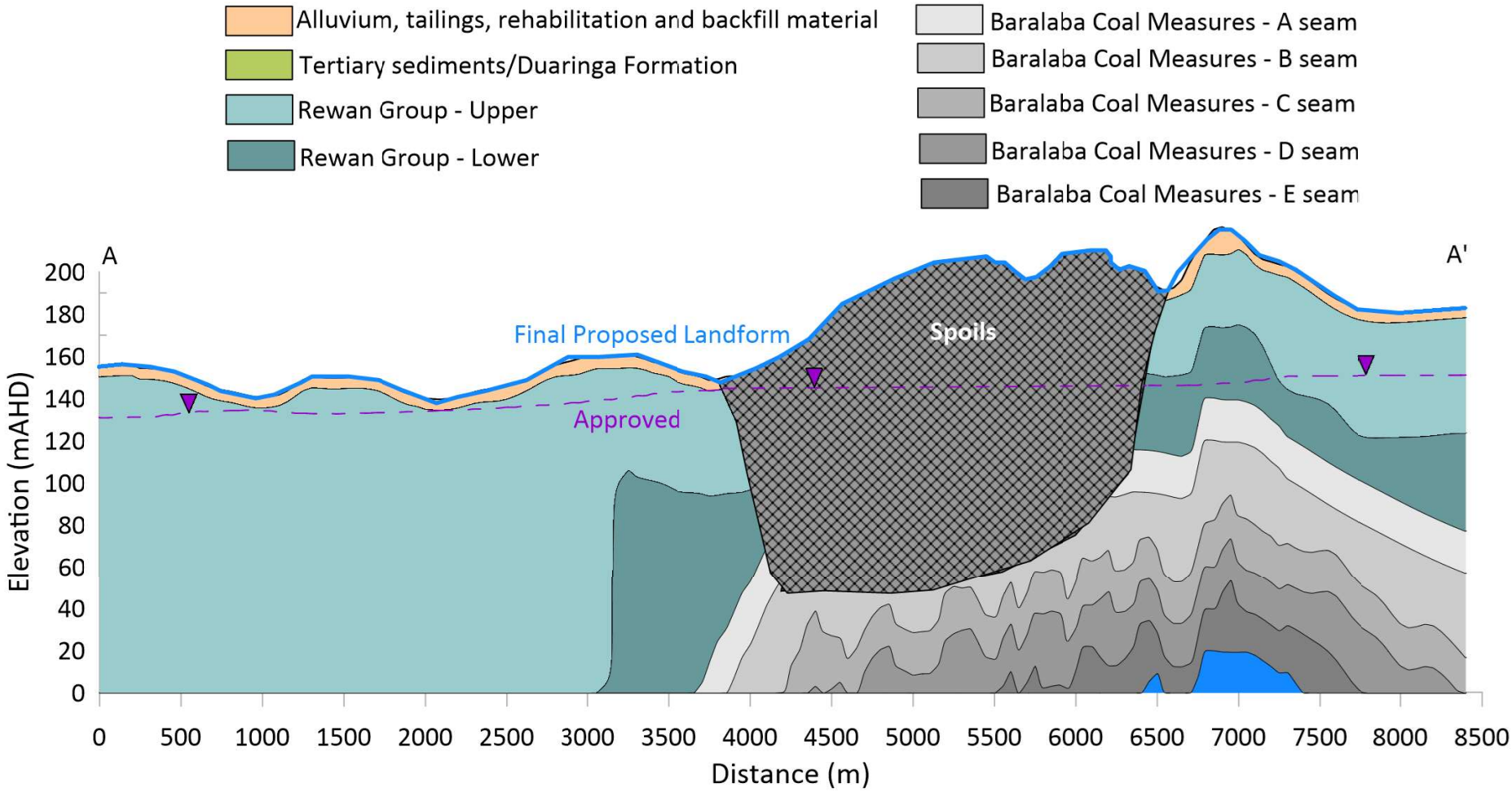


Figure 4.6 Cross-Section through Pit 25 (Approved Case): Water table at 1,000 years post-closure.

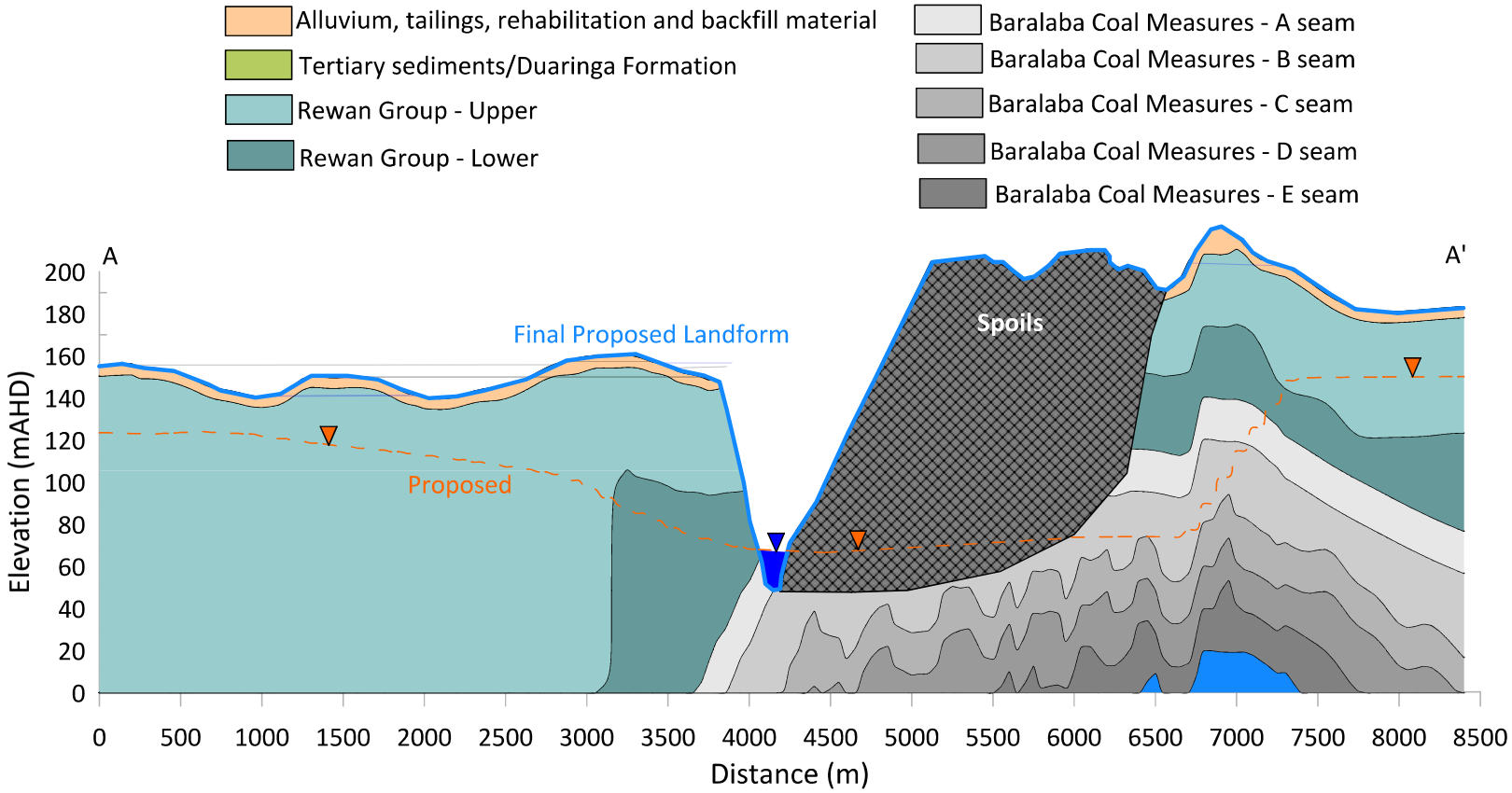


Figure 4.7 Cross-Section through Pit 25 (Proposed Case): Water table at 1,000 years post-closure.

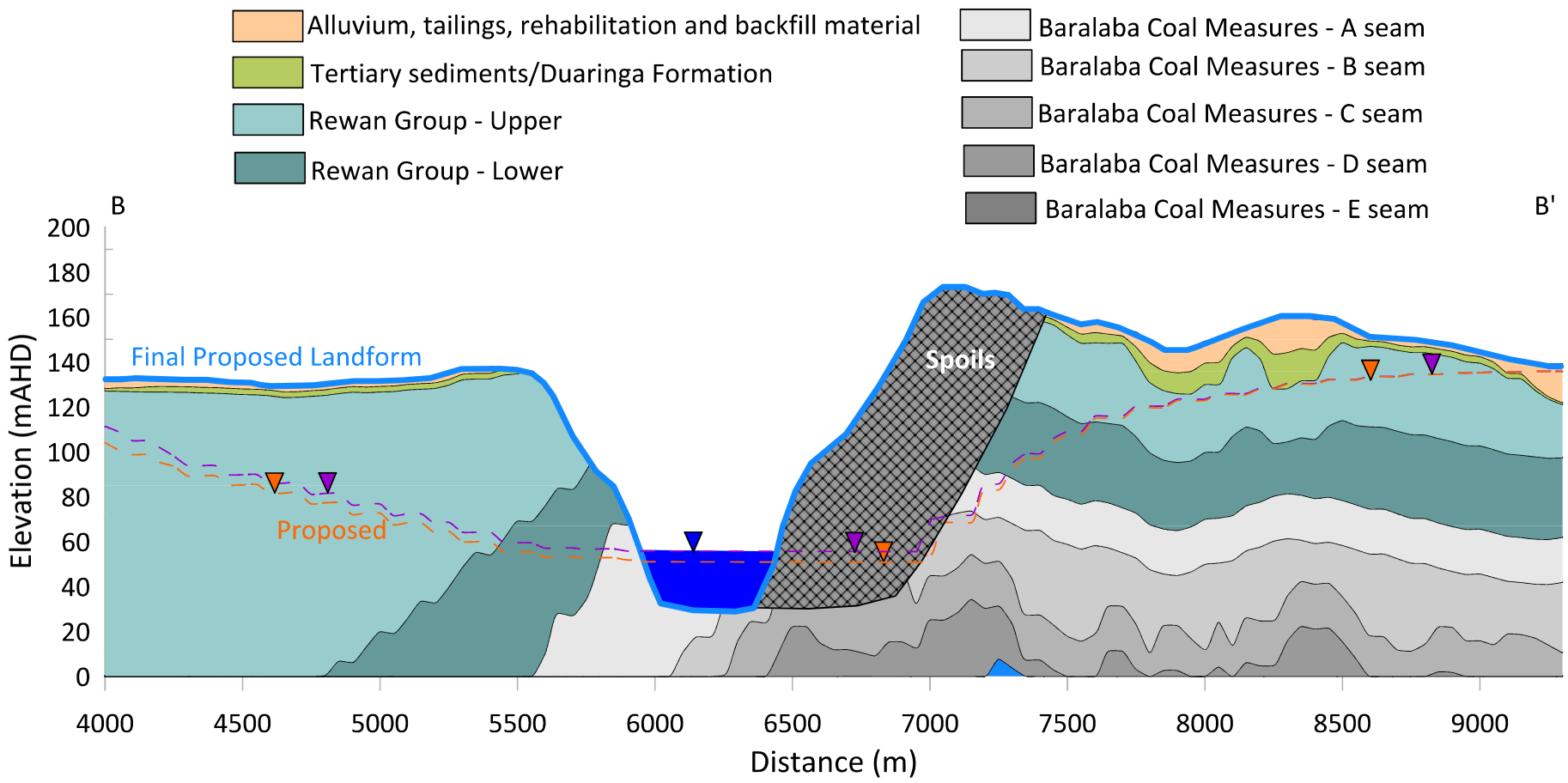


Figure 4.8 Cross-Section through Pit 28 (Approved and Proposed Case): Water table at 1,000 years post-closure.

Change in Groundwater Head

The difference in groundwater elevations between the two cases is driven by inclusion of the Pit 25 pit lake. The absolute difference between the cases alongside the 1,000 water levels is indicated on Figure 4.9.

The progressive development of the groundwater levels for the proposed case is provided for key hydrostratigraphic units on Figure 4.10 through Figure 4.17. It should be noted that for the critical unit (water table) the contrast over time is shown in sequence on a single figure for the Proposed and Approved but for the Rewan and Coal Measures a side-by-side comparison is provided for the post closure period (50, 500 and 1,000 years).

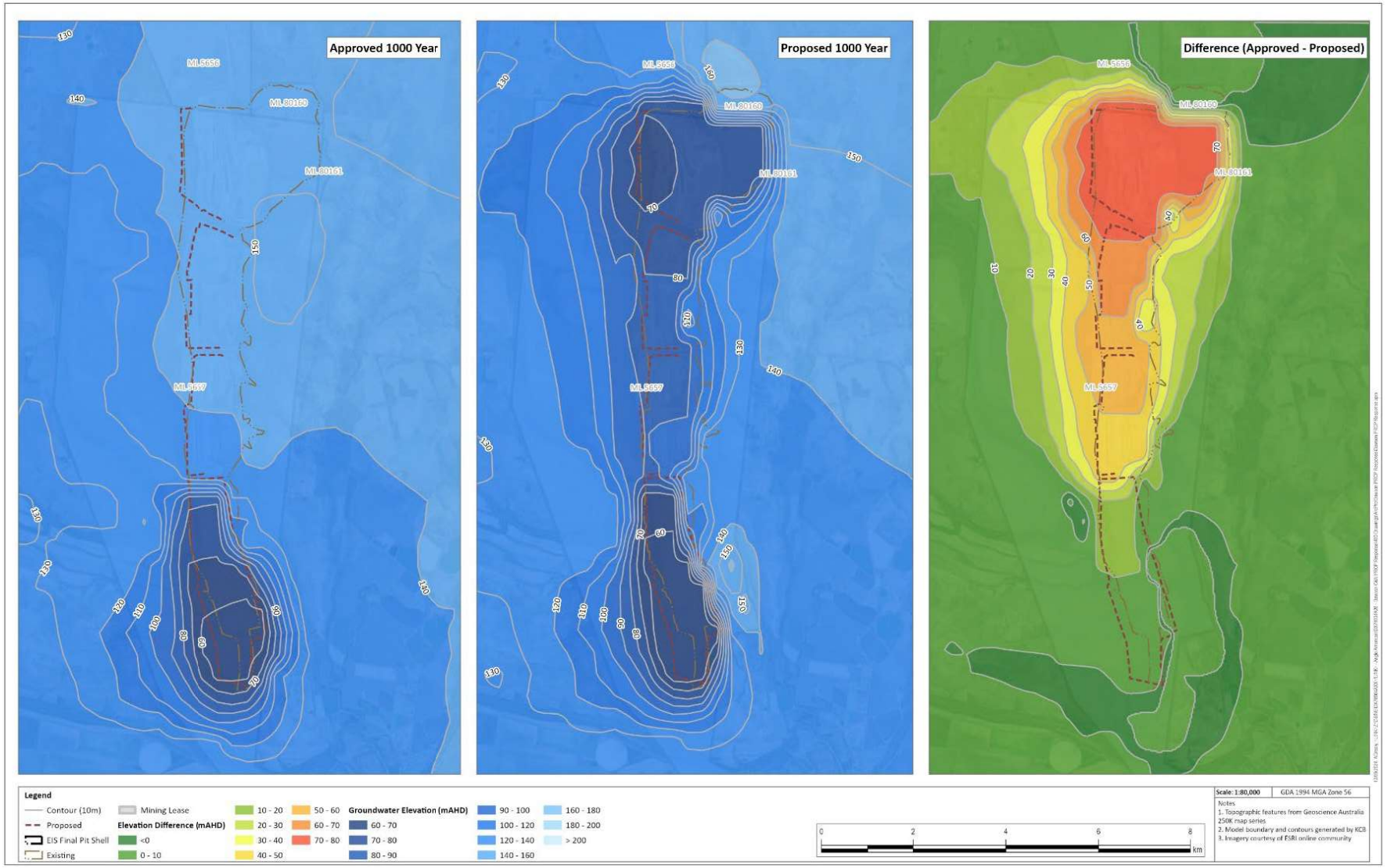


Figure 4.9 Groundwater Elevation for approved and proposed with difference illustrated

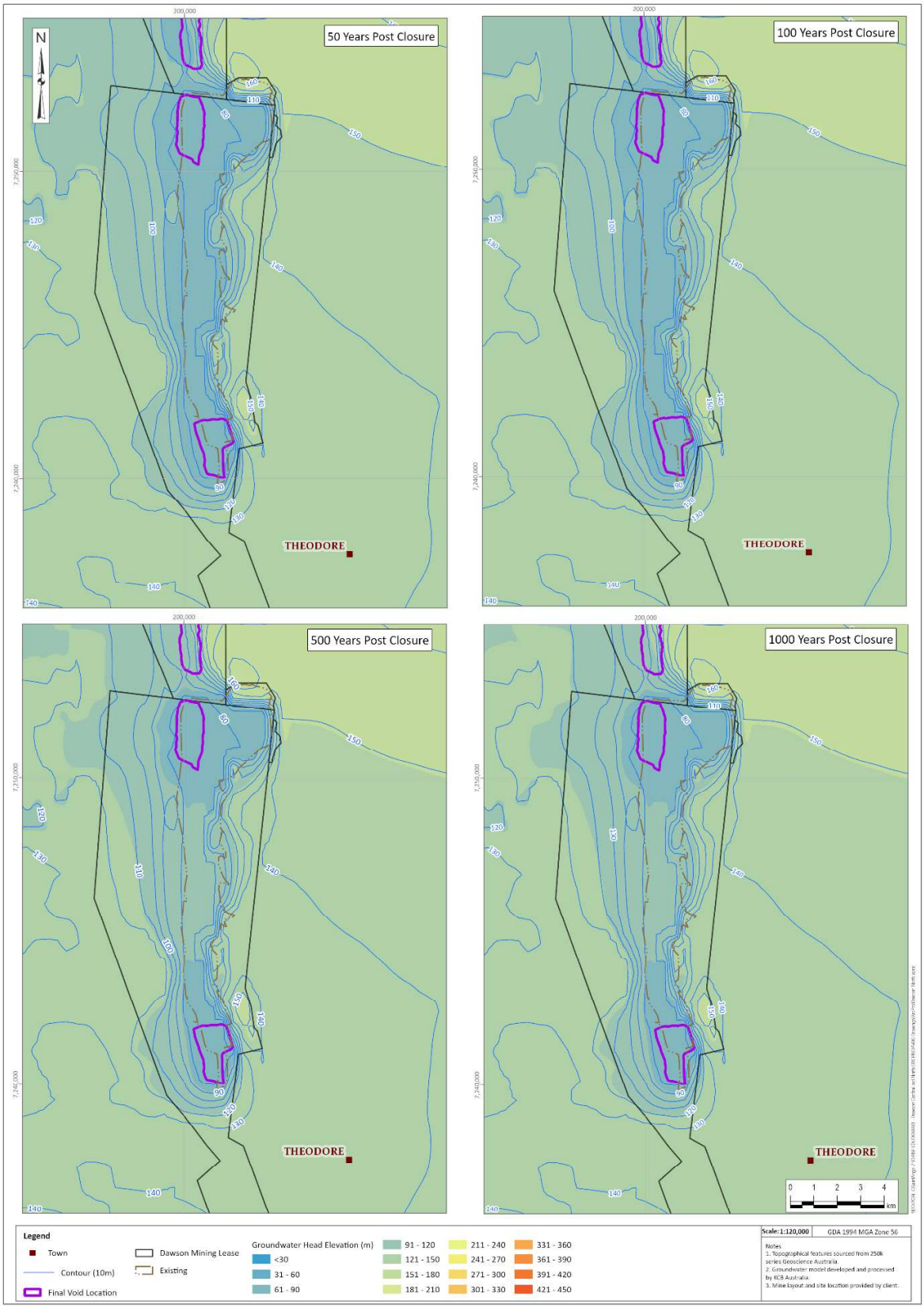


Figure 4.10 Groundwater Elevation Layer 2 – 50, 100, 500, 1000 Years Post-Closure (Proposed Project)

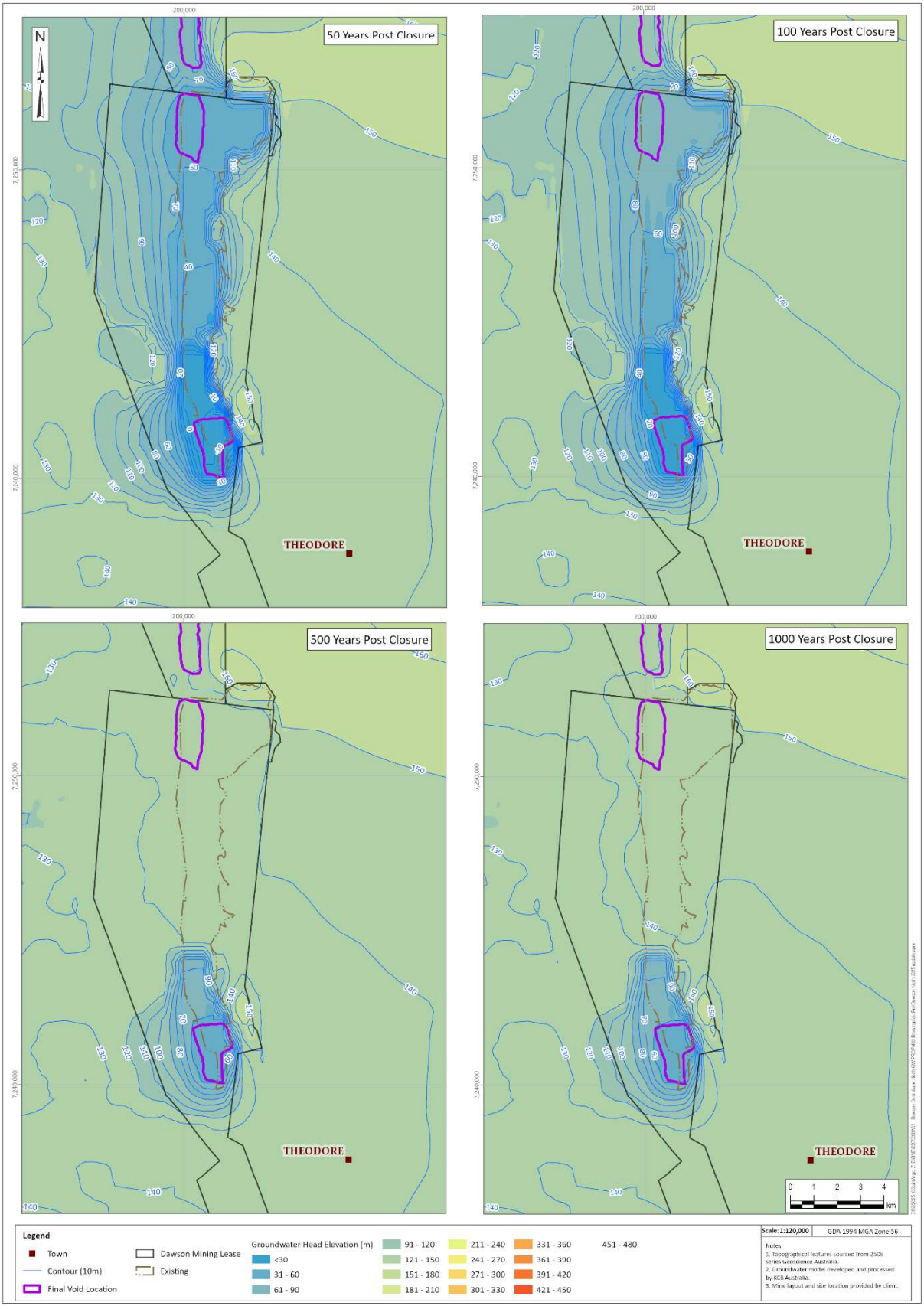


Figure 4.11 Groundwater Elevation Layer 2 – 50, 100, 500, 1000 Years Post-Closure (Approved Project)

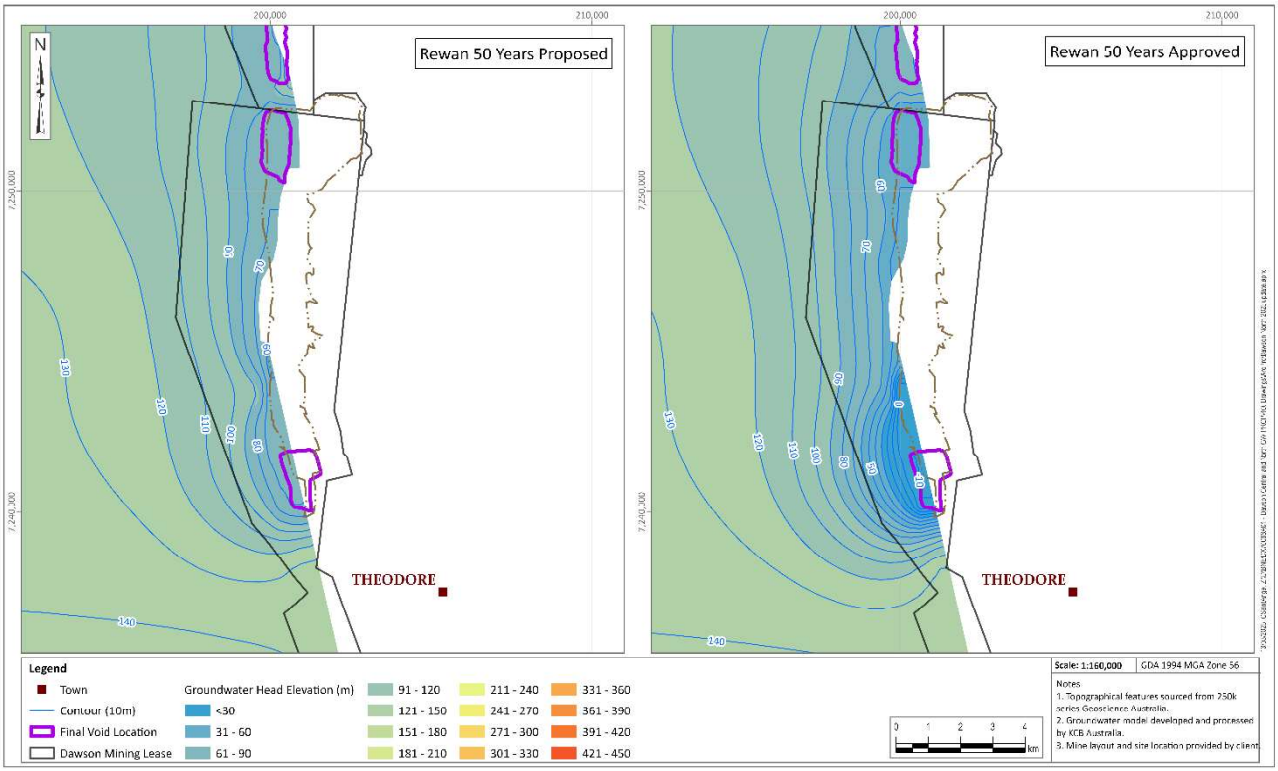


Figure 4.12 Groundwater Elevation Rewan Formation – 50 Years Post-Closure (Proposed vs Approved Project)

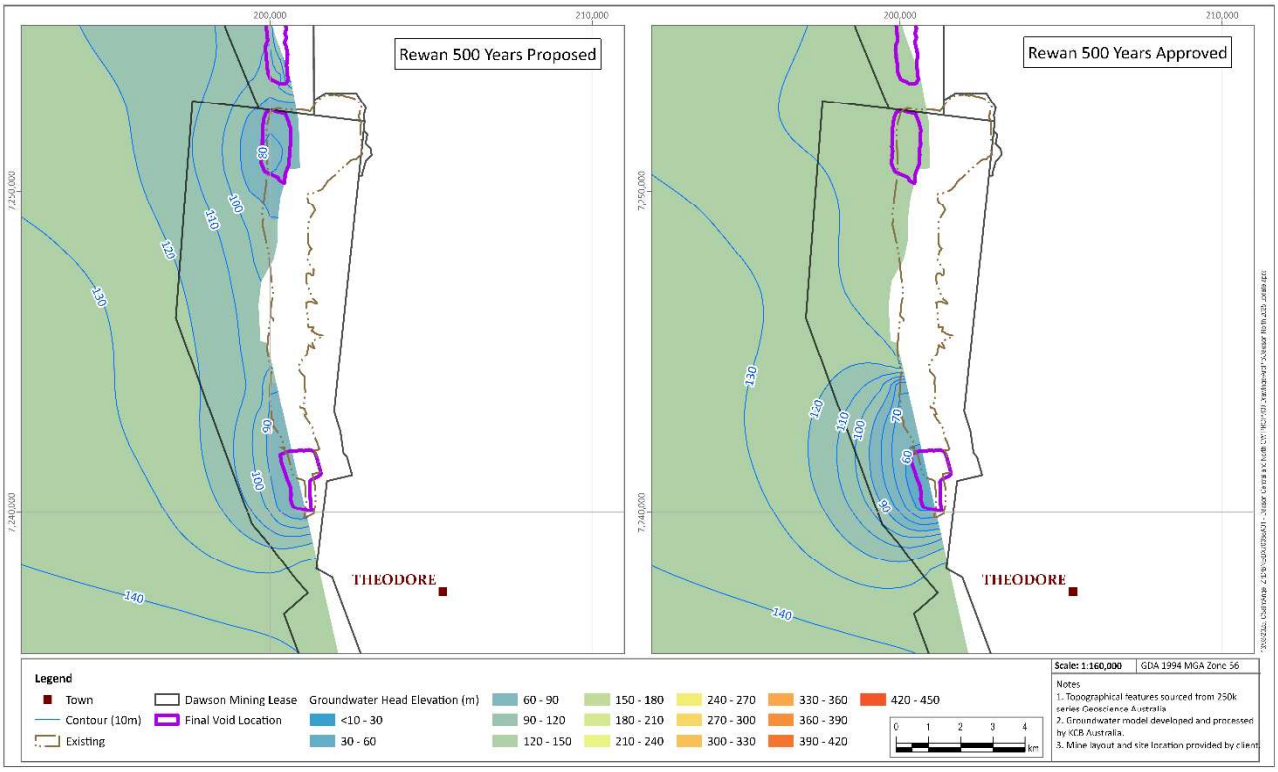


Figure 4.13 Groundwater Elevation Rewan Formation – 500 Years Post-Closure (Proposed vs Approved Project)

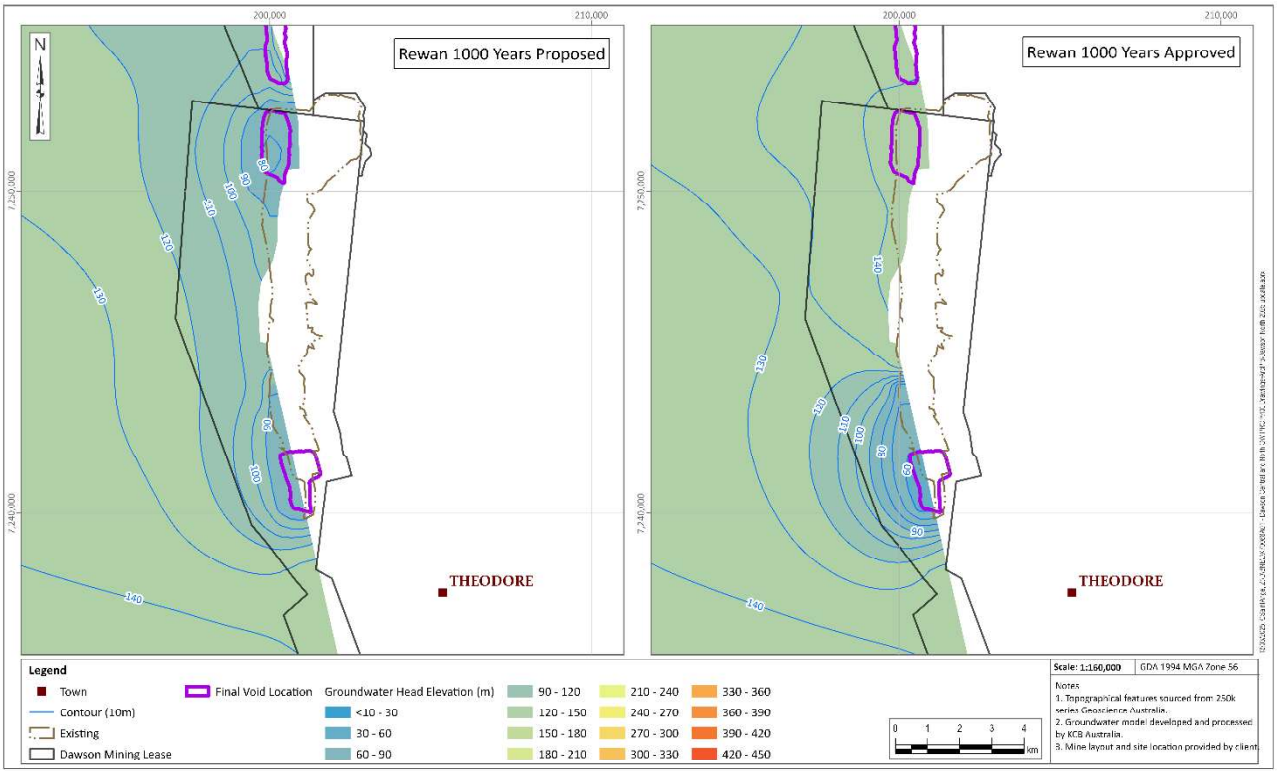


Figure 4.14 Groundwater Elevation Rewan Formation – 1000 Years Post-Closure (Proposed vs Approved Project)

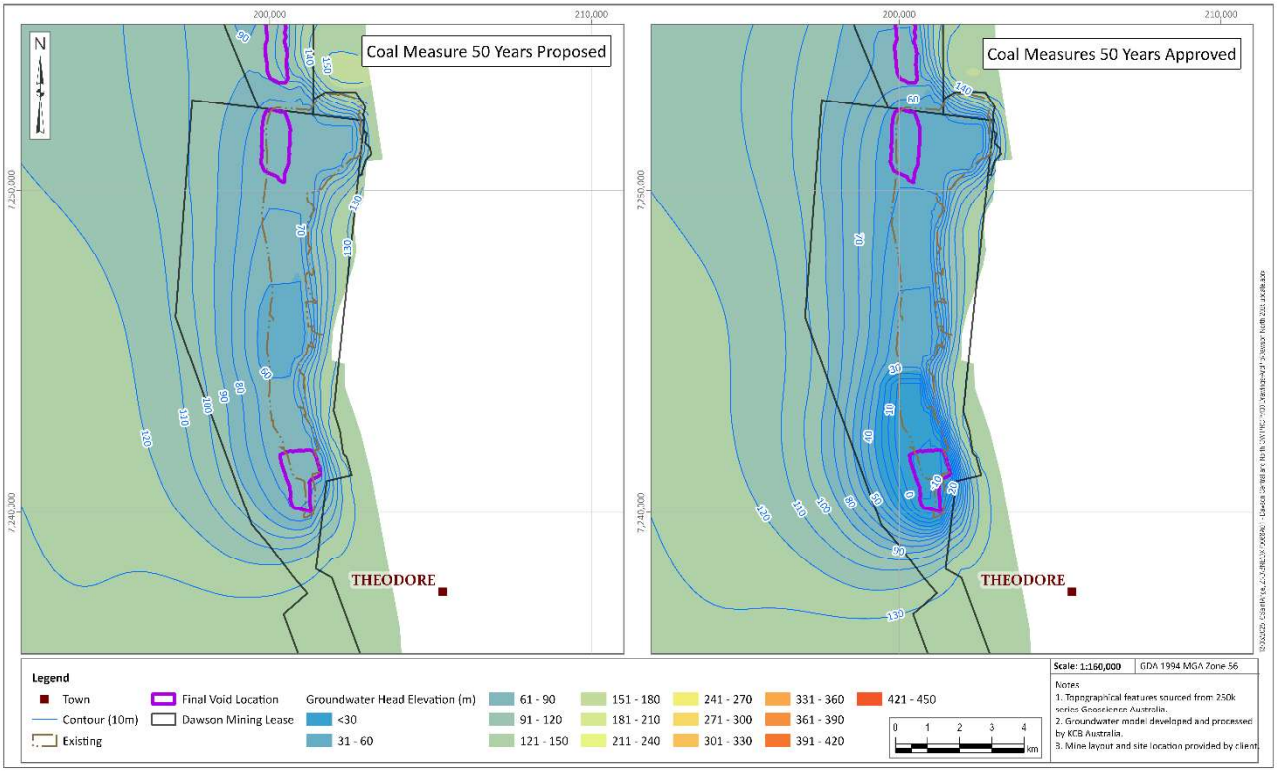


Figure 4.15 Groundwater Elevation Coal Measures – 50,Years Post-Closure (Proposed vs Approved Project)

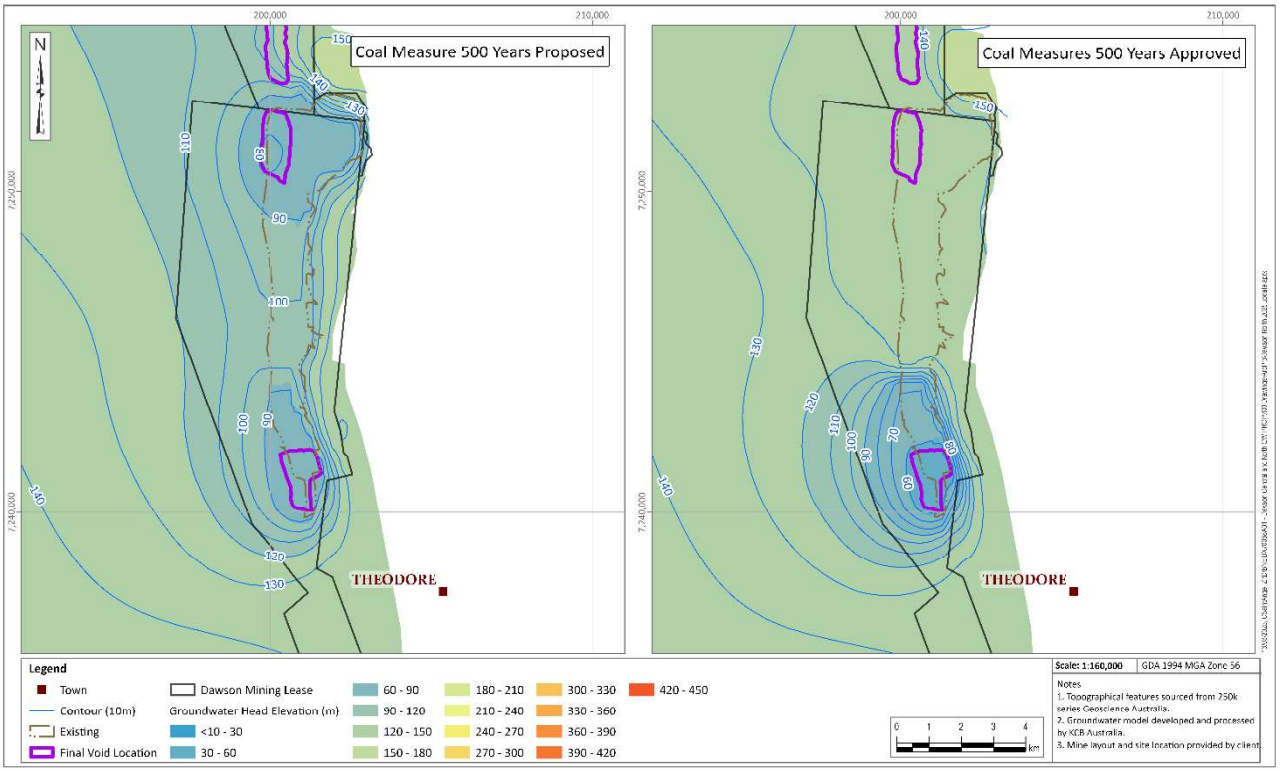


Figure 4.16 Groundwater Elevation Coal Measures – 500 Years Post-Closure (Proposed vs Approved Project)

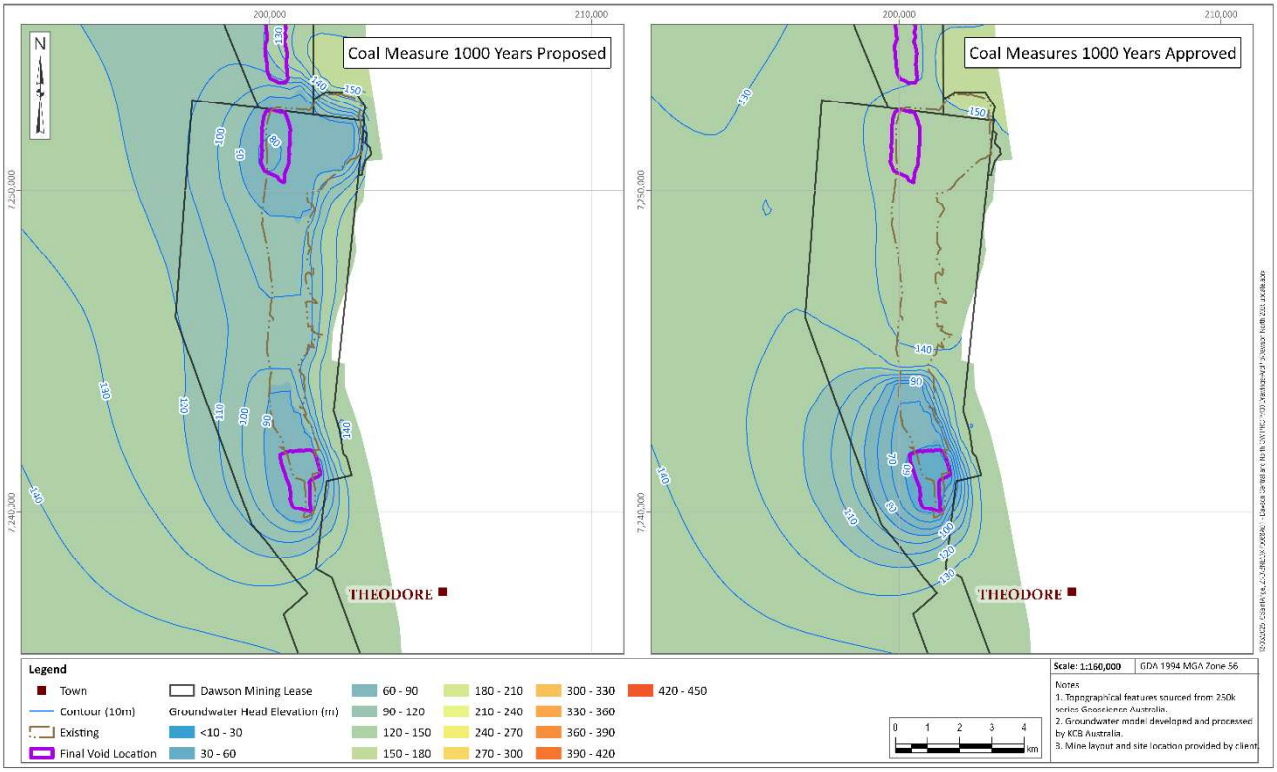


Figure 4.17 Groundwater Elevation Coal Measures –1,000 Years Post-Closure (Proposed vs Approved Project)

4.3.1 Particle tracking

In terms of post-closure risks, consideration of the particle tracking assessment confirms that that Pit 25 and Pit 28 will remain as long-term sinks. The forward projections (i.e. indications of flow paths from the final voids) for both North/Central and Dawson South are shown to assess the potential cumulative impact of the post-mining recovery. The results show that some inter-void flow will occur as the voids fill but that the successive voids act to limit flow away from the mining complex and that the void complex remain a sink after closure (Figure 4.18).

To further understand the post-closure environment, backward particle tracking was included. Particles were placed on the surface of the pit lakes and the pathways to the pit lack surface were evaluated. The backward particle traces for Pit 28 indicate the relatively small capture zone associated with the post-closure pit lakes. The results are indicated as both particle tracks (upper figure in Figure 4.19) and indicating the pathways as a function of intersected model cell (lower figure in Figure 4.19). As indicated by these figures, the pathways are largely associated with the flow in the upper coal seams and Rewan, with limited contributions from layers above this.

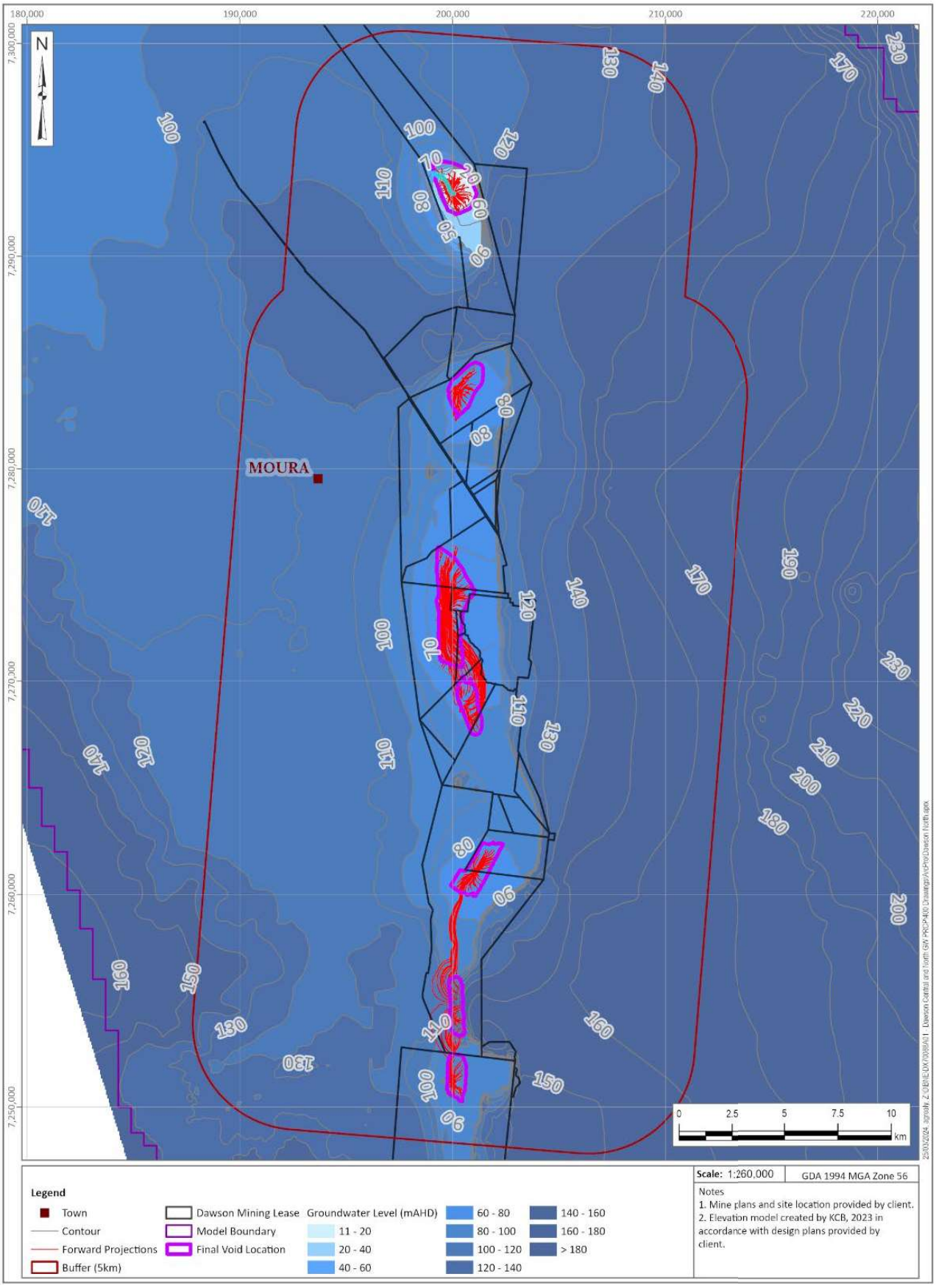


Figure 4.18 Particle tracking assessment from final voids (forward projections)

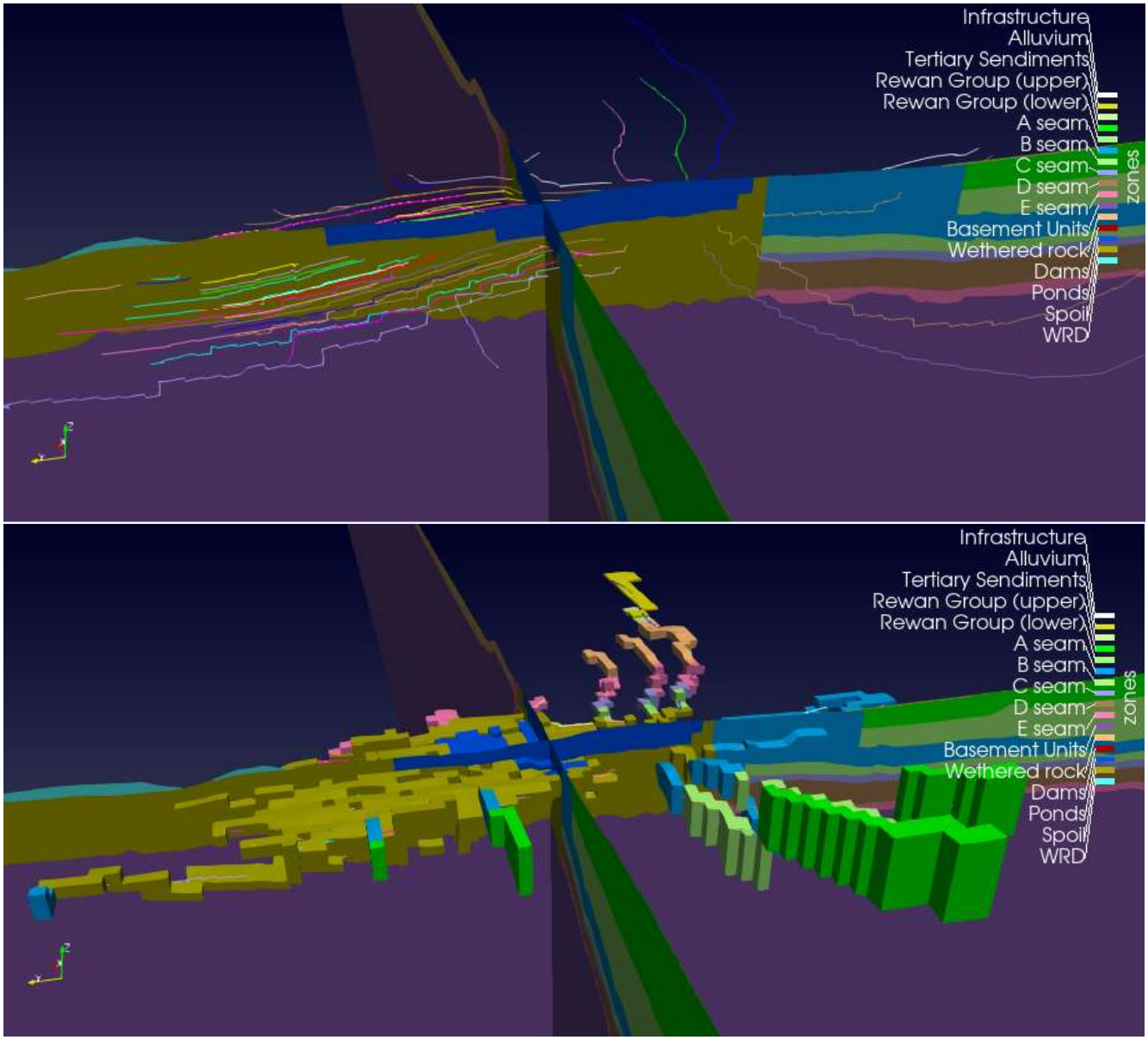


Figure 4.19 Particle tracking assessment from Pit 28 (backward projection)

Predicted Closure Drawdown Observations

The Proposed 1,000 year post-closure design but greater drawdown around the Pit 25 void. The drawdown remains higher in the Proposed closure design in the north due to the Pit 25 voids but due to the higher recovery level in Pit 28 drawdown is reduced in the south. These results have been simplified to show the potential maximum drawdown extent, represented by the 1 m and 0.2 m contours in Figure 4.20 and Figure 4.21 with registered bores and their purpose shown.

The groundwater drawdown at the end of mining is in the order of 160 m to 170 m at the mine voids with significantly greater drawdown impact beyond the mining voids compared to the recovered pit lake impact.

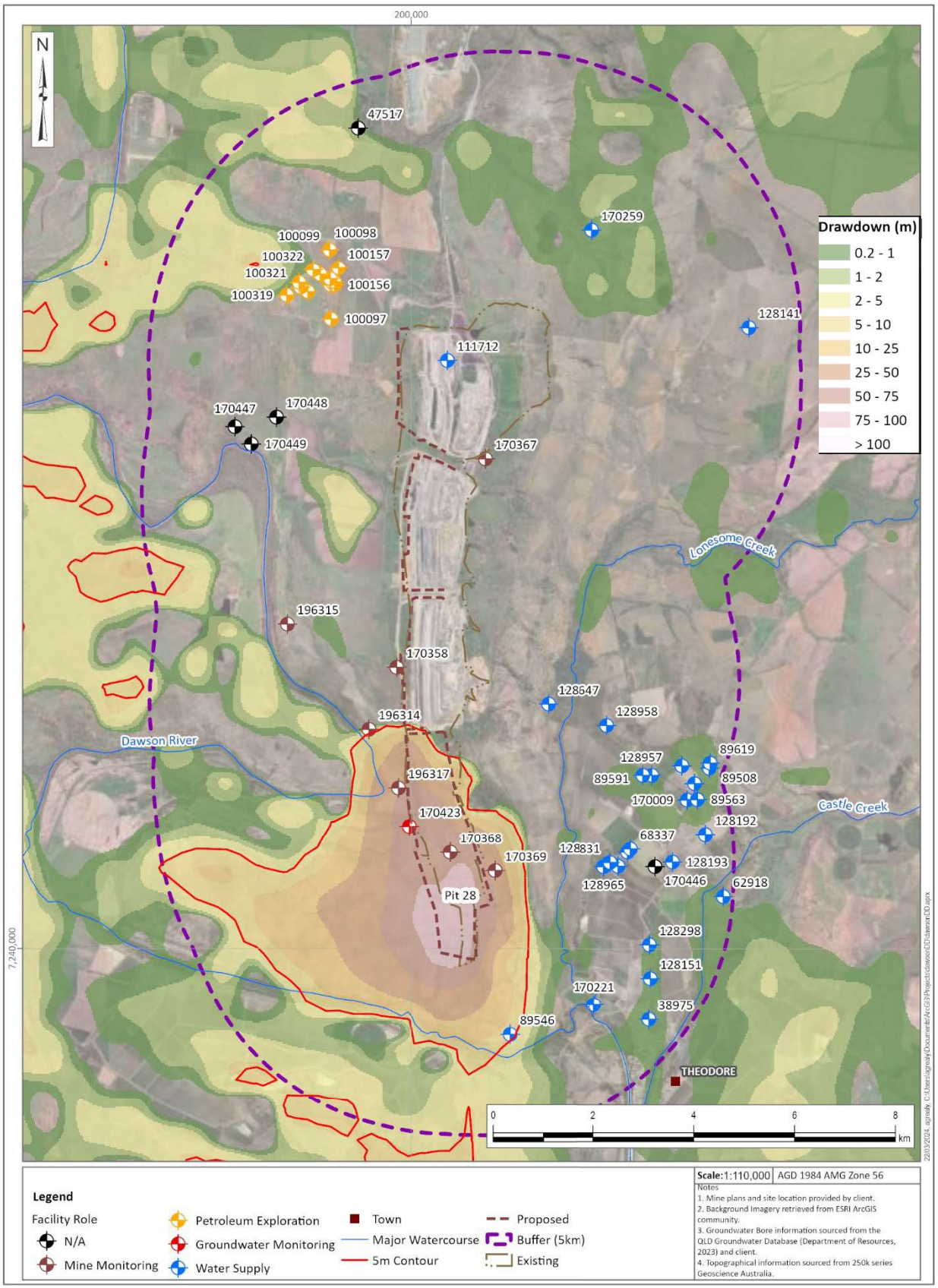


Figure 4.20 Existing mine plan Drawdown – 1,000 Years after Closure

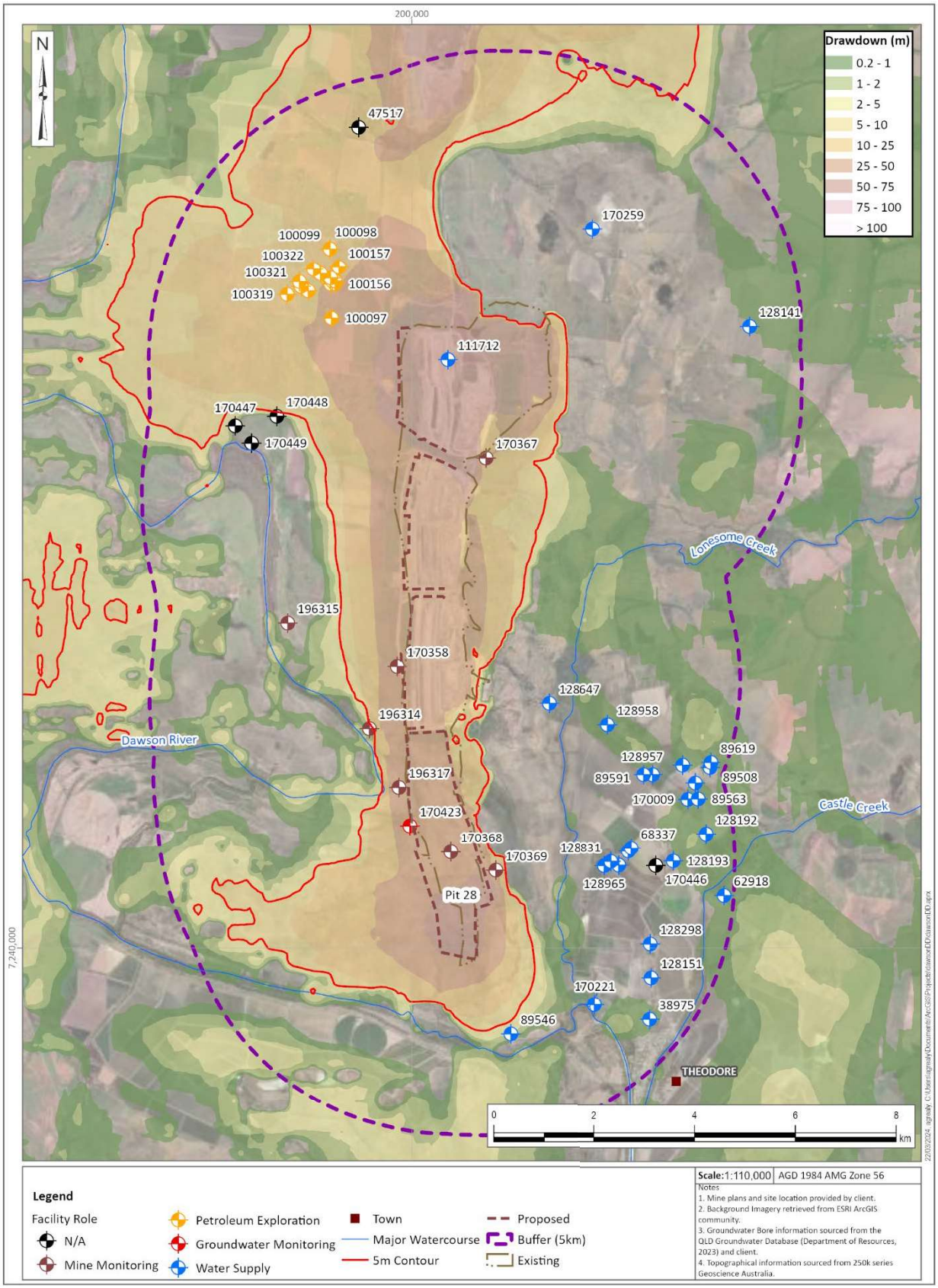


Figure 4.21 Proposed Project Case Drawdown – 1,000 Years after Closure

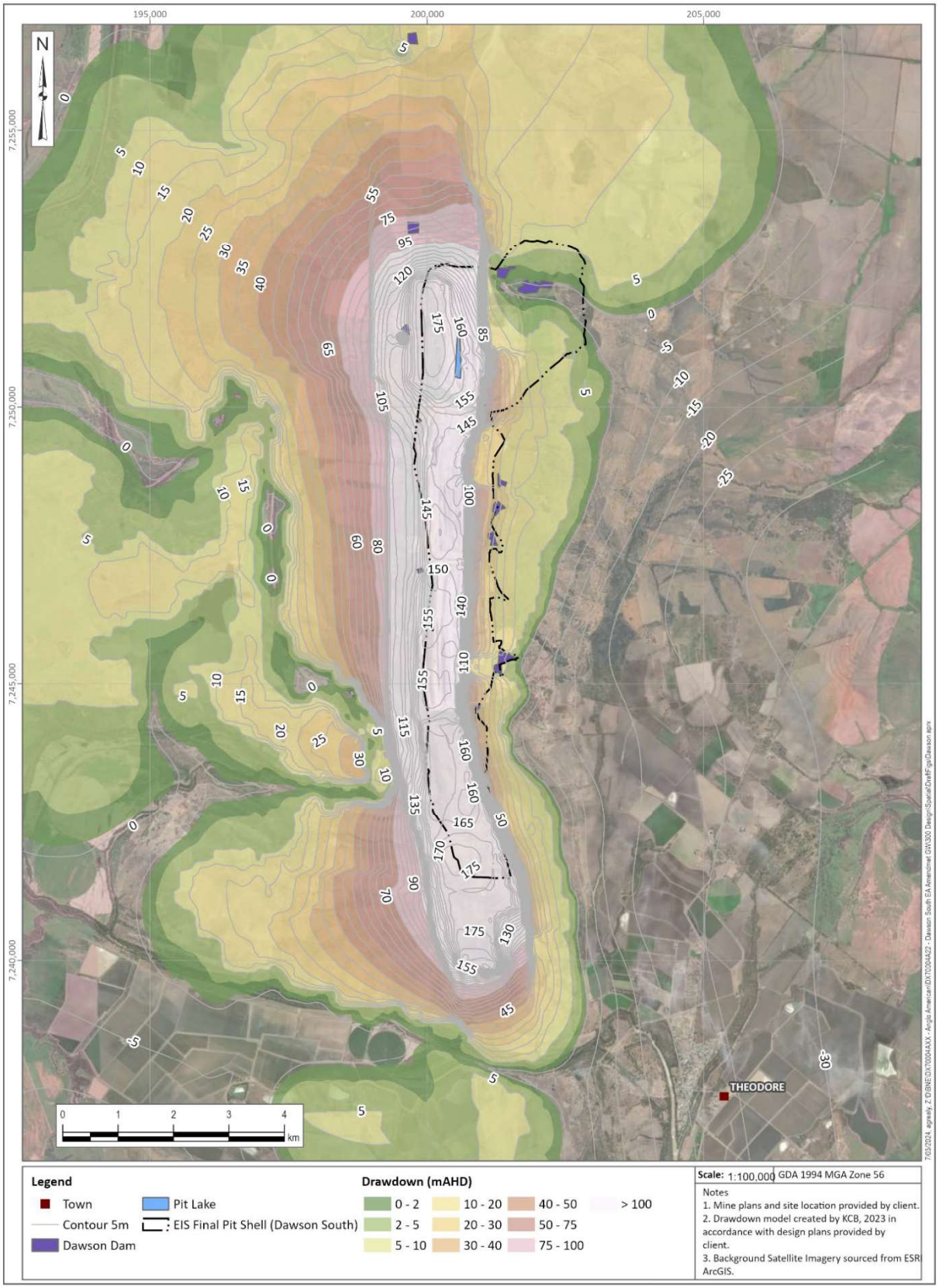


Figure 4.22 Groundwater Drawdown at End of Operations – Existing mine plan (Layer 2)

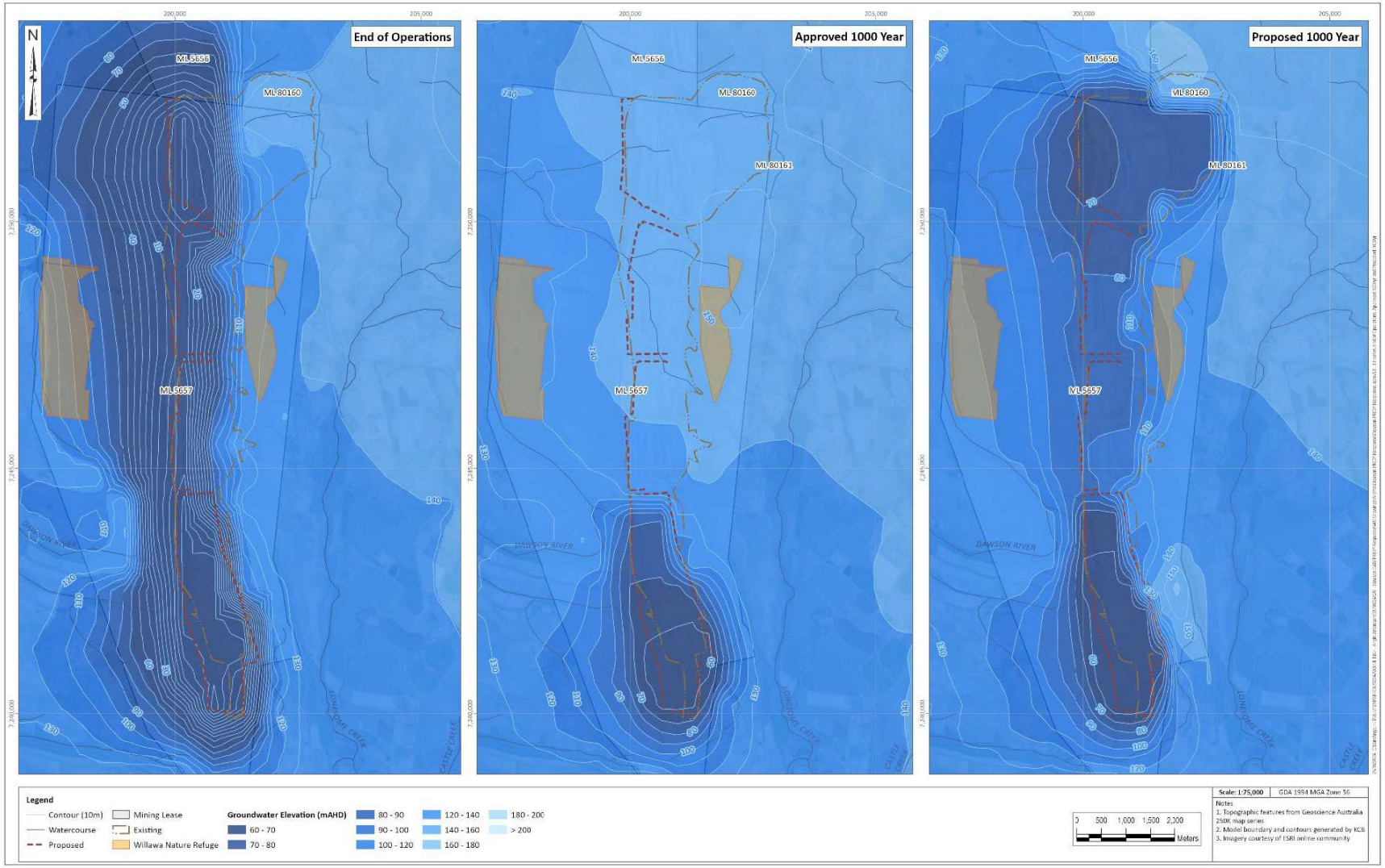


Figure 4.23 Heads at End of Operations, and 1,000 years after closure for the existing and proposed mine plan (with Rivers and Willowa Reserve indicated)

4.4 Potential Impacts to the Dawson River

During operations, the current and proposed cases have very similar impacts on groundwater and consequently, there is a negligible difference in associated Dawson River interaction. A comparison was obtained from the 1,000-year post-closure scenario, where the difference between the two cases is stable and at a maximum duration (i.e. the greatest incremental impact).

The River Boundary water balance across the entire extent of the Dawson South was extracted as comparison (Table 4.1). The results indicate that an additional water take of ~46 m^3/day could result from the Proposed scenario (i.e. ~ 0.5 L/s), across the entire length of the Dawson River.

Table 4.1 Comparison of the River Boundary Condition Flux across the Dawson South Mine Lease (1,000-Year Post-Closure)

		Influx (m^3/d)	Outflux (m^3/d)
Existing (Approved Mine Plan)	River	1416.7	-700.8
Proposed	River	1470.0	-654.6

4.5 Sensitivity Analysis for Predicted Project Impacts

A sensitivity analysis was performed for the entire model using PEST to assess the response of the model to varying hydraulic properties. This analysis provides a comparison of the influence of these properties on the outcomes of predictions made by the model. Impacts on predictions of mine groundwater inflows and maximum drawdown due to hydraulic parameters have been examined.

Parameters that were assessed during the predictive sensitivity analysis were grouped and varied by an order of magnitude in the following manner (Table 4.2):

- Horizontal (Kh) and vertical (Kv) hydraulic conductivity of select layers were varied above and below their calibrated values;
- Specific storage (Ss) and specific yield (Sy) values for select layers were varied above and below their calibrated value; and
- Rainfall recharge rates were varied.

Table 4.2 presents the scenarios assessed in the sensitivity analysis. This shows that the model is sensitive to changes in hydraulic conductivity and increasing recharge. Overall, the sensitivity of the model indicates that the groundwater levels increase with effective recharge and river conductance and vice versa suggesting that the cause-and-effect relationships in the model are consistently represented in the results. The sensitivity analysis indicates that within the plausible ranges of the model, reasonable calibrations can be obtained.

Table 4.2 Summary of Sensitivity Analysis

Sensitivity Scenario	Parameter adjustment	Scaled RMS (%)	Correlation Coefficient
1	Baseline	4.9%	0.86
2	Increase the hydraulic conductivity – multiply by 10	6.6%	0.79
3	Decrease the hydraulic conductivity – divide by 10	6.0%	0.81
4	Increase the recharge – multiply by 10	6.6%	0.78
5	Decrease the recharge – divide by 10	4.9%	0.86
6	Increase the storativity – multiply by 10	5.7%	0.84
7	Decrease the storativity – divide by 10	5.4%	0.81

4.5.1 Prediction Sensitivity Cases

The approach to assess the range of potential impacts is consistent with the 2023 IESC guidance (Peters and Middlemiss, 2023) in that both the impact of different ranges of parameters as well as an alternate final void water level (conservatively assumed to be at a significantly lower water level of ~ 55m RL compared to the Project which is projected to equilibrate to around 78m RL) was used to assess the potential groundwater impact.

To assess the potential impact of these ranges on inflows and drawdown, a further set of sensitivity cases was undertaken.

Table 4.3 Sensitivity Assessment on Predictions

ID	Predictive Sensitivity Model	Parameter adjustment
0	Base	Calibrated Parameters
1	S1	Decrease Alluvial K /10
2	S2	Increase Alluvial K x10
3	S3	Recharge (50%)
4	S4	Recharge (150%)
5	S5	River Boundary Conductance (10x lower)
6	S6	River Boundary Conductance (10x higher)
7	S7	Spoil Sy /2
8	S8	Spoil Sy x2

A summary of the results is provided on Model Appendix I - Figure 1, with specific comparisons to the base case provided as model snapshots Model Appendix I - Figure 2 to Model Appendix I - Figure 10.

4.5.2 Sensitivity Classification

The Murray Darling Basin Modelling Guidelines (MDBC, 2000) provide a framework for classification of a predictive model parameters in terms of their impacts on the model. These can be summarised as follows:

- Type I: Insignificant changes to calibration and predictions;

- Type II: Significant changes to calibration with insignificant changes to predictions;
- Type III: Significant changes to calibration with significant changes to predictions; and
- Type IV: Insignificant changes to calibration and significant changes to prediction.

Types I to III present no concern where management decisions are to be based on the model, provided the model is calibrated and encapsulates sufficient complexity to replicate the system. However, Type IV classification may be of concern as calibration may have done little to reduce potential for predictive error.

With consideration to the results of the sensitivity analysis, parameters employed in this model can be considered Type II to I classification and are suitable for the purpose of supporting a groundwater assessment for the Project.

5 CLOSING

We thank you for the opportunity to work on this assignment. Should you have any queries please do not hesitate to contact the undersigned.

KCB AUSTRALIA PTY LTD.





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Senior Hydrogeochemist, Principal
Project Manager

Greg Wang, MSc
Lead Groundwater Modeller

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MODEL APPENDIX I

Selected Model Outputs

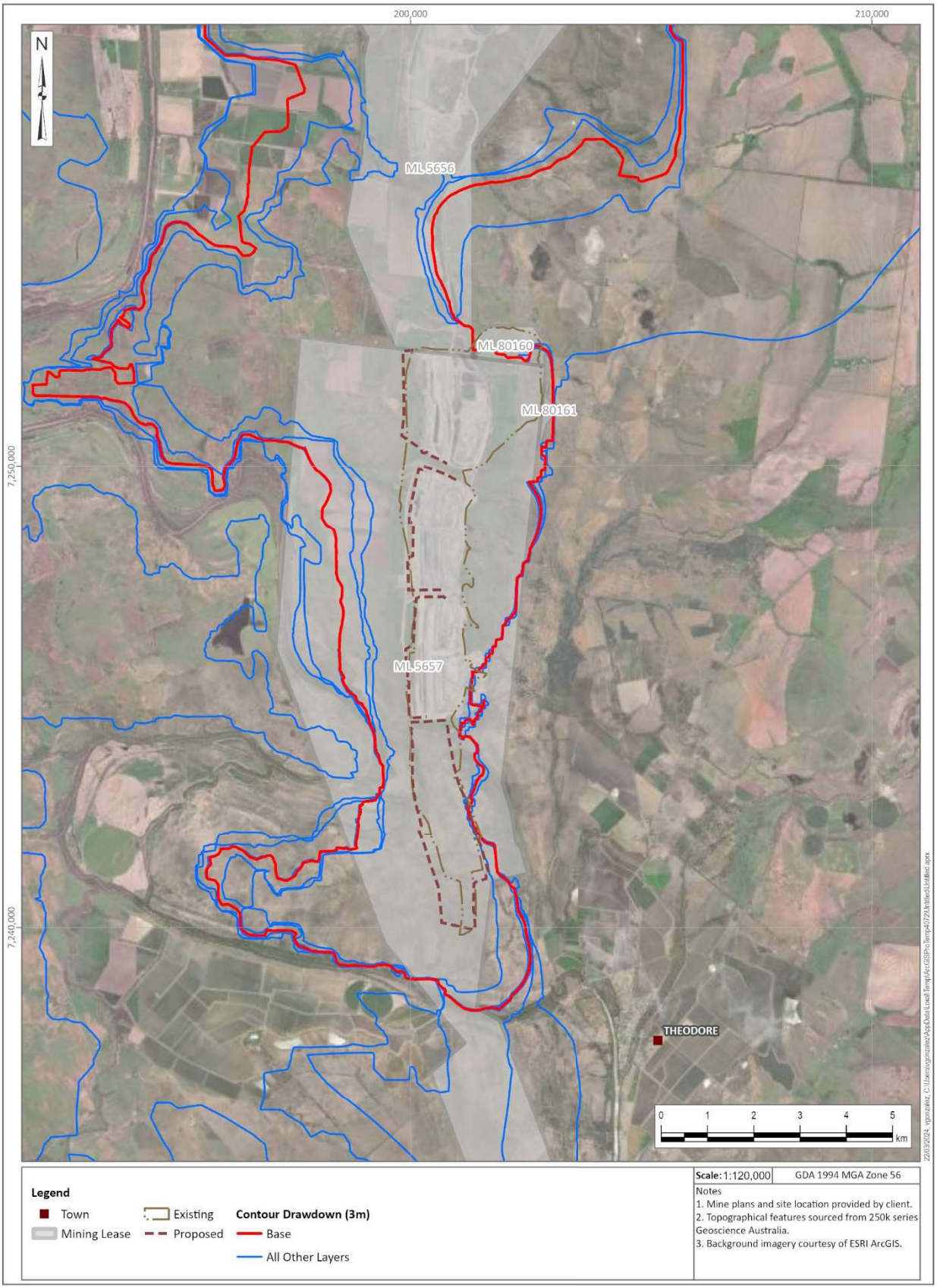


Figure I-1 Sensitivity of Drawdown (Layer 2; 3 m Drawdown used As Comparison; Proposed Case)

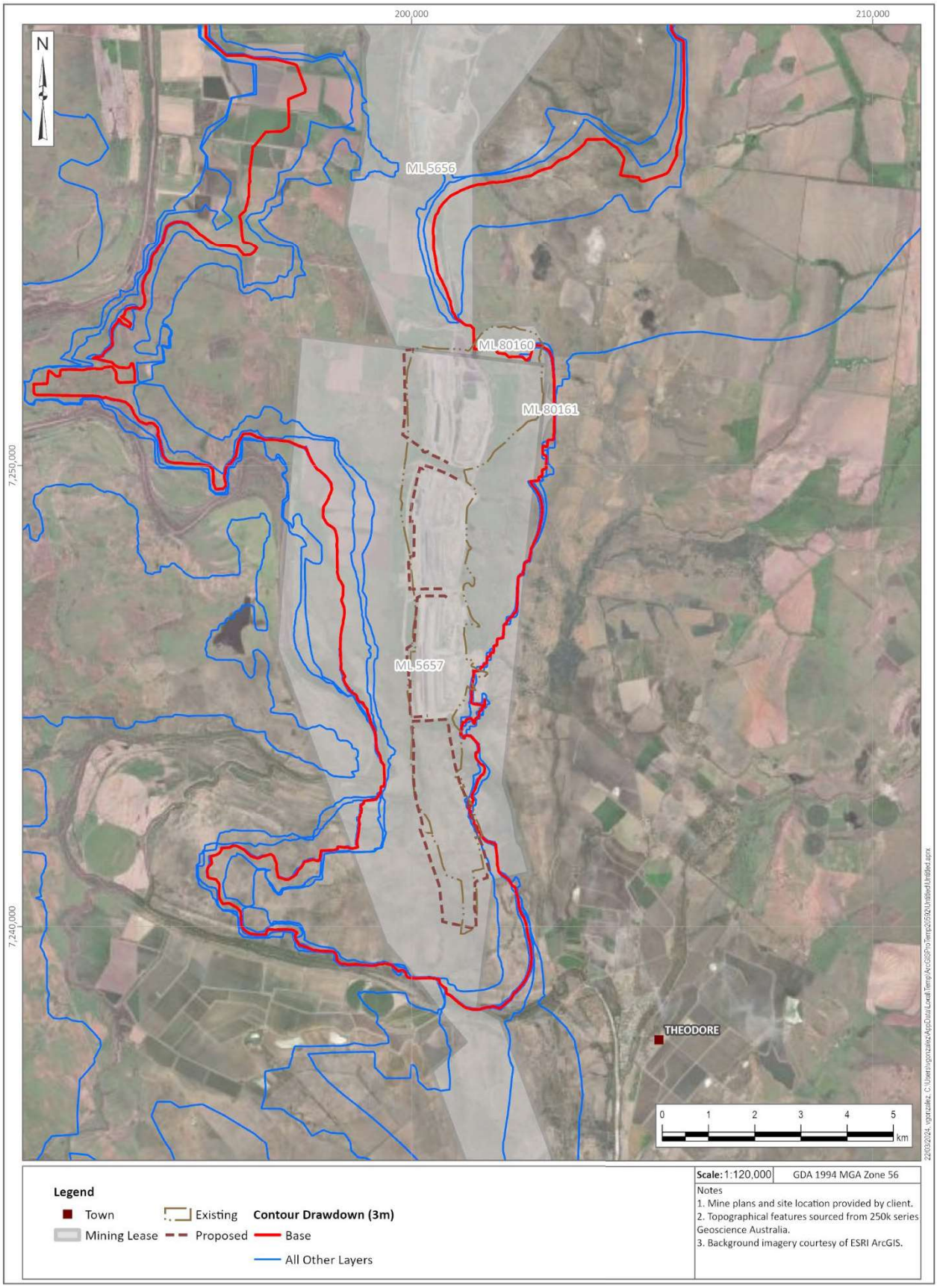


Figure I-2 Sensitivity of Drawdown (Layer 6; 3 m Drawdown used as Comparison; Proposed Case)

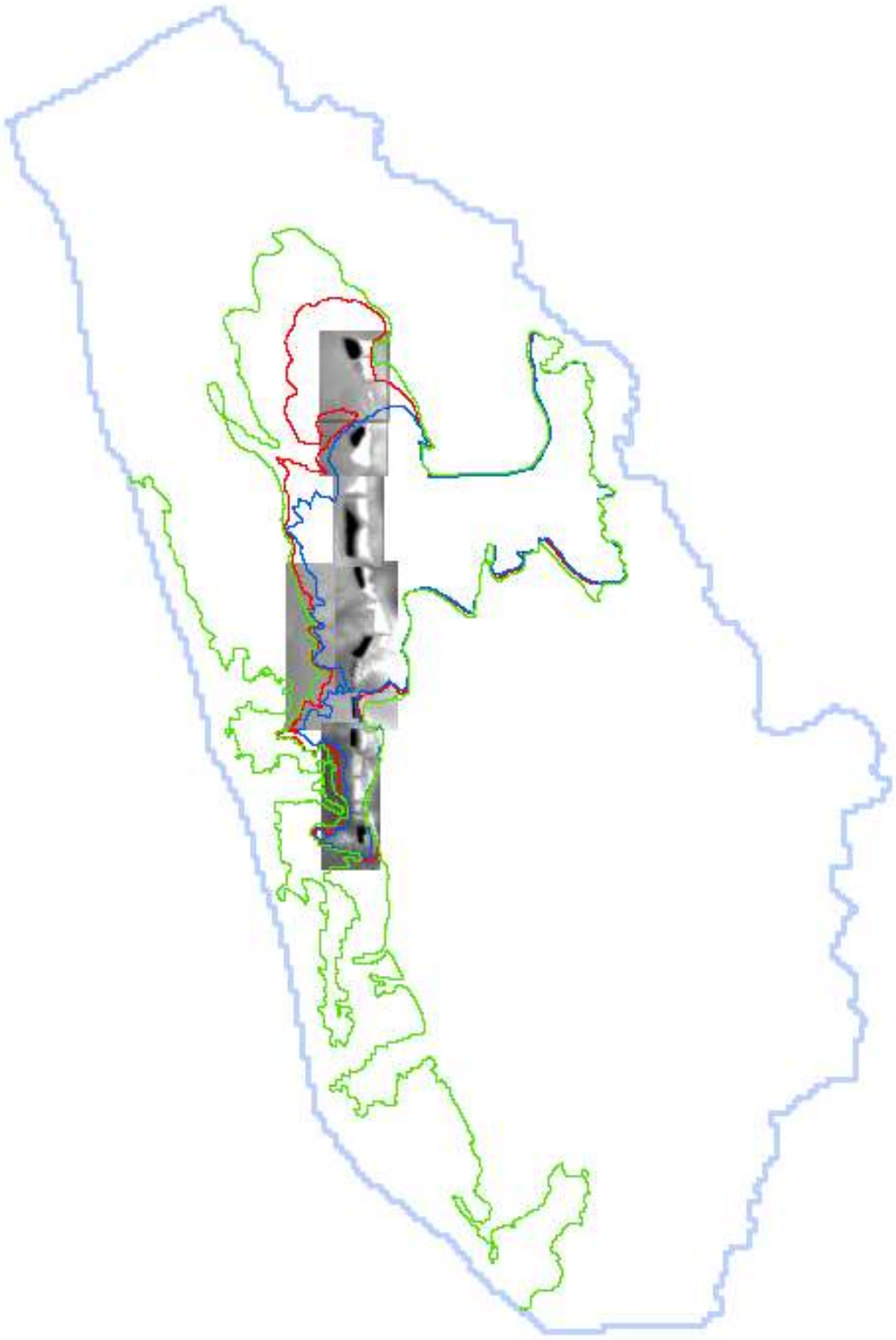


Figure I-3 Drawdown Sensitivity Layer 2

Base (red) and Sens ID 1 & 2 (cs Alluvium k /10 - blue, cs Alluvium k X10 - green)

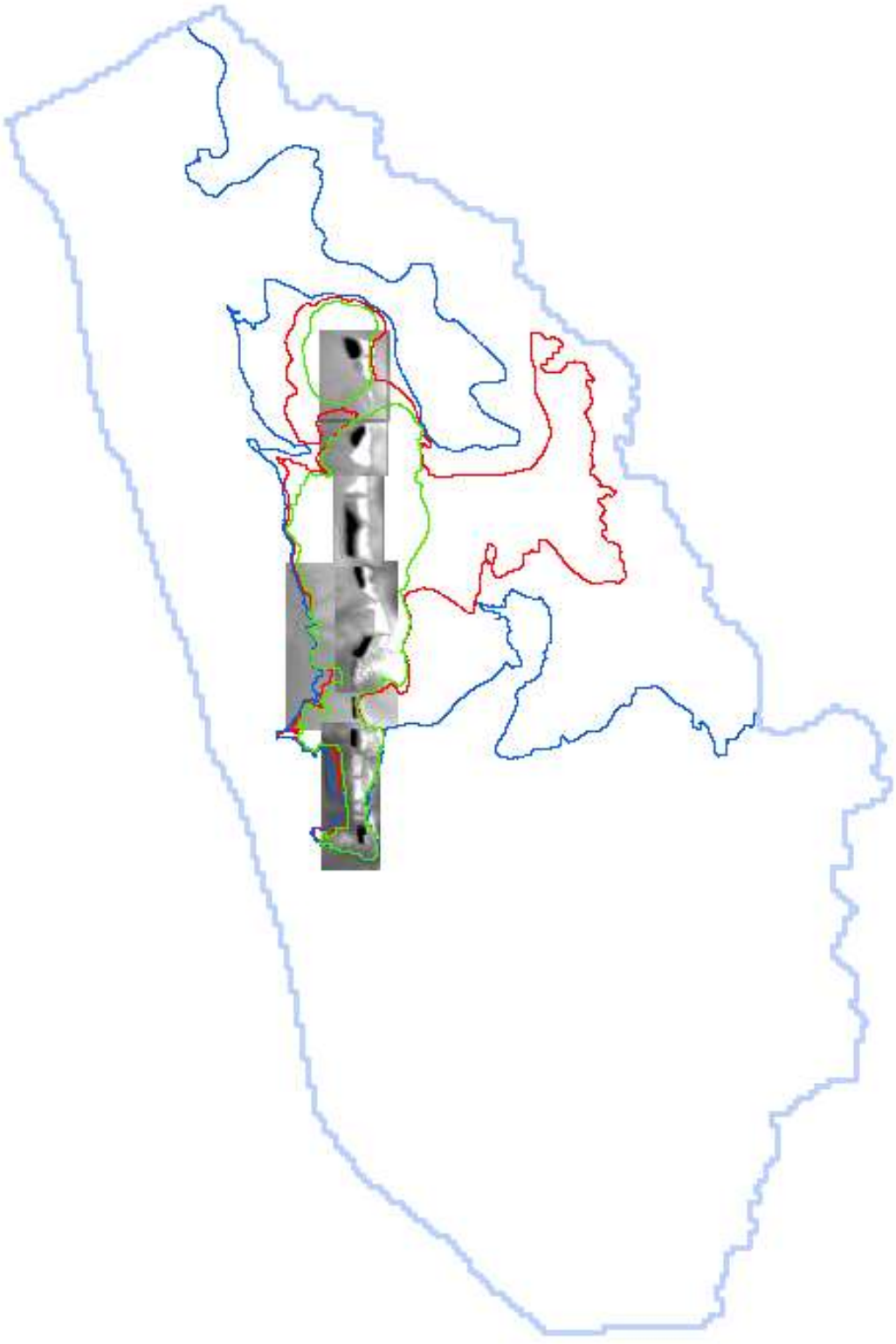


Figure I-4 Drawdown Sensitivity Layer 2

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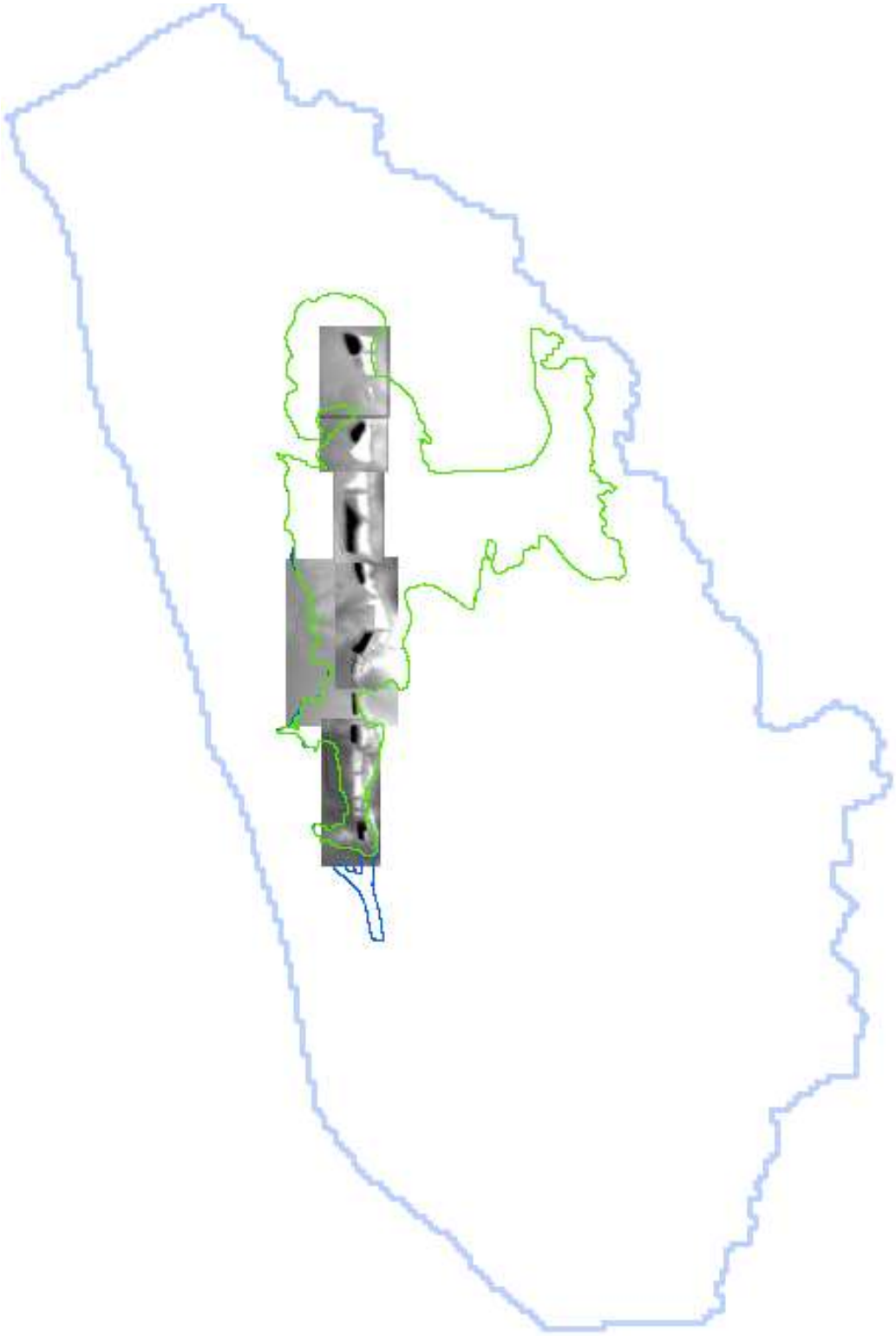


Figure I-5 Drawdown Sensitivity Layer 2

Base (red) and Sens ID 5 & 6 (River Conductance /10 - blue, River Conductance x10 - green)

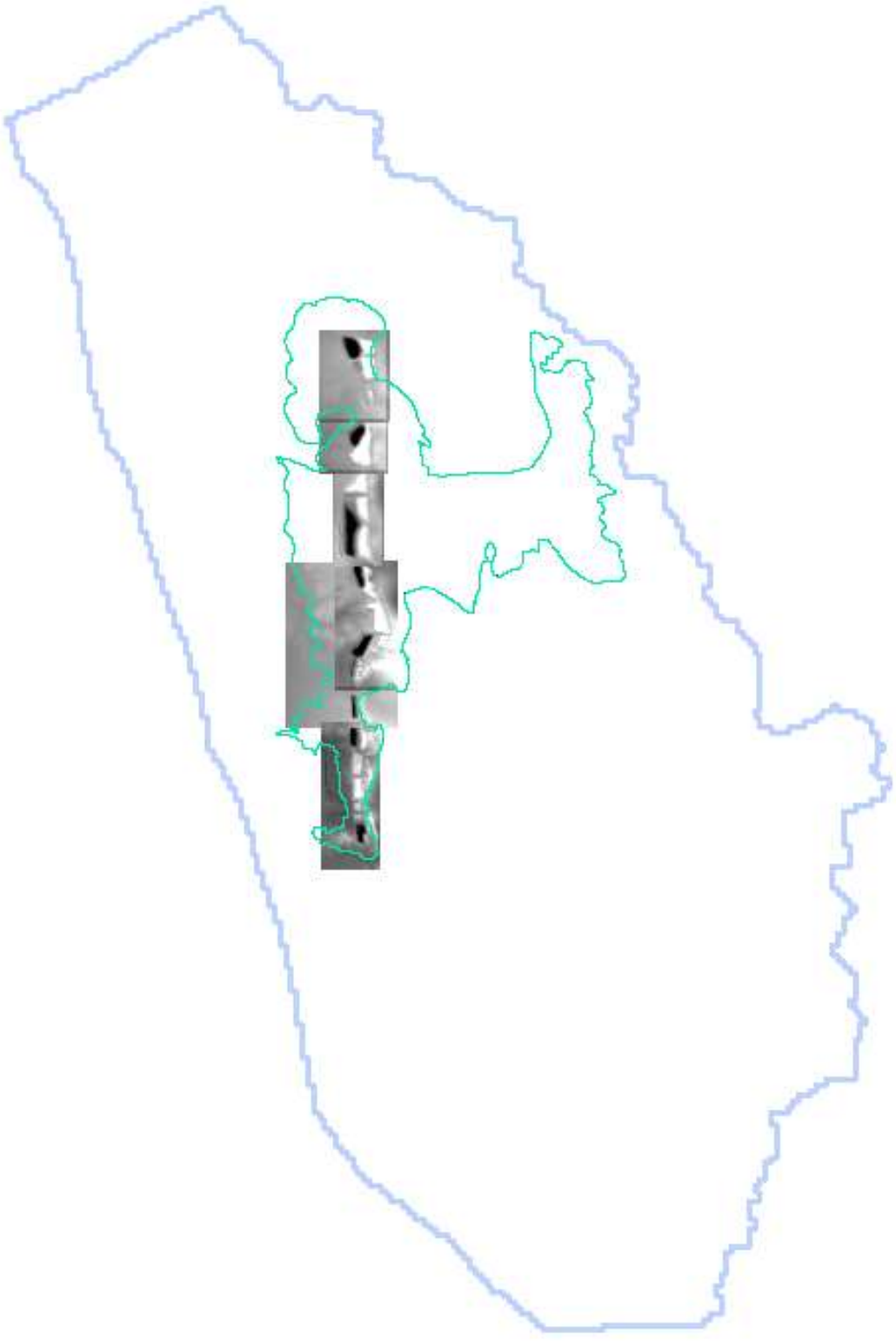


Figure I-6 Drawdown Sensitivity Layer 2

Base (red) and Sens ID 5 & 6 (Spoil Sy /2 - blue, Spoil Sy x2 - green)

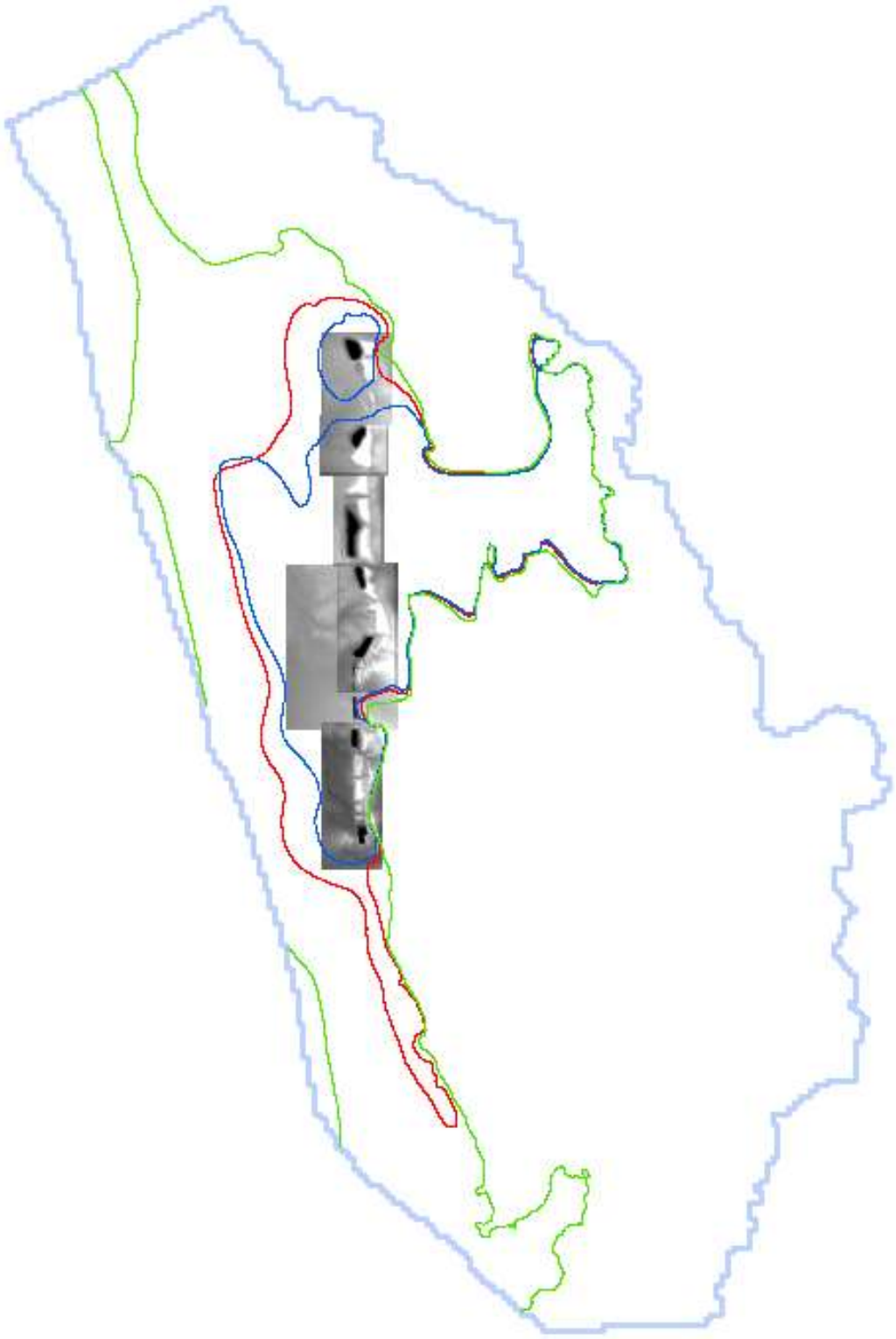


Figure I-7 Drawdown Sensitivity Layer 6

Base (red) and Sens ID 1 & 2 (cs Alluvium k /10 - blue, cs Alluvium k X10 - green)

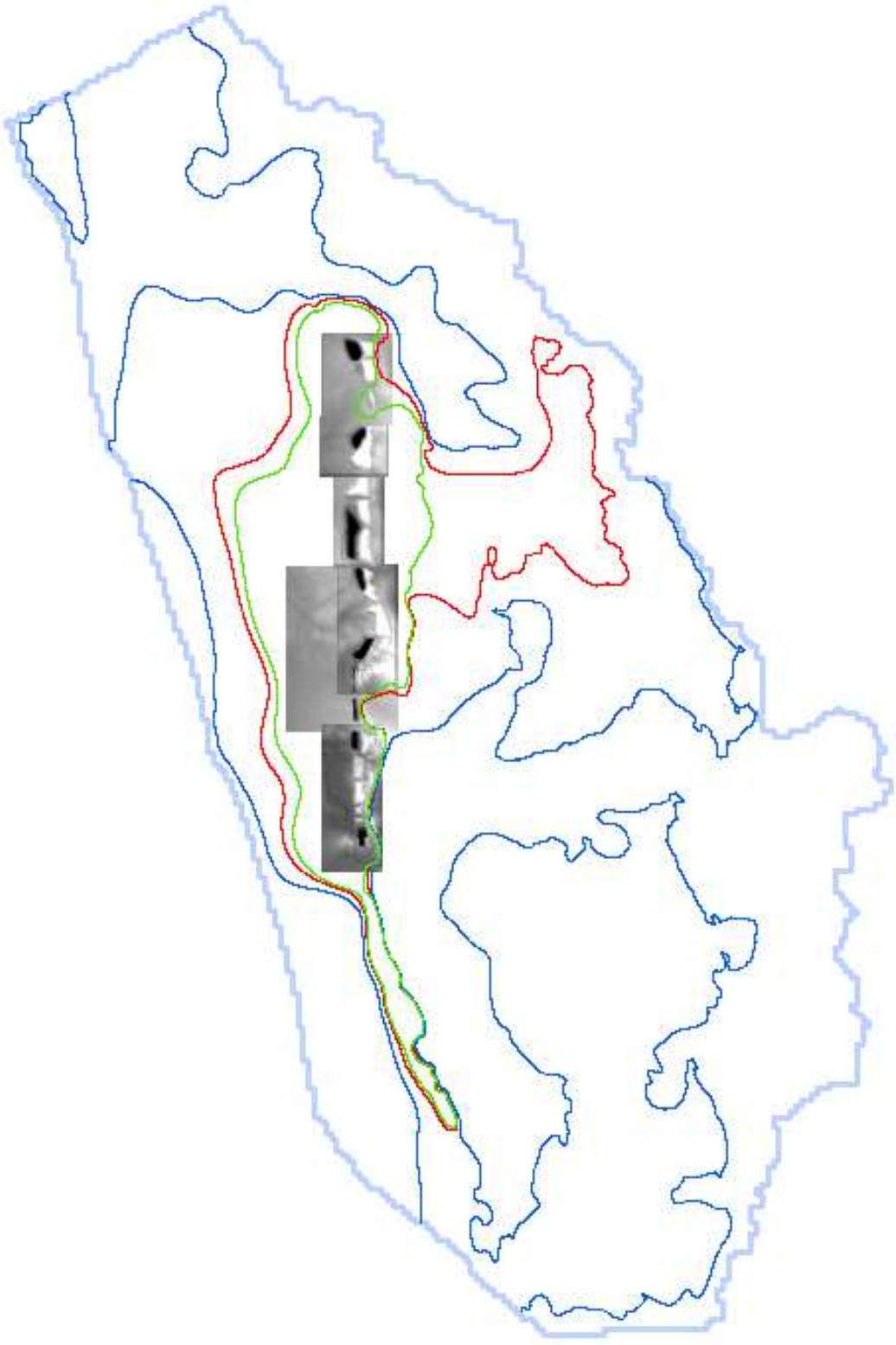


Figure I-8 Drawdown Sensitivity Layer 6

Base (red) and Sens ID 3 & 4 (recharge x 0.5 - blue, recharge x 2 - green)

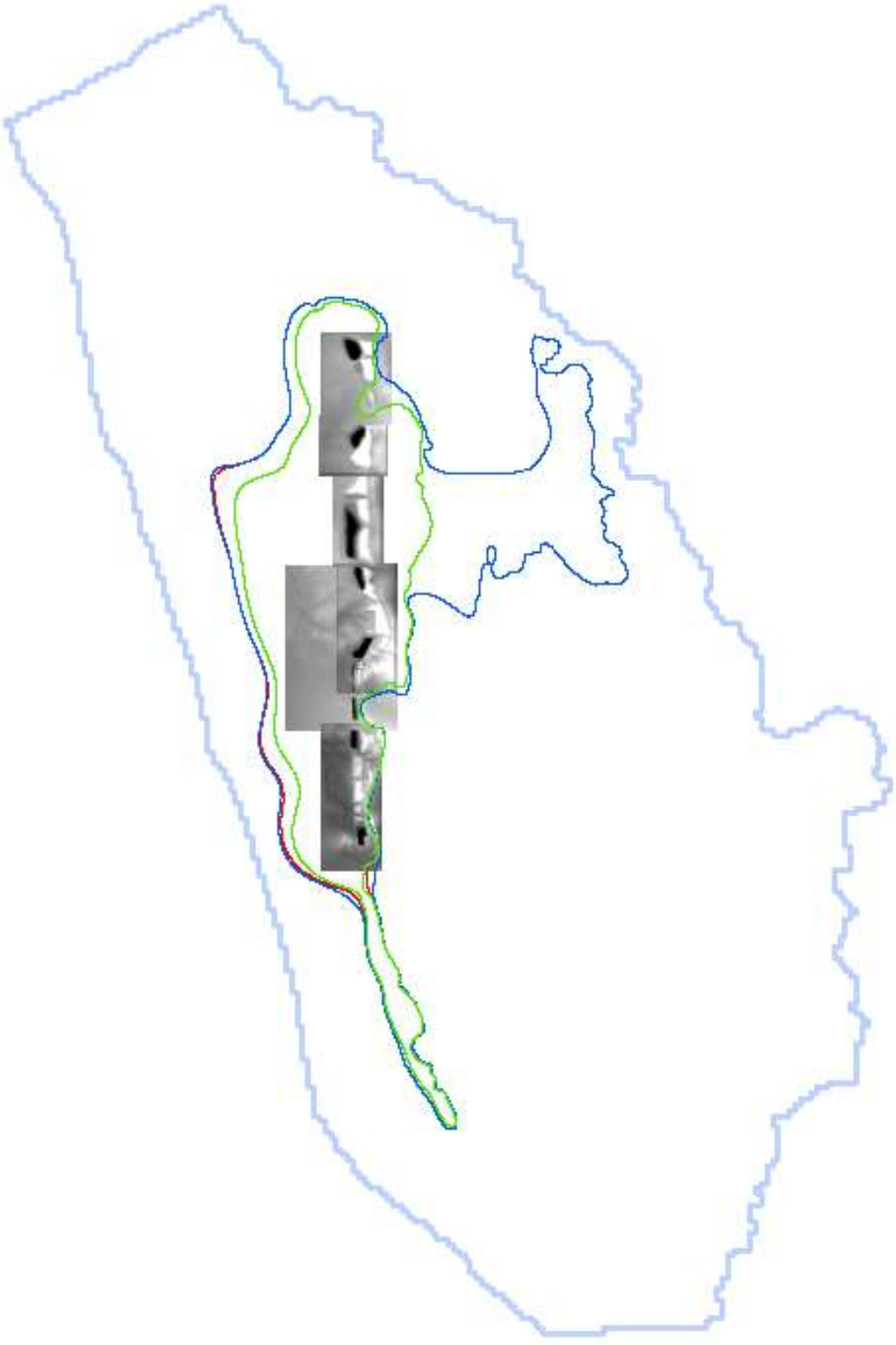


Figure I-9 Drawdown Sensitivity Layer 6

Base (red) and Sens ID 5 & 6 (River Conductance /10 - blue, River Conductance x10 - green)

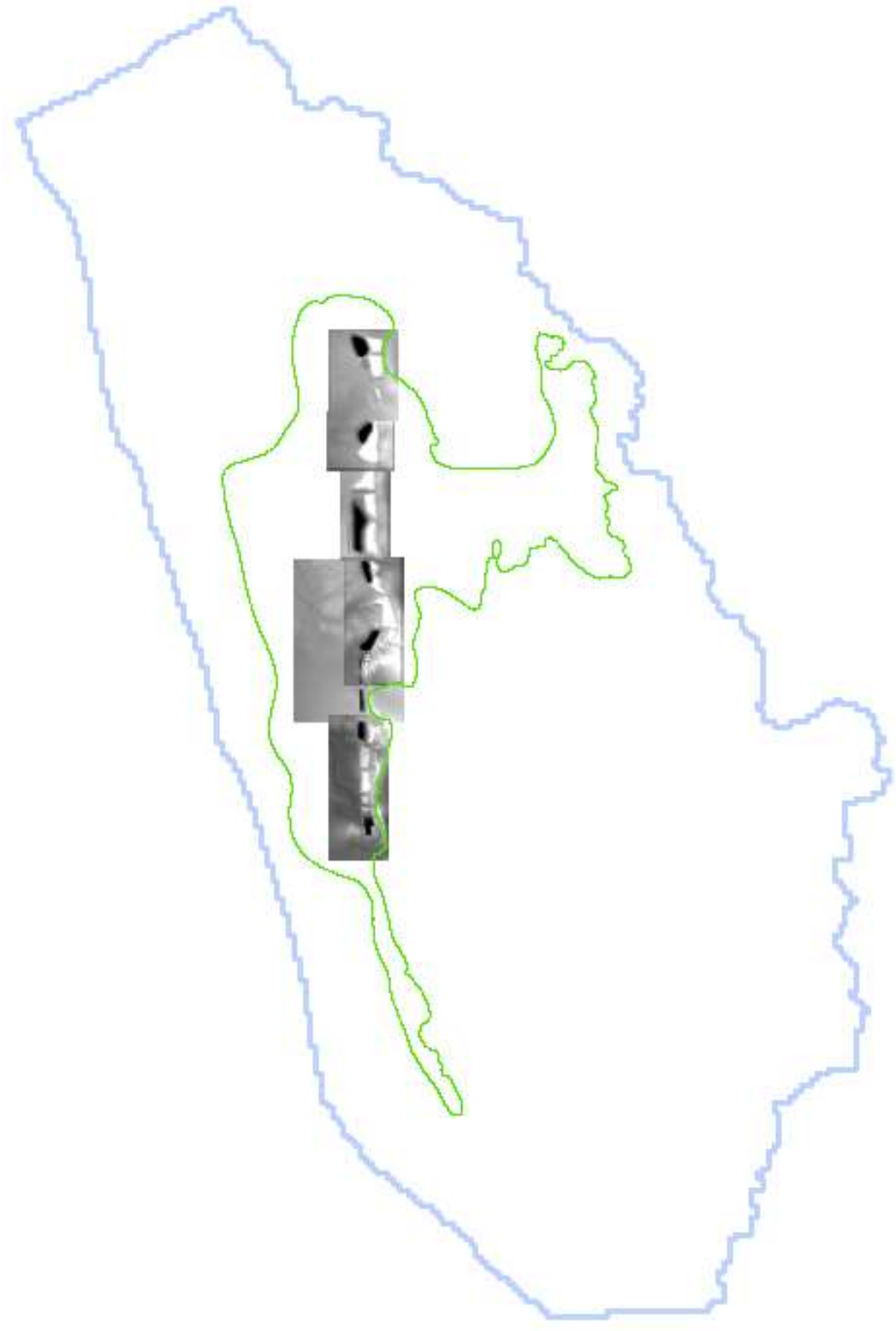


Figure I-10 Drawdown Sensitivity Layer 6

Base (red) and Sens ID 5 & 6 (Spoil Sy /2 - blue, Spoil Sy x2 - green)

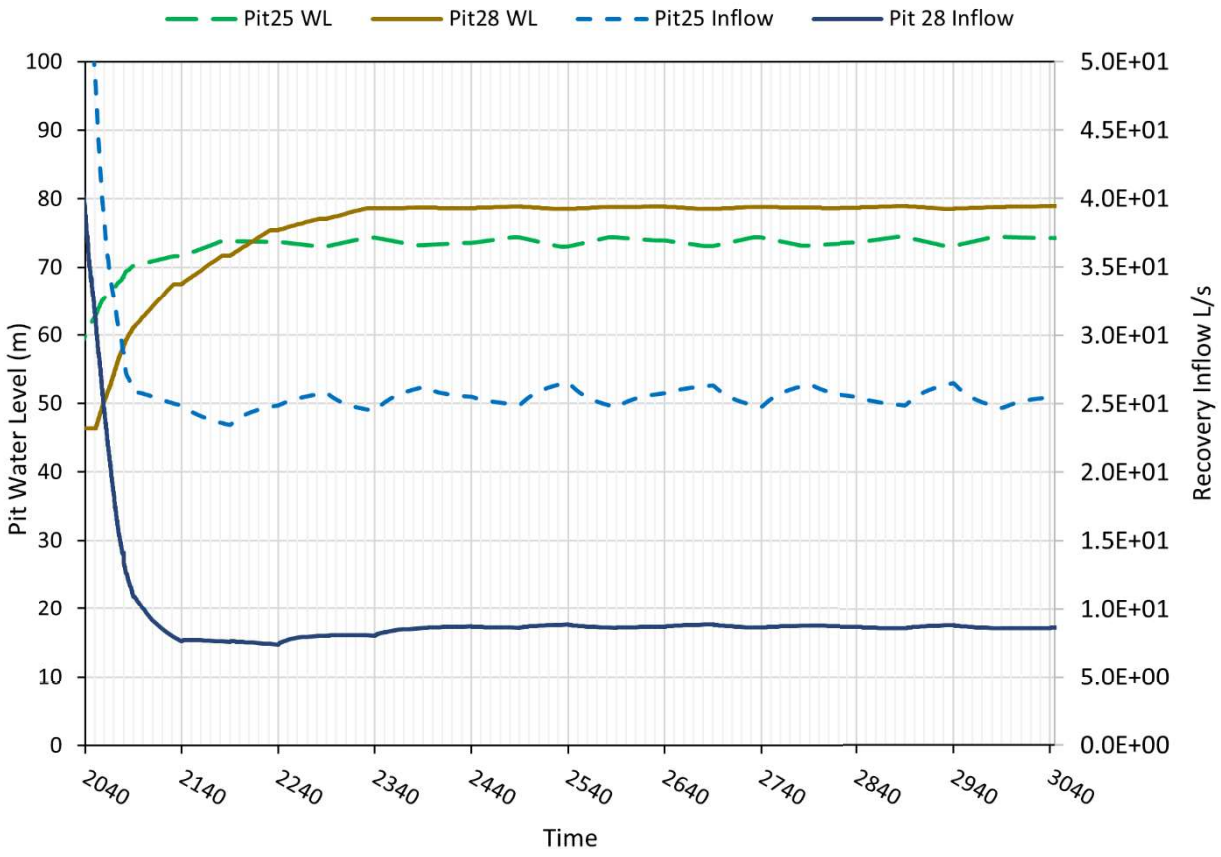


Figure I-11 Predicted Post-Closure Pit Water Levels and Inflows

MODEL APPENDIX II

Water Balances

1000 Year, Post Mine Closure

1. Existing mine plan case

For the last time step:

Layer 1				
	In (m^3/d)		Out (m^3/day)	
Category	Flux		Flux	
Bottom		3400.754024		-4483.69
Recharge		3953.354434		0
ET		0		-3276.22
Storage		0		-0.00031
River		**704.9819272**		**-347.722**
GHB		48.54440641		0

Layer 2	In		Out	
Category	Flux		Flux	
West		0.022146171		-0.00264
East		60.75982649		0
North		15.35006392		-0.94374
South		2.910982374		-1.09603
Top		4483.687078		-3400.75
Bottom		2218.09971		-3736.64
Storage		5.17E-08		-0.00021
River		**711.6759987**		**-353.073**
Error		0.000369264		0

All layers	in		out	
Category	Flux		Flux	
West		66.28280538		-0.20886
East		230.7264877		-0.50532
North		49.72493216		-56.3792
South		113.6838763		-6.05231
Recharge		3953.354434		0
ET		0		-3276.22
Storage		1.65E-05		-0.0066
River		**1416.657926**		**-700.796**
Error		0.052434474		**0**

2. Proposed case (Conservative Case)

Layer 1	in (m^3/day)	out (m^3/day)
Category	Flux	Flux
Bottom	2101.135125	-4212.23
Recharge	3430.122302	0
ET	0	-1912.66
River	**731.5447045**	**-324.77**
Error	1.15E-05	0

Layer 2		
Category	Flux	Flux
West	0.02009849	-0.000920704
East	59.20726712	0
North	14.28137883	-0.632766992
South	2.902723654	-1.075615736
Top	4212.226179	-2101.135125
Bottom	1039.279824	-3633.756452
Storage	1.33E-06	-8.51E-06
River	**738.4868303**	**-329.8034165**
Error		

All layers	in	out
Category	Flux	Flux
West	68.05849024	-0.149062377
East	248.7737578	-0.507775884
North	175.4043853	-15.95396382
South	117.7048141	-6.390152996
Recharge	3430.122302	0
ET	0	-1912.658827
Storage	0.000215878	-0.004394841
River	**1470.031535**	**-654.5737479**
Drain	0	-3106.68019
GHB	186.8532171	0
Error	0.030602008	0

2. Proposed case

Layer 1	in (m^3/day)	out (m^3/day)
Category	Flux	Flux
Bottom	2178.085895	-4576.670487
Recharge	3855.000252	0
ET	0	-1984.986483
River	**698.5551532**	**-336.6408597**
Error	166.6565294	0

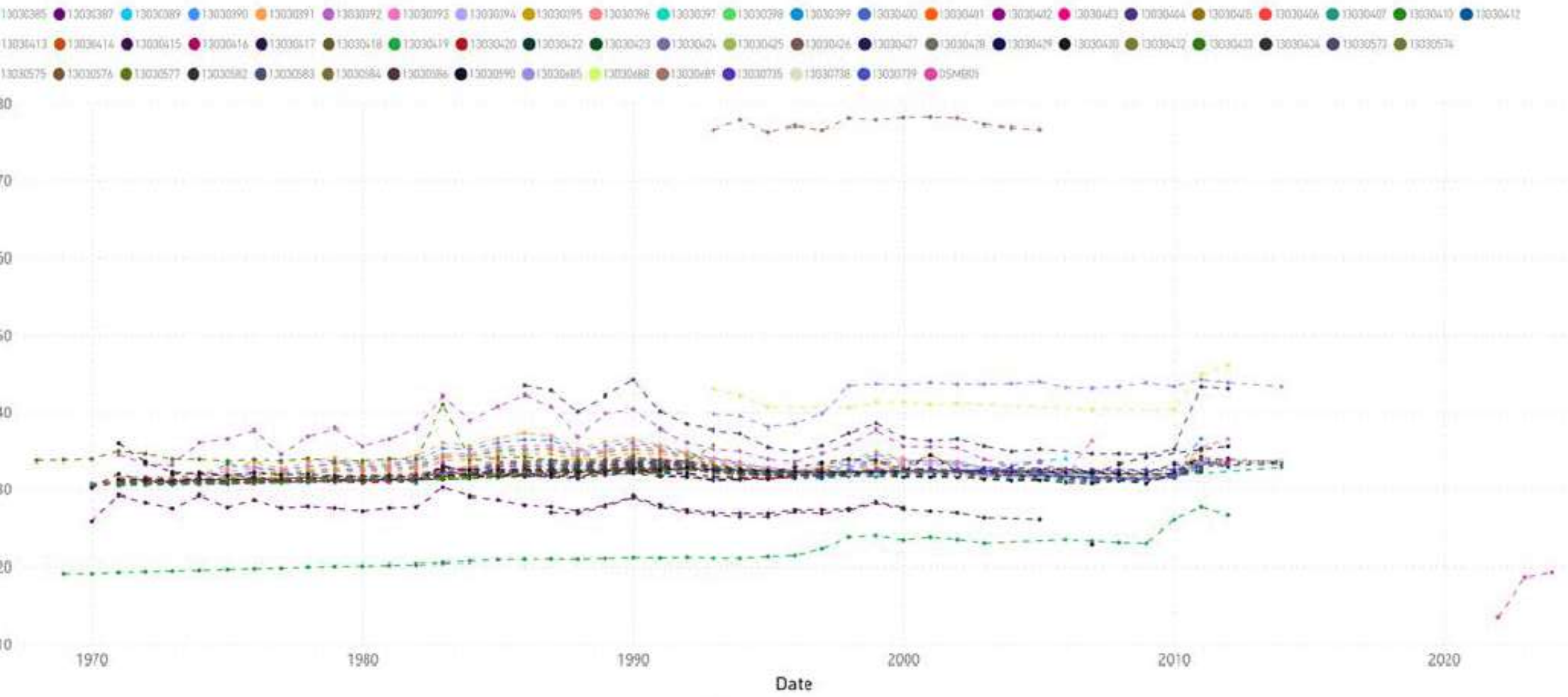
Layer 2		
Category	Flux	Flux
West	0.020321	-0.00069
East	59.12096	0
North	13.71801	-0.66954
South	2.91994	-1.10844
Top	4576.67	-2178.09
Bottom	1094.426	-3930.43
Storage	0	-0.02597
River	**705.2738**	**-341.829**
Error	1.27E-06	0

All layers	in	out
Category	Flux	Flux
West	65.89266557	-0.13789
East	231.6525269	-0.51721
North	115.6396993	-95.0438
South	110.1772149	-6.11199
Recharge	3855.000252	0
ET	0	-1984.99
Storage	5.998727167	-16.6355
River	**1403.82899**	**-678.47**
Error	-0.002724853	0

MODEL APPENDIX III

Groundwater Monitoring Hydrographs

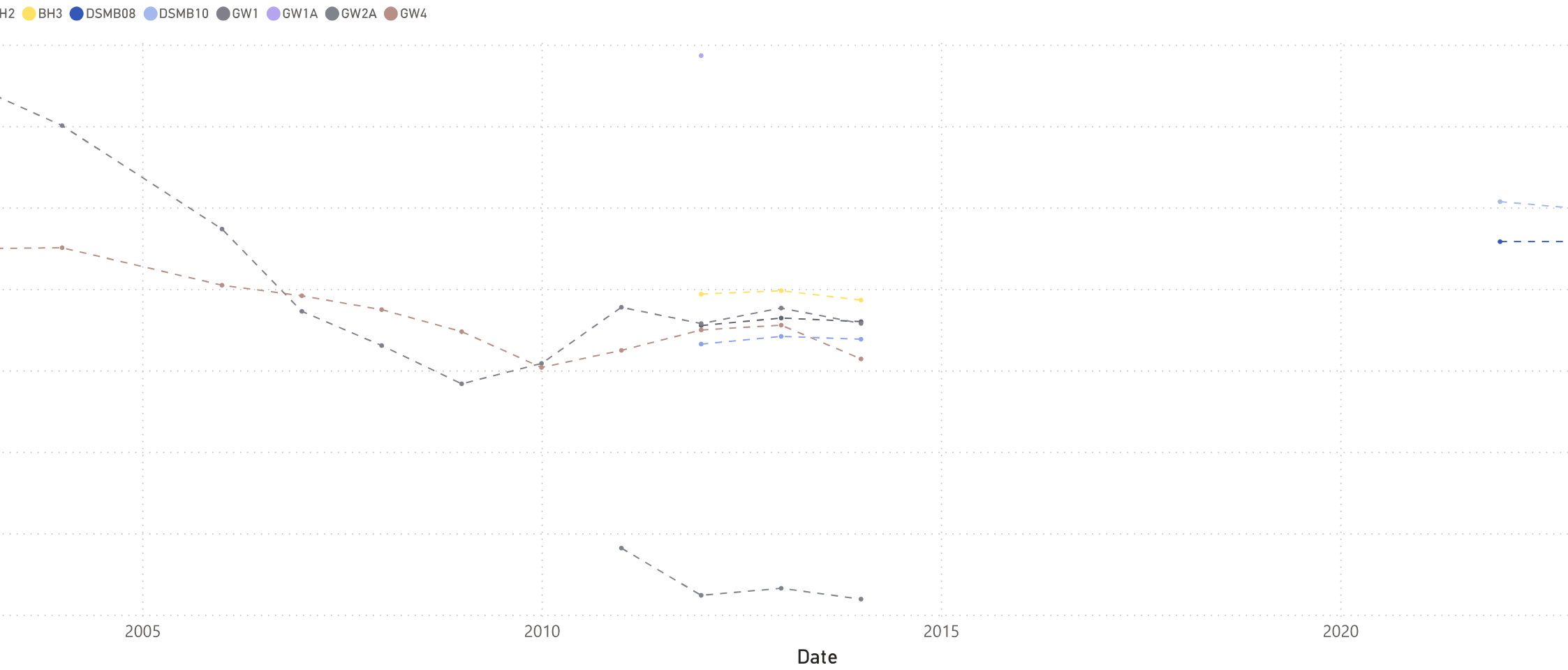
Groundwater Elevations (Alluvium)



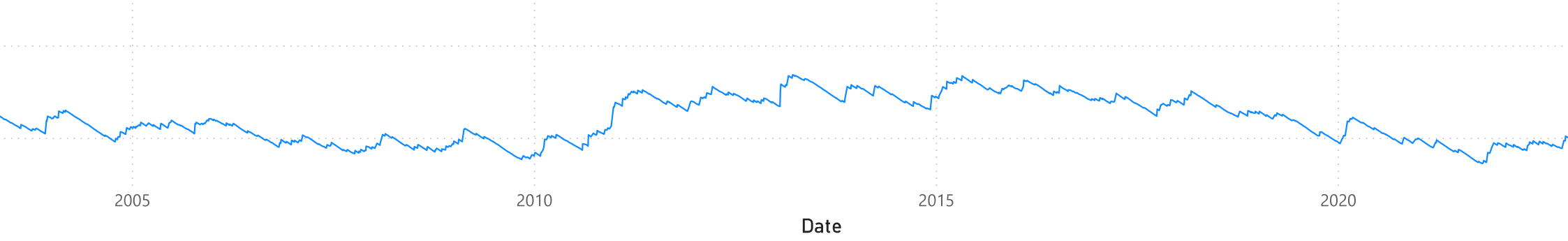
Cumulative Rainfall Departure



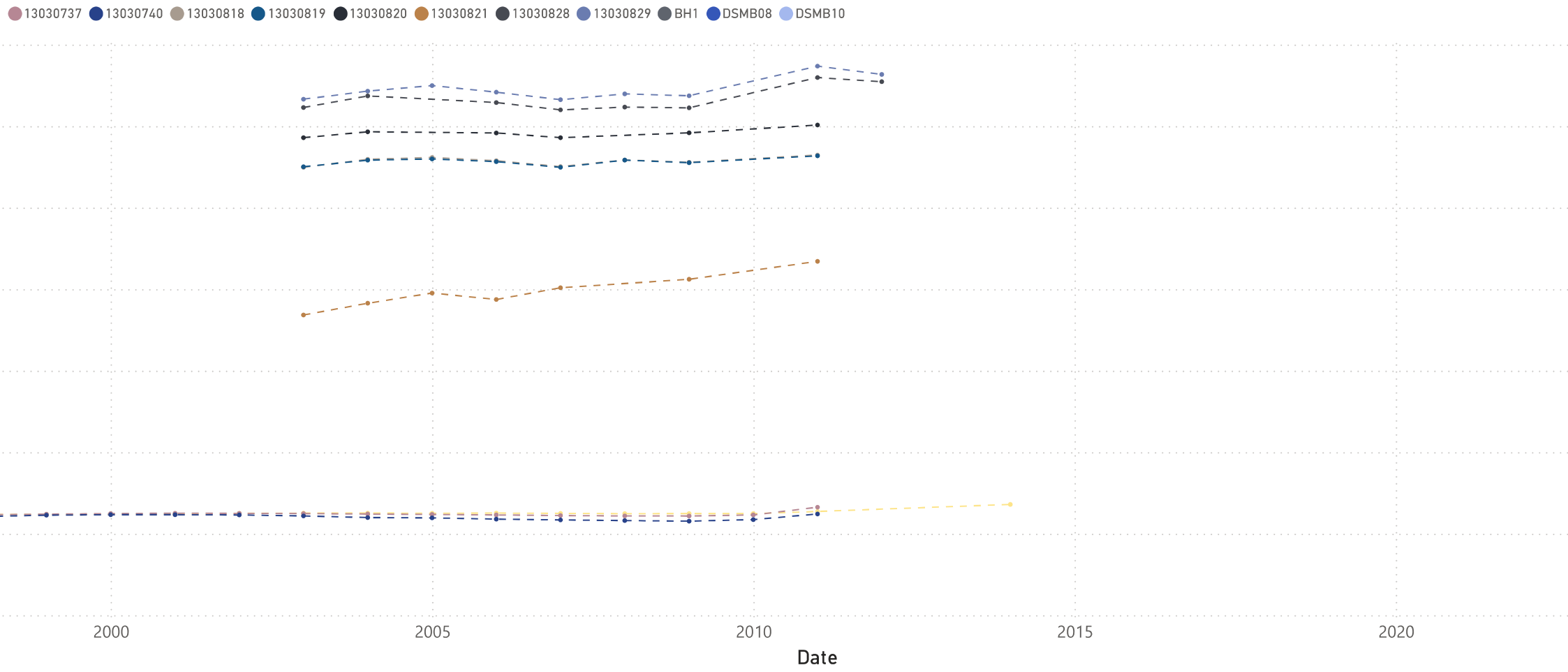
Groundwater Elevations (Rangal)



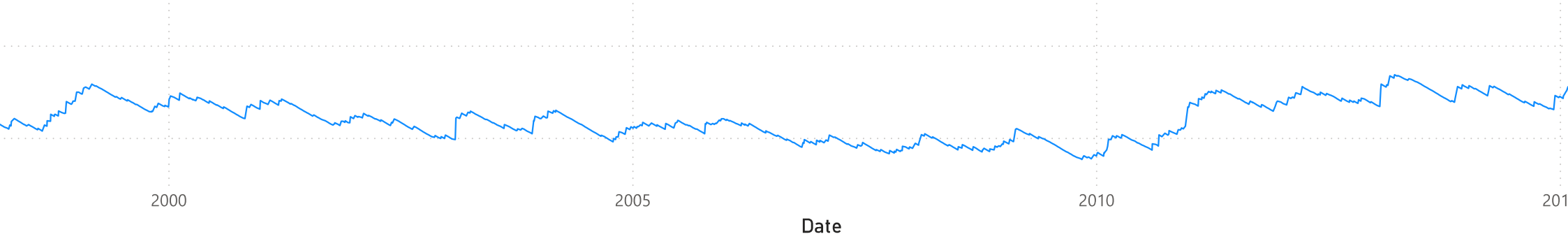
Cumulative Rainfall Departure



Groundwater Elevations (Permian)



Cumulative Rainfall Departure



Appendix 4.6 Water Quality and Balance

DAWSON MINE 2C WEST PIT LAKE DESKTOP REVIEW

PREPARED FOR **ANGLO AMERICAN METALLURGICAL COAL**

July 2020



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REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1.0	02/07/2020	Draft Report Internal Review	AH		FT	FT
2.0	08/07/2020	Draft Report to Anglo	AH		JF	
3.0	22/07/2020	Final Report to Anglo	AH			

Anglo American Metallurgical Coal

Dawson Mine Pit Lake Options Study

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Appendix A Database Search Results

1. Introduction

1.1 Project Background

Anglo American Metallurgical Coal (Met Coal) have two open cut and three underground metallurgical coal mines in Queensland's Bowen Basin, along with additional joint venture interests and growth projects in the broader region. Met Coal are currently planning for closure of the Dawson Mine, located approximately 15 km east of the town of Moura, and 185 km south-west of the port of Gladstone (**Figure 1-1**).

Pit lakes are common mine closure legacies for many open cut mines extending below water table. To date, the proposed post mining land use for the majority of central Queensland mining operations has been bushland and range land grazing. Final open cut mining voids typically remain as saline groundwater sinks providing little benefit to the environment. Mine closure guidelines increasingly require post-mining land uses that minimise long-term liabilities and provide beneficial environmental outcomes.

Dawson Mine 2C West Pit Lake was completed operations in 2009 to a maximum depth of 20 m AHD, which represents a depth of approximately 40 m below surrounding landform. The 2C West Pit Lake is the largest of four pit voids holding dewatering discharge. The closest surrounding pit void is 400 m to the north, while the remaining two are 1.3 km to the south (**Figure 1-2**). To the south and west of 2C West Pit Lake is the Queensland Nitrate Plant (QNP). The closest tributaries are Kianga Creek (5 km to the west) and Banana Creek (8 km to the east), with Dawson River approximately 13 km.

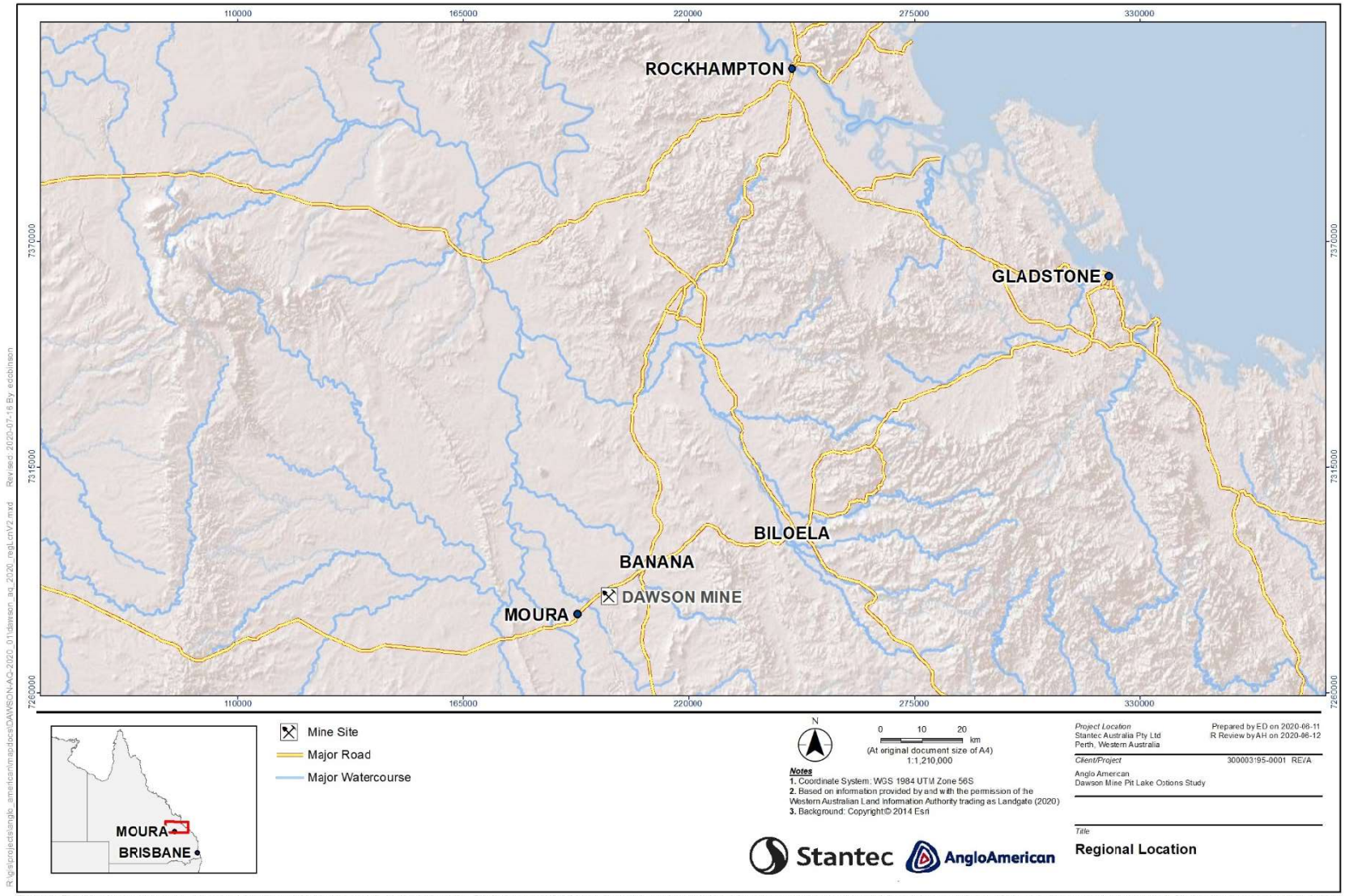
Met Coal are currently investigating the options to improve water quality and ecological functioning of their Dawson Mine 2C West Pit Lake, post closure, to mitigate some of the impacts associated with deep strip mining that occurs below the water table. Met Coal commissioned Stantec Australia Pty Ltd (Stantec), to undertake a desktop review and environmental risk assessment (the Assessment), to contribute to the understanding of aquatic biota values associated with the 2C West pit post mining.

1.2 Scope and Objectives

The objective of the Assessment was to investigate the range of aquatic biota (diversity and composition) that may be sustained by 2C West Pit Lake, under two closure scenarios compared to the existing void condition:

- **Do Nothing Closure Scenario** - based on output of the pit lake geochemical model, with no active mitigation to manage evapoconcentration and deteriorating water quality in the pit void over time; and
- **Preferred Closure Scenario** - based on output of the pit lake geochemical model, assuming additional external catchment (~1000 ha) will be diverted into the void and constant pumping (7 L/sec) out of void water to reduce salt accumulation in the pit void over time.

Key tasks included a desktop review (database search and literature review), qualitative environmental risk assessment and 2D conceptualisation of pit lake options, and ecological assessment and summary of environmental values. For each closure scenario, an assessment was undertaken to determine if water quality conditions would be within acceptable levels to promote and sustain a productive and biological diverse aquatic ecosystem, post closure.



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Figure 1-1: Regional location of Dawson Mine.

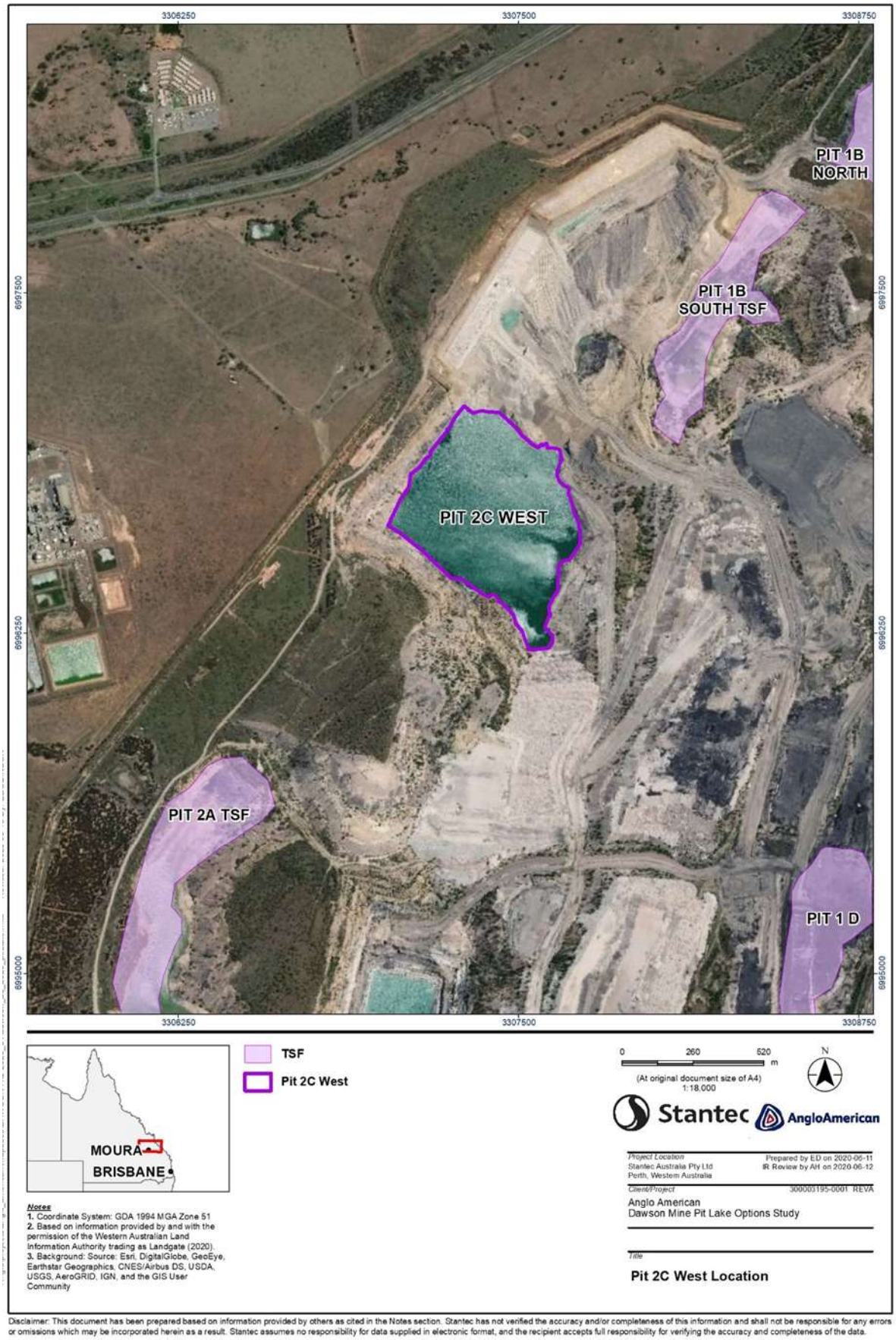


Figure 1-2: Site layout showing 2C West Pit Lake.

2. Existing Environment

2.1 Biogeographical Context

The Interim Biogeographic Regionalisation for Australia (IBRA) is a bioregional framework dividing Australia into 89 bioregions and 419 subregions based on climate, lithology and geology, landforms, soils, vegetation, flora and fauna, as well as land use (Thackway and Cresswall, 1995). The 2C West Pit Lake is located within the Dawson River Downs (BBS07) subregion (9,828.1 km²) of the Brigalow Belt South bioregion. The bioregion spans from central Queensland into northern New South Wales. The Brigalow Belt South region contains mixed landscapes, flat alluvial plains in the south, to undulating to hilly areas with low ridges characterised by river systems incised into deep valleys. The surrounding land is generally used for agriculture (i.e. grazing, dryland and irrigated cropping) with localised areas of water storage (dams and weirs), mining (i.e. coal and gold) and urban residential (i.e. Biloela, Moura & Theodore).

2.2 Catchments and Rivers

In vicinity of the Dawson Mine, waterbodies vary in size and geomorphology. Dawson River is the main drainage feature of the catchment, and comprises one of five major tributaries within the Fitzroy River Basin. The Dawson River has a catchment area of approximately 50,000 km^2 and is bounded by the Lynd and Expedition ranges to the west, the Great Diving Range to the south and Dee ranges to the east (Hydrobiology 2019). There are at least five ephemeral tributaries (Bottletree, Huon, Kianga, Banana, and Lonesome Creeks) located east of the Dawson River.

The Dawson River and its associated tributaries, as with most semi-arid systems, have a highly variable flow regime, with catchment flows typically occurring in late summer and autumn, but with considerable interannual variation. While the Dawson River does not support perennial flows in vicinity of the Dawson Mine, most riverine reaches support permanent pool habitats, influenced by the Moura and Baralaba weirs and their large impoundment areas. The majority of eastern tributaries are ephemeral, with highly episodic hydrological regimes, with limited perennial pools (Hydrobiology 2019).

2.3 Climate

The Brigalow Belt South bioregion has a subhumid climate, with hot summers and mild winters. Rainfall is highly variable and seaonable, with most occuring between the warmer months of October and March (**Figure 2-1**). Rainfall is also spatially variable, with some parts of the bioregion experiencing substantially heavier falls than others.

The average annual rainfall in the Dawson mining area is approximately 550 mm (**Figure 2-1**). Average annual evaporation is around 1,752 mm, nearly three times greater than average annual precipitation (BOM 2018). From October to April, daytime temperatures are above 30°C, with some days reaching in excess of 36°C between December to January. Winter temperatures remain above 20°C, with an average of approximately 22°C.

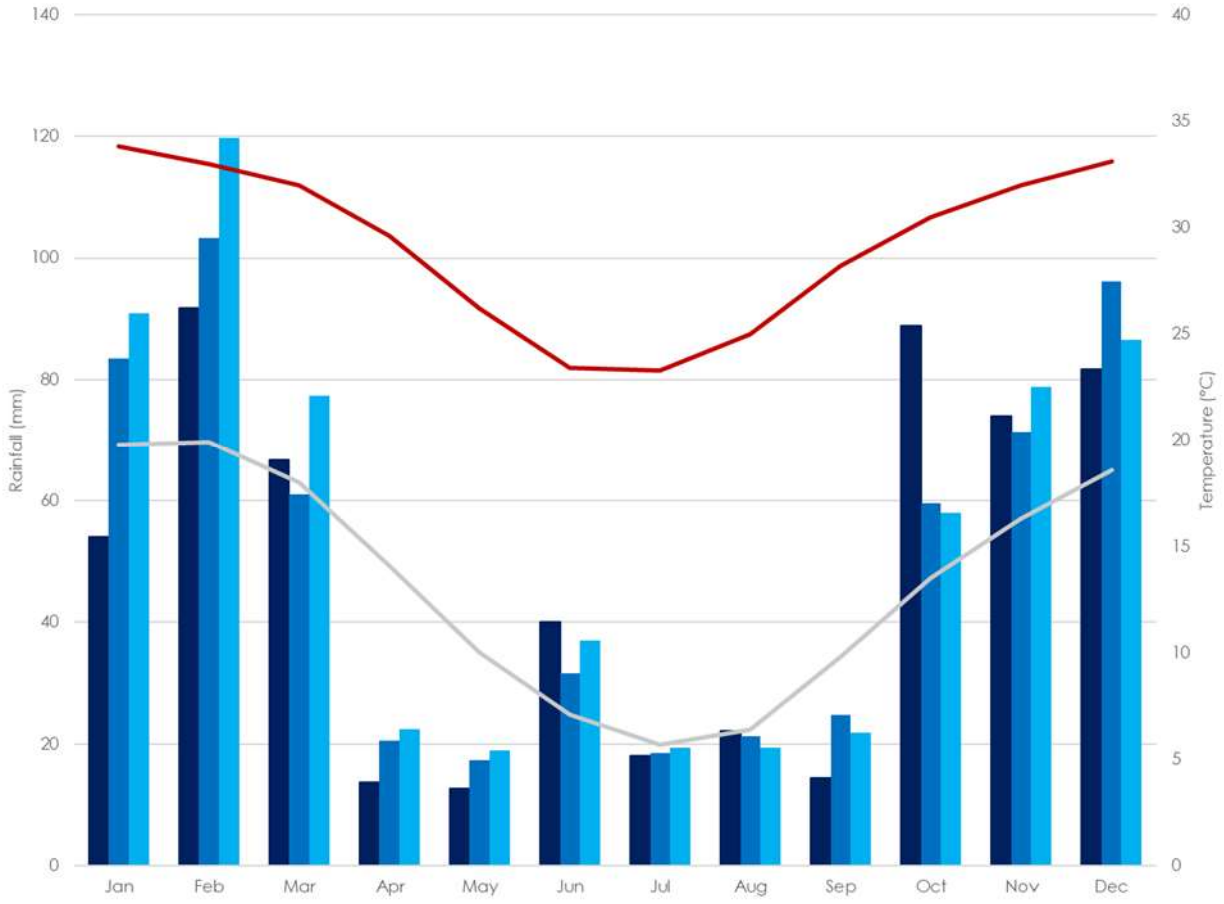


Figure 2-1. Mean monthly rainfall (1999 – 2019) from Bureau of Meteorology weather stations Theodore (039158, ■), Woodleigh (039142, ■) and Belvedere (039201, ■), with mean minimum (-) and maximum (-) temperatures (1991-2019) recorded at Thangool Airport (039089) (Bureau of Meteorology 2020).

3. Methods

3.1 Pit Lake Water Quality and Level Assessment

ALS Hydrographics (ALS) prepared a technical report from a bathymetric survey and water sampling program of 2C West Pit Lake in 2019 (ALS 2019). Water quality sampling was undertaken at six locations on the 4th November 2019 (**Figure 3-1**). This comprised vertical profiling of *in situ* water quality (in the form of water temperature and salinity), and the collection of water samples from varying depths and locations within the pit void to characterise major ions, dissolved metals and nutrients. A full list of the suite of parameters tested is presented in **Table 3-1.**

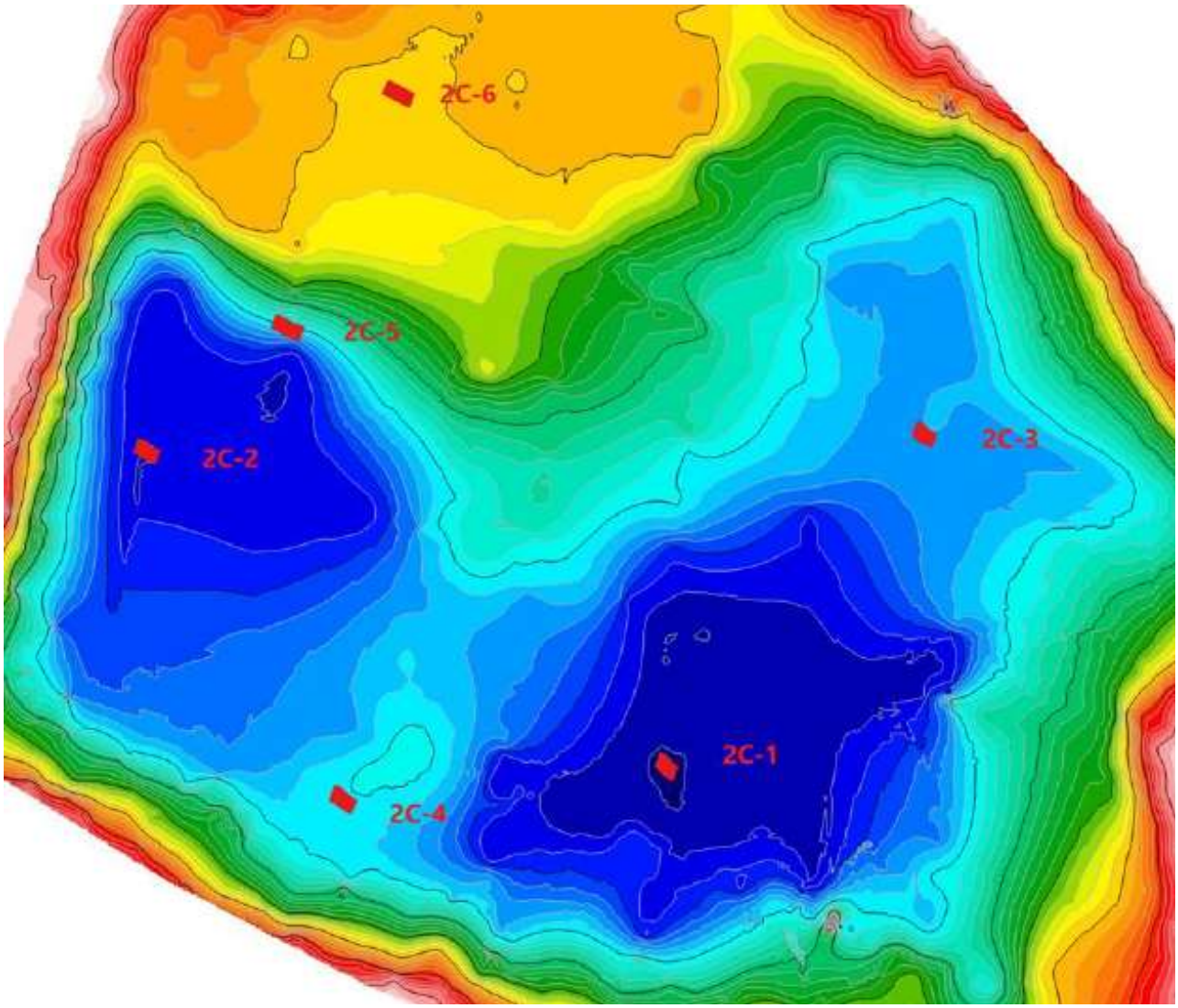


Figure 3-1. Water quality sampling locations (reproduced from ALS 2019).

Analytical water quality results were compared to the most recent Australian and New Zealand Guidelines (ANZG 2018) for freshwater lakes and reservoirs and/or wetlands in tropical Australia. These default guideline values (DGVs) are considered to best represent water quality conditions of slightly to moderately disturbed lentic wetlands in the dry tropics of central Queensland. However, for metals that have the potential to bioaccumulate (such as selenium), ANZG (2018) recommends the adoption of the 99% protection, which were applied.

Surface water pH was classified according to the system developed by Foged (1978), comprising acidic (4.5 to 6.5), circumneutral (6.5 to 7.5), and alkaline (>7.5) conditions. Salinity was based on the classification system developed by Hammer (1986); freshwater (<3,000 mg/L), hyposaline (3,000 to 20,000 mg/L), mesosaline (20,000 to 50,000 mg/L) and hypersaline (>50,000 mg/L).

Table 3-1. Water parameters analysed from the 2C West Pit Lake by ALS in November 2019.

Basic parameters	Major ions and nutrients	Dissolved Metals and Trace Elements	
pH	Calcium (Ca)	Antimony (Sb)	Lead(Pb)
Electrical Conductivity	Chloride (Cl)	Arsenic (As)	Manganese (Mn)
Total Dissolved Solids	Potassium (K)	Barium (Ba)	Mercury (Hg)
	Magnesium (Mg)	Boron (B)	Molybdenum (Mo)
	Nitrite as N	Cadmium (Cd)	Nickel (Ni)
	Nitrate as N	Chromium (Cr)	Selenium (Se)
	Sodium (Na)	Copper(Cu)	Silver (Ag)
	Sulfate (SO4)		
	Total Alkalinity (as CaCO3)		

Klohn Crippen Berger (KCB 2020) prepared a report on water quality and water level simulations and assessments for five scenarios of final void condition at 2C West Pit Lake. This involved consideration of the geochemistry and water balance to provide water quality and water level estimates for up to 100 years after operations. Only the potential impacts of changing salinity (TDS) and/or evapoconcentration (water level decline) were modelled (KCB 2020). However, GoldSim/PHREEQC simulations of water quality changes over the modelled TDS range of 4585 to 8014 mg/L were obtained to provide an indication of likely major ion, dissolved metal and nutrient concentrations, post closure. The parameters modelled were:

- Dissolved metals including As, B, Ba, Cd, Cr, Cu, Mn, Mo, Ni, Pb, Sb and Se.
- Nutrients including nitrate.
- Major ions including Ca, Cl, K, F, Mg, Na, and SO_4.
- Basic parameters including alkalinity, pH and TDS.

For the purposes of the Assessment, modelled salinity (as TDS mg/L) and water level elevation data were reviewed and interpreted for two closure scenarios (**Figure 3-2**) under low- and high-evaporation conditions over a 100-year period:

- **Do Nothing Closure Scenario** - represents no active mitigation to manage evapoconcentration effects in the pit void post closure.
- **Preferred Closure Scenario** - represents two active strategies to control void TDS including the provision of additional external catchment (approximately 1,000 ha) and constant pumping (7L/sec) out of void water to reduce salt accumulation post closure (i.e. scenario six in KCB 2020).

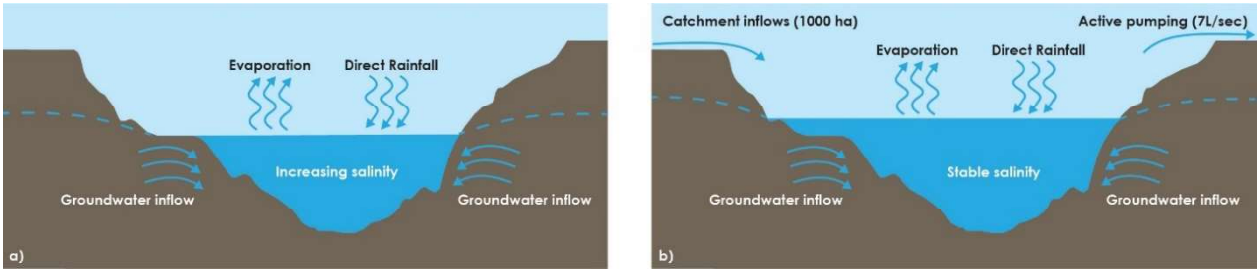


Figure 3-2. Conceptual diagram showing Do Nothing (left) and Preferred (right) closure scenarios.

3.2 Desktop Review

3.2.1 Database Search

Database searches were undertaken to identify the potential environmental values, habitats and species of significance that may occur within the vicinity of 2C West Pit Lake (**Table 3-2**). Several databases were accessed, for which a polygon search encompassing 2C West Pit lake and/or a central coordinate (24.535077°, 150.046708°) was submitted to the relevant regulatory or government department custodian.

Table 3-2: Summary of databases and search tools accessed for the Assessment.

Custodian	Database	Reference	Buffer (km)
Council of Heads of Australian Faunal Collections (CHAFC)	Online Zoological Collections of Australian Museums (OZCAM)	OZCAM 2020	10
Department of Environment and Energy	Protected Matters Search Tool (PMST) and Species Profile and Threats (SPRAT) database	DoEE 2020	50
Department of Environment and Energy	Directory of Important Wetlands	DoEE 2020	-
Department of Environment and Science	Matters of State Environmental Significance (MSES) Search Tool	DES 2020	2
Department of Environment and Science	WildNet Database	DES 2020	50
Department of Environment and Science	Biodiversity and Conservation Values	DES 2020	2
Department of Environment and Science	Regional Ecosystems	DES 2020	2
CSIRO	Atlas of Living Australia	ALA 2020	50
Queensland Government	Queensland Globe	QG 2020	-

3.2.2 Literature Review

A literature review of all publicly available information relating to the diversity and composition of common and/or endemic aquatic biota was undertaken to characterise those taxa with the potential to inhabit or utilise 2C West Pit Lake over time (**Table 3-3**). For the purposes of the Assessment, aquatic biota comprised the following trophic groups; primary producers (benthic algae and aquatic macrophytes), aquatic invertebrates, fish, and other vertebrate fauna. Information was compiled from previous technical reports, books, journals, and relevant government, university or regulatory publications. This included previous aquatic biota studies of other pit lakes of Dawson Mine, nearby riverine and creekline sites, and wetlands more broadly within the dry tropics of Central Queensland.

Publicly available information relating to the environmental tolerances of aquatic biota taxa recorded locally, or those known to occur more broadly in Central Queensland, with potential to utilise 2C West Pit Lake were also reviewed and summarised (**Table 3-3**). Environmental tolerance information included two types of data for assessing risk to aquatic biota. These were data from laboratory experiments (72-h LC_{50} acute lethal tolerance values) and upper salinity tolerance limits taxa have been recorded from.

Table 3-3: Summary of literature reviewed for the Assessment.

Reference	Survey Title	Summary of relevance to the Assessment
Allen *et al.* 2002	Field Guide to the Freshwater Fishes of Australia	Provides information on 300 freshwater fish species across Australia, including details on habitat requirements, distribution and biology.
ALS Hydrographics 2019	Pit 2C Bathymetry Survey and Sampling Report	Technical report from a bathymetric survey and water sampling program of 2C West pit lake in 2019. Details *in situ* vertical profile and laboratory water quality results.
Baker *et al.* 2005	2005 post-mining rehabilitation monitoring program for soils, vegetation & vertebrate fauna	Technical report describing the results of water quality and aquatic fauna monitoring from two mine voids in 2005.
Baker *et al.* 2008	2008 soils, vegetation & vertebrate fauna monitoring event – Dawson Post-mining Rehabilitation	Technical report describing the results of water quality and aquatic fauna monitoring from two mine voids in 2008.
Berghuis and Long 1996	Freshwater Fishes of the Fitzroy Catchment, Central Queensland	Fish catch records from a three year monitoring program sampling 21 sites throughout major rivers of Fitzroy Catchment.
Dunlop 2008	Effect of spatial variation on salinity tolerance of macroinvertebrates in Eastern Australia and implications for ecosystem protection trigger values	Journal article detailing 72-h acute salinity tolerance values for 102 macroinvertebrate taxa collected from 11 locations in Northeast Australia.
Dutney *et al.* 2008	The Suitability of Dawson Mine Water for Aquaculture	Technical report on the suitability of void water sourced from Dawson Mine for aquaculture. Bioassay trials were conducted for silver perch and barramundi.
KCB 2020	Anglo American Dawson Final Void Water Quality Pit 2C West Water Quality Assessment	Technical report on water quality concentrations and water level elevation simulations and assessments for five scenarios of final void condition at 2C West Pit Lake.
Kefford *et al.* 2004	Comparing test systems to measure the salinity tolerance of freshwater invertebrates	Journal article detailing acute salinity tolerance values (artificial and natural) for macroinvertebrate taxa collected from south-east Australia
Hydrobiology 2019	Dawson Mining Operations 2018/2019 Annual Receiving Environment Monitoring Program Report	Technical report describing the results of monitoring of habitat, surface flows, water quality and macroinvertebrate richness and composition at control and test sites for the July 2018 to June 2019 monitoring period.
Platten *et al.* 2011	Fish Water Quality Guidelines for Fitzroy Basin Freshwaters: Pursuant to the Environmental Protection (Water) Policy 2009	Paper outlining the approach to derive water quality guidelines for fish species in the Fitzroy River Basin. Species occurrence by catchment is detailed.
Prasad *et al.* 2014	Impact of salinity and ionic composition on freshwater macroinvertebrates in the Fitzroy River Catchment, Central Queensland, Australia	Journal article detailing 72-h and 92-h acute salinity tolerance values for five macroinvertebrate taxa collected from Nebo with a comparison of results with other areas in Queensland.
Proctor & Grigg 2006	Aquatic invertebrates in final void water bodies at an open-cut coal mine in central Queensland	Journal article describing the aquatic invertebrate diversity and composition of eleven final voids and three natural sites at Dawson Mine sampled in December 1998 and again in March 1999.
Pusey *et al.* 2004	Freshwater Fishes of North-Eastern Australia	Provides information on 79 fish species (primary focus on easterly flowing coastal rivers of Queensland and northern NSW), including distribution patterns and abundance, habitat requirements and biology.

Reference	Survey Title	Summary of relevance to the Assessment
Stitz 2013	Macroinvertebrate Tolerance across a Range of Conductivities in the Isaac River Catchment (Central Queensland)	Journal article describing patterns in macroinvertebrate assemblages (39 families from 13 orders identified) in the upper Isaac River catchment at the end of the dry season in 2012. Patterns in the assemblages were examined together with water quality parameters, in order to gauge the ability of macroinvertebrates to survive at conductivity concentrations up to 9791 µS/cm.
Whisson & Evans 2003	Aquaculture in final voids	Technical report describing commercial aquaculture and/or recreational fish stocking as a relinquishment option for final mining voids for coal mining companies
Young et al. 1999	BHP Coal Moura Mine Fish Survey	Technical report detailing sampling methodology, *In situ* water quality data and fish species richness and composition from nine mining voids and three natural sites sampled in December 1998 and March 1999.

3.3 Environmental Risk Assessment

A qualitative environmental risk assessment (ERA) was undertaken to understand key threats (such as water level changes/habitat availability) and associated stressors (such as salinity, dissolved oxygen, pH, metals and nutrients) may represent the greatest risk to aquatic biota under existing void conditions, and the modelled closure scenarios.

The ERA was based on the environmental consequence and the likelihood of each threat/stressor being impacting aquatic biota, using a standard risk evaluation framework (**Table 3-4**). A measure of the knowledge gap in determination of impact predictions relates to the robustness of monitoring and/or modelling data available. Each threat/stressor was allocated a severity level rating based on the level of impact as follows:

- Low: risk that does not necessarily require management.
- Medium: risk that with management may be reduced to more acceptable levels.
- High: risk requiring management to mitigate and reduce risk to an acceptable level.
- Critical: risk that should be avoided.

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost certain	Low	Medium	High	Critical	Critical
Likely	Low	Medium	Medium	High	Critical
Moderate	Low	Low	Medium	Medium	High
Unlikely	Low	Low	Low	Medium	Medium
Rare	Low	Low	Low	Low	Medium

Consequence

Table 3-4. Environmental risk evaluation framework (Source: MRM 2018).

3.4 2D Conceptual Model

The risk assessment was assisted through the development of a generalised pit lake conceptual model of existing void condition, and final void condition according to each closure scenario. These conceptual model diagrams indicate the interaction between parameters and processes, to better understand ecological risks associated with changes in water levels and quality over time.

Bathymetry contour data collected by ALS (2019) was used to produce a basic 2D contour map showing the existing void landform design at 2 m intervals (**Figure 3-3**). Four cross sections of this contour map were produced to show the variation in the mine void profile according to orientation (**Figure 3-3, Figure 3-4**). While void profiles varied according to orientation, line 4 (**Figure 3-3**, **Figure 3-4**) was considered to provide the greatest spatial cross-section of 2C West Pit Lake. This was the base profile used to demonstrate ecological zones and ecosystem processes in the 2D conceptual model of existing void condition, and for each modelled closure scenario.

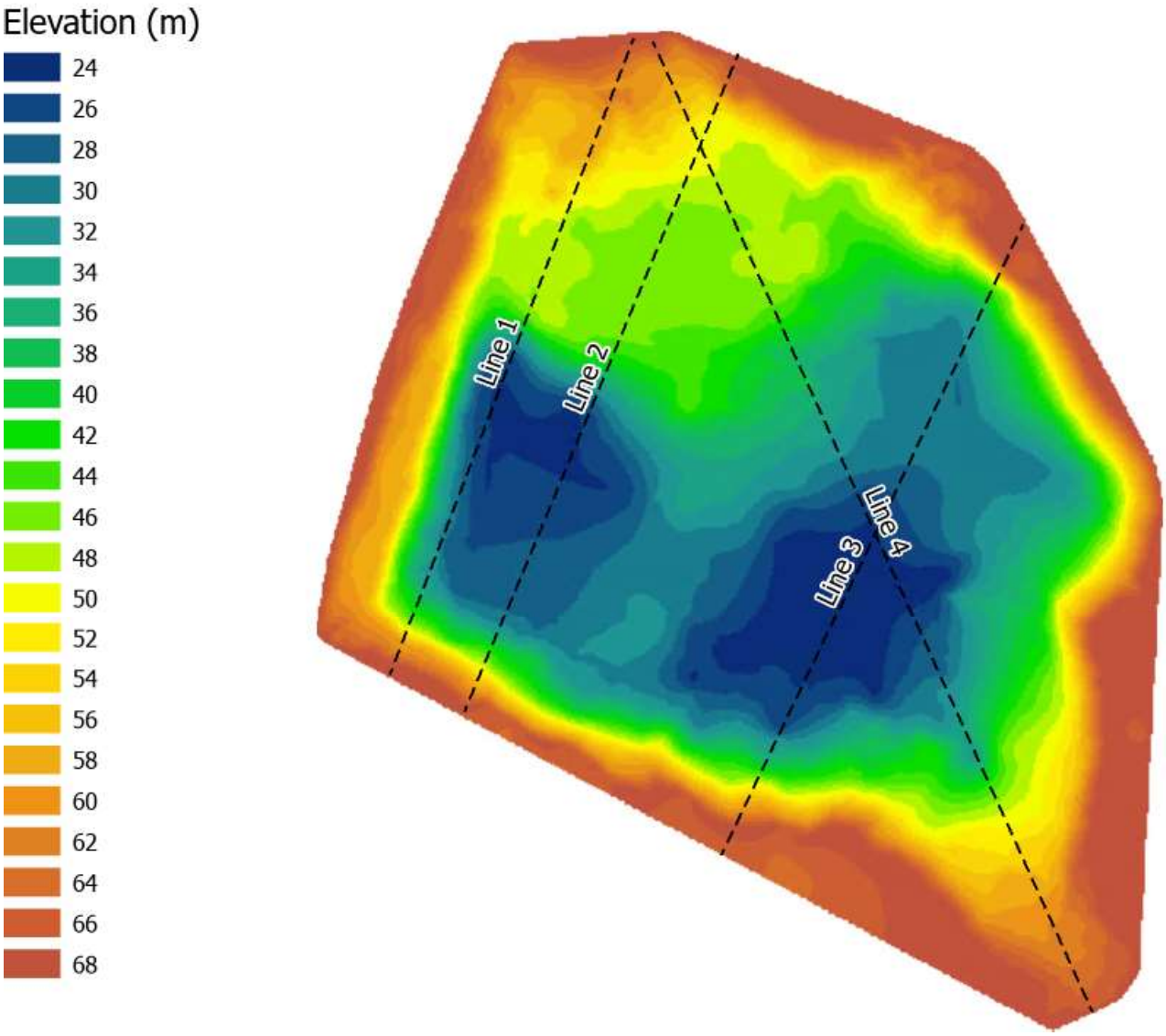


Figure 3-3. 2C West pit lake contour map showing four cross sections.

3.5 Ecological Assessment and Environmental Values

Based on the key findings of the desktop review and ERA, a brief ecological evaluation was undertaken to provide a summary of the range of aquatic biota (diversity and composition) that may be sustained by 2C West Pit Lake, under changing water levels and quality for each modelled closure scenario. The scenario that maximises environmental values in a post-mining landscape and provides likely hydrological requirements to progress 2C West Pit Lake to a self-sustaining wetland over the long-term was outlined, along with recommendations to improve habitat availability through landform design.

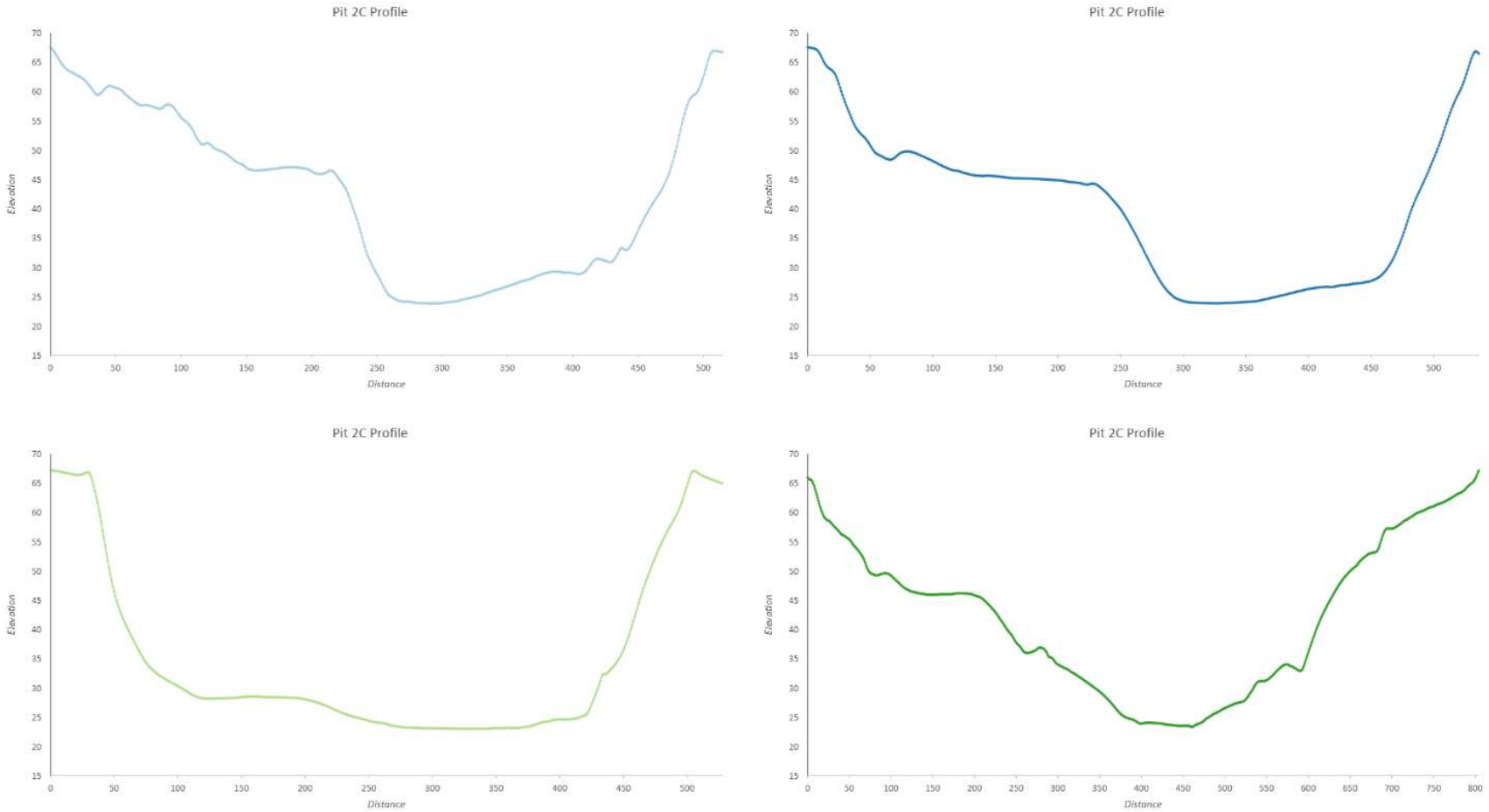


Figure 3-4. 2C West Pit Lake existing void profile for cross sections Line 1 (top left), Line 2 (top right), Line 3 (bottom left) and Line 4 (bottom right).

4. Results

4.1 Pit Lake Water Quality and Level Assessment

4.1.1 Existing Void Conditions

Existing void water quality data from November 2019, compared against ANZG (2018) DGVs, where available, is provided in **Table 4-1**, and can be summarised as follows:

- The water level at the time of bathymetric survey was 58.73 m AHD (ALS 2019). This was consistent with historic LIDAR measurements in 2018 (60.00 m AHD) and 2019 (59.00 m AHD).
- the mine void was stratified with a prominent thermocline (distinct temperature layer), with the separation of waters below 10 m in depth from surface water. Water temperature was consistent at 26˚C to 5 m depth, showing a gradual decline to approx. 19.5˚C at 12.5 m depth and below (**Figure 4-1**).
- The pH ranged from 8.32 to 8.55, classified as alkaline (>7.5), exceeding the upper limit of the ANZG (2018) 95% DGV (pH 8.0). High alkalinity levels suggest a good buffering capacity against changes in pH.
- Salinity, measured as EC, ranged from 6630 µS/cm to 7040 µS/cm, classified as hyposaline (Hammer 1986). Salinity exceeded the ANZG (2018) 95% DGV (900 µS/cm). There was a prominent chemocline (salinity change), with surface water electrical conductivity (EC) approximately 7200 µs/cm to 6 m depth, showing a gradual decline to approximately 6150 µs/cm at 15 m depth and below (**Figure 4-1**). The dominance of cations followed Na>Mg>Ca>K. Anion concentrations were greatest for SO_4 compared to Cl.
- Nitrogen nutrient levels (N-NO_X) exceeded the ANZG (2018) 95% DGV which suggests potential for eutrophication. No data were available for total or soluble Phosphorus.
- The majority of dissolved metal concentrations (Ag, Cd, Cr, Cu, Hg, Pb, Sb, Se) were low, and below the limit of reporting (LOR).
- Dissolved boron (B) levels (median, mean, 80%ile and max values) exceeded the ANZG (2018) 95% DGV, although were below the 90% DGV (0.68 mg/L).
- The LOR for Silver (Ag) was insufficient for comparison against ANZG (2018) 95% DGV.

Although no monitoring data were available for dissolved oxygen (DO) or turbidity, historic data for other Dawson mine pit lakes provide insight into likely concentrations (Baker *et al.* 2005, 2008, Young *et al.* 1999). A summary is provided below:

- DO saturation within the surface layer was >5 mg/L, however, major declines were observed below 3 to 5 m depth, with middle and bottom layer considered anoxic. It is likely that similar stratification of 2C West Pit Lake also occurs.
- Turbidity levels ranged from approximately 8 to 50 NTU, which suggests increased water clarity in the upper layer, and resuspension of accumulated organic material and/or sediments at depth.

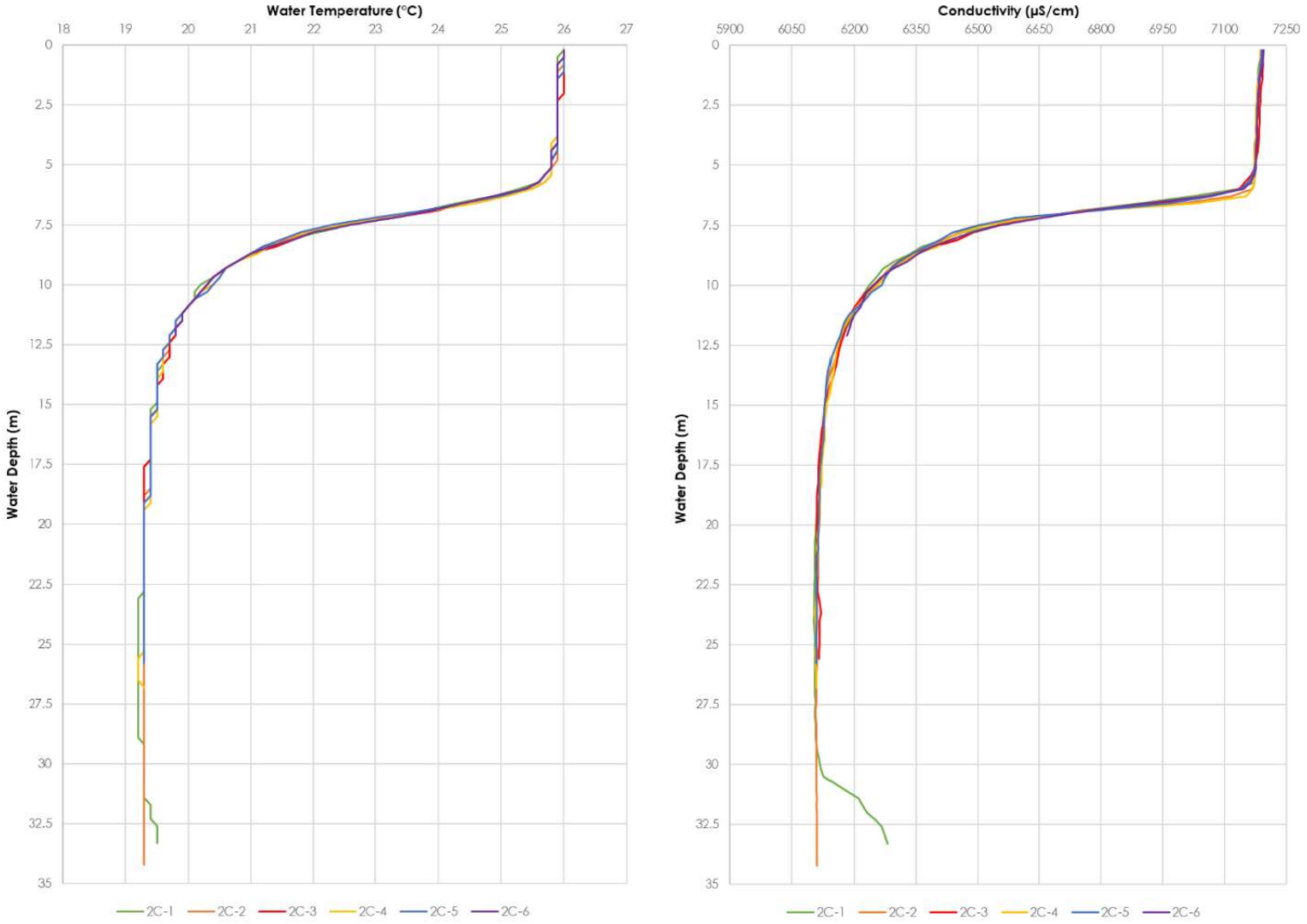


Figure 4-1. Vertical profile data for water temperature (left) and salinity (right) recorded from six locations in 2C West Pit Lake in November 2019.

Table 4-1: Water quality of 2C West Pit Lake during November 2019, compared to ANZG (2018) 95% DGVs.

Type	Parameter	n	Min.	20%ile	Median	Mean	80%ile	Max.	ANZG 95% DGV
Basic	pH-lab	25	8.32	8.408	8.45	8.458	8.52	8.55	6.0 - 8.0
	EC-lab (µs/cm)	25	6630	6674	6820	6827.6	6984	7040	900
	TDS-calc	19	4310	4320	4430	4436	4544	4580	NP
Major ions	Alk-total	25	458	481.4	494	494.36	512.8	534	NP
	Ca	25	82	91	107	107	122	128	NP
	Cl	25	1150	1158	1180	1180	1210	1220	NP
	CN	6	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	NP
	K	25	18	19	20	20	20	21	NP
	Mg	25	139	145	158	154	162	166	NP
	Na	25	1230	1278	1370	1355	1432	1460	NP
	SO4	25	1420	1440	1480	1526	1610	1710	NP
Nutrients	N Nitrate (N-NO_3)	6	0.07	0.25	0.25	0.24	0.26	0.36	0.7
	N Nitrite (N-NO_2)	6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NP
	N-NO_X	0	0.07	0.25	0.25	0.24	0.26	0.36	0.01
Metals and Metalloids	Ag	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00005
	As-total	6	0.003	0.003	0.003	0.003	0.003	0.003	0.024*
	B	6	0.28	0.31	0.42	0.39	0.42	0.5	0.37
	Ba	6	0.066	0.082	0.085	0.083	0.088	0.09	NP
	Cd	6	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
	Cr-total	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001*
	Cu	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0014
	Hg	6	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	ID
	Mn	6	0.007	0.031	0.045	0.055	0.073	0.127	1.9
	Mo	6	0.021	0.022	0.0235	0.023	0.024	0.024	ID
	Ni	6	0.002	0.003	0.003	0.003	0.004	0.004	0.011
	Pb	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0034
	Sb	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NP
	Se-total **B**	6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.005

*Note: yellow shading indicates spot exceedance of respective DGV; **B** denotes potentially bioaccumulating toxicant, compared against 99% DGV in accordance with ANZG (2018).*

4.1.2 Do Nothing Closure Scenario

Under the Do Nothing Closure Scenario, with no active mitigation to manage evapoconcentration effects in 2C West Pit Lake post closure, water levels and quality will change over time as follows:

- Water level in the pit will decline steadily, only reaching partial equilibrium at approximately year 70 (**Figure 4-2**). Predicted final void water level elevation is approximately RL 32 m and RL 30 m for low and high evaporation cases, respectively. This represents a decline in water level up to 28 m post closure. At this point, the pit acts as a strong sink for groundwater and surface water runoff from the surrounding catchment (KCB 2020).
- Evapoconcentration will result in a near linear increase in salinity post closure, with TDS concentration at year 100 representing close to a five-fold increase (**Figure 4-2**). Predicted mean TDS concentration is approximately 22,500 mg/L and 24,000 mg/L for low and high evaporation cases, respectively. Final void salinity would be classified as mesosaline by Hammer (1986).

4.1.3 Preferred Closure Scenario

Under the Preferred Closure Scenario, with the implementation of two strategies to mitigate water levels and quality; the provision of additional external catchment (approximately 1,000 ha) and constant pumping (7 L/s) out of void water to manage evapoconcentration effects post closure, water levels and quality will change over time as follows:

- Water level decline in the pit will be variable, between the low- and high-evaporation cases (**Figure 4-3**).
- For the low evaporation case, water level in the pit will decline gradually reaching partial equilibrium at approximately year 20, until year 40 where a more rapid decline is observed until approximately year 70. Water level will continue to decline gradually reaching another partial equilibrium at approximately year 85 onwards. Predicted final void water level elevation is approximately RL 37 m.
- For the high evaporation case, water level in the pit will decline more rapidly, although will reach partial equilibrium at approximately year 20. Although a slight decline in water level will be observed around year 70, predicted final void water level elevation will be relatively stable, at approximately RL 40 m.
- Evapoconcentration has a negligible influence on salinity post closure, with predicted mean TDS concentrations relatively stable, increasing to approximately 5000 to 6000 mg/L under low and high evaporation cases, respectively. It should be noted that for the high evaporation case, there will be a degree of variability in predicted TDS levels, with the 95%ile occasionally exceeding 7000 mg/L from approximately year 85 onwards. Final void salinity will be classified as hyposaline (Hammer 1986).
- Geochemical modelling outputs (**Table 4-2**) over the modelled salinity range (4585 to 8015 mg/L) indicate:
    - The pH will be circumneutral (7.66) to alkaline (8.46). The maximum predicted pH (8.46) exceeds the ANZG 95% DGV.
    - Void water has good buffering capacity with total-alkalinity (as $CaCO_3$) ranging from 472 to 605 mg/L.
    - Nitrogen nutrients in the form of nitrate levels are low.
    - Dissolved metal concentrations remain low, however, there is potential for boron (mean 0.52 mg/L) and selenium levels (mean 0.006 mg/L) to exceed their respective ANZG (2018) 95% (0.37 mg/L) and 99%[1] DGVs (0.005 mg/L).

[1] The 99% protection level is recommended for bioaccumulating toxicants such as selenium (ANZG 2018).

Table 4-2: Predicted dissolved metal and nutrient concentrations of 2C West Pit Lake post closure, compared to ANZG (2018) DGVs.

Type	Parameter	n	Min.	20%ile	Median	Mean	80%ile	Max.	ANZG 95% DGV
Basic	pH-lab	59	7.66	7.69	7.71	7.78	7.74	8.46	6.0 - 8.0
	TDS-calc	59	4586	5011	5877	5985	6981	8015	NP
Major ions	Alk-total	59	472	502	530	535	565	605	NP
	Ca	59	87	92	101	100	107	129	NP
	Cl	59	1156	1281	1514	1555	1827	2129	NP
	K	59	18	21	25	25	30	36	NP
	Mg	59	140	163	193	198	229	275	NP
	Na	59	1236	1438	1702	1754	2091	2525	NP
	SO4	59	1447	1676	1977	2029	2406	2868	NP
Nutrients	N Nitrate N-NO_3	59	0.000	0.0003	0.0003	0.0003	0.0004	0.0006	0.7
Metals and Metalloids	As-total	59	0.003	0.003	0.004	0.004	0.005	0.005	0.024*
	B	59	0.281	0.408	0.502	0.523	0.644	0.902	0.37
	Ba	59	0.006	0.007	0.007	0.015	0.008	0.090	NP
	Cd	59	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
	Cr-total	59	0.001	0.001	0.001	0.001	0.001	0.001	0.001*
	Cu	59	0.0005	0.0005	0.0006	0.0007	0.0008	0.0009	0.0014
	Mn	59	0.00	0.01	0.05	0.06	0.09	0.23	1.9
	Mo	59	0.021	0.025	0.030	0.031	0.037	0.043	ID
	Ni	59	0.002	0.003	0.004	0.004	0.005	0.007	0.011
	Pb	59	0.0005	0.0005	0.0006	0.0007	0.0008	0.0009	0.0034
	Sb	59	0.0005	0.0005	0.0006	0.0007	0.0008	0.0009	NP
	Se-total **B**	59	0.005	0.005	0.006	0.007	0.008	0.009	0.005

*Note: yellow shading indicates spot exceedance of respective DGV; **B** denotes potentially bioaccumulating toxicant, compared against 99% DGV in accordance with ANZG (2018).*

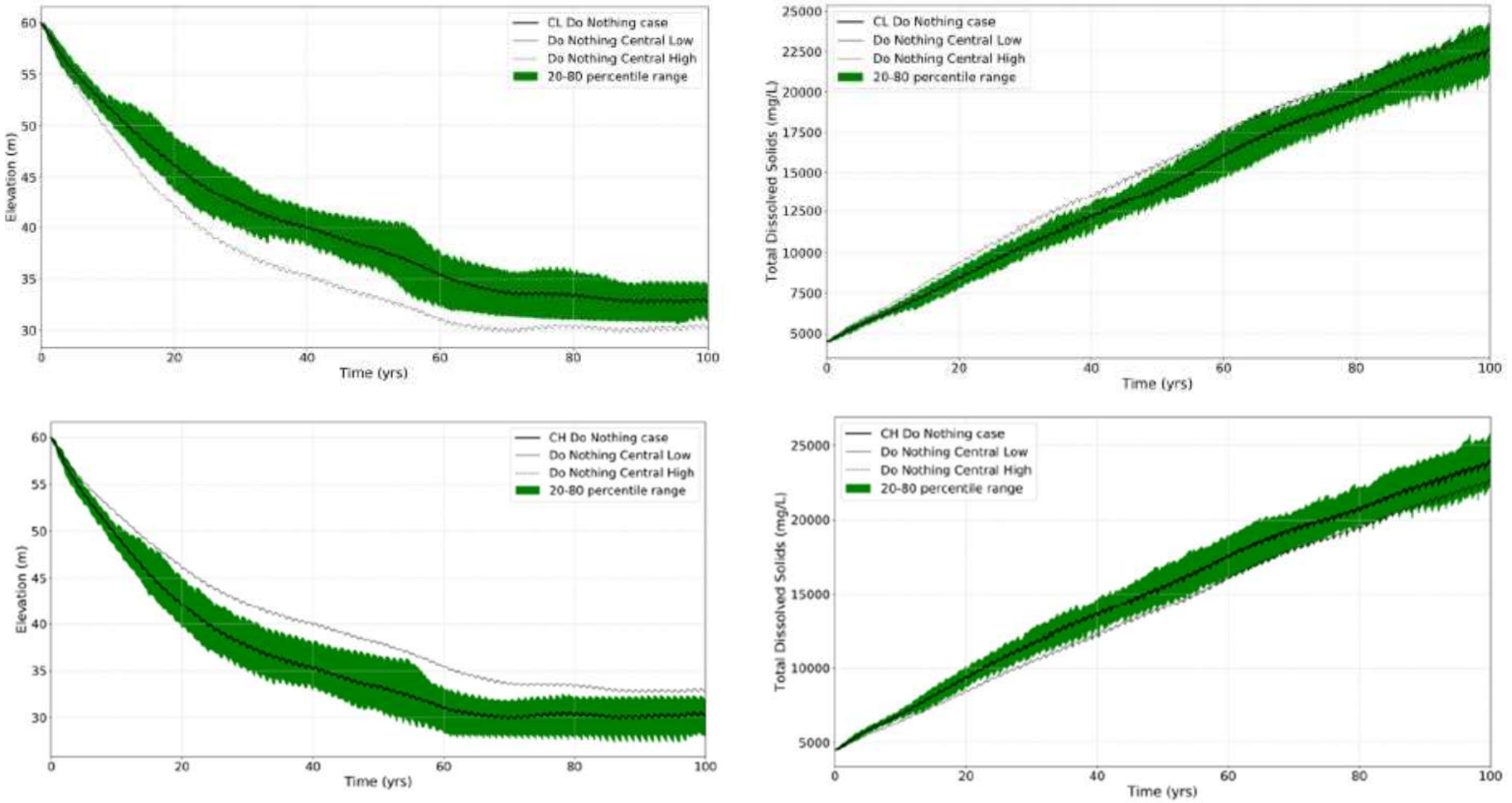


Figure 4-2. Water level elevation (left) and TDS (right) data for low (top) and high (bottom) evaporation cases for the Do Nothing Closure Scenario. Source: KCB (2020).

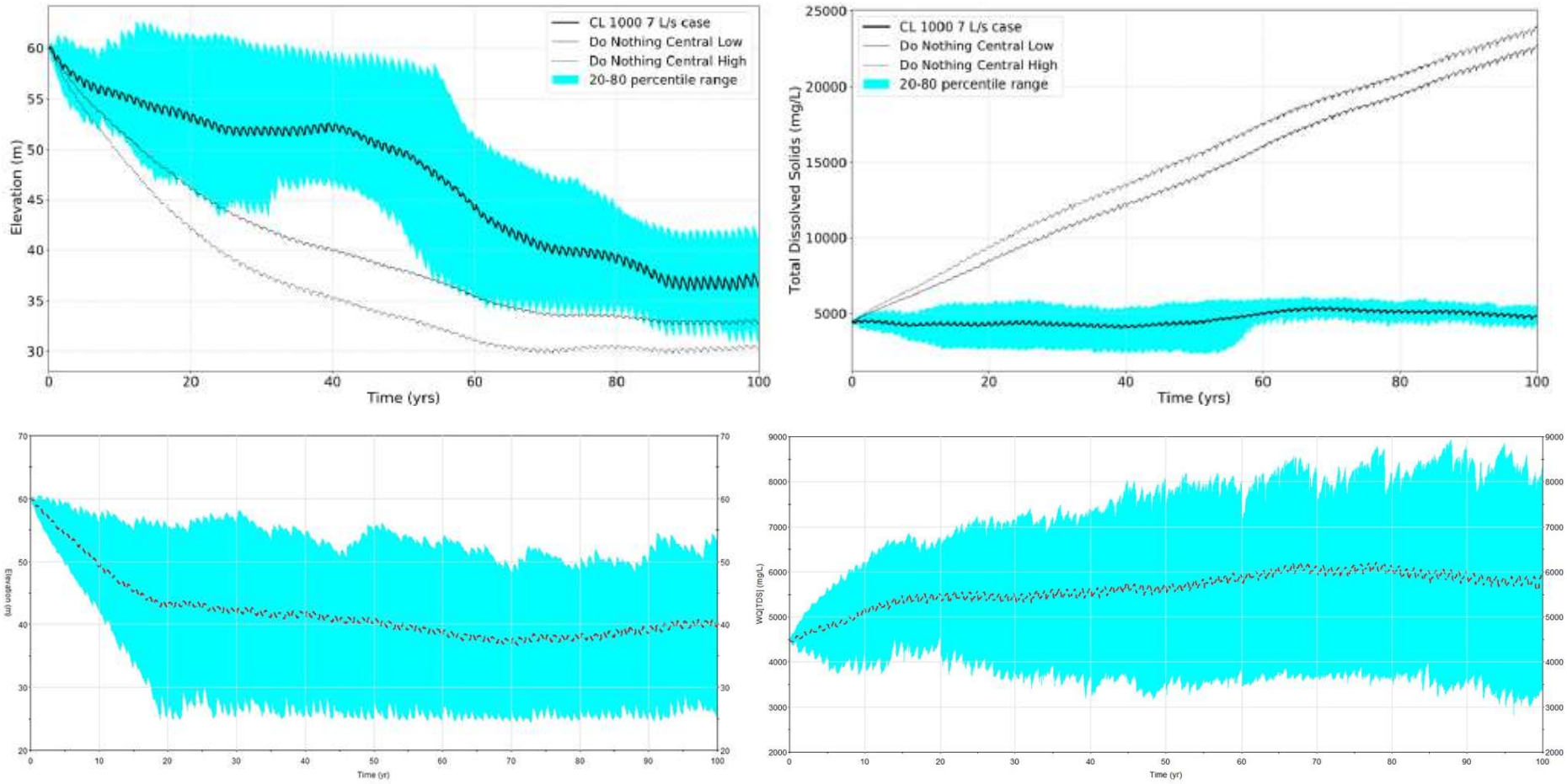


Figure 4-3. Water level elevation (left) and TDS (right) data for low (top) and high (bottom) evaporation cases for the Preferred Closure Scenario. Source: KCB (2020).

4.2 Desktop Review

According to the database searches, a single Threatened Ecological Community (TEC) is known to occur within a 50 km radius of 2C West Pit Lake, while four TECs are listed as "likely to occur" within a 50 km radius (**Table 4-3**). However, none of the TECs are considered to represent aquatic environments. In addition, no wetlands of national or international importance were listed within a 50 km radius. The Brigalow TEC known to occur within a 50 km radius, is an open forest/open woodland characterised by the high abundance of Brigalow (*Acacia harpophylla*) trees. It supports nine species of threatened flora and 17 species of threatened fauna listed at a state or Commonwealth level.

Table 4-3: Threatened Ecological Communities known or likely to occur within a 50 km radius of 2C West pit lake.

TEC	Status	Presence	Distance (km)
Brigalow (*Acacia harpophylla* dominant and codominant)	Endangered	Known to occur	< 5km
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Likely to occur	-
Poplar Box Grassy Woodland on Alluvial Plains	Endangered	Likely to occur	-
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Likely to occur	-
Weeping Myall Woodlands	Endangered	Likely to occur	-

A total of 30 taxa of state significance, including 19 birds, five mammals, three reptiles, one insect, one ray-finned fish, and one snail were identified within 50 km of the 2C West Pit Lake (**Appendix A**). Of these, 12 species are of national significance. Nine species of significance were also considered to be associated with aquatic environments (**Table 4-4**). There are also 19 introduced species known to occur within a 50 km radius of 2C West Pit Lake (**Appendix A**).

Table 4-4: Significant taxa associated with aquatic environments, within 50 km of 2C West Pit Lake.

Group	Family	Scientific Name	Common Name	NCA 1992	EPBC Act 1999
Birds	Scolopacidae	*Calidris acuminata*	Sharp-tail sandpiper	SL	
		Gallinago hardwickii	Latham's snipe	SL	
		Numenius phaeopus	Whimbrel	SL	
		Tringa glareola	Wood sandpiper	SL	
		Tringa stagnatilis	Marsh sandpiper	SL	
	Threskiornithidae	*Plegadis falcinellus*	Glossy ibis	SL	
Mammals	Ornithorhynchidae	*Ornithorhynchus anatinus*	Platypus	SL	
Ray-finned Fish	Terapontidae	*Bidyanus bidyanus*	Silver perch **T**		CE
Reptiles	Chelidae	*Rheodytes leukops*	Fitzroy River turtle	V	V

*Note: classifications as follows; CE = critically endangered, SL = species least concern, and V = vulnerable. **T** denotes native translocated species outside natural distribution*

4.2.1 Aquatic Biota

The most comprehensive surveys of aquatic biota in the vicinity of the 2C West Pit Lake have been in surrounding pit lakes and nearby natural creeklines and semi-natural dams by Baker *et al.* (2005, 2008), Proctor and Grigg (2006) and Young *et al.* (1999). Annual monitoring of habitat, surface flows, water quality, and aquatic invertebrates was also undertaken as part of the Receiving Environment Monitoring Program (REMP) for the Dawson Mine (Hydrobiology 2019).

Based on database results and review of relevant literature, a total of at least 195 aquatic biota taxa are known to occur within the Dawson River drainage sub-basin, comprising 16 algae, 14 macrophytes, 83 aquatic invertebrates, 38 fish, 33 frogs, eight freshwater turtles and three mammals (**Table 4-6**). Six species are listed as significant at the state and/or federal level (**Table 4-6**). Taxa with confirmed records from Dawson Mine pit lakes and/or nearby natural creeklines and semi-natural dams are detailed in **Sections 4.2.1.1 to 4.2.1.4.**

4.2.1.1 Primary productivity

Literature on the diversity and composition of benthic algae and macrophytes (aquatic plants) of pit lakes is limited. Studies of the structure and the dynamics of primary producers in pit lakes across the world have shown initial development of communities comprising restricted taxa tolerant to a wide range of environmental conditions, with increasing diversity of taxa as more favourable water quality conditions establish (Axler *et al.* 1998, Kalin *et al.* 2001, Kalin *et al.* 2006).

Database search results for the Dawson River drainage sub-basin indicated at least 16 primary producers are known to occur, including:

- Blue green algae (*Aphanothece stagnina*, *Limnothrix vacuolifera*, *Schizothrix calcicole*, *Scytonema hofman-bangii*, *Stigonema hormoides* and *Stigonema multipartitum*), some species of which are known to contain toxic forms.
- Green algae (*Klebsormidium flaccidum*, *Klebsormidium flaccidum*, *Spirogyra communis*, *Uronema confervicola*, *Zygnema cruciatum* and *Zygogonium ericetorum*), common in slow moving waters.
- Charophytes (*Chara* sp., *Chara evanida*, *Nitella* sp., and *Nitella pseudoflabellata*), also considered macrophytes due to their size and submerged growth habit.

A review of aquatic biota studies which report macrophyte communities in pit lakes associated with Dawson Mine and/or nearby natural creeklines and semi-natural dams indicated the following:

- Few truly aquatic plants were observed in pit lakes by Proctor & Grigg (2006). The greatest diversity occurred at Kianga Creek sites, which supported the native waterlily (*Nymphaea violacea*), curly pondweed (*Potamogeton crispus),* water snowflake (*Nymphoides* sp.) and sedges (*Cyperus* sp.).
- Similar to observations by Young et al. (1999), Area 9 Dam had a thick submerged carpet of Sago pondweed (*Potamogeton pectinatus*) and was fringed with bulrush (*Typha orientalis*). Water bodies within Pits 2D, 9E and 12E contained the truly aquatic stonewort (*Nitella* sp.). In addition, most pit lakes contained submerged pasture grasses including rhodes grass (*Chloris gayana*), red natural grass (*Melinis repens*), buffel grass (*Cenchrus ciliaris*) and forage sorghum (*Sorghum bicolor*).
- Young *et al.* (1999) recorded sago pondweed (*Potamogeten pectinatus*) in some mining pits, with the emergent macrophyte bulrush (*Typha orientalis*) recorded at a dammed ephemeral watercourse (Area 9 Dam).
- The most recent annual REMP at Dawson Mine (Hydrobiology 2019) identified 11 aquatic macrophytes (emergent, floating and submerged native and exotic species) in nearby tributary and riverine sites including duckweed (*Lemna* sp.), knotweed (*Persicaria* sp.), mat-rush (*Lomandra longifolia*), para grass (*Urochloa mutica*), rushes (*Juncus* sp.), sedges (*Cyperus* sp., *Eleocharis* sp.), water snowflake (*Nymphoides indica*), water fern (*Azolla* sp.), water primrose (*Ludwigia peploides*), and the water lily (*Nymphaea* sp.).

4.2.1.2 Aquatic invertebrates

Database search results for the Dawson River drainage sub-basin indicate 25 macroinvertebrate taxa comprising 11 families are known to occur (**Appendix A**). The majority of records are either damselflies or dragonflies (Order: Odonata) representing adult flying stages, however, the common yabby (*Cherax destructor*) has also been recorded.

A review of aquatic biota studies which report aquatic invertebrate communities in pit lakes associated with Dawson Mine and/or nearby natural creeklines and semi-natural dams indicated the following:

- Proctor & Grigg (2006) recorded 58 macroinvertebrate families across eleven pit lakes at Dawson Mine and three natural creekline and/or semi-natural dam sites in December 1998 and April 1999. Insecta dominated the overall aquatic invertebrate community, with Coleoptera (aquatic beetles), Diptera (two-winged or "true" fly larvae), Hemiptera (true bugs), Odonata (dragonflies and damselflies), and Trichoptera (caddisflies) the most prominent Orders. Several groups of crustaceans were also collected, including Cladocera (water fleas), Copepoda, and Decapoda (freshwater crayfish, shrimps and prawns) and recorded in high abundance at pit lakes.
- Family-level richness of many of the final void waterbodies approached or even exceeded that of natural creekline and/or semi-natural dam sites in the surrounding landscape (**Table 4-5**). There was a weak relationship reported between salinity and taxa richness, however SIGNAL grades (Chessman 2003) indicated that resident aquatic invertebrates are relatively resilient to local conditions, and possibly more tolerant of poor conditions than most members of their orders. Multivariate analysis of invertebrate assemblages indicated natural sites were not distinct from mining voids. However, some voids lacked representatives of major invertebrate groups (i.e. insects, mites and molluscs), with a strong dominance of macrocrustaceans.
- Baker *et al.* (2005) recorded two macrocrustaceans from two pit lakes associated with Dawson Mine and a semi-natural dam site, including the freshwater shrimp (*Atyidae spp.*) and freshwater prawn (*Macrobrachium* sp.). Although no records exist, Baker *et al.* (2008) suggests there is anecdotal evidence for the presence of two freshwater crayfish in Dawson Mine pit lakes including the common yabby (*Cherax destructor*) and redclaw crayfish (*Cherax quadricarinatus*).
- The most recent annual REMP at Dawson Mine (Hydrobiology 2019) identified at least 42 macroinvertebrate taxa across tributary and river sites in the receiving environment. Insecta dominated the overall aquatic invertebrate community, with Coleoptera (Dytiscidae, Hydrophilidae and Spercheidae), Diptera (Chironominae and Tanypodinae), Hemiptera (Micronectidae), and Odonata (Coenagrionidae and Libellulidae) the most prominent Orders. Sites which generally exhibited higher salinity levels were dominated by aquatic beetles (Coleoptera), copepods (Copepoda) and seed shrimp (Ostracoda).

Table 4-5: Total abundance and family level richness of aquatic invertebrates collected at Dawson Mine pit lakes and surrounding natural creeklines or semi-natural dams in December 1998 and April 1999. Source: reproduced from Proctor & Grigg (2006).

Site	Dec 1998 survey		April 1999 survey	
	Total no.	No. families	Total no.	No. families
Pit 11A	291	7	441	13
Pit 15DU	724	17	1262	25
No.1 underground	1392	18	959	16
Pit 2CD	917	18	1003	23
Pit 14DU	264	14	849	22
Pit 2D	1223	22	1177	26
Pit 12E	498	18	601	20
Pit 17DU	490	20	n.a.	n.a.
Pit 6E	635	18	819	25
Pit 9C	339	12	388	14
Pit 9E	965	17	702	22
Area 9 Dam	793	22	1655	29
Kianga Weir	1020	24	947	25
Kianga Crossing	910	23	1311	26
Total	10461		12114	

Note: n.a. denotes not available.

4.2.1.3 Freshwater fish

Database search results for the Dawson River drainage sub-basin indicated 38 species of fish, comprising 21 families, are known to occur (**Appendix A**). Of these, 35 species have a natural distribution in Queensland, or the east coast of Australia, while three are introduced exotic species. The most diverse families of fish included gudgeons (Eleotridae, nine species), grunters (Terapontidae, five species) and eel tailed catfish (Plotosidae, three species). Silver perch (*Bidyanus bidyanus*) is listed as critically endangered at the Commonwealth level, however, represents a translocated native species outside its natural distribution (**Table 4-5**, **Appendix A**). Other native translocated species include golden perch (*Macquaria ambigua*), firetail gudgeon (*Hypseleotris galii*) and the southern saratoga (*Scleropages leichardti*).

Platten (2011) provides a summary of 16 native fish species recorded from the Dawson River and the probability of occurrence as part of deriving fish water quality guidelines for Fitzroy Basin Freshwaters. Three species were recorded in all sampling events, carp gudgeons (*Hypseleotris* spp.), golden perch (*Macquaria ambigua oriens*) and the freshwater catfish (*Tandanus tandanus*). Other common native species (>50% occurrence) included bony bream (*Nematalosa erebi*), blue-eye (*Psuedomugil signifer*), eastern rainbowfish (*Melanotaenia splendida*), glassfish (*Ambassis agassizii*) and spangled perch (*Leiopotherapon unicolor*). Three exotic species were recorded infrequently including goldfish (*Carasius auratus*), guppy (*Poecillia reticulate*), and mosquitofish (*Gambusia holbrooki*).

A review of aquatic biota studies which report freshwater fish communities in pit lakes associated with Dawson Mine and/or nearby natural creeklines and semi-natural dams indicated the following:

- Young et al. (1999) undertook a survey of nine pit lakes at Dawson Mine and three natural creekline and/or semi-natural dam sites in December 1998 and April 1999. A total of at least six native fish species were recorded including bony bream (*Nematalosa erebi*), carp gudgeon (*Hypseleotris* spp.), eastern rainbowfish (*Melanotaenia splendida*), glassfish (*Ambassis agassizi*), fly-specked hardyhead (*Craterocephalus stercusmuscarum stercusmuscarum*) and spangled perch (*Leiopotherapon unicolor*).

- It was noted that several species of gudgeon likely occur (i.e. *H. compressa, H. galii* and *H. klunzingeri*), however, these species are difficult to rapidly separate under field conditions, therefore convention was to refer to the genus group. Spangled perch were the most dominant native species, with no exotic recorded. Taxa richness were highest for natural creekline sites (six species), however three mining voids and one semi-natural dam recorded five species. No fish were recorded from three voids.

- Baker et al. (2005, 2008) identified six fish species from targeted sampling of two mining voids (13B and 16DS) and a semi-natural dam including the crimson spotted rainbowfish (*Melanotaenia duboulayi*), eastern rainbowfish (*Melanotaenia splendida*) firetail gudgeon (*Hypseleotris galli*), fly-specked hardyhead (*Craterocephalus stercusmuscarum stercusmuscarum*), western carp gudgeon (*Hypseleotris klunzingeri*) and spangled perch (*Leiopotherapon unicolor*). The western carp gudgeon was the most dominant species recorded.

4.2.1.4 Other vertebrate fauna

Database search results for the Dawson River drainage sub-basin indicated 33 species of frog, eight species of turtle (Chelidae), and three mammals, the swamp rat (*Rattus lutrelous*), water rat (*Hydromys chrysogaster*) and platypus (*Ornithorhynchus anatinus*) are known to occur (**Appendix A**). Four of these taxa are listed under state or Commonwealth legislation (**Table 4-6**).

A review of aquatic biota studies which report other vertebrate fauna in pit lakes associated with Dawson Mine and/or nearby natural creeklines and semi-natural dams indicated the following:

- Baker *et al.* (2008) observed ten frog species noting species richness was low and likely to represent an underestimate given the dry conditions at the time of sampling. The assemblage comprised five tree frogs (Hylidae) and four southern frogs (Myobatrachidae) and the introduced Cane Toad (*Bufo marinus*), which is considered widely distributed throughout the post-mining landscape.

- Baker *et al.* (2005, 2008) recorded two freshwater turtles from two mining voids, Krefft's river turtle (*Emydura krefftii*) and the eastern long-necked tortoise (*Chelodina longicollis*). The former species appears common, with 27 individuals recorded from mining voids.

• 16 taxa	• 14 taxa • Visual observations of periphyton and filamentous algae	• Four invasive pasture grasses. • Visual observations of floating and benthic algal mats	None	-	-
• 25 taxa comprising 11 families	• At least 58 taxa comprising mainly Insecta. • Anecdotal evidence of redclaw crayfish and common yabby	• At least 26 taxa dominated by micro- and macro-crustacea • Anecdotal evidence of redclaw crayfish and common yabby	None	-	-
• 38 taxa comprising 21 families	• At least 16 taxa	• At least eight taxa	Silver perch (*Bidyanus bidyanus)*	-	Critically Endangered
• 44 taxa comprising 33 frogs, eight turtles and three mammals	• 12 taxa comprising 10 frog species and two freshwater turtles		Kroombit treefrog (Litoria kroombitensis)	Endangered	Critically Endangered
			Kroombit tinkerfrog (Taudactylus pleione)	Endangered	Critically Endangered
			Tusked frog (*Adelotus brevis*)	Vulnerable	-
			Southern snapping turtle (Elseya albagula)	Endangered	Critically Endangered
			Fitzroy River turtle (Rheodytes leukops)	Vulnerable	Vulnerable

4.2.2 Salinity Tolerances of Aquatic Biota

The majority of aquatic biota known to occur in the dry tropics of central Queensland, particularly those taxa with potential to colonise 2C West Pit Lake are considered vulnerable to increasing salinity. While representatives of benthic algae, macrophytes and aquatic invertebrates are tolerant of hypersaline conditions in temporary wetlands across Australia (i.e. salt lakes), representatives of these groups known to occur in the vicinity of the 2C West Pit Lake are considered stenohaline, adapted to freshwater and brackish environments. However, many of the known native freshwater fish species are considered euryhaline, adapted to a wide range of salinities. The greater salinity tolerance of euryhaline fishes represents a number of species are diadromous, and require elevated salinity to complete a part of their life cycle.

Information on the environmental tolerance literature reviewed included two types of data for assessing risk to aquatic biota. These were data from laboratory experiments (72-h LC_{50} acute lethal tolerance values), where available, and upper salinity tolerance limits taxa have been recorded.

Aquatic invertebrate salinity tolerance information were compiled from numerous aquatic ecotoxicity studies within the dry tropics of central Queensland (**Table 3-3**). The majority of available information related to macroinvertebrate 72-h LC_{50} acute lethal tolerance values at the family-level. Although this information was limited for primary producers, freshwater fish and other vertebrate fauna known, or likely to occur in 2C West Pit Lake. Therefore, upper salinity tolerance limits taxa were used to determine likelihood of sustaining populations under each closure scenario.

Based on the review of relevant literature, a summary of salinity tolerances and likely aquatic biota taxa supported under the existing void condition, and predicted water quality under each closure scenario is provided in **Table 4-8** and detailed in **Sections 4.2.2.1** to **4.2.2.4.**

4.2.2.1 Primary producers

For primary producers, including algae and macrophytes, there is limited publicly available data for environmental tolerances in the dry tropics of central Queensland (Nielson et Brock 2003). Within Australia, the majority of algae do not appear to be tolerant of increasing salinity (Hart et al. 1991), with only a few taxa able to withstand salinities greater than 10,000 mg/L (Bailey and James 2000). As salinity increases, algal species diversity decreases. However, some species, such as the green alga *Dunaliella salina*, are able to withstand a broad range of salinities due to morphological and physiological adaptations, including the ability to produce salt resistant cysts (Borowitska 1981).

Similarly, the upper tolerance limit of most freshwater plants is approximately 4,000 mg/L (Nielson Brock *et al* 2003). At salinities above 1,000 mg/L, reduced growth rates and development of roots and leaves occur, with both sexual and asexual reproduction suppressed (James and hart 1993; Warwick and Bailey 1997). Salinity also has a significant impact on the germination of seeds. Even salt tolerant species such as *Ruppia megacarpa* has shown reduced reproduction at high salinity (Brock 1982).

A review of upper salinity tolerance limits for macrophyte communities in pit lakes associated with Dawson Mine and/or nearby natural creeklines and semi-natural dams indicated the following:

- *Typha* sp. observed in Pit 9E were found in a salinity of up to 1,315 mg/L.
- *Potamogeton* sp. was observed in Pit 17DU at salinities of 1,200 mg/L, while Sago Pondweed (*P. tricarinatus*) was found to be an extremely hardy species tolerant of salinities up to 15,000 mg/L (Sainty and Jacobs 1994).
- The charophyte Stonewort (*Nitella pseudoflabellata*) was found in multiple pits in salinities of up to 3,685 mg/L.

4.2.2.2 Aquatic Invertebrates

For aquatic invertebrates, salinity tolerance information was compiled for 25 taxa, comprising 19 families from the dry tropics of central Queensland. While most studies were undertaken on lotic (i.e. flowing) systems, they were considered most relevant to represent local taxa tolerances to ambient conditions.

Salinity 72-h LC_{50} values ranged from 3,410 mg/L to 24,750 mg/L, with a mean concentration of 11,500 mg/L (**Figure 4-4**). The most sensitive taxa (lowest salinity tolerance) included mayflies (Baetidae and Leptophlebiidae), water flea (Cladocera), water boatman (Corixidae), backswimmers(Notonectidae) and the introduced aquatic snail *Physa acuta* (Physidae). The most tolerant taxa included aquatic beetles (Dytiscidae, Hydrochidae), macrocrustaceans including shrimp (Atyidae), prawns (Palaemonidae) and crayfish (Parastacidae).

More broadly across Australia, several studies into the salinity tolerance of freshwater aquatic invertebrates found:

- Kefford *et al.* (2003) reported the mean salinity tolerance of 57 macroinvertebrates collected from the Barwon River, Victoria was 31,000 µs/cm (~17,000 mg/L), with macrocrustaceans (Decapoda, Isopoda and Amphipoda) ranging from 38,000 to 76,000 µs/cm (~21,000 to 42,000 mg/L).
- Hart et al. (1990, 1991) suggested salt sensitive aquatic invertebrates are deliriously affected when salinities exceed 1,000 mg/L, and significant adverse biological effects would occur when salinities exceeded 7,000 mg/L. While true for some saline sensitive taxa, several studies more broadly across Australia, indicate the majority of aquatic invertebrates likely show little response to salinities ≤10,000 mg/L (Williams et al. 1991, Bunn and Davies 1992, Mitchell and Richards 1992).
- Nielsen *et al.* (2003) suggested that substantial changes in wetland macroinvertebrate biodiversity did not occur until salinities exceeded 10,000 mg/L.
- Pinder *et al.* (2005) found that in wetlands of the Western Australian wheatbelt, total macroinvertebrate species richness showed no response below salinities of 4,100 mg/L, however decreased rapidly as salinity increased above this level, with approximately 50% loss of species above 10,000 mg/L.
- Kefford *et al.* (2005) reviewed the salt sensitivity database (Bailey *et al.* 2002) against maximum salinities which species are observed in the field (MFD), reporting a salinity threshold of 10,000 mg/L exceeds the minimum, mean and maximum tolerance of 42%, 51% and 62% of 125 macroinvertebrate families, respectively.

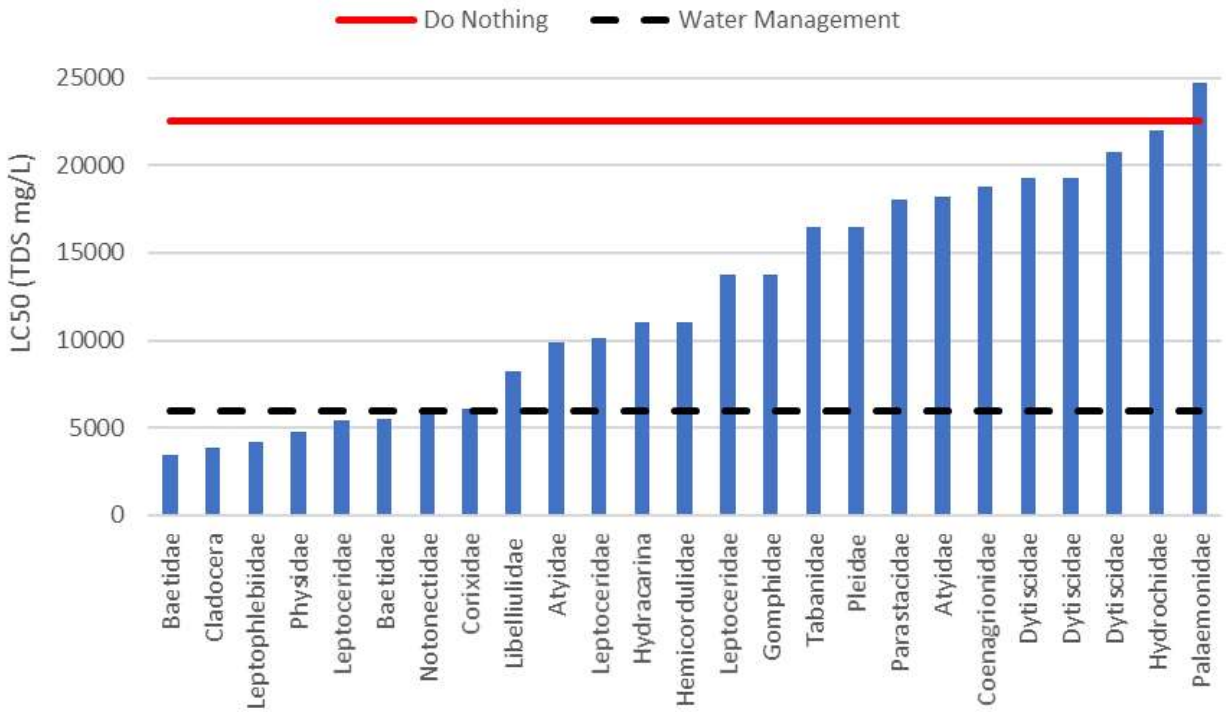


Figure 4-4. Salinity 72-h LC_{50} values for 25 aquatic invertebrate taxa known to occur in the dry tropics of inland Central Queensland.

A review of upper salinity tolerance limits which report aquatic invertebrate communities of pit lakes associated with Dawson Mine and/or natural rivers of the Fitzroy River drainage basin indicated the following:

- Within the Isaac River drainage sub-basin, Stitz (2013) reported no statistical difference in macroinvertebrate richness between sites of differing salinity, ranging from 477 µS/cm to 9791 µS/cm across 39 families. Assemblage composition were dominated by Dipterans, as well as the traditionally more pollution-sensitive families Ephemeroptera and Trichoptera. Stitz (2013) suggested that macroinvertebrate taxa richness occurs independently of salinity up to approximately 5,400 mg/L, at least in this particular cohort of mining and/or grazing influenced ephemeral systems in central Queensland.

- Proctor & Grigg (2006) reported comparable family-level macroinvertebrate richness across eleven pit lakes of the Dawson Mine and nearby natural creeklines and semi-natural dams (**Table 4-5**). This suggests that macroinvertebrate taxa richness occurs independently of salinity up to approximately 3,800 mg/L. However, Proctor & Grigg (2006) suggested the strong dominance of mine pits by macrocrustaceans (i.e. 80–90% crustaceans in Pit11A) indicated an 'unbalanced' assemblage in which the food or habitat resources are too restricted to support a wide array of different types of animals. This suggests habitat availability is a key limiting factor to a diverse assemblage composition of mine voids.

4.2.2.3 Freshwater Fish

For freshwater fish, a summary of the range in upper salinity tolerance limits for 21 species, comprising 12 families is provided in **Table 4-7**, where available. This comprises species with populations known to occur in the Dawson River and associated tributaries, pit lakes associated with the Dawson Mine, or those species considered suitable for commercial stocking. Information were compiled from a range of available literature (Allen *et al.* 2002, Pusey *et al.* 2004, McDowall 1996, Merrick & Schmida 1984). The most tolerant freshwater fish are either diadromous species which migrate between freshwater and estuarine habitats to complete their life cycle, or hardy potamodromous species that complete their lifecycle wholly in freshwater. Tolerant species include Australian bass (*Macquaria novemaculeata*), barramundi (*Lates calcarifer*), golden perch (*Macquaria ambigua oriens*) and spangled perch (*Leiopotherapon unicolor*). In addition, silver perch (*Bidyanus bidyanus*) a commonly stocked freshwater fish is also considered saline-tolerant.

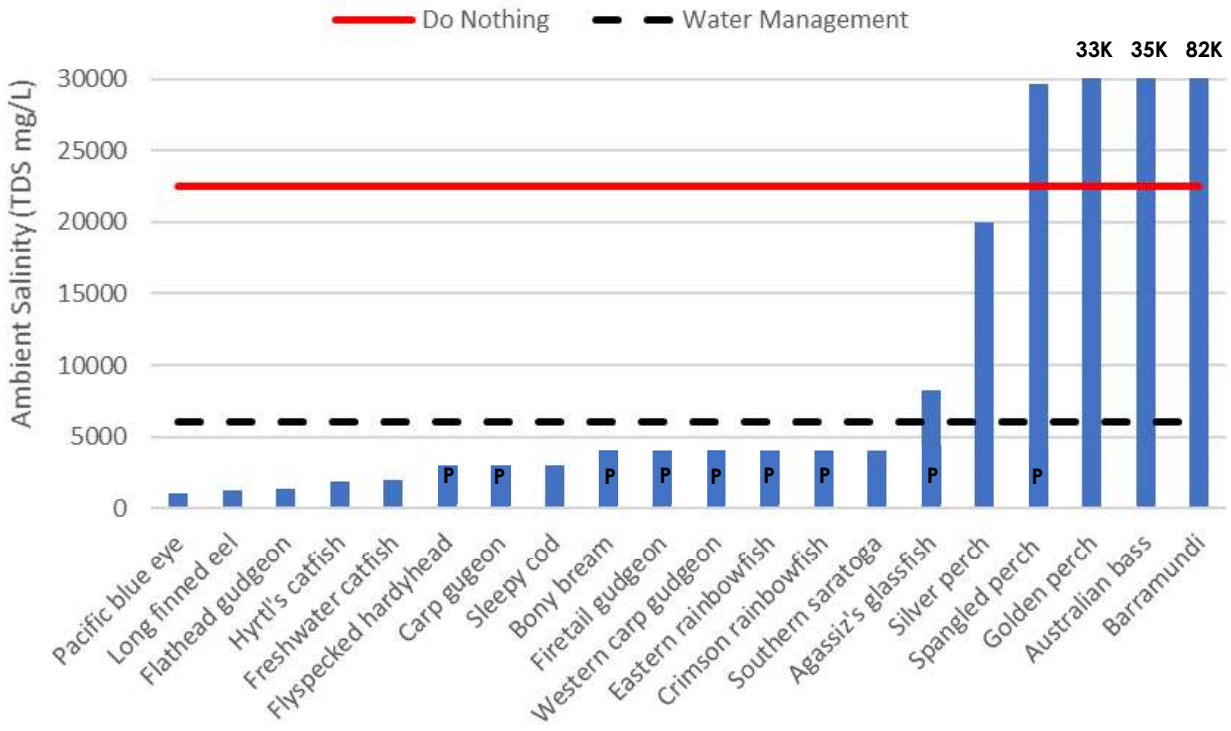


Figure 4-5. Upper salinity tolerance limits for 16 freshwater fish known to occur in the Dawson River. Those species present in Dawson Mine pit lakes are denoted P.

Recent investigations into the suitability of the Dawson Mine void water quality to support commercial aquaculture and/or recreational fish stocking as a relinquishment option indicated:

- A desktop study by Whisson & Evans (2003) on fish fauna in existing mine voids of Dawson Mine indicated that some lakes would be suitable for commercial aquaculture and/or recreational fish stocking. However, further monitoring was recommended to characterise seasonal changes in environmental conditions and presence of heavy metals or other pollutants (i.e. nutrients).
- Bioassay trials by Dutney *et al.* (2008) demonstrated that silver perch (*Bidyanus bidyanus*) survive and grow well in raw mine void water, and barramundi (*Lates calcarifer*) can be grown without compromise in potassium treated mine void water.

uilla reinhardtii	Long finned eel	yes			8.4 - 31.7	0.3 - 16.2	5.6 - 9.1	1,235	0.4 - 331
terocephalus stercusmuscarum	Flyspecked hardyhead	yes			22.0 - 28.0	4.8 - 11.0	7.3 - 8.2	2,960	5 - 190
es calcarifer	Barramundi			yes	15.5 - 36	1.0 - 7.6	4.0 - 9.1	82,500	NA
natalosa erebi	Bony bream	yes	yes		24 - 29	4.0 - 12.0	6.66 - 8.46	4,000	0.3 - 20
seleotris sp.	Carp gugeon	yes			11.7 - 31.0	1.7 - 11.3	4.4 - 9.1	29,60	0.2 - 144
seleotris galii	Firetail gudgeon		yes		NA	NA	NA	4,000	NA
seleotris klunzingeri	Western carp gudgeon	yes	yes		8.4 - 31.7	0.6 - 12.8	4.8 - 9.1	4,000	0.5 - 65
eleotris lineolatus	Sleepy cod	yes			24.0 - 27.5	4.6 - 8.0	7.0 - 7.4	29,60	5 - 190
ypnodon grandiceps	Flathead gudgeon	yes			1.0 - 31.0	2.6 - 12.0	6.0 - 8.6	1,375	0.7 - 36
anotaenia splendida	Eastern rainbowfish	yes	yes		15.0 - 32.5	1.1 - 10.8	6.8 - 8.4	4,000	0.6 - 16.0
anotaenia doublayi	Crimson spotted rainbowfish		yes		8.4 - 31.7	0.6 - 19.5	4.4 - 9.1	4,000	0.3 -250
ropages leichardti	Southern saratoga	yes		yes	22.5 - 40.0	3.6 - 8.3	7.2 - 8.3	4,000	NA
cquaria ambigua oriens	Golden perch	yes		yes	24 - 31	3.6 - 10.0	7.2 - 8.8	33,000	0.3 -250
cquaria novemaculeata	Australian bass			yes	15.8 - 26.1	5.5 - 9.3	6.3 - 8.1	35,000	3.0 - 9.1
silurus hyrtlii	Hyrtl's catfish	yes			12.8 - 32.2	5.2 - 11.4	7.0 - 8.67	1,855	1.5 - 15
danus tandanus	Freshwater catfish	yes			8.4 - 33.6	0.3 - 17.1	4.8 - 9.1	1,969	0.2 - 250
udomugil signifer	Pacific blue eye	yes			8.4 - 31.7	3.6 - 12.3	6.0 - 9.1	1,045	0.3 - 144
anus bidyanus	Silver perch			yes	12.0 - 35.0	NA	6.0 - 10.0	20,000	NA
potherapon unicolor	Spangled perch	yes	yes		7.3 - 37.5	≥ 0.4	4 - 8.6	29,700	1.5 - 260
rtum hillii	Leathery grunter	yes			NA	NA	NA	NA	NA

ailable

4.2.2.4 Other vertebrate fauna

Of those other vertebrate fauna known to occur in the Dawson River drainage sub-basin, confirmed records in pit lakes of Dawson Mine and/or nearby riverine and creekline sites exist for only frogs and freshwater turtles. Other vertebrate fauna database records for swamp rats, water rats and platypus are considered unlikely to utilise mining voids and were not considered.

A review of upper salinity tolerance limits for freshwater frogs and turtles known or with potential to occur in 2C West Pit Lake indicated the following:

- In general, frogs, in both their adult and larval (tadpole) form, are known to be susceptible to high salinity, primarily due to their soft, permeable skin and poor osmoregulatory capabilities (Kearney *et al.* 2012).
- Ten frog species have previously been recorded in the vicinity of Dawson mine pit lakes (Baker *et al.* 2005, 2008), which suggests the recorded salinities of approximately 4,000 mg/L TDS may not be limiting to frogs.
- Kearney *et al.* (2012) studied the salinity tolerance of three common Australian frog species, including the spotted marsh frog (*Limnodynastes tasmaniensis*) known to occur in the Dawson River sub-basin reporting elevated salinity (16% that of seawater, approximately 5,600 mg/L TDS) had a negative impact on survival.
- Wild tadpoles of the introduced cane toad (*Bufo marinus*) have been observed in salinities exceeding 27,500 mg/L TDS (de-Leon and Castillo 2015). However, laboratory studies have shown limited adult survival at 14,000 mg/L, with 100% mortality at around 17,500 mg/L (Liggins and Grigg 1985).
- Freshwater turtles are also known to be relatively sensitive to high salinities, with many species known to lose body weight and eventually perish when exposed to brackish conditions over extended periods (Bower *et al.* 2016).
- Baker *et al.* (2005, 2008) recorded two freshwater turtles from two mining voids, Krefft's river turtle (*Emydura krefftii*) and the eastern long-necked tortoise (*Chelodina longicollis*), suggesting these species can tolerate salinities of approximately 4,000 mg/L.
- Bower *et al.* (2016) conducted a salinity tolerance study on two similar species, *Emydura macquarii* and *Chelodina expansa,* finding that both could survive for over 50 days in salinities approximating 15% that of seawater (approx. 5,250 mg/L TDS), with reduced feeding activity and significant increases in bodily sodium, chloride and uric acid. These results suggested both species have metabolic and physiological mechanisms enabling survival in saline environments (Bower *et al.* 2016). However, uncertainty remains over whether these mechanisms would enable survival over extended periods (Bower *et al.* 2016).
- Agha *et al*. (2020) suggest that, despite some freshwater turtle species being able to tolerate brackish salinities for short periods, many species rapidly lose body mass and even face mortality within seven days when exposed to concentrations over 17,000 mg/L.

• Majority taxa adversely affected >1,00 mg/L • Threshold ~ 10,000 mg/L	• Existing salinity level within known threshold for majority of primary producers • Low diversity expected	• primary producers. • Only the most tolerant taxa (i.e. sago pondweed) may persist • Low diversity expected	• producers • Moderate diversity expected, provide sufficient habitat and food resource availability.
• 72-h LC_{50} range 3,410 mg/L to 24,750 mg/L, mean 11,500 mg/L • Threshold ~ 10,000 mg/L	• Existing salinity level within known threshold for the majority of aquatic invertebrates, except for some sensitive (i.e. EPT) taxa • Low diversity expected	• Predicted salinity level exceeds known threshold for the majority of aquatic invertebrates. • Only the most tolerant taxa (i.e. crustaceans) will likely be sustained. • Low diversity expected	• Predicted salinity level within known threshold for the majority of aquatic invertebrates, except for some sensiti (i.e. EPT) taxa • Potential short-term loss of sensitive species during periods of elevated salinity • Moderate diversity expected
• Majority species <4,000 mg/L • Tolerant euryhaline species >20,000 mg/L	• Existing salinity level similar to known upper limit for majority of freshwater fish • Low diversity expected	• Predicted salinity level exceeds known ambient range for the majority of freshwater fish • Only the most tolerant euryhaline species may be sustained • Low diversity expected	• Predicted salinity level similar to know upper limit for majority of freshwater f • Moderate diversity expected
• Majority of frog < 6,000 mg/L • Freshwater turtles tolerate >6,000 mg/L for short periods, mortality >17,000 mg/L	• Existing salinity level below known upper limit for majority of freshwater frogs and turtles • Low diversity expected	• Predicted salinity level exceeds known upper limit for all species • Low diversity expected	• Predicted salinity level similar to know upper limit for majority of freshwater frogs and turtles • Low to Moderate diversity expected • Tadpole survival at risk during periods elevated salinity.

4.3 Environmental Risk Assessment

There is no baseline data to characterise existing diversity and composition of aquatic biota values in 2C West Pit Lake. However, based on available information from nearby pit lakes associated with Dawson Mine there is potential three aquatic macrophytes, 26 aquatic invertebrates, eight fish, 10 frogs and two turtles would be supported under the existing void condition. The majority of these aquatic biota are considered stenohaline, adapted to a narrow salinity range typical of freshwater assemblages, except for the fishes, of which several have euryhaline tolerances.

A qualitative ERA was undertaken to understand the key threats and associated stressors (pH, salinity, DO, nutrients, metals and turbidity) which present the greatest risk to local aquatic biota and ecosystem services under existing void conditions, and each modelled closure scenario. **Table 4-9** provides the results of the ERA. The greatest risks include salinity, habitat availability, and DO saturation within 2C West Pit Lake, ranked as follows:

- Habitat availability was ranked as **high** under Existing Void Condition and **medium** each closure scenario.
- Salinity was ranked as **critical** under the Do Nothing Closure Scenario, and **medium** under Existing Void Condition and the Preferred Closure Scenario.
- DO saturation was ranked as **medium** under Existing Void Condition and each closure scenario.

4.3.1 Habitat availability

Bathymetry contour data shows the existing landform design is characterised by a high depth-to-surface-area ratio with steep walls, which is unlikely to provide sufficient shallow habitat (littoral zone) within the photic zone to support benthic primary production. Sunlight driven photosynthesis by algae (periphytic and planktonic) and aquatic macrophytes is a key driver of food webs, providing habitat for, and supporting overlying levels of herbivores (zooplankton), planktivores and carnivores (aquatic invertebrates and fish).

The lack of shallow water and limited algal and macrophyte growth also limits habitat for aerially breathing aquatic macroinvertebrates that constitute the bulk of poor water quality-tolerant freshwater invertebrate fauna (Smith *et al.* 1999). Habitat availability to aquatic biota is further complicated due to stratification of void water. In addition, there is limited fringing riparian vegetation to provide an ongoing supply of organic matter and large woody debris input. Therefore, habitat availability will likely limit the ability of the pit lake to develop and sustain ecological productivity without intervention. Few components to an aquatic food chain are expected to be present in 2C West Pit Lake under the existing landform. Therefore, the risk ranking was **High**.

Under the existing landform design, littoral habitat availability varies amongst each closure scenario according to the rate of water level decline and periods of partial equilibrium. A gradual decline in water level under the Do Nothing Closure Scenario provides limited opportunity for colonisation of littoral habitat, only reaching partial equilibrium at year 70. While rapid decline (or loss) of water level in the pit void under the Preferred Closure Scenario may result in stranding of aquatic biota (notably primary producers), as well as fringing riparian vegetation, frequent periods of partial equilibrium provide stable water level conditions whereby benthic algae and aquatic plants have sufficient time to colonise.

Met Coal will amend the existing landform as part of mine closure, blasting the high- and low-wall to improve (reduce) pit slope and create suitable shallow littoral habitat around margins of 2C West Pit Lake. Therefore, the risk ranking for each closure scenario was **Moderate**.

4.3.2 pH

The pH is a measure of the acidity or alkalinity of water and has a scale from 0 (extremely acidic) to 7 (neutral), through to 14 (extremely alkaline)(ANZECC/ARMCANZ 2000). Shifts in pH and/or low (acidic) pH levels are of concern to aquatic biota when:

- low pH (acidic conditions) prevail, which can cause direct adverse effects on all trophic levels (CCREM 1991) (USEPA 1986b).
- pH changes occur (particularly decreases in pH), which can affect the physiological functioning of aquatic biota and result in the increased toxicity of potential contaminants, such as heavy metals (Collier & Winterbourn 1987, Alabaster & Lloyd 1982, CCREM 1991).

Modelling of the 2C West Pit Lake indicates that conditions are expected to remain circumneutral to slightly alkaline. This suggests direct low pH and associated direct and indirect impacts to aquatic biota are unlikely to occur post closure. Void water also has good capacity to buffer (or resist) changes in pH. Therefore, the risk ranking was **Low**.

4.3.3 Salinity

While salts are essential to the physiology of all plants and animals, high concentrations of salts are toxic to freshwater plants and animals (Bailey and James 2000; Clunie et al. 2002; Kefford et al. 2002). Salinity changes may affect aquatic organisms directly through physiological changes (particularly osmoregulation), or indirectly by modifying the species composition of the ecosystem and affecting species that provide food or refuge (ANZECC/ARMCANZ 2000). Aquatic biota are classified as stenohaline; able to adapt to only a narrow range of salinities, or euryhaline; able to adapt to a wide salinity range (ANZECC/ARMCANZ 2000).

Without intervention, the salinity in the void will continue to increase as the rate of evaporation exceeds the dilution effects of local run-off and rainfall. Evapoconcentration results in an elevated salinity under the Do Nothing Closure Scenario, at approximately 22,500 mg/L to 24,000 mg/L under low and high evaporation cases, respectively. This will exceed the known salinity tolerances of stenohaline but not euryhaline taxa. The 2C West Pit Lake under this scenario is likely to support only the most salt tolerant taxa post closure. Therefore, the risk ranking was **Critical.**

The existing void is considered hyposaline with salinity levels around 4,000 mg/L. The Preferred Closure Scenario, , is predicted to result in only a marginal increase in salinity to approximately 5,000 mg/L to 6,000 mg/L, under low and high evaporation cases, respectively. There is also the potential for spikes in salinity under high evaporation conditions (95%ile 7,000mg/L). The literature suggests that the majority of aquatic biota (except for salt-sensitive taxa) have known salinity tolerances enabling them to persist in these conditions, with a threshold of approximately 10,000 mg/L. A large number of aquatic biota are also resilient and have traits that allow for rapid re-colonisation during favourable conditions (lower salinity). Therefore, the risk ranking was **Medium**.

A review of the major ionic constituents indicates that the existing void water has high concentrations of SO_4 and low concentrations of K. These results are consistent with historic water samples taken from three nearby pit lakes associated with Dawson Mine, which indicates K deficiency compared to seawater (Dutney *et al.* 2008). While high sulfate levels are unlikely to have a negative effect on fish production (Dutney *et al.* 2008), low potassium concentration is known to limit the growth and production of commercially stocked fish including barramundi (Patridge & Lymbery 2008). However, silver perch are one of the few species that can grow and survive under low potassium conditions (Doroudi et al. 2007). The presence of six native small bodied fish species in pit lakes associated with Dawson Mine suggest water treatment may not be required, unless stocking (translocation) of larger bodied native fishes such as barramundi may be considered to enhance environmental and/or recreational use post closure.

4.3.4 Dissolved oxygen

There is a high knowledge gap of impact predictions due to the absence of DO saturation data for the 2C West Pit Lake. However, historic vertical profiling data for other pit lakes associated with the Dawson Mine (Baker *et al.* 2005, 2008, Young *et al.* 1999), together with the thermal stratification evident in 2019, suggests the epilimnion (surface layer) is well oxygenated, while the hypolimnion (bottom layer) is anoxic.

There is also limited mixing potential in the 2C West Pit Lake, given the steep pit walls, water depth (approximately 40 m), and low surface area. However, changes can occur during rainfall and storm events when water mixes, which may result in anoxic conditions throughout the pit lake. This adversely effects aquatic biota and most notably can result in fish deaths. Mixing events of sufficient magnitude to cause anoxic conditions are considered unlikely. Therefore, the risk ranking was **Medium**.

4.3.5 Nutrients

Nitrogen and phosphorus are essential nutrients for the growth of primary producers (ANZECC/ARMCANZ 2000). Generally, phosphorus is the nutrient limiting algal and plant growth in freshwater environments, however, as salinity increases, this shifts towards nitrogen (Enell *et al.* 1995). Conversely, excessive nutrient input is associated with eutrophication, which can degrade aquatic environments (ANZECC/ARMCANZ 2000).

Although there is a medium knowledge gap of impact predictions due to the absence of phosphorus data (total and soluble), existing and predicted nitrogen concentrations are mostly below levels of concern up to salinity 8,000mg/L. Nutrient levels are unlikely to change seasonally due to limited inputs and current landform design. Therefore, the risk ranking was **Low**. Low nutrient availability has potential to limit primary production (algae, diatoms, aquatic plants) and food availability for higher trophic levels (i.e. aquatic invertebrates, fish, turtles).

4.3.6 Dissolved metals

Although there is medium knowledge gap of impact predictions due to absence of metals data, existing and predicted dissolved metal concentrations (Ag, Cd, Cr, Cu, Hg, Pb, Sb and Se) are mostly below levels of concern up to salinity 8,000 mg/L. Elevated boron likely represents natural background levels in groundwater and broader catchment geology.

While predicted total selenium levels exceed the ANZG (2018) 99% DGV post closure, speciation testing would be required to ascertain valency and ultimately the bioavailability and toxicity risk posed to aquatic biota. Existing and predicted alkaline pH however, suggests that more broadly, metal solubility and bioavailability is unlikely (ANZECC/ARMCANZ 2000). Therefore, the risk ranking was **Low**.

4.3.7 Turbidity

There is high knowledge gap of impact predictions due to absence of turbidity data for the 2C West Pit Lake. However, the historic data for other pit lakes associated with the Dawson Mine (Baker *et al.* 2005, 2008, Young *et al.* 1999) suggests water clarity in the surface layer is good, with the resuspension of accumulated fine sediments at depth. Therefore, the risk ranking was **Low**.

4.4 2D Conceptual Model

A conceptual 2D model of existing landform design, on an approximately north west to south east cross section through 2C West Pit Lake is presented in **Figure 4-6** for existing void condition. The key ecological concepts for the pit lake are:

- The current water level is approximately 59 m AHD (2019 LiDAR data 58.73 m) with the bottom of the pit estimated at 20 m AHD based on the ALS bathymetric survey conducted in 2019.
- The mine void acts as a local sink with evaporation maintaining the water level below the pre-mining groundwater level, with groundwater flow radially towards the pit. In rare short term events, rainfall and runoff may raise the water level above the ambient groundwater level, with the pit lake becoming a source for groundwater recharge.
- The water quality in the pit is alkaline, hyposaline with low nutrient and heavy metal levels.
- Thermal and salinity stratification occurs within the pit lake waterbody at approximately 10 m depth. Although unknown, stratification suggests the epilimnion is well oxygenated, while the hypolimnion is (anoxic.
- There is limited shallow habitat (littoral zones on the margins of the void) where light penetrates (photic zone) and likely limited primary productivity (benthic algae and aquatic macrophytes), potentially supporting a low diversity of aquatic invertebrates, freshwater fish, frogs and turtles.
- Fringing vegetation is sparse (if any) and likely dominated by trees, with ground layer consisting of introduced pasture grasses and sedges which extend into the riparian zone (or even in shallow littoral habitats).

A conceptual 2D model is also presented for each closure scenario to illustrate the predicted change in water level and quality from the Existing Void Condition, and range of aquatic biota values likely to be supported under each scenario, provided improved landform design to establish sufficient littoral habitat. **Figure 4-7** illustrates the Do Nothing Closure Scenario and **Figure 4-8** illustrates the Preferred Closure Scenario. A summary of the major hydrological and ecological concept differences for each closure scenario are:

- Water level decline is greatest under the Do Nothing Closure Scenario, approx. 10m greater than Preferred Closure Scenario.
- Evapoconcentration and final void salinity is greatest under the Do Nothing Closure Scenario up to 24,000 mg/L. Salinity levels under Preferred Closure Scenario (~6,000 mg/L) are similar to existing void condition (~4,500 mg/L).
- A more diverse aquatic biota assemblage is likely to be supported under the Preferred Closure Scenario, due to the lower salinity concentrations over time. A less diverse community can be expected under the Do Nothing Closure Scenario, with only a few, salt tolerant taxa persisting.

Stressors	Likelihood	Consequence	Risk Rating	Knowledge	Risk Rating
Habitat availability	Likely	Major	**High**	**Low**	**High Risk** of depauperate primary productivity due to limited littoral habitat within photic zone. Current landform design has high depth-to-surface-area ratio with steep w riparian vegetation to provide allochthonous input and complex habitat structure for aquatic biota.
Salinity	Likely	Moderate	**Medium**	**Low**	**Medium Risk** electrical conductivity and associated ions (K) outside of natural range. Elevated EC impacts aquatic biota diversity and composition through loss of sensit and physiological responses; decreases metabolism, feeding, growth and reproduction. Knowledge gap is low as salt load will continue to accumulate over time.
pH	Unlikely	Moderate	**Low**	**Medium**	**Low Risk** pH levels outside of natural range. Low pH can adversely impact aquatic biota and influences toxicity of other parameters (heavy metals, ammonia). Laboratory pH is alkaline, however, knowledge gap is medium due to a lack of field measurement.
Dissolved Oxygen	Unlikely	Extreme	**Medium**	**High**	**Medium Risk** dissolved oxygen levels outside of natural range. DO availability is critical to aquatic biota diversity and composition. Knowledge gap is high due to lack o data, however, likely anoxic conditions at depth. Potential for stratified water column to turn over and reduce DO levels throughout water column, resulting in death aquatic biota.
Dissolved Metals	Unlikely	Moderate	**Low**	**Medium**	**Low Risk** heavy metals are bioavailable. Dissolved metals at low concentrations and currently mitigated by buffering capacity of water. Knowledge gap is medium due suite of parameters and lack of seasonal and/or temporal data.
Nutrients	Unlikely	Moderate	**Low**	**Medium**	**Low Risk** of eutrophication due to low nutrient levels. However, nitrogen and phosphorus are essential nutrients for the growth of aquatic macrophytes and algae. Pote factor. Knowledge gap is medium due to absence of phosphorus data. Nutrient levels unlikely to change seasonally due to limited inputs and current landform design.
Turbidity	Unlikely	Moderate	**Low**	**High**	**Low Risk** turbidity levels outside of natural range. Water clarity is critical to primary production within the photic zone. High suspended sediment loads can prevent photosy can adversely impact aquatic biota diversity and composition through smothering of habitats, eggs and tracheal gills. Knowledge gap is high due to lack of monitoring dat likely good water clarity in surface layers.
Habitat availability	Unlikely	Major	**Medium**	**Low**	**Medium Risk** of depauperate primary productivity due to limited littoral habitat within photic zone. Current landform design will be improved to reduce pit slope and cre shallow littoral habitat. Limited riparian vegetation to provide allochthonous input and complex habitat structure for aquatic biota. Gradual decline in water level or partial equilibrium at year 70, provides limited opportunity for colonisation of littoral habitat.
Salinity	Likely	Extreme	**Critical**	**Low**	**High Risk** electrical conductivity outside of natural range. Low and high evaporation case show near linear increase in EC to levels uninhabitable by majority of aquatic bi richness and composition likely depauperate. Knowledge gap is low as salt load will continue to accumulate over time.
Dissolved Oxygen	Unlikely	Extreme	**Medium**	**High**	**Medium Risk** dissolved oxygen levels outside of natural range. DO availability is critical to aquatic biota diversity and composition. Knowledge gap is high due to lack data, however, likely anoxic conditions at depth. Potential for stratified water column to turn over and reduce DO levels throughout water column, resulting in death aquatic biota.
Dissolved Metals	Unlikely	Moderate	**Low**	**High**	**Low Risk** heavy metals are bioavailable up to salinity 8,000 mg/L. Dissolved metals mitigated by buffering capacity of water. Knowledge gap is high as concentrations 24,000 mg/L.
Nutrients	Unlikely	Moderate	**Low**	**High**	**Low Risk** of eutrophication up to salinity 7,000 mg/L. Knowledge gap is high as nitrate concentrations unknown at 24,000 mg/L and lack of phosphorus data.

		Likelihood	Consequence	Risk Rating	Knowledge	
	Habitat availability	Unlikely	Major	**Medium**	**Low**	**Medium Risk** of depauperate primary productivity due to limited littoral zone. Current landform design will be improved to reduce pit slope and create suitable shallow litt Limited. Steady decline in water level, however, periods of partial equilibrium provide for colonisation of primary producers in littoral zone and fringing riparian vegetatio
	Salinity	Likely	Moderate	**Medium**	**Low**	**Medium Risk** electrical conductivity outside of natural range. Elevated EC impacts aquatic biota diversity and composition through loss of sensitive species, and p responses; decreases metabolism, feeding, growth and reproduction. Knowledge gap is low as water management (catchment flows and pumping) will prevent salt ac over time.
	pH	Unlikely	Moderate	**Low**	**Low**	**Low Risk** pH levels outside of natural range. Low pH can adversely impact aquatic biota and influences toxicity of other parameters (heavy metals, ammonia). Modelling pH is circum-neutral to alkaline.
o tic al	Dissolved Oxygen	Unlikely	Extreme	**Medium**	**High**	**Medium Risk** dissolved oxygen levels outside of natural range. DO availability is critical to aquatic biota diversity and composition. Knowledge gap is high due to lack c data, however, likely anoxic conditions at depth. Potential for stratified water column to turn over and reduce DO levels throughout water column, resulting in death aquatic biota.
	Dissolved Metals	Unlikely	Moderate	**Low**	**Medium**	**Low Risk** heavy metals are bioavailable. Predicted dissolved metals at low concentrations and mitigated by buffering capacity of water. Knowledge gap is medium due suite of parameters modelled.
	Nutrients	Unlikely	Moderate	**Low**	**Medium**	**Low Risk** of eutrophication due to low nutrient levels. However, nitrogen and phosphorus are essential nutrients for the growth of aquatic macrophytes and algae. Pote factor. Knowledge gap is medium due to restricted suite of parameters (only nitrate) modelled.
	Turbidity	Unlikely	Moderate	**Low**	**High**	**Low Risk** turbidity levels outside of natural range. Water clarity is critical to primary production within the photic zone. High suspended sediment loads can prevent photosy can adversely impact aquatic biota diversity and composition through smothering of habitats, eggs and tracheal gills. Knowledge gap is high due to lack of modelling dat likely good water clarity in surface layers.

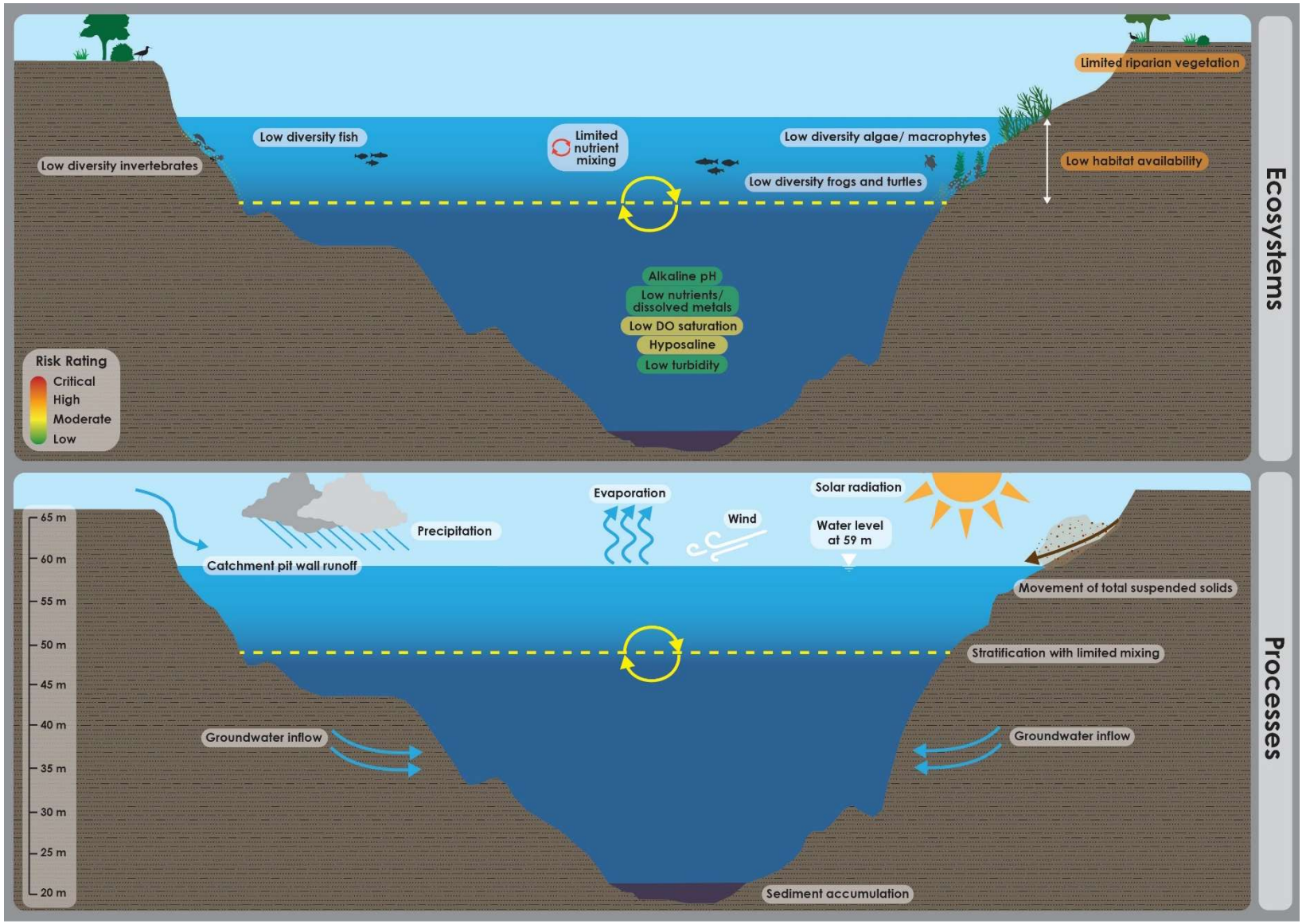


Figure 4-6. Conceptual diagram of 2C West Pit Lake showing existing landform design and environmental values and services.

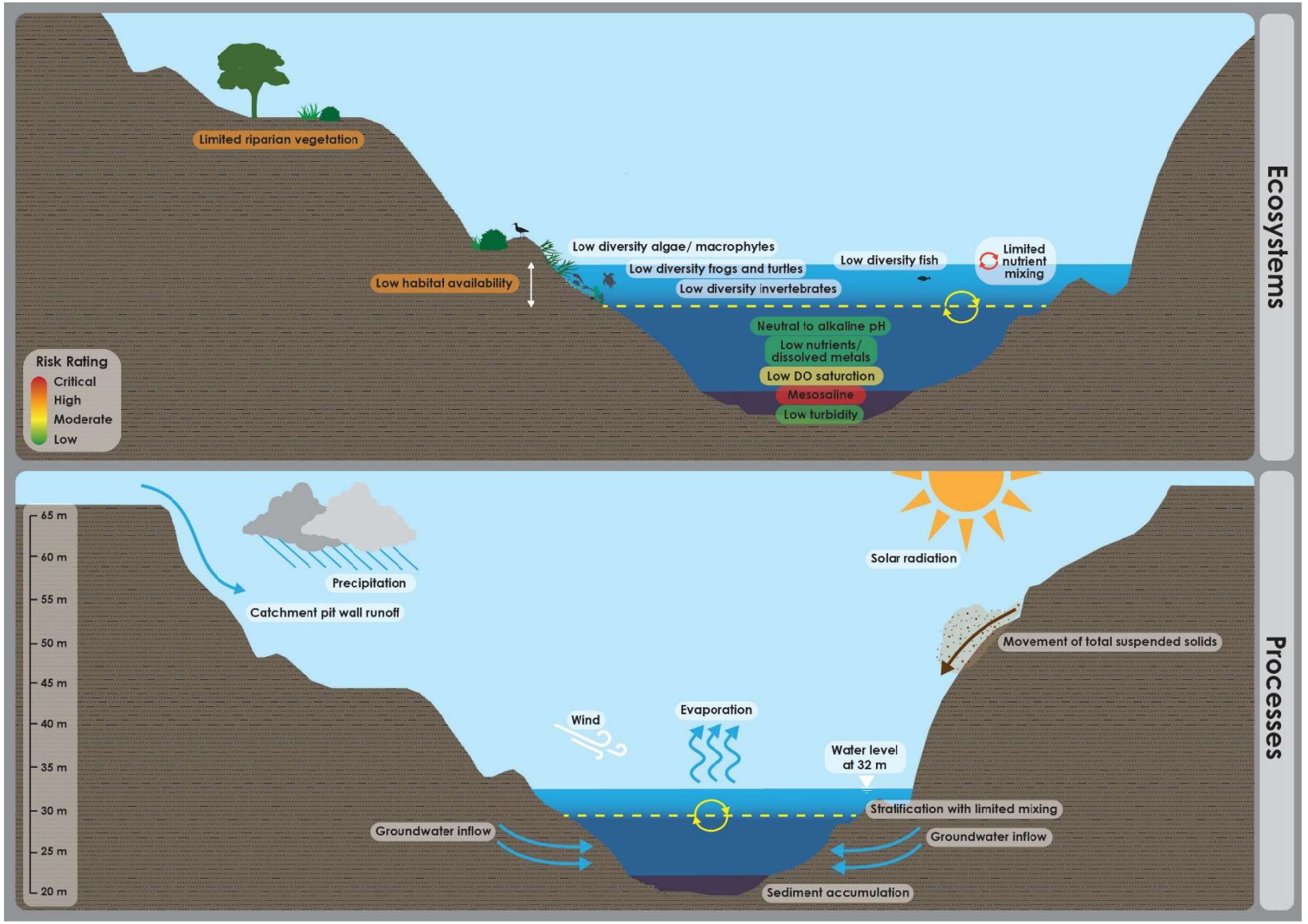


Figure 4-7. Conceptual diagram of 2C West Pit Lake showing existing landform design and environmental values and services under the Do Nothing Closure Scenario.

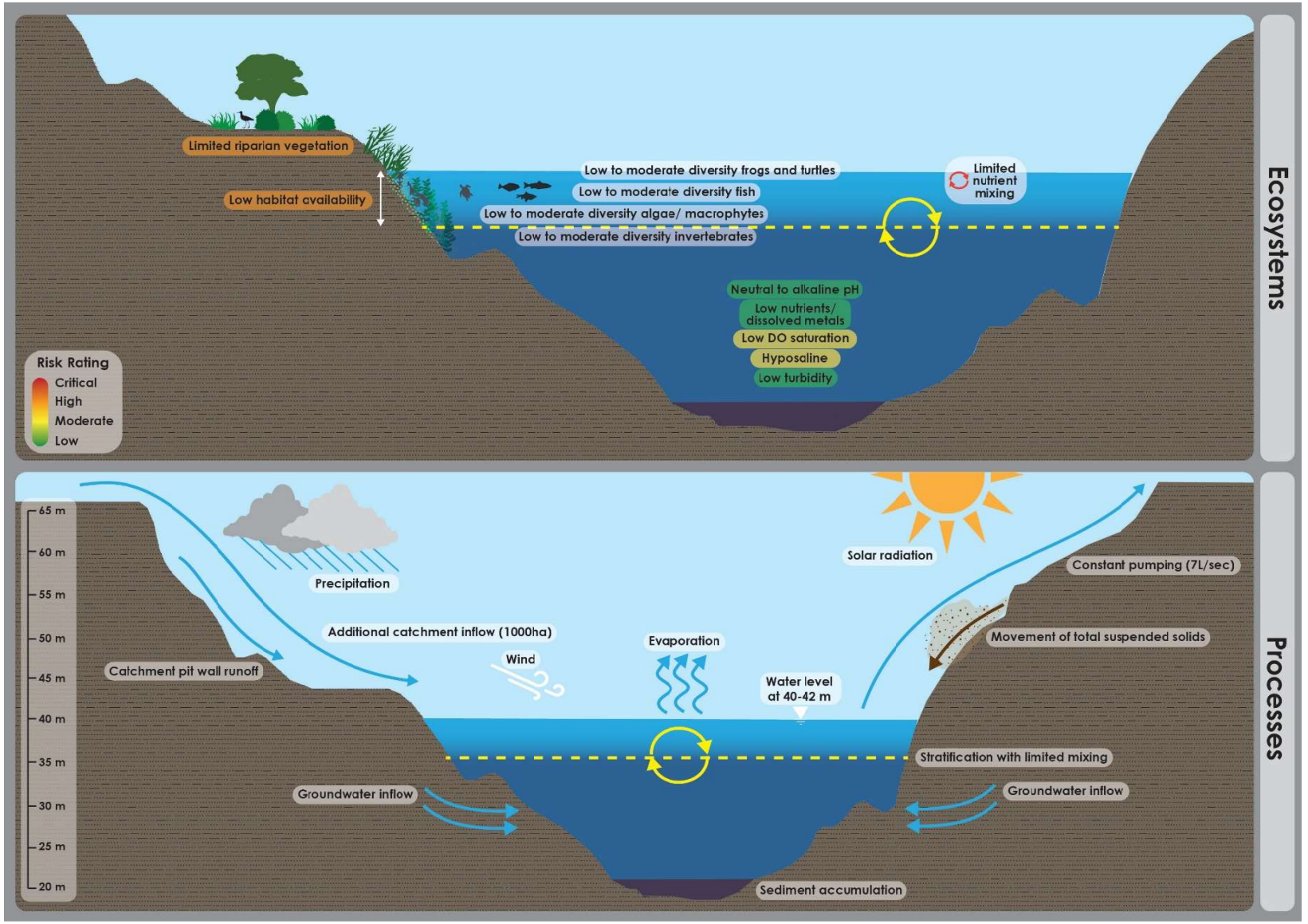


Figure 4-8. Conceptual diagram of 2C West Pit Lake showing existing landform design and environmental values and services under the Preferred Closure Scenario.

5. Summary and Conclusions

Met Coal are investigating the options to improve water quality and ecological functioning of 2C West Pit Lake at the Dawson Mine, post closure, to maximise environmental values and provide beneficial use to the local area and broader region. Environmental values may be limited by poor water quality and landform design under current legislative frameworks, limiting ecosystem services. Met Coal have recently commissioned several studies to understand changes in water level and quality over time, with and without active water management strategies.

Existing void water quality currently reflects the chemistry of inflowing groundwater, which is slightly alkaline, hyposaline and with low concentrations of nutrients and metals. Without active management of void water quality (Do Nothing Closure Scenario), evaporation will result in a long-term decline in water level and increase in salinity. However, modelling indicated two water management strategies (Preferred Closure Scenario); the provision of additional catchment inflows and removal of pit void water via constant pumping, will likely offset evaporation and limit salinity increases over time (**Table 5-1**).

There have been no studies and there is no data available on the existing environmental values of the 2C West Pit Lake, with the likely biological assemblage inferred based on the findings of the desktop review. The Assessment indicated that the aquatic biota associated with nearby pits at Dawson Mine and surrounding natural rivers/creeklines and semi-natural dams is characterised by 14 primary producers (mainly aquatic macrophytes), 58 aquatic invertebrates (dominated by insects), 16 freshwater fish, 10 frogs and two freshwater turtles. Of these taxa, six are listed species under state or national legislation, including the Silver perch (*Bidyanus bidyanus*), Kroombit treefrog (*Litoria kroombitensis*), Kroombit tinkerfrog(*Taudactylus pleione*), Tusked frog (*Adelotus brevis*), Southern snapping turtle (*Elseya albagula*), and Fitzroy River turtle (*Rheodytes leukops*).

The majority of primary producers, aquatic invertebrates, frogs and turtles known to occur in the local area, particularly those taxa with potential to colonise 2C West Pit Lake are considered vulnerable to increasing salinity, characterised by the freshwater assemblage. In comparison, many of the fish species associated with the area have a broader salinity tolerance, are considered euryhaline and can persist under high salinity levels. The implications of this are that the lower trophic levels, particularly benthic algae and aquatic macrophytes, are likely to be more susceptible to increases in salinity within the pit lake over time, than the higher order consumers comprising fish.

The environmental risk assessment of predicted change in water level and quality from the existing conditions of 2C West Pit Lake identified salinity and habitat availability as posing the greatest risk to progressing towards a self-sustaining wetland, post closure, ranked as:

- Salinity was **critical** under the Do Nothing Closure Scenario, and **medium** under Existing Void Condition and the Preferred Closure Scenario; and
- Habitat availability was **high** under Existing Void Condition and **medium** under each closure scenario.

Void water has good capacity to buffer (or resist) changes in pH, with existing and predicted alkaline pH limiting metal solubility and bioavailability, and potential toxicity to aquatic biota. Nutrient (nitrogen) levels were low, however, this may also be considered a limiting factor for the growth and colonisation of primary producers. Potentially anoxic conditions deeper in the pit lake was also ranked as a **medium** risk to aquatic biota should a mixing event occur, although considered a low probability.

Under the Do Nothing Closure Scenario, increasing salinity is considered the key constraint (up to 24,000 mg/L by year 100) to maximising the environmental values of the 2C West Pit Lake, post closure. This is because salinity will likely increase above the majority of the upper tolerance limits (>10,000 mg/L by year 20) for the majority of primary producers, aquatic invertebrates, frogs and turtles that typically form part of the freshwater assemblage of waterbodies in the local area (including other pit lakes at Dawson Mine), for which published information is available. Only the most salt tolerant species are likely to be sustained, including micro- and macrocrustaceans (copepods, crayfish, ostracods, freshwater prawns, and shrimp), aquatic beetles (Coleoptera), some true bugs (Hemiptera) and euryhaline fishes (barramundi, bass, golden and silver perch). Low diversity and a distinct community structure to the surrounding aquatic environments is expected (**Table 5-1**).

In contrast, the Preferred Closure Scenario allows for dilution and removal mechanisms to maintain lower salinity in the 2C West Pit Lake (up to 8,000 mg/L by year 85), post closure. While predicted void salinity will still preclude colonisation of some sensitive freshwater aquatic biota (i.e. some EPT taxa and freshwater fish), the majority of aquatic biota known to occur in the local area are likely to be sustained. Moderate diversity and similar community structure to the surrounding aquatic environments is expected, provided sufficient habitat availability (**Table 5-1**).

Variability in salinity post closure, specifically spikes related to dry conditions (under the high evaporation case) may result in the loss of some tolerant species (or life stages i.e. tadpoles), if ambient concentrations exceed individual taxa tolerances. However, the majority of aquatic biota known to occur in pit lakes of Dawson Mine or the surrounding natural aquatic environments are considered hardy taxa, tolerant of a wide range of environmental conditions, and with resilient life history traits which allow for recolonisation when favourable water quality conditions return.

Bathymetry contour data shows the existing landform design of the 2C West Pit Lake is characterised by high depth-to-surface-area ratio, with steep walls that are unlikely to provide sufficient shallow habitat (littoral) within the photic zone to support benthic primary production and habitat provision for higher trophic levels, post closure. Diverse shallow micro-habitats and landscape connectivity are required to ensure maintenance of ecosystem services. Sunlight driven photosynthesis by algae and aquatic macrophytes is a key driver of food webs supporting overlying higher order consumers such as fish. The productivity of this zone also largely depends on the organic content of the sediment, which is closely related to the breakdown and cycling of detrital material typically sourced from primary producers and/or riparian vegetation. Currently, it is assumed that there is limited allochthonous organic carbon input into 2C West Pit Lake, a function of the pit design and sparse fringing riparian vegetation. As a result, there is limited habitat availability, reducing the complexity of the aquatic food chain and therefore environmental values.

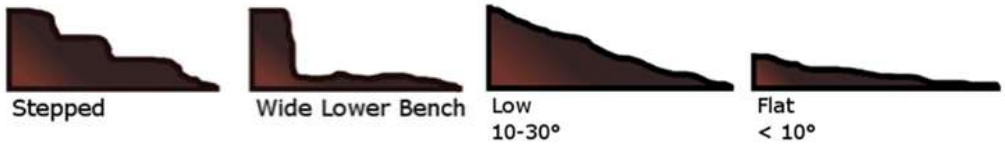
The Do Nothing Closure Scenario for the 2C West Pit Lake post closure contributes limited environmental values and beneficial use to the local area and broader region over the long-term, due to the more saline conditions and lack of available habitat for aquatic biota. While the Preferred Closure Scenario maintains a lower salinity over time, engineering solutions would still be required to create additional littoral habitat at stages of partial equilibrium and/or final void water level elevation, post closure. Provision of additional external catchment inflows would also facilitate passive input of allochthonous carbon (e.g., leaf litter), nutrient input and colonisation of less mobile aquatic biota. This would support a more diverse biological assemblage and enable the pit lake to progress towards a self-sustaining wetland, providing greatest beneficial use to the local area and broader region. However, there are knowledge gaps that should be addressed prior to implementing this option.

	Low habitat diversity due to limited shallow littoral margin within photic zone. Limiting factor for primary production. Limited riparian vegetation input. Majority of void is open water.	pit slope and create suitable shallow littoral habitat within photic zone. Steady decline in water level elevation only reaching partial equilibrium at year 70 limits opportunity for riparian vegetation and primary producers to colonise.	Current landform design will be improved to reduce pit slope and create suitable shallow littoral habitat within photic zone. Periods of partial equilibrium provide opportunity for riparian vegetation and primary producers to colonise.
	Unknown but likely to be Low (anoxic) at depth due to void stratification. Potential for mixing events to reduce DO throughout pit lake.		
	Moderate TDS concentrations (~4000 mg/L) likely exceed sensitive taxa tolerances, but within the natural range of most tolerant taxa.	High TDS concentrations (~22,500 mg/L) likely exceed majority of taxa tolerances. Only saline tolerant taxa will persist.	Moderate TDS concentrations (~5000 mg/L) likely exceed sensitive taxa tolerances, but within the natural range of most tolerant taxa.
	High pH (alkaline) exceeding ANZG (2018) DGV. Good buffering capacity limits pH shift. Local fauna likely adapted to conditions.	Same as Preferred Closure Scenario up to salinity 8000 mg/L . Unknown dissolved metal levels above 8000 mg/L TDS.	Moderate (circum-neutral) to High (alkaline) Peak pH exceeding ANZG (2018) DGV. Good buffering capacity limits pH shift. Local fauna likely adapted to conditions.
	Low levels of nitrogen nutrients. Unknown but likely Low total and soluble phosphorus levels. Nutrients potential limiting factor for primary production.		Low levels of nitrogen nutrients. Unknown but likely Low total and soluble phosphorus levels. Nutrients potential limiting factor for primary production.
	Low levels for majority of dissolved metals. Boron levels exceed ANZG (2018) DGV.		Low levels for majority of dissolved metals. Potential for boron and selenium levels to exceed ANZG (2018) 95% and 99% DGVs, respectively.
	Unknown but likely Low turbidity (good water clarity) but increasing at depth due to resuspension of organics and sediments.		
	Unknown but likely Low diversity of benthic algae and aquatic plants.	Low diversity due to steady decline in water level elevation limiting colonisation of shallow littoral margins within photic zone. Aquatic macrophytes may be adversely impacted under high salinities. Only saline tolerant primary producers likely to be sustained.	Moderate diversity due to decline in water level elevation, however, periods of partial equilibrium will allow for colonisation of shallow littoral margins within photic zone. Some sensitive and most tolerant primary producers likely to be sustained.
	Unknown but likely Low diversity of aquatic invertebrates.	Low diversity and composition with majority of aquatic biota adversely impacted under high salinities. Only the most tolerant taxa (i.e. crustaceans, beetles) likely to be sustained.	Moderate diversity and composition with some sensitive (EPT) and most tolerant taxa likely to be sustained, provided sufficient habitat diversity.
	Unknown but likely Low diversity with composition dominated by more tolerant small bodied species.	Low diversity and composition with majority of native freshwater fish adversely impacted under high salinities. Only the most tolerant euryhaline species (i.e. barramundi, bass, spangled perch, silver perch, golden perch) may be sustained.	Moderate diversity with a range of small and large bodied tolerant species likely to be sustained, provided sufficient habitat diversity and food resource availability. Potential for stocking of translocated native species (i.e. barramundi, bass, silver perch, golden perch).
	Unknown but likely Low diversity of freshwater turtles and frogs.	Low diversity and composition with majority of freshwater turtles and frogs (including tadpoles) adversely impacted under high salinities.	Low to Moderate diversity and composition of freshwater turtles and frogs provided sufficient habitat diversity and food resource availability.
alues	Improved landform design is required to construct suitable shallow (littoral) habitat within the photic zone to ensure primary production.		
	Potential to support a diverse aquatic biota community. Presents an opportunity to provide environmental beneficial use to local area and broader region in post mining landscape.	Unlikely to support a diverse aquatic biota community. Closure scenario provides no environmental beneficial use to local area and broader region in post mining landscape.	Potential to support a diverse aquatic biota community. Presents an opportunity to provide environmental beneficial use to local area and broader region in post mining landscape.

6. Recommendations

Following the outcomes of the Assessment and the identification of several knowledge gaps, the following recommendations are provided for consideration by Met Coal:

- Additional water quality monitoring data is collected for 2C West pit lake to address existing knowledge gaps for some parameters (i.e. dissolved oxygen, ionic composition, some dissolved metals, phosphorus loads), characterise seasonal and/or temporal variability and better understand void stratification. This should consider speciation testing for toxicants with potential to bioaccumulate (i.e. Se), to ascertain valency and ultimately the bioavailability and toxicity risk posed to aquatic biota.
- A basic ecosystem health condition assessment of 2C West pit lake and surrounding mine voids should be undertaken to characterise existing biotic values concomitant with additional water quality monitoring. Several lines of evidence should be targeted, including primary producers (benthic algae and macrophytes), aquatic invertebrates, and fish. This will help characterise the known salinity tolerance of local taxa occurring in pit lakes associated with Dawson Mine.
- The basic ecosystem health condition assessment would then inform whether a targeted ecotoxicological investigation and environmental risk assessment should be undertaken to better understand aquatic biota tolerances to existing mine pit lake water, and predicted salinity levels for each closure scenario, to validate end use options. If required, bioassay species should be selected carefully to represent a range of aquatic biota groups, including those with natural distributions for inland Central Queensland, species likely to be translocated and introduced, or those currently present in 2C West pit lake.
- Following greater confidence in hydrology (inputs/outputs) and final void water level variation under the preferred closure scenario, undertake a conceptual engineering design that increases littoral areas along the margins of 2C West pit lake to promote colonisation by primary producers. This should encompass any modifications required for additional incoming catchment flows to optimise water level and quality.
    - Physical contouring of the pit void wall should aim to enhance and promote littoral areas (i.e. shallow, gentle sloping habitats at the pit lake edge) to increase both the area of shallow water and diversity of depths and habitats to promote primary productivity. Bank shape should be stepped including provision of wide lower benches, with a low (10-30°) or flat (<10°) slope.



    - While it is not considered feasible to create littoral areas around the perimeter of 2C West Pit Lake, at a minimum, three discrete areas should be targeted, representing improved landform at approximately a third of the perimeter of 2C West Pit Lake. Ideally, this would increase to five discrete areas, representing approx. half of the perimeter of 2C West Pit Lake, where possible.
    - The detail design report should also identify any local sources of suitable topsoil, and native riparian vegetation (i.e. *Juncus* sp., *Eleocharis* sp., *Schoenoplectus* sp., *Cyperus* sp.) which is self-propagating and suitable for seeding/planting or large woody debris input to enhance the littoral zones of 2C West pit lake (in both spatial complexity and nutrient content).
- Investigate the potential to revegetate the surrounding landform to limit erosion and sediment loading and reduce the run-off and excessive deposition of fine silts that may smother benthos aquatic biota. This will also contribute organic matter to the pit lake and nutrient cycling within the food web. Consider adding large woody debris to mine void at varying depths for structural habitat complexity.
- Investigate the potential to translocate native (endemic) self-sustaining (and self-propagating) primary producers (i.e. *Ruppia* sp., *Chara* sp., *Lamprothamnium* sp.) and fish species (i.e. perch) with known salinity tolerances within those predicted under the preferred closure scenario, including all relevant development translocation approvals needed.
- Investigate substrate and water quality requirements to support the growth of the local seaweed Asparagopsis sp., and determine potential to seed 2C West Pit Lake for cultivation and addition to livestock fodder, providing an alternative potential beneficial end use.

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Appendices



Appendix A Database Search Results

Hirundapodidae	Hirundapus caudacutus	white-throated needletail	Vulnerable	Vulnerable
Cacatuidae	Calyptorhynchus lathami erebus	glossy black-cockatoo (northern)	Vulnerable	
Columbidae	Geophaps scripta	squatter pigeon (southern subspecies)	Vulnerable	Vulnerable
Falconidae	Falco hypoleucos	grey falcon	Vulnerable	
Laridae	Gelochelidon nilotica	gull-billed tern	Special Least Concern	
	Hydroprogne caspia	Caspian tern	Special Least Concern	
Monarchidae	Monarcha melanopsis	black-faced monarch	Special Least Concern	
	Myiagra cyanoleuca	satin flycatcher	Special Least Concern	
	Symposiachrus trivirgatus	spectacled monarch	Special Least Concern	
Psittacidae	Psephotus pulcherrimus	paradise parrot	Extinct in the Wild	Extinct
Rhipiduridae	Rhipidura rufifrons	rufous fantail	Special Least Concern	
Scolopacidae	Calidris acuminata	sharp-tailed sandpiper	Special Least Concern	
	Gallinago hardwickii	Latham's snipe	Special Least Concern	
	Numenius phaeopus	whimbrel	Special Least Concern	
	Tringa glareola	wood sandpiper	Special Least Concern	
	Tringa stagnatilis	marsh sandpiper	Special Least Concern	
Threskiornithidae	Plegadis falcinellus	glossy ibis	Special Least Concern	
Turnicidae	Turnix melanogaster	black-breasted button-quail	Vulnerable	Vulnerable
Lycaenidae	Jalmenus eubulus	pale imperial hairstreak	Vulnerable	
Ornithorhynchidae	Ornithorhynchus anatinus	platypus	Special Least Concern	
Phascolarctidae	Phascolarctos cinereus	koala	Vulnerable	Vulnerable
Pseudocheiridae	Petauroides volans volans	southern greater glider	Vulnerable	Vulnerable
Pteropodidae	Pteropus poliocephalus	grey-headed flying-fox	Least Concern	Vulnerable
Tachyglossidae	Tachyglossus aculeatus	short-beaked echidna	Special Least Concern	
Terapontidae	Bidyanus bidyanus	silver perch		Critically Endangered
Chelidae	Rheodytes leukops	Fitzroy River turtle	Vulnerable	Vulnerable
Elapidae	Acanthophis antarcticus	common death adder	Vulnerable	
	Denisonia maculata	ornamental snake	Vulnerable	Vulnerable
Camaenidae	Adclarkia dawsonensis	boggomoss snail	Endangered	Critically Endangered

Table A1-2: WildNet database search results for introduced fauna recorded within 50km of Pit 2C West

Class	Family	Scientific Name	Common Name
Amphibians	Bufonidae	Rhinella marina	cane toad
Birds	Anatidae	Anas platyrhynchos	northern mallard
	Columbidae	Columba livia	rock dove
	Passeridae	Passer domesticus	house sparrow
	Phasianidae	Pavo cristatus	Indian peafowl
	Sturnidae	Acridotheres tristis	common myna
		Sturnus vulgaris	common starling
Insects	Pieridae	Pieris rapae	cabbage white
Mammals	Bovidae	Bos taurus	European cattle
	Canidae	Canis familiaris	dog
		Vulpes vulpes	red fox
	Felidae	Felis catus	cat
	Leporidae	Lepus europaeus	European brown hare
		Oryctolagus cuniculus	rabbit
	Muridae	Mus musculus	house mouse
		Rattus rattus	black rat
	Suidae	Sus scrofa	pig
Ray-finned fishes	Cyprinidae	Carassius auratus	goldfish
	Poeciliidae	Gambusia holbrooki	mosquitofish

Table A1-3: WildNet database search results for aquatic invertebrates in the Dawson River drainage sub-basin.

Family	Scientific Name	Common Name
Aeshnidae	*Anax papuensis*	Australian Emperor
	Austrogynacantha heterogena	Australian duskhawker
Coenagrionidae	*Agriocnemis pygmaea*	pygmy wisp
	Ischnura aurora	aurora bluetail
	Ischnura heterosticta heterosticta	common bluetail
Corduliidae	*Hemicordulia australiae*	Australian emerald
	Hemicordulia intermedia	yellow-spotted emerald
	Hemicordulia tau	tau emerald
Gomphidae	*Austroepigomphus praeruptus*	Twinspot Hunter
Lestidae	*Austrolestes leda*	wandering ringtail
Libellulidae	*Crocothemis nigrifrons*	black-headed skimmer
	Diplacodes bipunctata	wandering percher
	Diplacodes haematodes	scarlet percher
	Hydrobasileus brevistylus	water prince
	Orthetrum caledonicum	blue skimmer
	Pantala flavescens	wandering glider
	Rhyothemis graphiptera	graphic flutterer
	Tramea loewii	common glider
	Zyxomma elgneri	short-tailed duskdarter
Lindeniidae	*Ictinogomphus australis*	Australian tiger
Megapodagrionidae	*Austroargiolestes icteromelas*	common flatwing
Parastacidae	*Cherax destructor*	common yabbie
Platycnemididae	*Nososticta solida*	orange threadtail
Synthemistidae	*Eusynthemis nigra nigra*	black tigertail
	Parasynthemis regina	royal tigertail

Table A1-4: WildNet database search results for freshwater fish in the Dawson River drainage sub-basin.

Family	Scientific Name	Common Name
Native species		
Ambassidae	*Ambassis agassizii*	Agassiz's glassfish
	Ambassis sp.	Glassfish
Anguillidae	*Anguilla reinhardtii*	Long finned eel
Apogonidae	*Glossamia aprion*	Mouth almighty
Ariidae	*Neoarius graeffei*	Forktailed catfish
Atherinidae	*Craterocephalus stercusmuscarum*	Flyspecked hardyhead
Belonidae	*Strongylura krefftii*	Freshwater longtom
Centropomidae	*Lates calcarifer*	Barramundi
Clupeidae	*Nematalosa erebi*	Bony bream
Eleotridae	*Hypseleotris* sp.	Carp gudgeon
	Hypseleotris sp. 1	Midgley's carp gudgeon
	Hypseleotris compressa	Empire gudgeon
	Hypseleotris galii	Firetail gudgeon
	Hypseleotris klunzingeri	Western carp gudgeon
	Mogurnda adspersa	Purple spotted gudgeon
	Oxyeleotris aruensis	Aru gudgeon
	Oxyeleotris lineolata	Sleepy cod
	Philypnodon grandiceps	Flathead gudgeon
Hemiramphidae	*Arrhamphus sclerolepis*	Snubnose garfish
Megalopidae	*Megalops cyprinoides*	Oxeye herring, tarpon
Melanotaeniidae	*Melanotaenia splendida splendida*	Eastern rainbowfish
Mugilidae	*Mugil cephalus*	Sea mulet
Osteoglossidae	*Scleropages leichardti*	Southern saratoga
Percichthyidae	*Macquaria ambigua*	Golden perch
Plotosidae	*Neosilurus hyrtlii*	Hyrtl's catfish
	Porochilus rendahli	Rendahl's catfish
	Tandanus tandanus	Freshwater catfish
Pseudomugilidae	*Pseudomugil signifer*	Pacific blue eye
Retropinnidae	*Retropinna semoni*	Australian smelt
Scorpaenidae	*Notesthes robusta*	Bullrout
Terapontidae	*Amniataba percoides*	Barred grunter
	Bidyanus bidyanus	Silver perch
	Hephaestus fuliginosus	Sooty grunter
	Leiopotherapon unicolor	Spangled perch
	Scortum hillii	Leathery grunter
Introduced species		
Peocilliidae	*Gambusia holbrooki*	Mosquitofish
Cyprinidae	*Carassius auratus*	Goldfish
Cyprinidae	Cyprinus carpio	European carp

Table A1-5: WildNet database search results for frogs in the Dawson River drainage sub-basin.

Family	Scientific Name	Common Name
Native species		
Hylidae	*Cyclorana brevipes*	Superb collared frog
	Cyclorana cultripes	Grassland collared frog
	Cyclorana novaehollandiae	Eastern snapping frog
	Cyclorana verrucosa	Rough collared frog
	Litoria fallax	Eastern sedgefrog
	Litoria gracilenta	Graceful treefrog
	Litoria nasuta	Striped rocketfrog
Limnodynastidae	*Adelotus brevis*	Tusked frog
	Limnodynastes peronii	Striped marshfrog
	Limnodynastes salmini	Salmon striped frog
	Limnodynastes tasmaniensis	Spotted grassfrog
	Limnodynastes terraereginae	Scarlet sided pobblebonk
	Platyplectrum ornatum	Ornate burrowing frog
Myobatrachidae	*Crinia signifera*	Clicking froglet
	Taudactylus pleione	Kroombit tinkerfrog
Introduced species		
Bufonidae	Rhinella marina	Cane toad

Table A1-6: WildNet database search results for freshwater turtles in the Dawson River drainage sub-basin.

Family	Scientific Name	Common Name
Chelidae	*Chelodina expansa*	Broad-shelled river turtle
	Chelodina longicollis	Eastern snake-necked turtle
	Elseya albagula	Southern snapping turtle
	Emydura macquarii krefftii	Krefft's river turtle
	Emydura macquarii macquarii	Murray turtle
	Rheodytes leukops	Fitzroy River turtle
	Wollumbinia latisternum	Saw-shelled turtle

Table A1-5: WildNet database search results for mammals in the Dawson River drainage sub-basin.

Family	Scientific Name	Common Name
Muridae	*Hydromys chrysogaster*	Water rat
	Rattus lutreolus	Swamp rat
Ornithorhynchidae	*Ornithorhynchus anatinus*	Platypus

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Dawson Voids Water Quality Water Balance modelling

Post-Closure Water Quantity and Quality

PREPARED FOR
AASC

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15 April 2024

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0655820



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Dawson Voids Water Quality Water Balance modelling

Post-Closure Water Quantity and Quality

0655820





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ACRONYMS AND ABBREVIATIONS

Acronyms	Description
ACCESS	Australian Community Climate and Earth System Simulator
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ASL	Above sea level
AWBM	Australia Water Balance Model
DCN	Dawson Central / North Mine
DEM	Digital Elevation Model
DESI	Department of Environment, Science and Innovation
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change's
mg/L	milligrams per litre
ML	Mining Lease
QA/QC	Quality Assurance / Quality Control
RCP	Representative Concentration Pathways
RL	Reduced Level
SRES	Special Report on Emission Scenarios
TDS	Total Dissolved Solids
TSF	Tailing Storage Facilities
°C	Degrees Celsius
µS/cm	Micro siemens per centimetres

1. MODEL APPROACH AND ASSUMPTIONS

The Post-Closure Water Quantity and Quality model for the Dawson Mining Complex (Dawson) was developed utilizing Goldsim software version 14.0 (Goldsim, 2021) and its contaminant transport module. Primary components influencing the hydrological equilibrium, inclusive of variables like precipitation, evaporation, and parameters inherent to the Australia Water Balance Model (AWBM), were derived from the 2022 update of the water balance model conducted by KCB. The groundwater flow inputs were simulated using a hydrogeological model, the specifics of which were furnished by KCB (see reference). Additionally, geochemical source terms pertaining to total dissolved solids (TDS) were integrated to proactively assess the water quality within each void.

1.1 CONCEPTUAL MODEL

Figure 1 shows the conceptual model of the water balance during post-closure. The key inflows and outflows are:

- Inflow
  - Precipitation on the water surface
  - Surface runoff from the surrounding catchments
  - Surface runoff and baseflow from the pit shell not inundated by the pit lake
  - Baseflow and seepages from the surrounding catchment and spoils
  - Groundwater inflow
- Outflow
  - Evaporation from the free water surface
  - Groundwater outflow (where relevant)

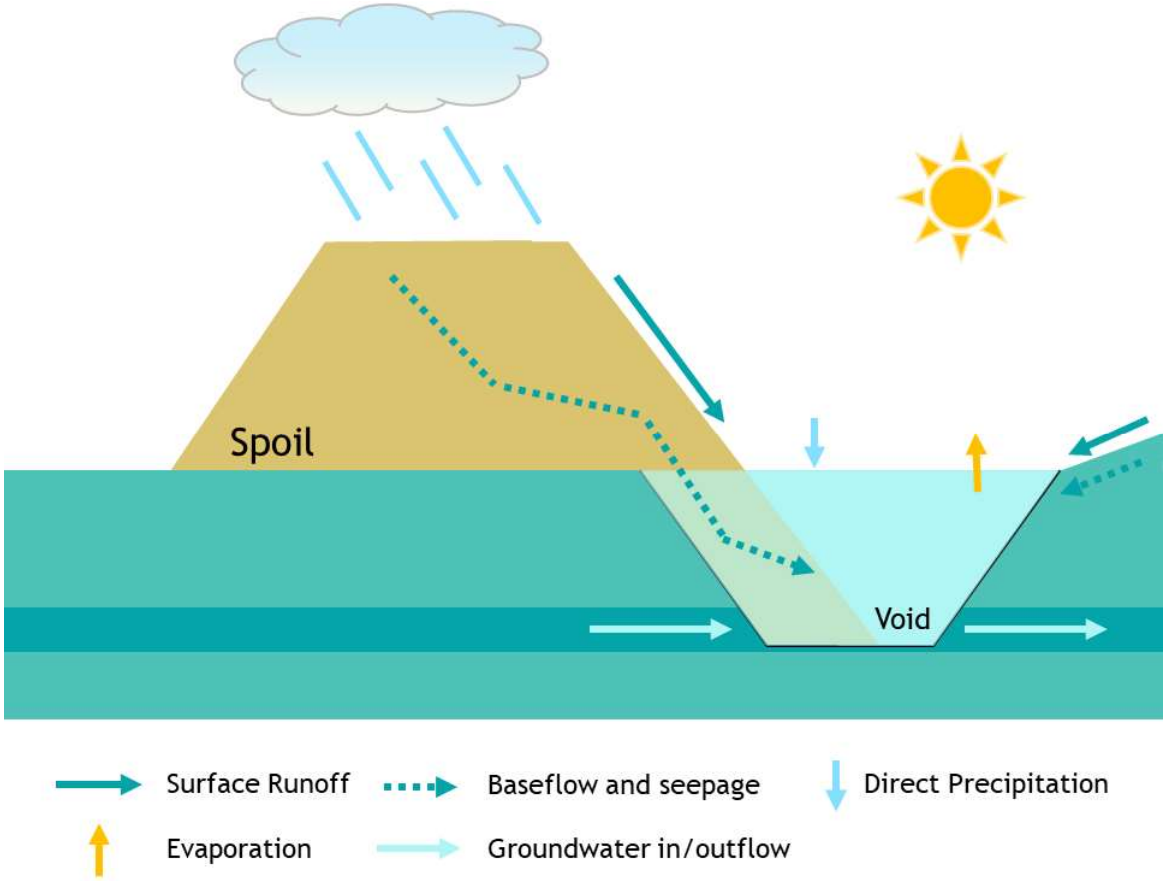


FIGURE 1-1 CONCEPTUAL FLOW DIAGRAM OF DAWSON VOIDS WATER BALANCE AND QUALITY MODEL.

1.2 MODEL SETUP AND ASSUMPTIONS

In the water balance model, water flow and storage change were calculated for each void based on the following equation:

$$S_t = S_{t-1} + RO_s + RO_b + GW_i + P - E - GW_o$$

Where:

S_t=Water volume of the void at time step t;

RO_s = inflow of surface runoff;

RO_b = inflow of baseflow, including seepage from surrounding spoils;

GW_i = groundwater inflow;

P= direct precipitation;

E= evaporation;

GW_o= Groundwater outflow.

The computation of direct precipitation and evaporation from the water surface was predicated on the temporal variation in the surface water area. Within the modeling framework principal inflows encompassing surface runoff and baseflow were determined utilizing the AWBM. The model employed three surface stores to emulate distinct runoff areas within the catchment. Saturation overland flow was conceptualized as the residual rainfall surplus subsequent to the replenishment of the catchment's surface storage capacity. The extent of rainfall abstraction was contingent upon the antecedent moisture conditions of the catchment. The model executed the water balance assessment for each distinct area on a daily basis. At each time increment, rainfall contributed to each of the three surface stores, while evaporation was subtracted from each store. In instances where the stored water exceeded the designated capacity, surplus water translated into runoff. A portion of the excess runoff could potentially recharge the baseflow store, contingent upon the presence of a baseflow component. A schematic representation of the AWBM model is depicted in Figure 2. The parameters utilized in the AWBM, as detailed in Table 1, were derived from the updated Dawson water balance model of 2022.

The following assumptions were relevant to the assessment, and justification is provided below:

1. Each void was treated as an isolated entity in the water balance model, with interactions assessed through the groundwater model inputs to the water balance model.

2. Two land types were adopted for the hydrology model based on the catchment response - spoil and pit wall.

3. The water representation within each void encompasses both the unconfined water within the void and the pore water within the waste rock positioned in the pit shell. The water level was determined by considering the storage curve of each pit shell, accounting for both the unconfined water and pore water. However, the computation of evaporation exclusively considered the surface area of the unconfined water.

4. The pore water level in the waste rock within each pit follows the movement of the free water level in each void, maintaining a consistent relationship between them.

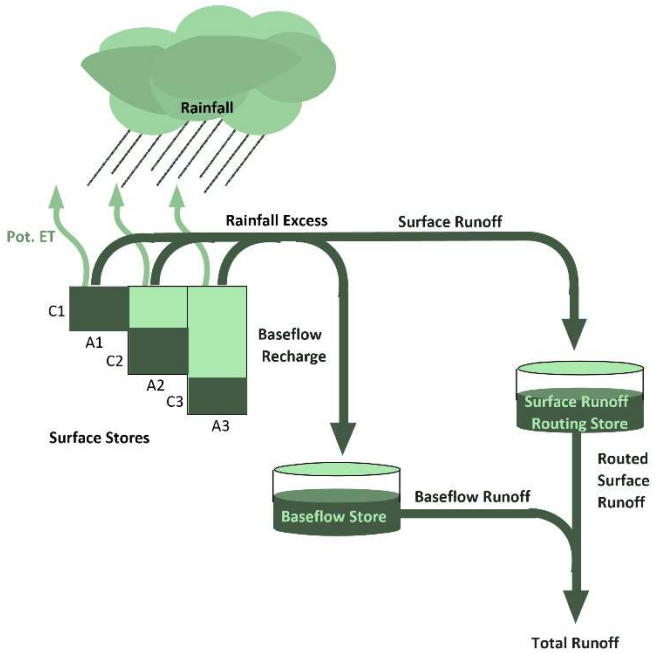


FIGURE 1-2 SCHEMATIC DIAGRAM OF AWBM

In the computation of water quality, the mass load, derived from the integration of water quality source terms and flow rates, was incorporated into each water stream. The intricate calculations pertaining to mass loading and its release into the water column were entirely adopted from the 2022 update of the water balance model. (Engeny, 2023).

TABLE 1-1 AWBM PARAMETERS

Parameter	Unit	Mining Pit	Rehabilitated	Spoil
C1	mm	12	30	15
C2	mm	38	80	55
C3	mm	0	200	120
A1	-	0.1	0.134	0.134
A2	-	0.9	0.433	0.433
A3	-	0	0.433	0.433
BFI	-	0	0.5	0.5
Kb	-	0	0.95	0.95
Ks	-	0	0	0

1.3 MODEL SCENARIOS

Model scenarios were conducted with different catchment sizes derived from the final landform and climate data:

Scenario 1: Flow from original Catchment only.

Scenario 2: Flow from original Catchment, with baseflow from spoils nearby (e.g. pit shell area).

Scenario 3: Flow from original Catchment, with baseflow from spoils nearby (e.g. pit shell area) under climate change condition.

1.4 MODEL INPUTS

1.4.1 WATER BALANCE MODEL

The description of water balance inputs including catchment size, geometric information of voids, groundwater flow, along with climate data were summarized in Table 1-2 The coefficients used in AWBM model adopted from the 2022 water balance model were listed in Table 1-2.

TABLE 1-2 WATER BALANCE INPUTS

Input	details	source
Precipitation and evaporation	Historic data covers the period of January 1889 to January 2023 (134 years).	SILO database facility hosted by the Queensland Department of Environment and Science (DES).
Groundwater flow	Timeseries of in/outflow	predicted by a hydrogeologic model and provided by KCB
Geometric information	Storage curve of eight voids, catchment size	Derived from the digital elevation model (DEM) of the final landform

1.4.1.1 CLIMATE INPUT

Inputs for precipitation and evaporation in the Dawson north, center, and south regions were compiled based on long-term historical rainfall and Morton evaporation time-series obtained from the SILO Data Drill service. The SILO Data Drill service extracts gridded climate data interpolated from point observations hosted by the Bureau of Meteorology (BoM). A dataset spanning 134 years, from 1889 to 2023, was utilized in the Monte Carlo model run, incorporating repeated and shifted historical data. The catchment's evaporation was determined by applying a constant ratio of 0.95 to the daily lake evaporation time series. The monthly averages of precipitation and lake evaporation are presented in Table 1-3.

TABLE 1-3 MONTHLY AVERAGE OF PRECIPITATION AND LAKE EVAPORATION APPLIED TO THE DAWSON SITE.

Month	Precipitation			Lake Evaporation		
	North	Center	South	North	Center	South
	mm	mm	mm	mm	mm	mm
Jan	98	96	100	200	200	200
Feb	91	86	91	167	167	167
Mar	68	63	62	163	163	163
Apr	38	36	36	126	125	124
May	33	32	34	93	93	92
Jun	34	34	37	72	71	70
Jul	29	28	30	81	80	79
Aug	21	21	23	108	108	107
Sep	27	27	29	141	140	140
Oct	53	53	55	178	177	176
Nov	67	69	71	192	191	191
Dec	94	88	90	206	206	206
Annual	652	635	657	1728	1722	1713

1.4.1.2 CLIMATE CHANGE SCENARIOS

In the context of the Intergovernmental Panel on Climate Change's (IPCC Fifth Assessment Report AR5), novel Representative Concentration Pathways (RCPs) were introduced to supersede the preceding emission scenarios outlined in the Special Report on Emission Scenarios (SRES)(IPCC, 2013). Diverging from the SRES, the four endorsed RCPs delineate trajectories of greenhouse gas concentrations, as opposed to emissions trajectories. These scenarios, namely RCP2.6, RCP4.5, RCP6, and RCP8.5, corresponding to radiative target forcing levels of +2.6, +4.5, +6.0, and +8.5 W/m^2, respectively, derive their nomenclature from the radiative forcing target for the year 2100. This target is predicated on the forcing exerted by greenhouse gases and other agents, relative to pre-industrial levels (Van et. al., 2011). Figure 3 depicts the concentrations of all forcing agents, expressed in parts per million (ppm) of CO2-equivalence, across the four RCP scenarios.

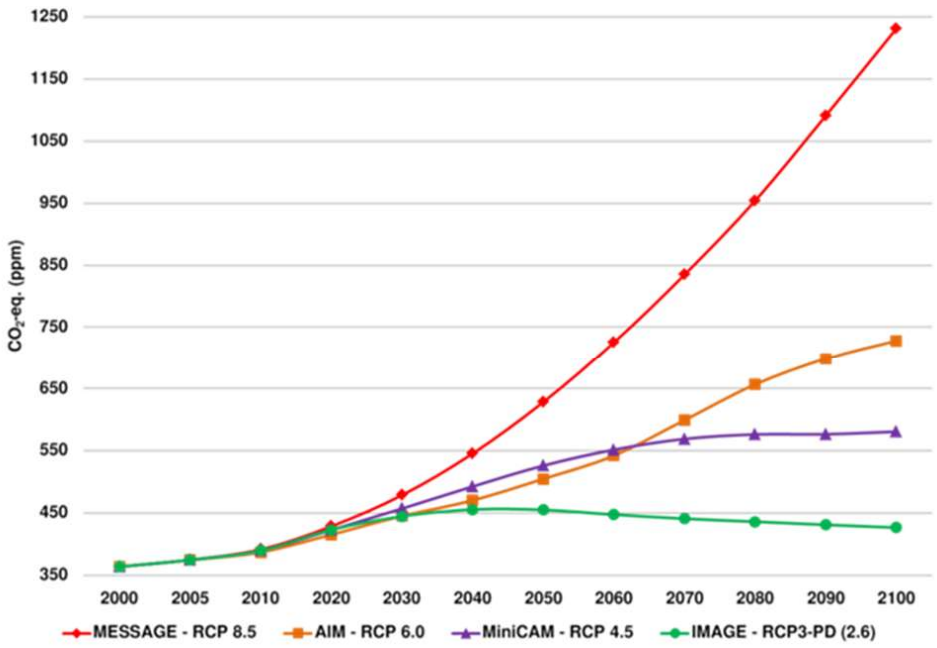


FIGURE 1-3 ALL FORCING AGENTS' ATMOSPHERIC CO2-EQUIVALENT CONCENTRATIONS ACCORDING TO FOUR RCP SCENARIOS.

The Queensland Future Climate Dashboard presented downscaled climate data corresponding to two climate change scenarios, namely RCP8.5 and RCP4.5. Each scenario entailed the provision of 12 model outcomes pertaining to alterations in precipitation and evaporation within the central Queensland region. Within this array of models, the predictions derived from the Australian Community Climate and Earth System Simulator (ACCESS) model, specifically ACCESS1-3 under the RCP 8.5 scenario, were employed in this investigation to assess the impact of climate change on the Dawson void. The percentage shifts in precipitation and evaporation from the year 2020 to 2100 are delineated in Table 1-4 and Table 1-5. These percentage alterations were subsequently applied to the historical climate data inputs within the specified scenario.

TABLE 1-4 CHANGE OF PRECIPITATION PREDICTED BY ACCESS 1-3 MODEL UNDER RCP8.5 SCENARIO FROM 2020 TO 2100.

Month	2020-2039	2040-2059	2060-2079	2080-2099
	% change	% change	% change	% change
Jan	2.7	-4.5	9	15
Feb	2.7	-4.5	9	15
Mar	-9.1	-15	-31	-10
Apr	-9.1	-15	-31	-10
May	-9.1	-15	-31	-10
Jun	1.2	16	-33	-23
Jul	1.2	16	-33	-23

Month	2020-2039	2040-2059	2060-2079	2080-2099
	% change	% change	% change	% change
Aug	1.2	16	-33	-23
Sep	40	-5.6	-10	-33
Oct	40	-5.6	-10	-33
Nov	40	-5.6	-10	-33
Dec	2.7	-4.5	9	15

TABLE 1-5 CHANGE OF EVAPORATION PREDICTED BY ACCESS 1-3 MODEL UNDER RCP8.5 SCENARIO FROM 2020 TO 2100.

Month	2020-2039	2040-2059	2060-2079	2080-2099
	% change	% change	% change	% change
Jan	13	26	28	34
Feb	13	26	28	34
Mar	12	22	36	39
Apr	12	22	36	39
May	12	22	36	39
Jun	11	17	36	40
Jul	11	17	36	40
Aug	11	17	36	40
Sep	3.6	20	32	43
Oct	3.6	20	32	43
Nov	3.6	20	32	43
Dec	13	26	28	34

1.4.1.3 GROUNDWATER FLOW

The associations between water level and groundwater flow rates for each pit shell were provided by KCB and are visually depicted in Appendix B. According to the data, the overarching trend suggests a rise in groundwater inflow as water levels decrease, with the exception of pits in the South mining area. Significantly, Pit 25 and Pit 28 exhibit a projected increase in groundwater inflow concurrent with the elevation of water levels.

1.4.1.4 CATCHMENT SIZE AND STORAGE CURVE

The catchment size, area of each void, elevation of bottom and crest of each void were all delineated and derived from the final landform DEM file received. The summarized information for each void are listed in Table 1-6.

Since the voids are generally surrounded by backfill of the mining shell, base flow from the waste rock placed in the mining pit was assumed to report the final void even the surface landscape of these area is not part of the catchment of the void for scenarios 2 and 3. The extra spoil size of each void was derived from the final landscape surface and prime surface after mining, and listed in Table 1-6.

TABLE 1-6 GEOMETRIC INPUTS OF EACH VOID AND CORESPONDING CATCHMENT

Void name	Catchment size	Extra Spoil size	Max surface area	Max depth
	ha	ha	ha	m
Northern Pit	282	558	344	221
Pit 2	402	371	242	163
Pit3-12	1307	823	634	208
Pit 13	581	370	188	121
Pit 19	814	1225	275	157
Pit 24	120	351	160	68
Pit 25	184	170	162	88
Pit 28	170	600	152	94

1.4.1.5 STORAGE CURVE

The water area-depth curves for the voids were derived using the DEM file representing the final landform. These curves were employed to calculate the free water surface in the model for evaluating evaporation loss. However, the calculation of the void's water level utilized a distinct storage curve. Since most voids are situated on partially filled mining pits, the water level is influenced by the high porosity of the waste rock surrounding the final void. In brief, the assumption was made that the pit would receive all the inflow, and the surface of the free water in the void would ascend in tandem with the water table in the waste rock. In this study, the storage curve considered both the free water column and the pore water in the waste rock within the pit shell. A uniform porosity of 0.4 was assumed and applied to all waste rock in the pit. The storage curves for each void, representing the void alone and the void with additional pore water, have been graphically presented for each void in Appendix A.

1.4.2 WATER QUALITY MODEL

Table 8 consolidates the constant TDS values allocated to runoff from individual sub-catchments, along with values for precipitation and groundwater inflow. The entirety of this data is derived from the 2022 water balance model update conducted by KCB, which is based on a calibrated operational site water balance model.

TABLE 1-7 WATER QUALITY INPUTS

Water type	TDS (mg/L)
Land use Runoff water quality	
Mining Pit	6000
Spoil	6000
Rehabilitated spoil	4000
Other water	
Precipitation	30
Groundwater	8000

2. MODEL RESULTS

2.1 WATER LEVEL

The model outcomes indicate that the water levels in all voids will stabilize after varying durations under the different scenarios assessed. The projected minimum, median, and maximum equilibrium water levels for three scenarios have been documented in Table 2-1. Additionally, the minimum freeboard required to prevent overflow, listed in Table 2-2 for three scenarios, and the estimated time needed to attain equilibrium water levels, presented in Table 11. The changes in water levels for each void post-mining are illustrated in Appendix C.

As per the model results, there is no chance of future overflow in these voids based on the current model configuration. In general, water levels are low for all the voids, especially if only the original catchment size were considered. The minimum predicted freeboard is 32 meters in Pit 24, while the North pit is anticipated to have the largest freeboard, exceeding 100 meters in all three scenarios. Under the climate change scenario, an elevated evaporation rate is expected to expedite the attainment of water level equilibrium for most voids, excluding Pit 2, Pit 3-12, and Pit 28, as these voids possess smaller surface area/volume ratios.

TABLE 2-1 MINIMUM, MEDIAN AND MAXIMUM EQUILIBRIUM WATER LEVEL PREDICTED FOR EACH VOID.

Mining Area	Void ID	Equilibrium Level (m AHD)								
		Scenario 1			Scenario 2			Scenario 3		
		Min	Med	Max	Min	Med	Max	Min	Med	Max
North	North Pit	7	10	15	17	21	27	0	2	7
Center	Pit 2	71	72	75	72	73	76	50	51	55
	Pit 3-12	52	53	56	53	54	57	20	22	25
	Pit 13	75	77	85	81	83	92	59	61	70
	Pit 19	66	68	73	85	87	92	49	52	59
	Pit 24	89	90	94	92	93	99	82	84	89
South	Pit 25	71	73	76	76	78	81	61	63	67
	Pit 28	78	79	80	79	80	83	72	75	77

TABLE 2-2 MINIMUM FREEBOARD PREDICTED FOR EACH VOID.

Mining Area	Void ID	Min Freeboard to Surface Overflow RL (m)		
		Scenario 1	Scenario 2	Scenario 3
North	North Pit	121	109	129
Center	Pit 2	51	50	71
	Pit 3-12	39	38	70
	Pit 13	51	44	66
	Pit 19	62	43	76
	Pit 24	37	32	42
South	Pit 25	59	54	68
	Pit 28	50	47	53

TABLE 2-3 ESTIMATED TIME TO REACH WATER LEVEL EQUILLIBRIUM FOR EACH VOID.

Mining Area	Void ID	Estimated Time to Reach Equilibrium (years.)		
		Scenario 1	Scenario 2	Scenario 3
North	North Pit	120	240	80
Center	Pit 2	240	200	280
	Pit 3-12	300	240	320
	Pit 13	250	280	60
	Pit 19	450	450	150
	Pit 24	100	100	80
South	Pit 25	280	320	100
	Pit 28	320	120	300

2.2 WATER QUALITY

The water quality is anticipated to exhibit a sustained upward trend in each void. This trend is attributed to the concentrating effect induced by the high evaporation rate. The projected TDS concentrations for each void after 100 years are presented in Table 2-4. Generally, a higher TDS corresponds to a greater surface area/volume ratio of the void. Concentration of TDS predicted in Scenario 3 are higher than other two scenarios because climate change condition has the highest evaporation rate. Concentration predicted by Scenarios 1 and 2 are similar. The changes in TDS for each void are graphically represented in the plot found in Appendix D.

The water quality computation employed in this study relies on straightforward assumptions, including a fully mixed water column and conservative mass loading. Nevertheless, the TDS of the water does not indefinitely increase; it precipitates out as a salt when it reaches the saturation limit. Based on the ionic composition this is not expected to occur for any salt species until at least 100,000 mg/l, and widespread precipitation is not expected until concentrations approach mid 200,000 mg/l. Furthermore, the simplistic assumption of a fully mixed water body is not applicable in these deep voids. Stratification is expected to occur in the water column, and a concentration gradient will exist between the free water body and the pore water of the spoil in the pit shell. To accurately predict water quality at various locations within each void, a more sophisticated model must be employed.

TABLE 2-4 PROJECTED TDS CONCENTRATIONS FOR EACH VOID AFTER 100 YEARS

Mining Area	Void ID	TDS after 100 years (mg/L)		
		Scenario 1	Scenario 2	Scenario 3
North	North Pit	18,000	17,000	24,000
Center	Pit 2	12,000	12,000	16,000
	Pit 3-12	11,000	11,000	14,000
	Pit 13	15,000	15,000	22,000
	Pit 19	12,000	12,000	16,000
	Pit 24	30,000	29,000	48,000
South	Pit 25	19,000	18,000	32,000
	Pit 28	9,000	10,000	12,000

3. SUMMARY

Key findings of this study include:

1. No overflow is anticipated in any of the voids across all scenarios, with the minimum predicted freeboard consistently exceeding 30 meters.

2. Water levels projected in Scenario 2 marginally surpass those in Scenario 1, attributed to the higher inflow rate. The predicted water quality exhibits similarities between these two scenarios.

3. Under climate change conditions, voids were projected to have the lowest water levels and the highest concentrations of TDS, due to a high evaporation/precipitation ratio.

4. The stabilization of water levels is forecasted to take 100-450 years under historical climate conditions. For most voids, the time needed for equilibrium is expected to decrease under climate change conditions due to a heightened evaporation rate. However, Pit 2, Pit 3-12, and Pit 28 are anticipated to require similar or longer periods for water level stabilization under climate change conditions, owing to a lower surface area/volume ratio.

5. The concentration of TDS is predicted to continuously rise in all voids based on current assumptions. Nonetheless, a more intricate model will be necessary to accurately predict changes in water quality across all voids.

6. The diverse predicted TDS concentrations in each void are primarily contingent upon the ratio of base flow (groundwater inflow) to total inflow and the surface area/volume ratio specific to each void.

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APPENDIX A STORAGE CURVE

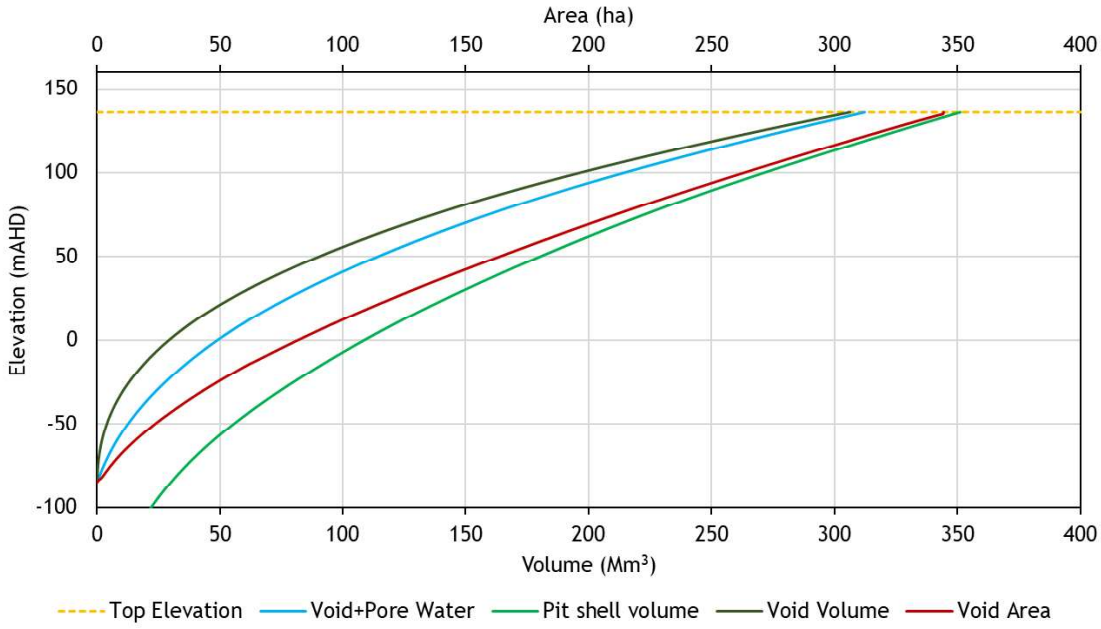


FIGURE A1: STORAGE CURVE OF NORTH PIT SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

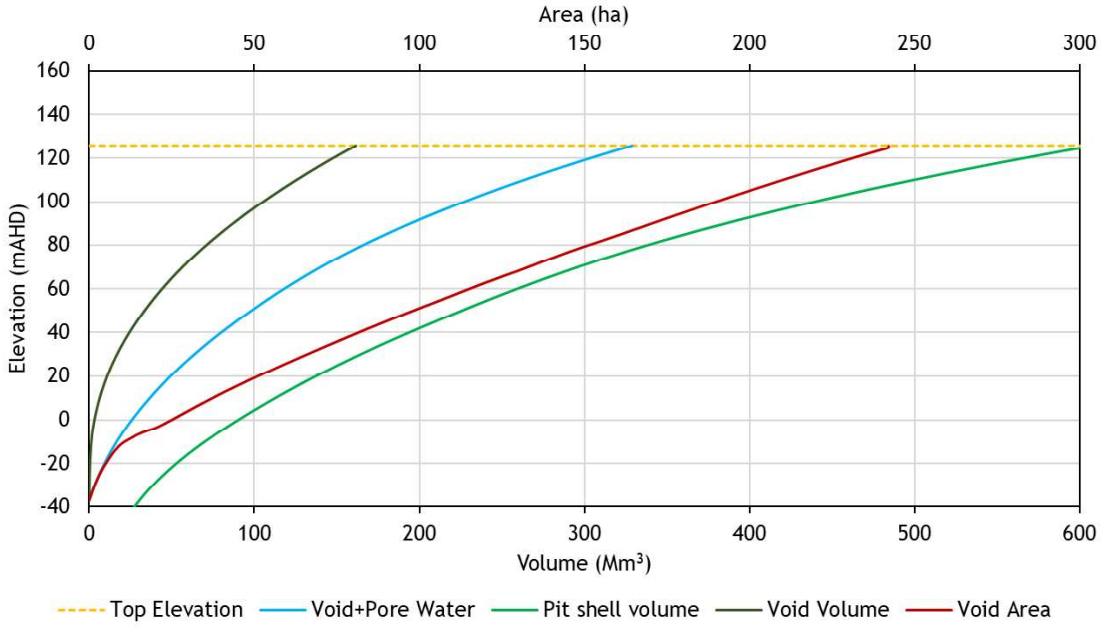


FIGURE A2: STORAGE CURVE OF PIT 2 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

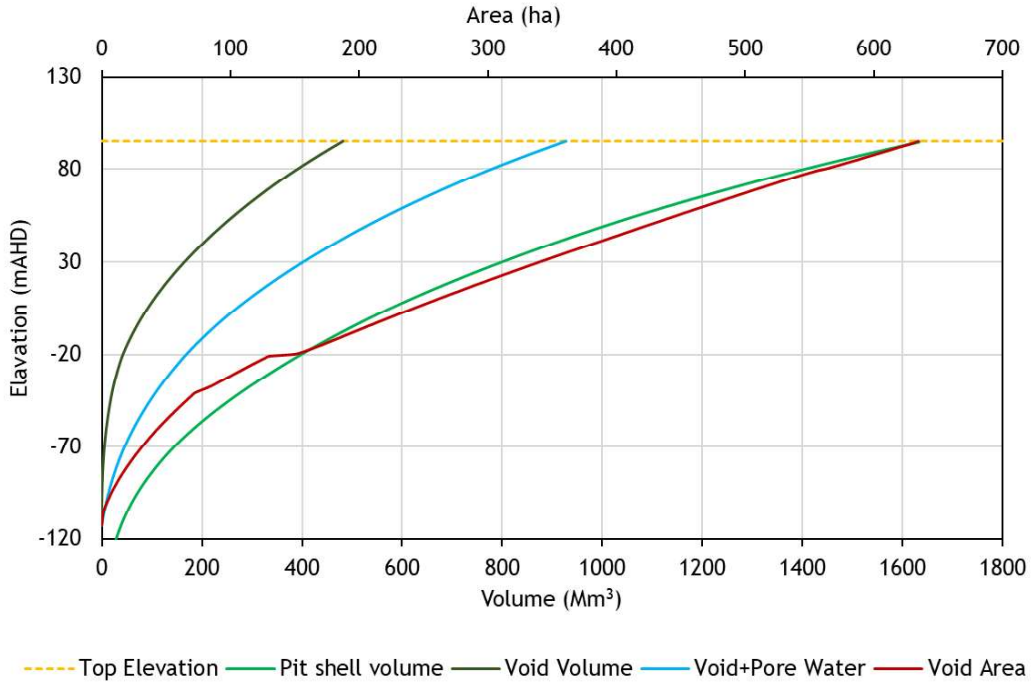


FIGURE A3: STORAGE CURVE OF PIT 3-12 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

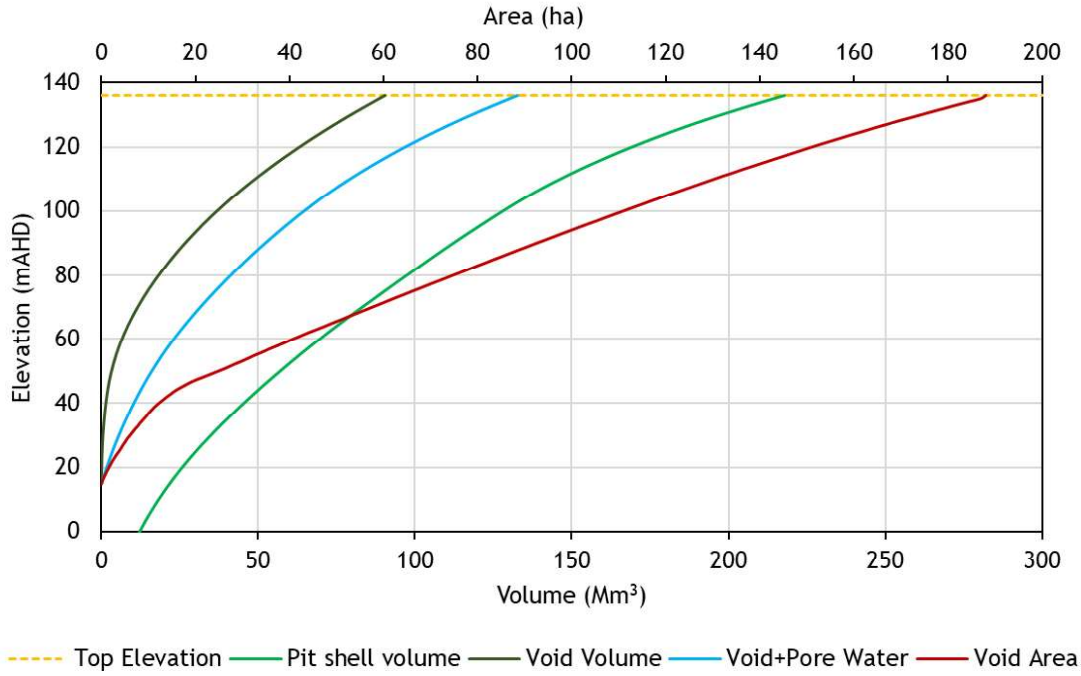


FIGURE A4: STORAGE CURVE OF PIT 13 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

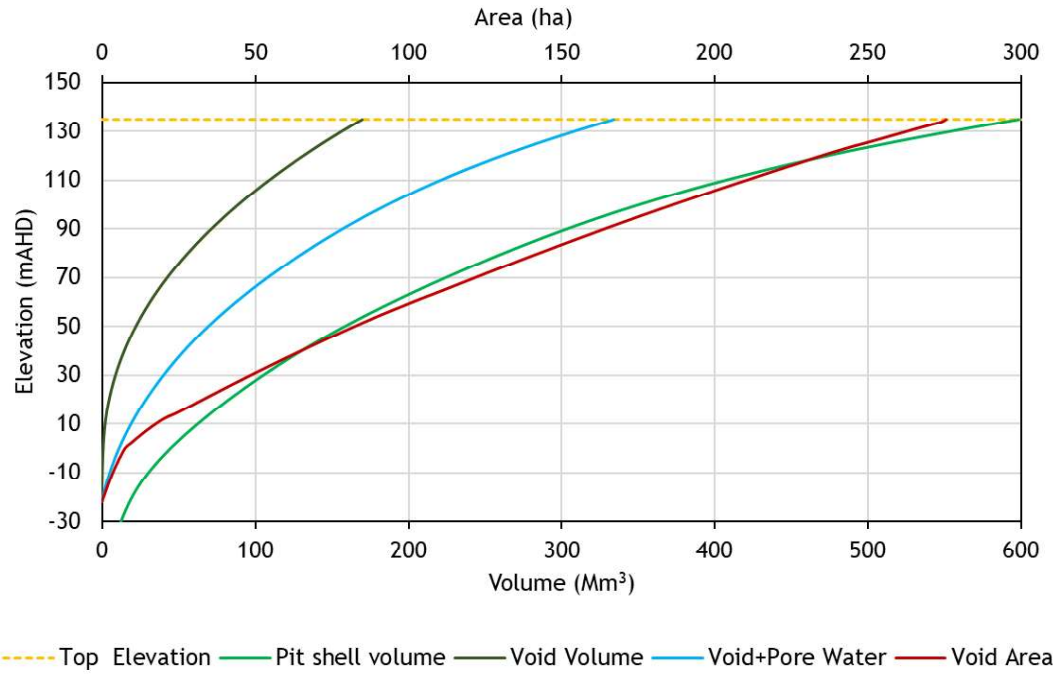


FIGURE A5: STORAGE CURVE OF PIT 19 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

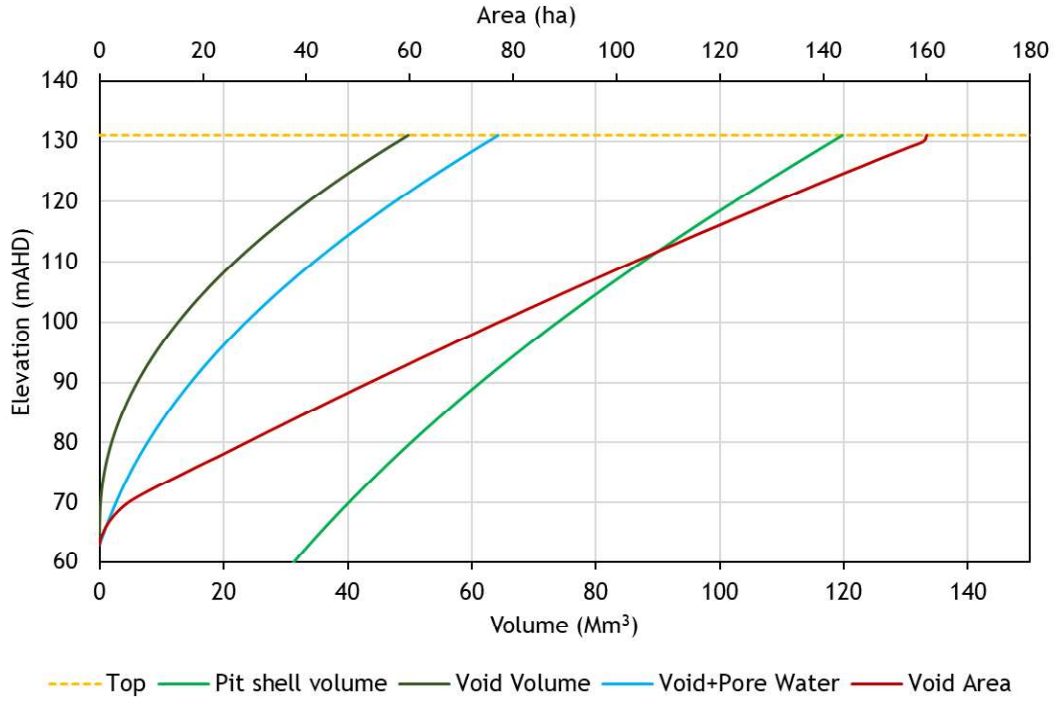


FIGURE A6: STORAGE CURVE OF PIT 24 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

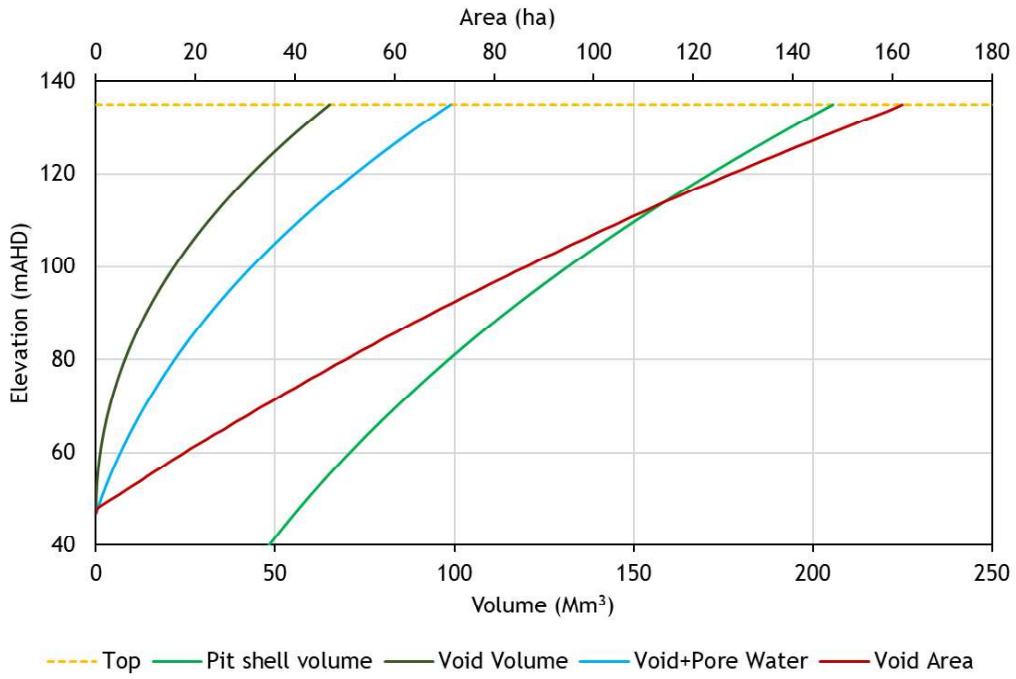


FIGURE A7: STORAGE CURVE OF PIT 25 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

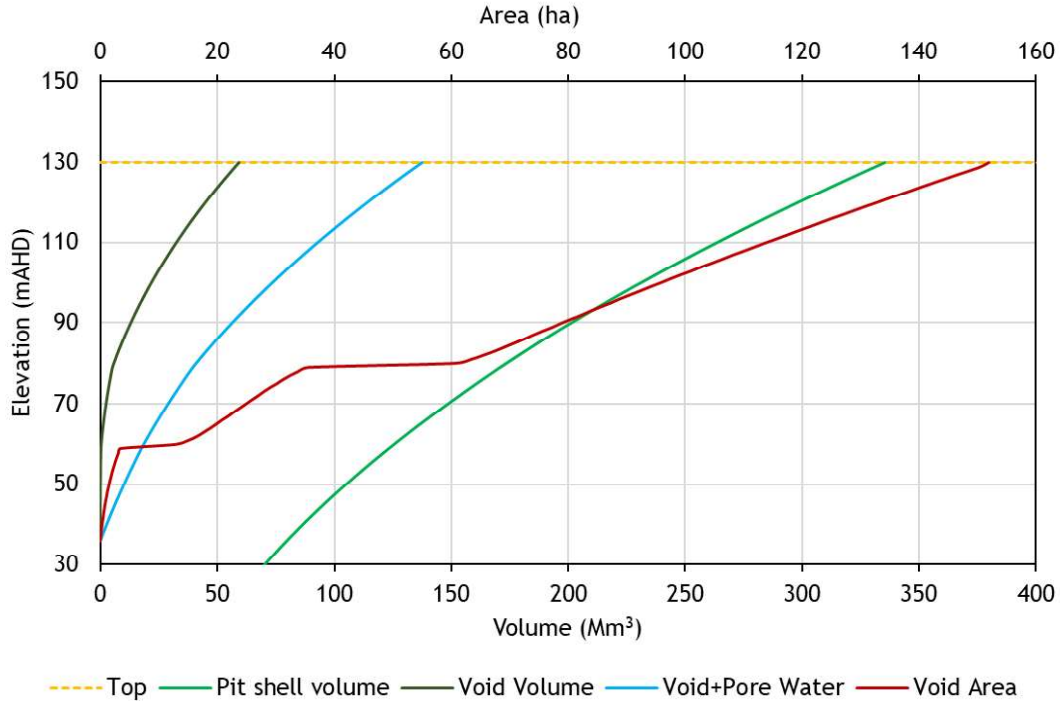


FIGURE A8: STORAGE CURVE OF PIT 28 SHELL AND VOID, WITH AN ASSUMPTION OF POROSITY 0.4 FOR WASTE ROCK IN PIT.

APPENDIX B GROUNDWATER INFLOW

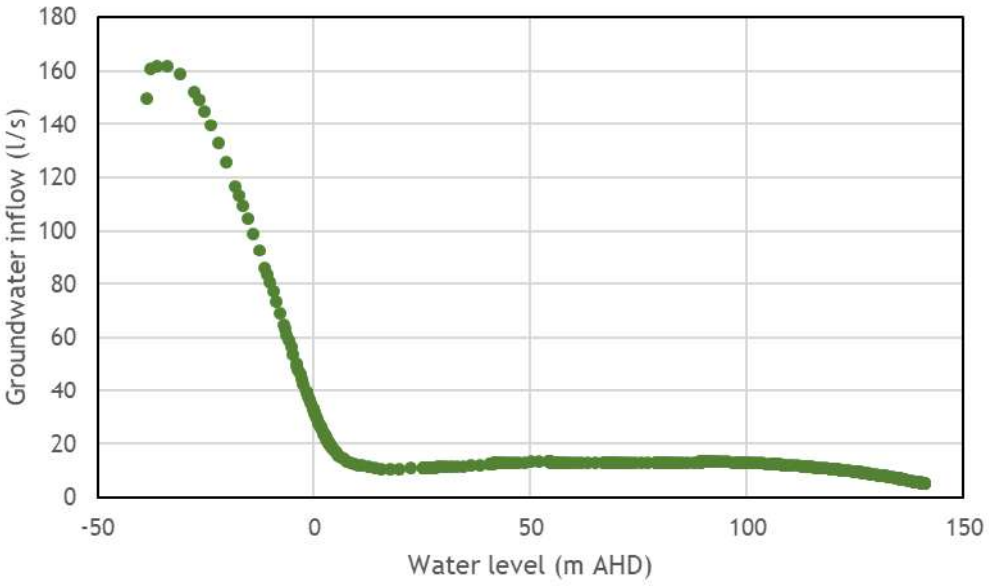


FIGURE B1: WATER LEVEL – GROUNDWATER RELATIONSHIP OF NORTH PIT SHELL.

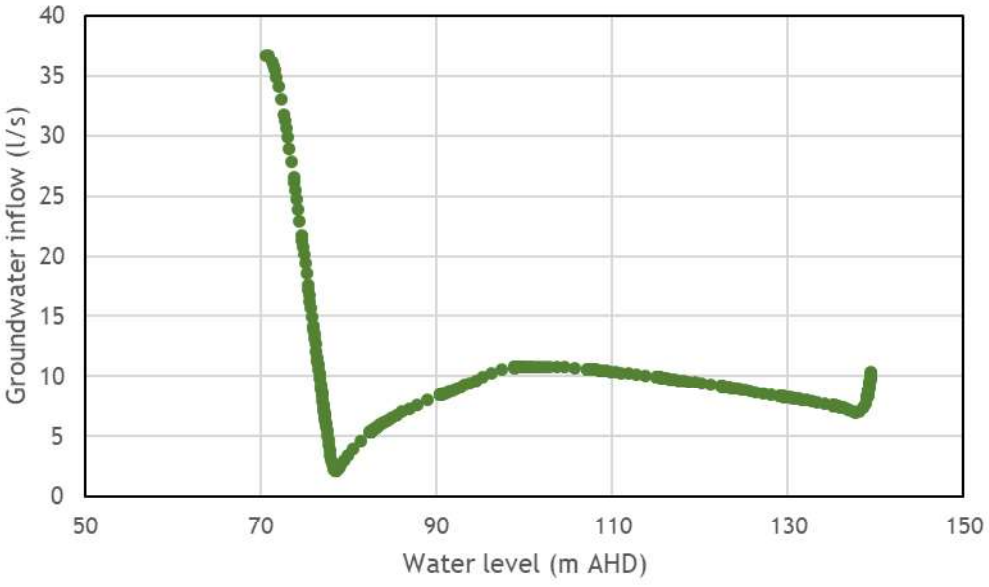


FIGURE B2: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 2 SHELL.

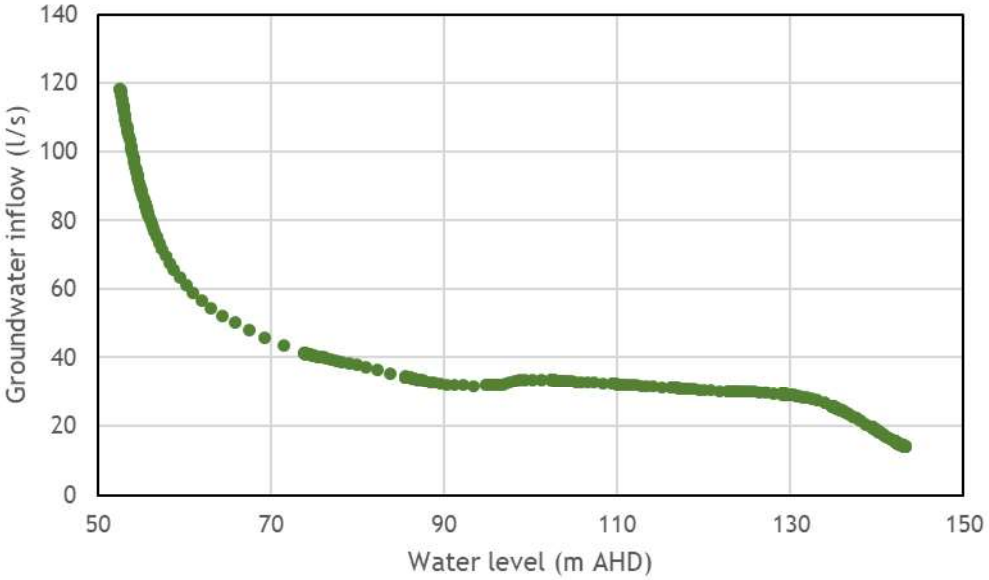


FIGURE B3: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 3-12 SHELL.

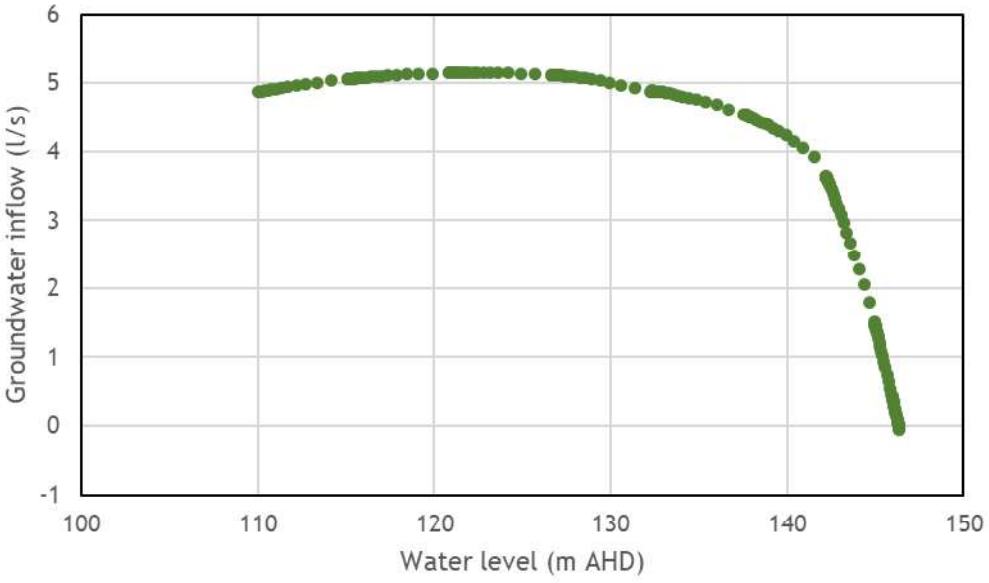


FIGURE B4: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 13 SHELL.

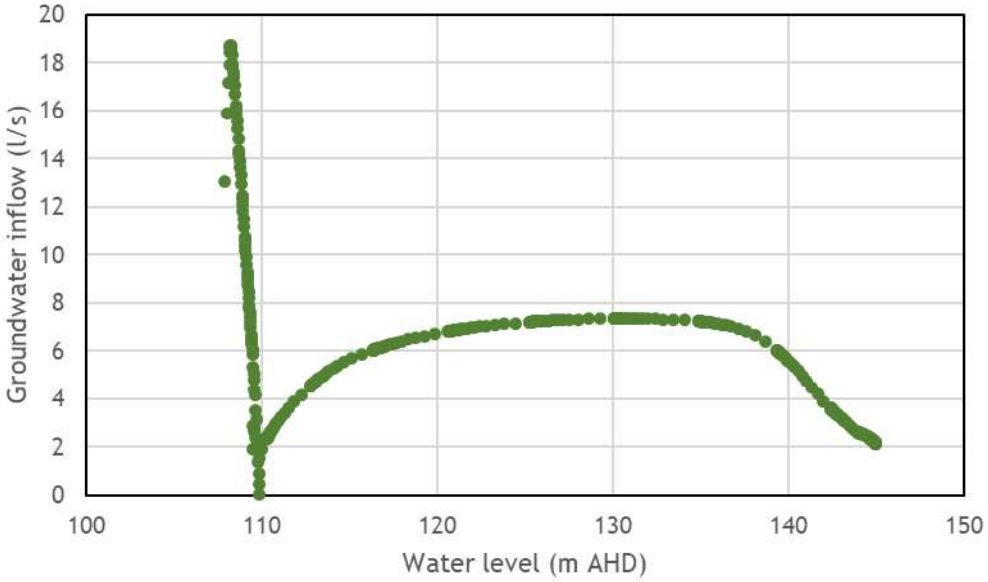


FIGURE B5: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 19 SHELL.

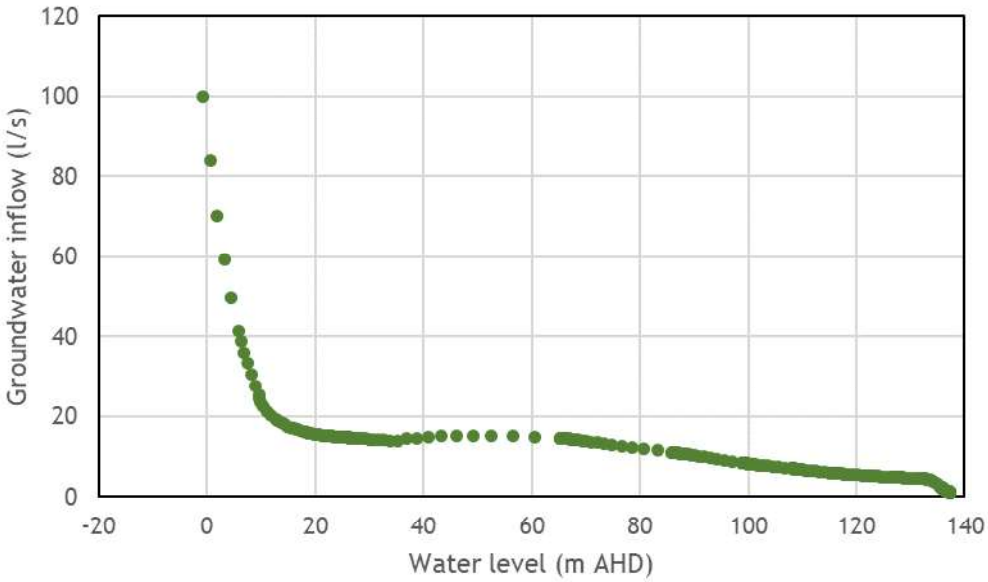


FIGURE B6: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 24 SHELL.

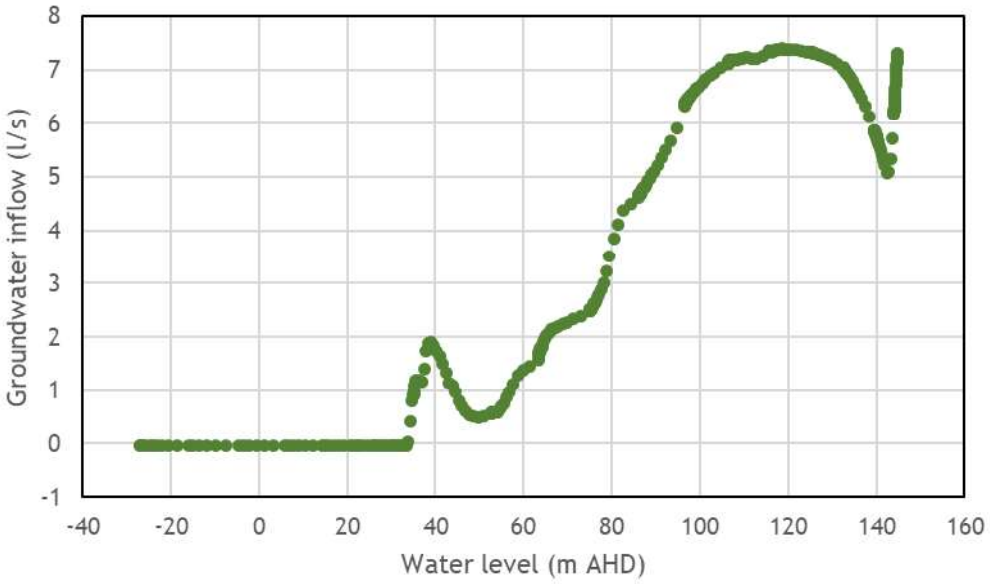


FIGURE B7: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 25 SHELL.

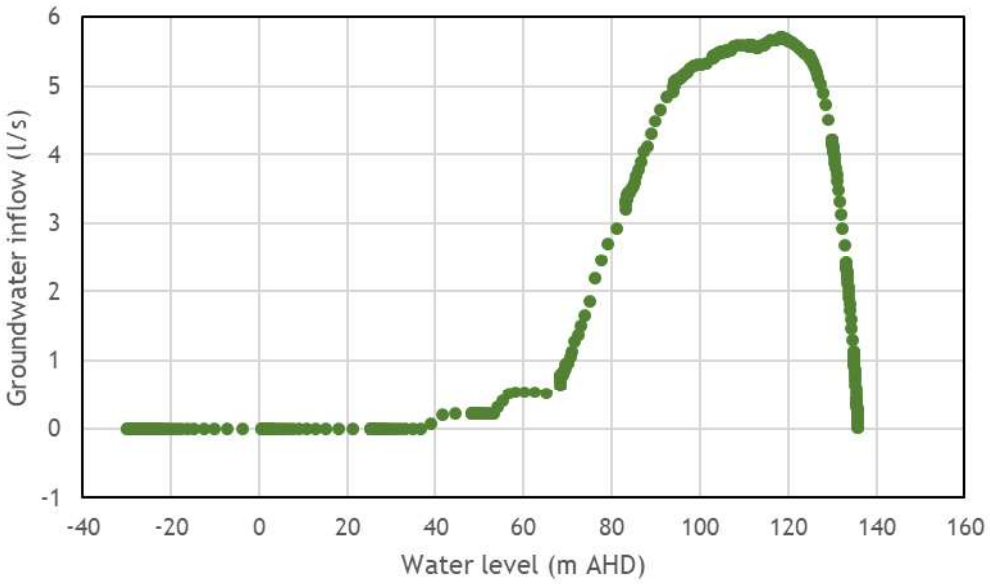


FIGURE B8: WATER LEVEL – GROUNDWATER RELATIONSHIP OF PIT 28 SHELL.

APPENDIX C WATER LEVEL RESULTS

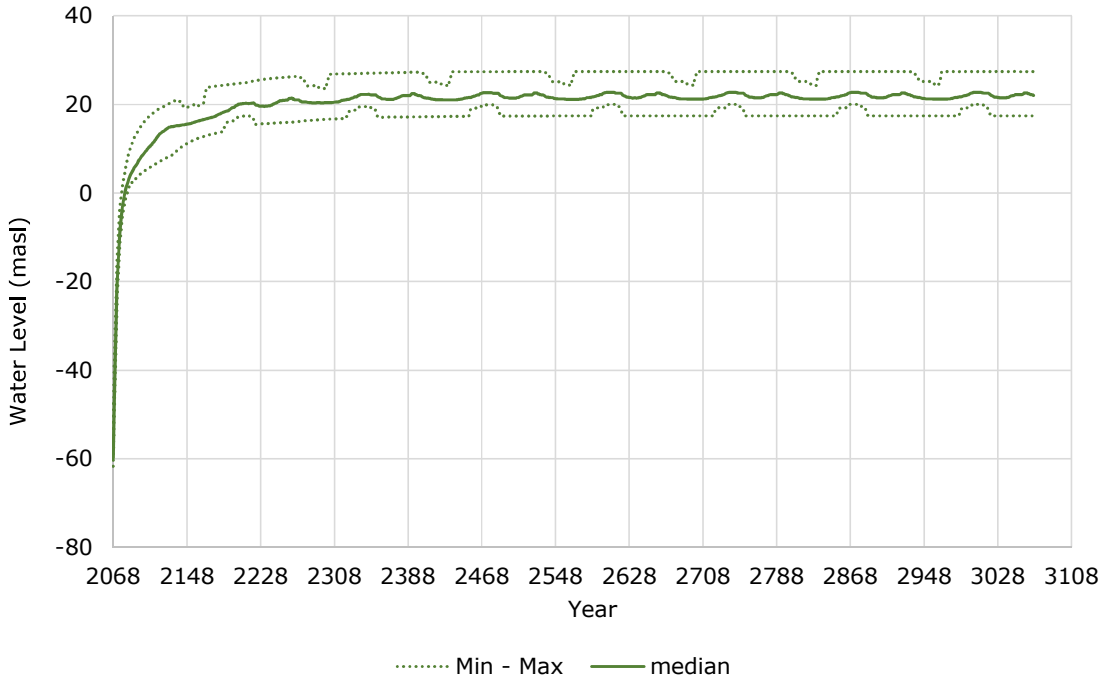


FIGURE C 1.1: PREDICTED WATER LEVEL FOR NORTH PIT - SCENARIO1

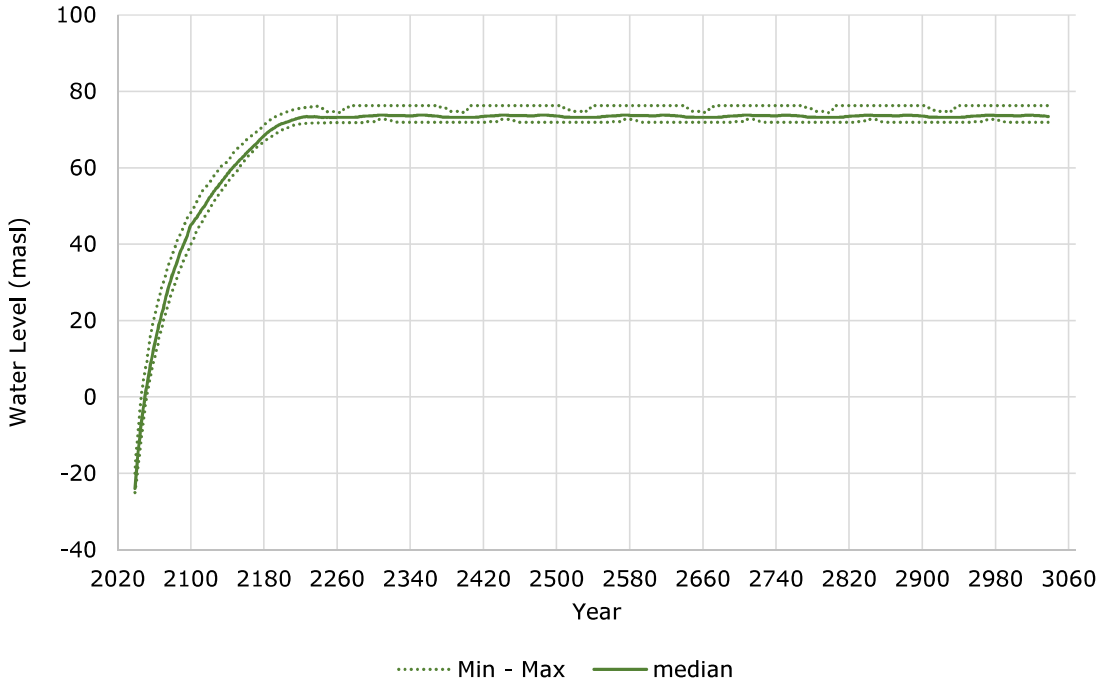


FIGURE C 1.2: PREDICTED WATER LEVEL FOR PIT 2 - SCENARIO1

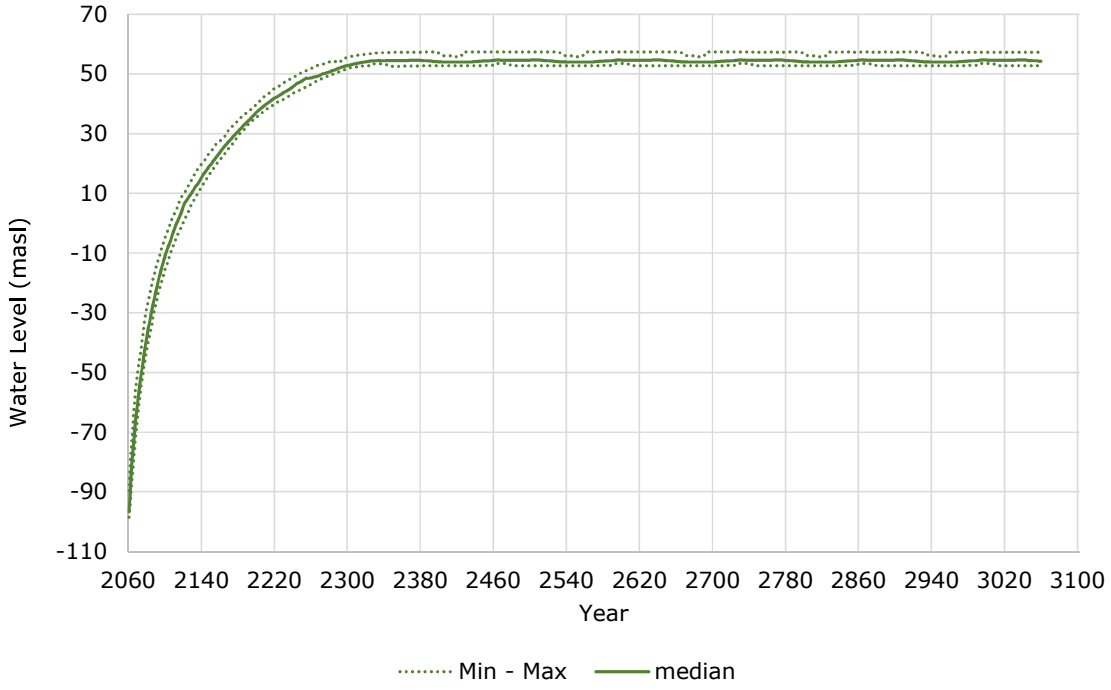


FIGURE C 1.3: PREDICTED WATER LEVEL FOR PIT 3-12 - SCENARIO1

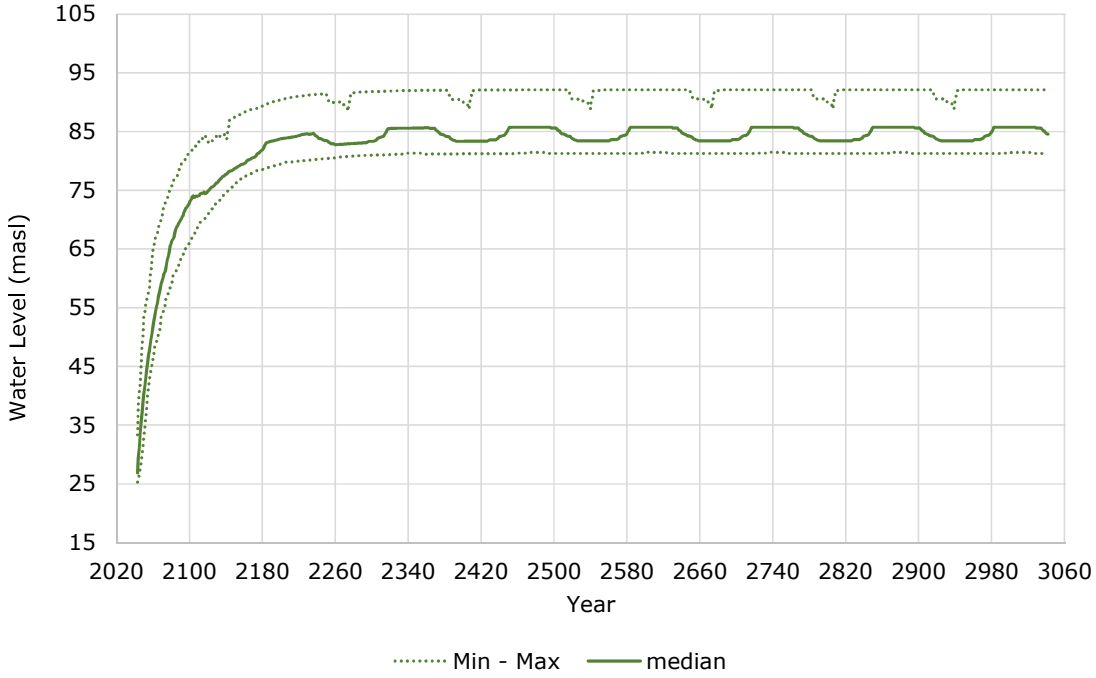


FIGURE C 1.4: PREDICTED WATER LEVEL FOR PIT 13 - SCENARIO1

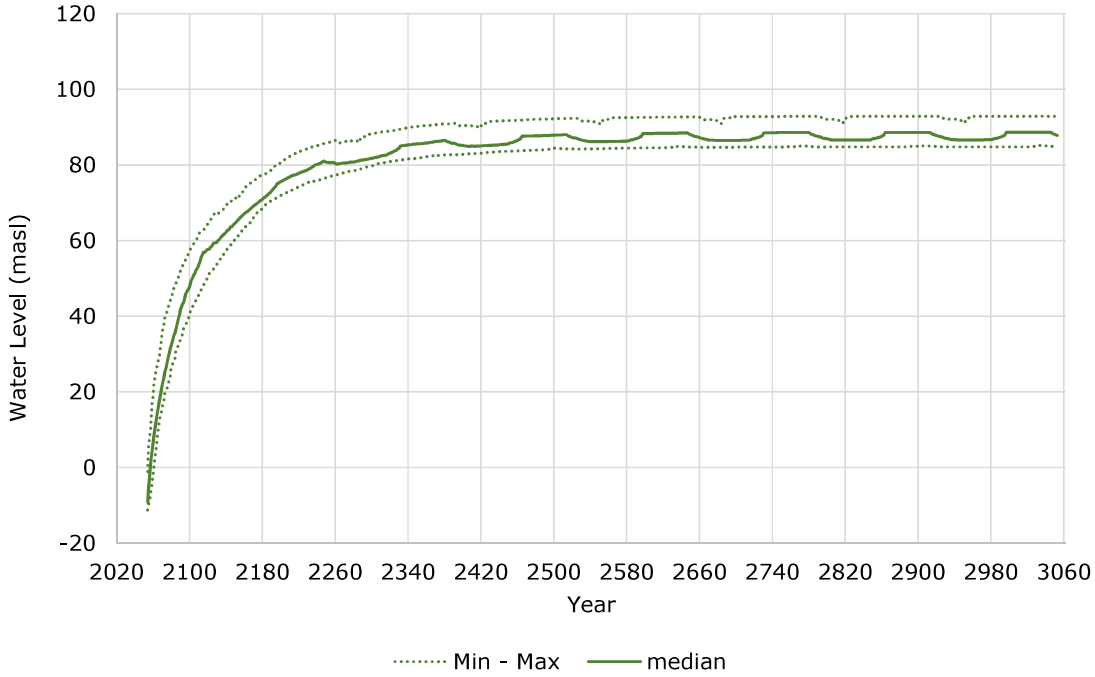


FIGURE C 1.5: PREDICTED WATER LEVEL FOR PIT 19 - SCENARIO1

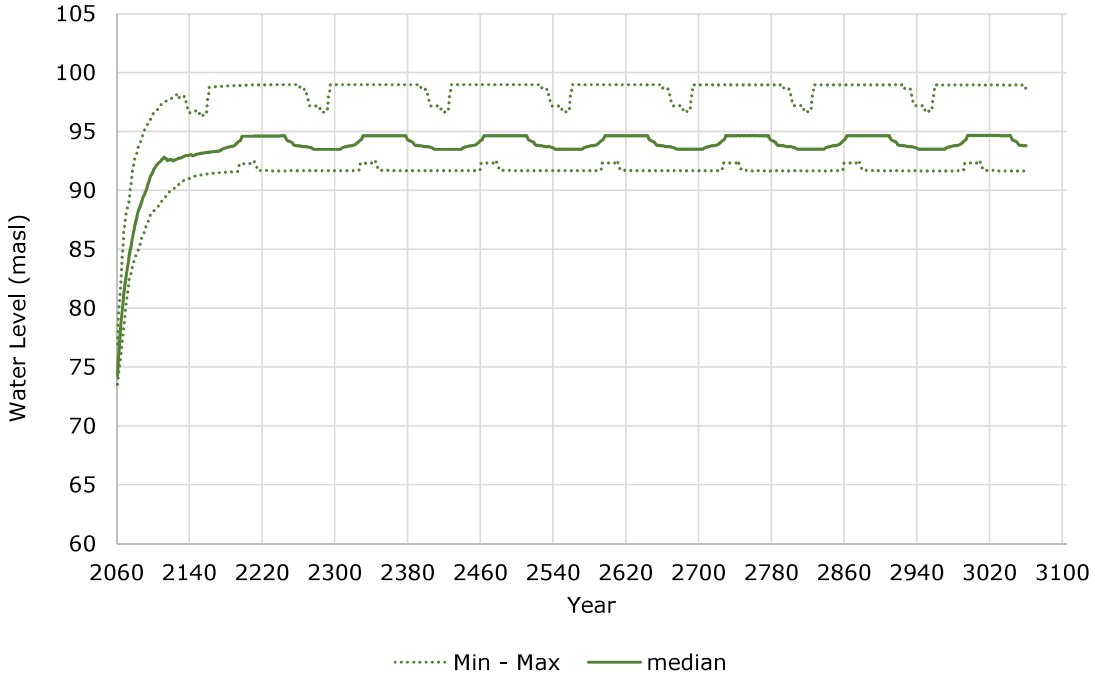


FIGURE C 1.6: PREDICTED WATER LEVEL FOR PIT 24 - SCENARIO1

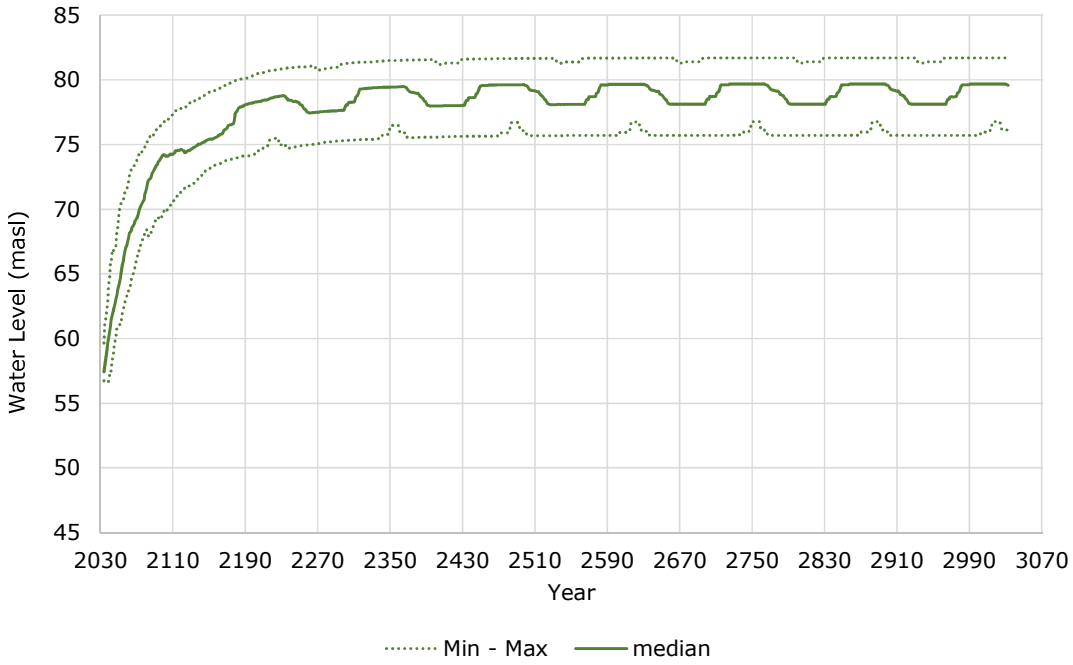


FIGURE C 1.7: PREDICTED WATER LEVEL FOR PIT 25 - SCENARIO1

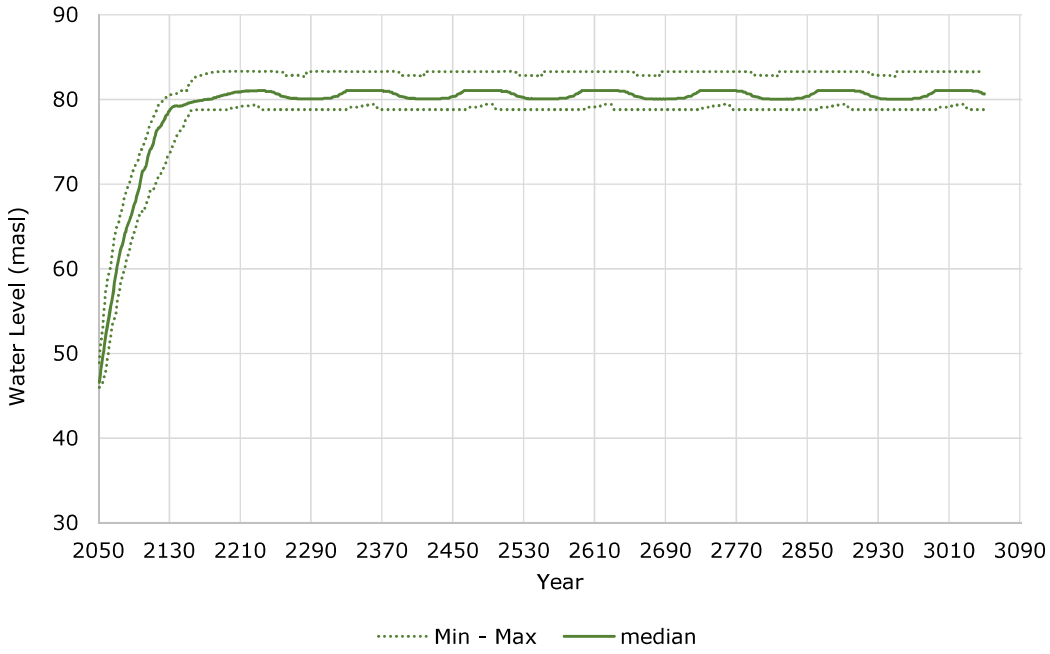


FIGURE C 1.8: PREDICTED WATER LEVEL FOR PIT 28 - SCENARIO1

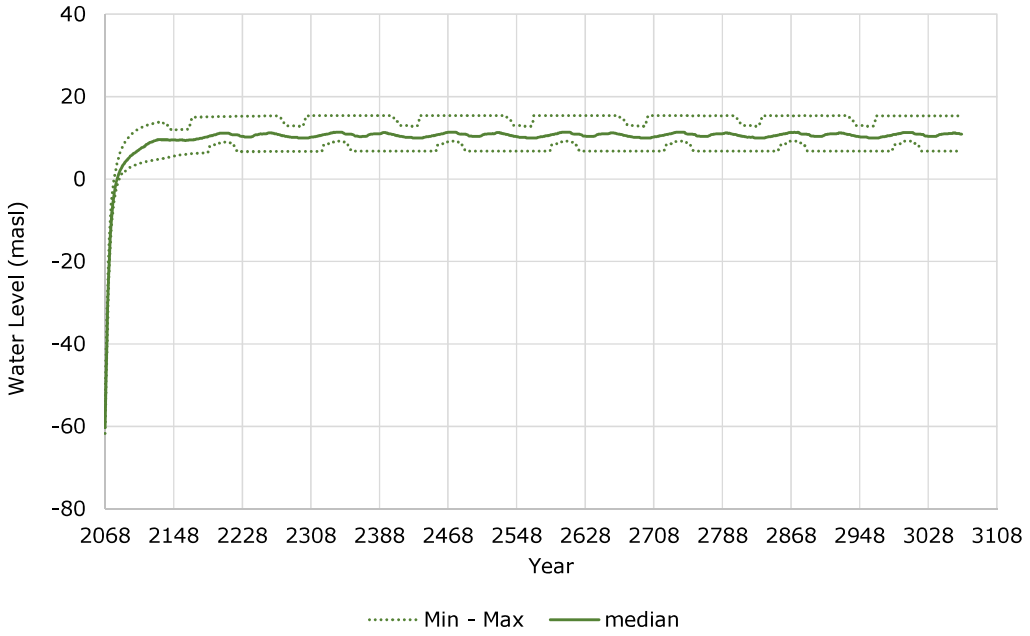


FIGURE C 2.1: PREDICTED WATER LEVEL FOR NORTH PIT - SCENARIO2

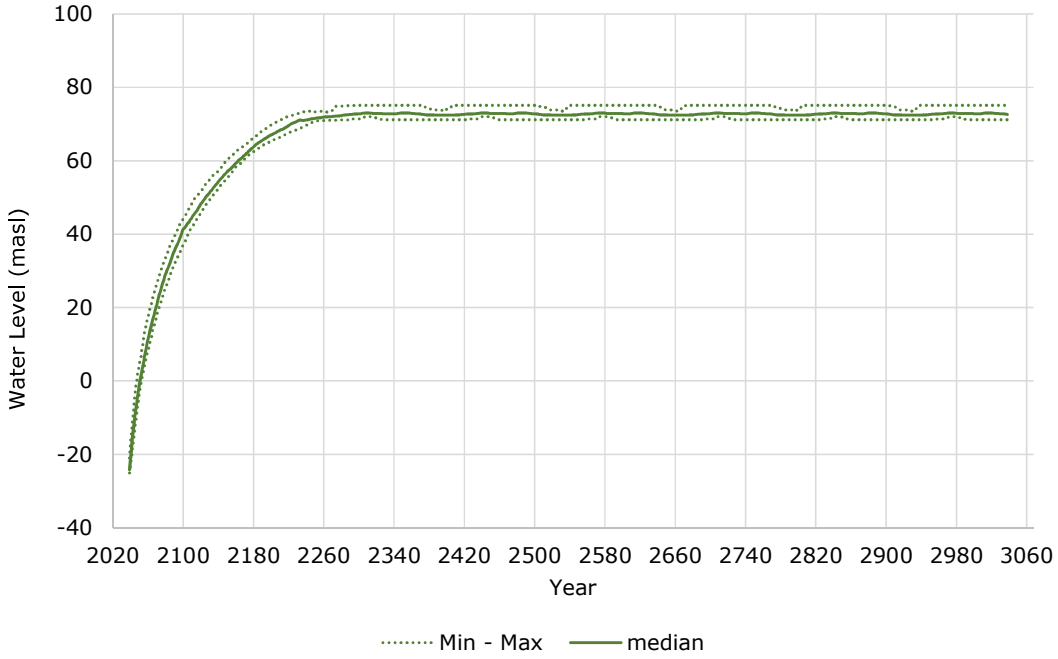


FIGURE C 2.2: PREDICTED WATER LEVEL FOR PIT 2 - SCENARIO2

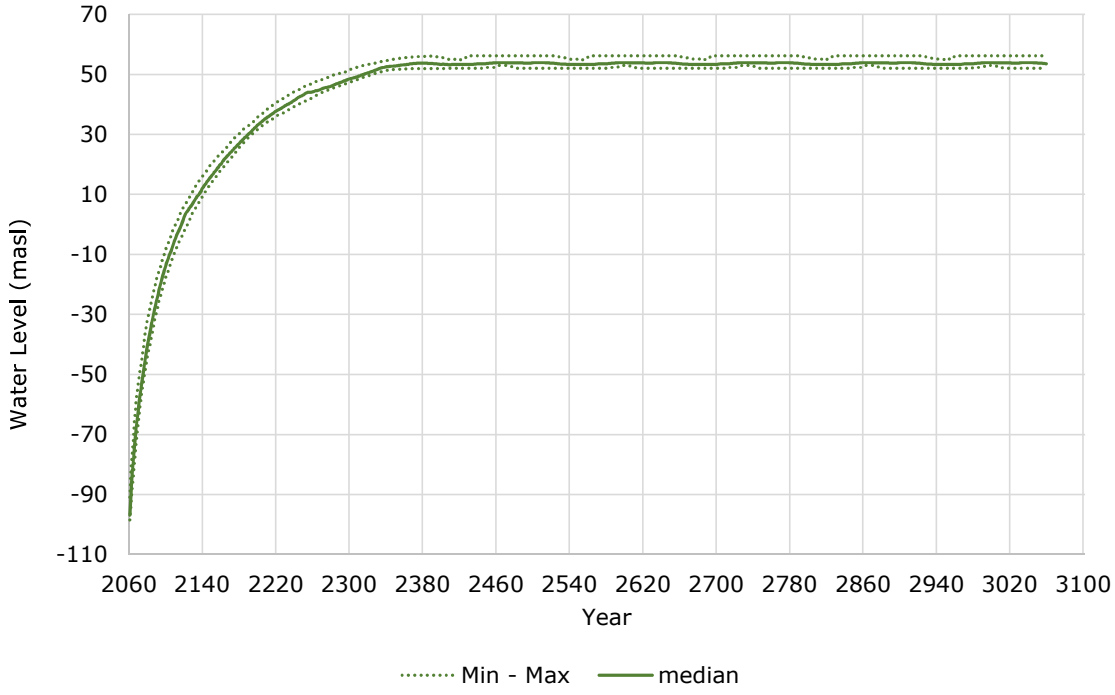


FIGURE C 2.3: PREDICTED WATER LEVEL FOR PIT 3-12 - SCENARIO2

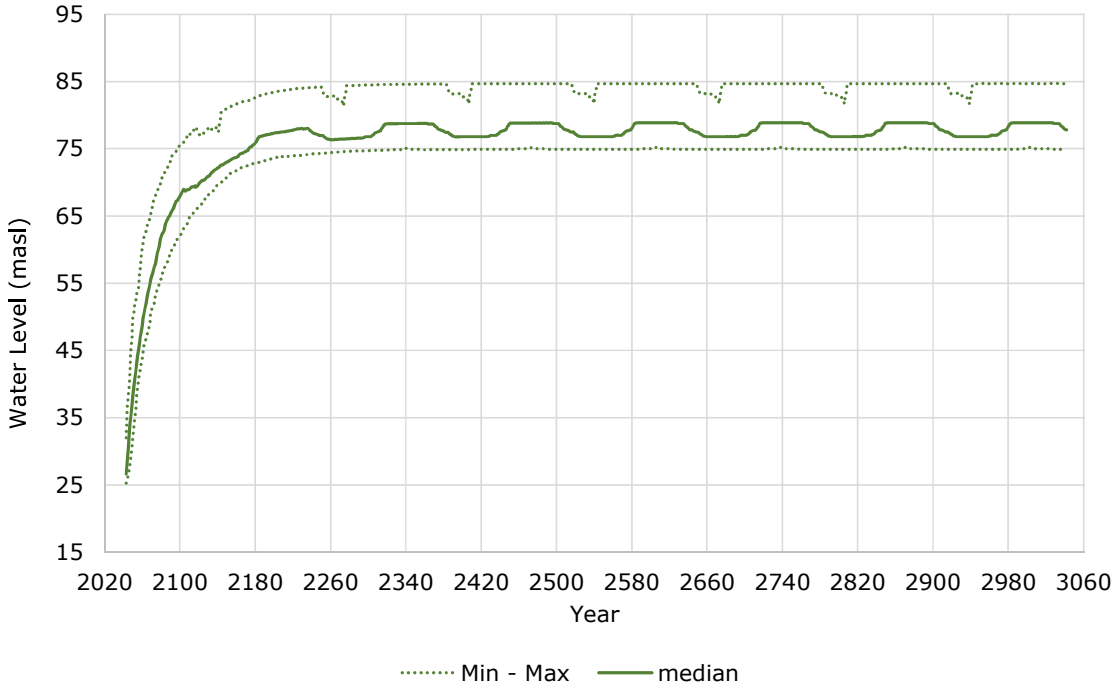


FIGURE C 2.4: PREDICTED WATER LEVEL FOR PIT 13 - SCENARIO2

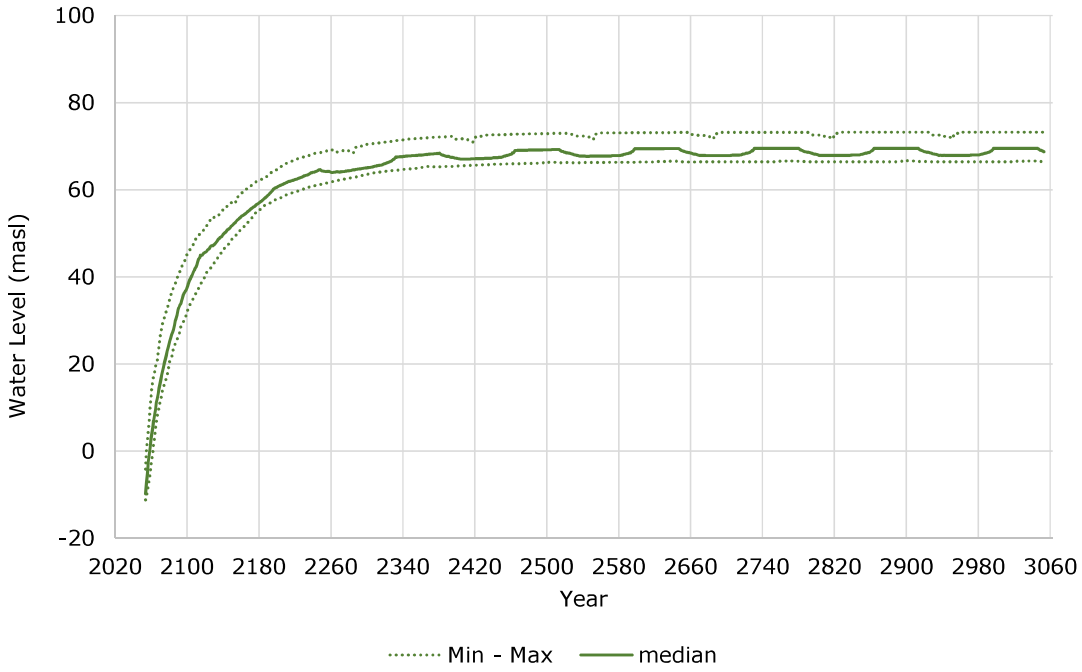


FIGURE C 2.5: PREDICTED WATER LEVEL FOR PIT 19 - SCENARIO2

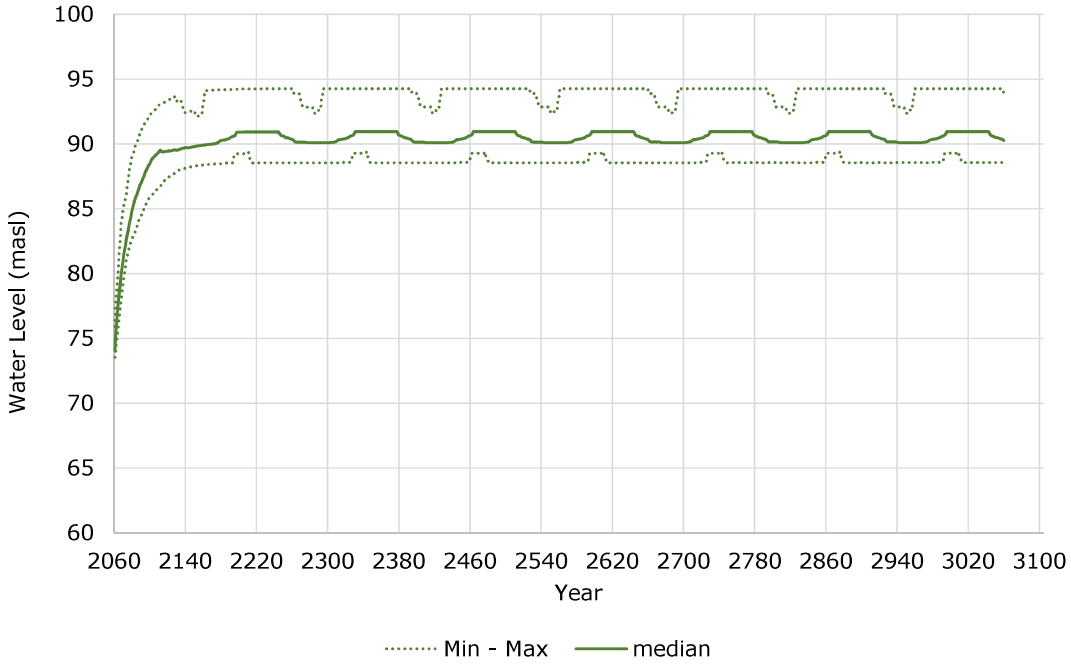


FIGURE C 2.6: PREDICTED WATER LEVEL FOR PIT 24 - SCENARIO2

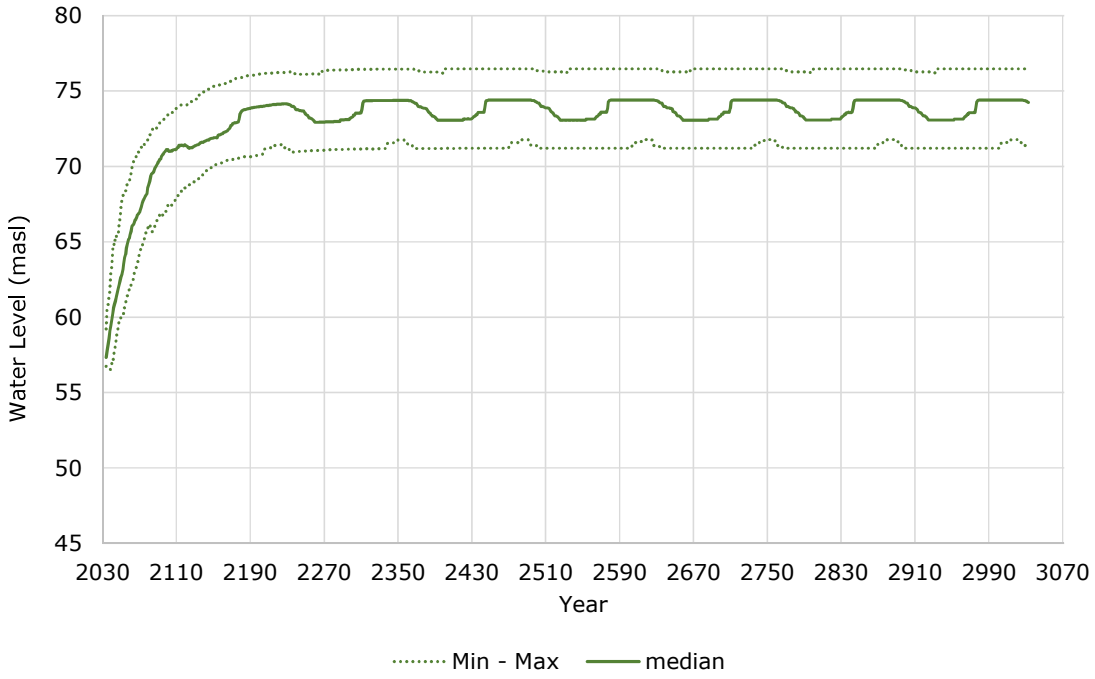


FIGURE C 2.7: PREDICTED WATER LEVEL FOR PIT 25 - SCENARIO2

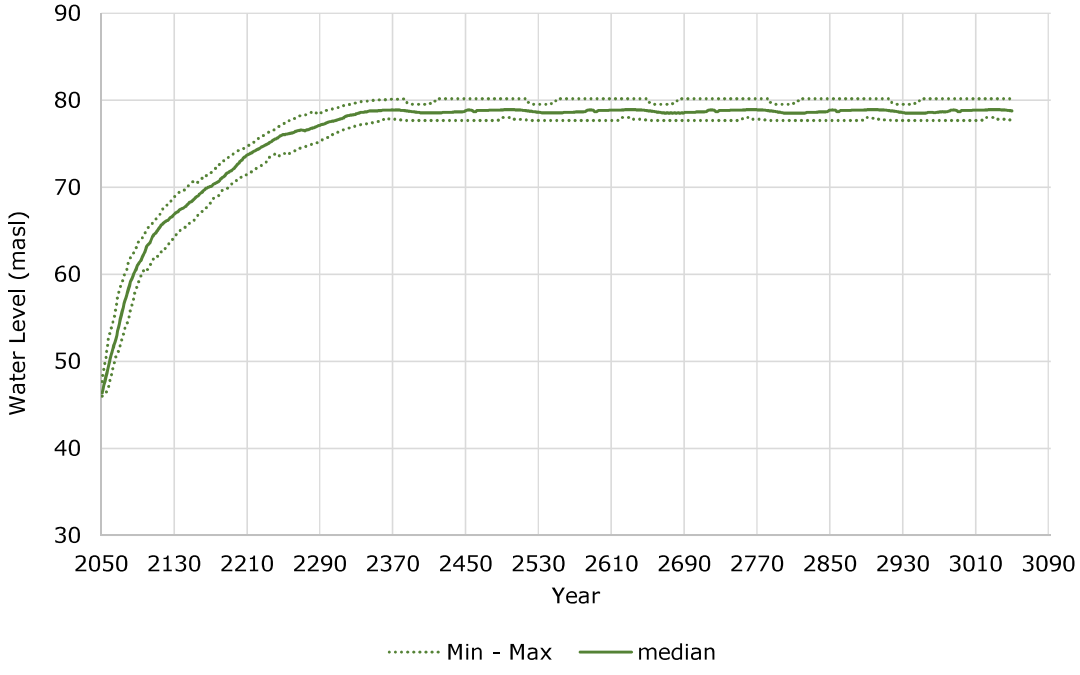


FIGURE C 2.8: PREDICTED WATER LEVEL FOR PIT 28 - SCENARIO2

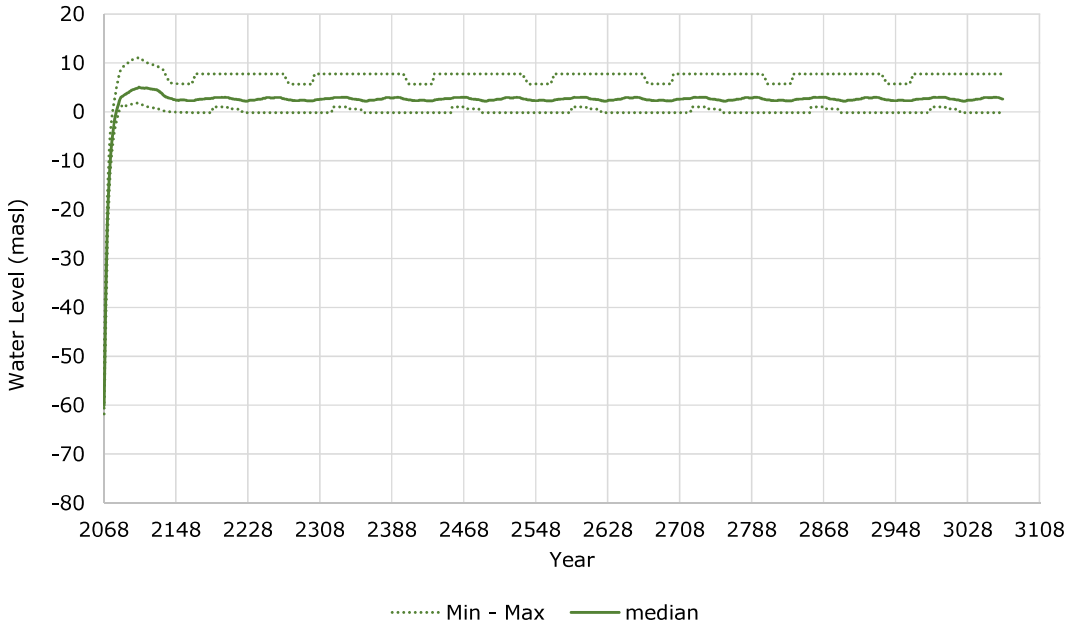


FIGURE C 3.1: PREDICTED WATER LEVEL FOR NORTH PIT - SCENARIO3

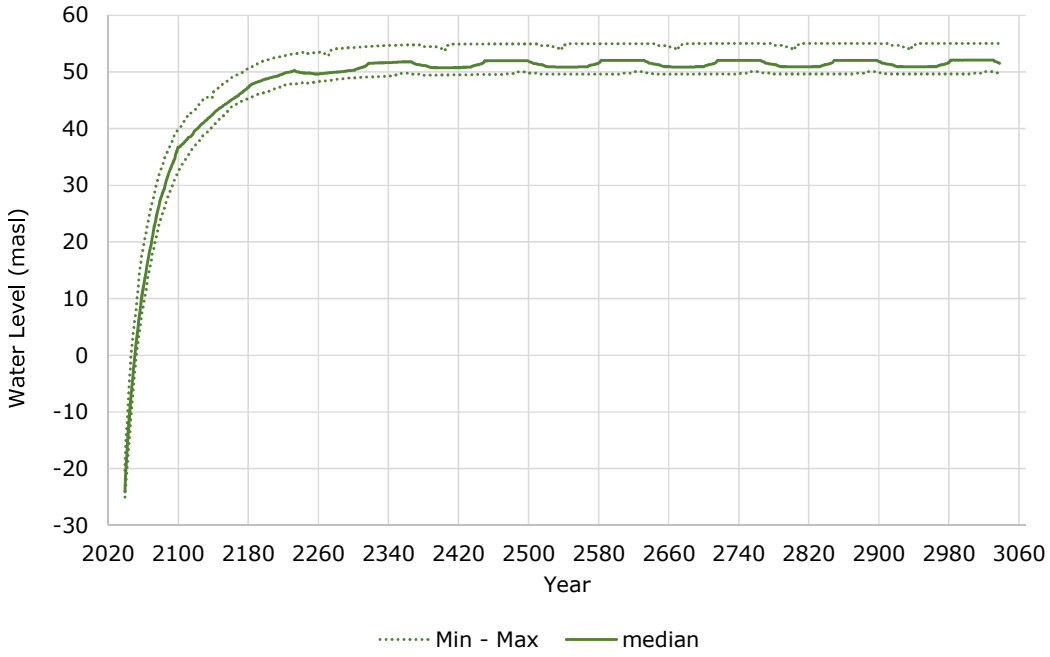


FIGURE C 3.2: PREDICTED WATER LEVEL FOR PIT 2 - SCENARIO3

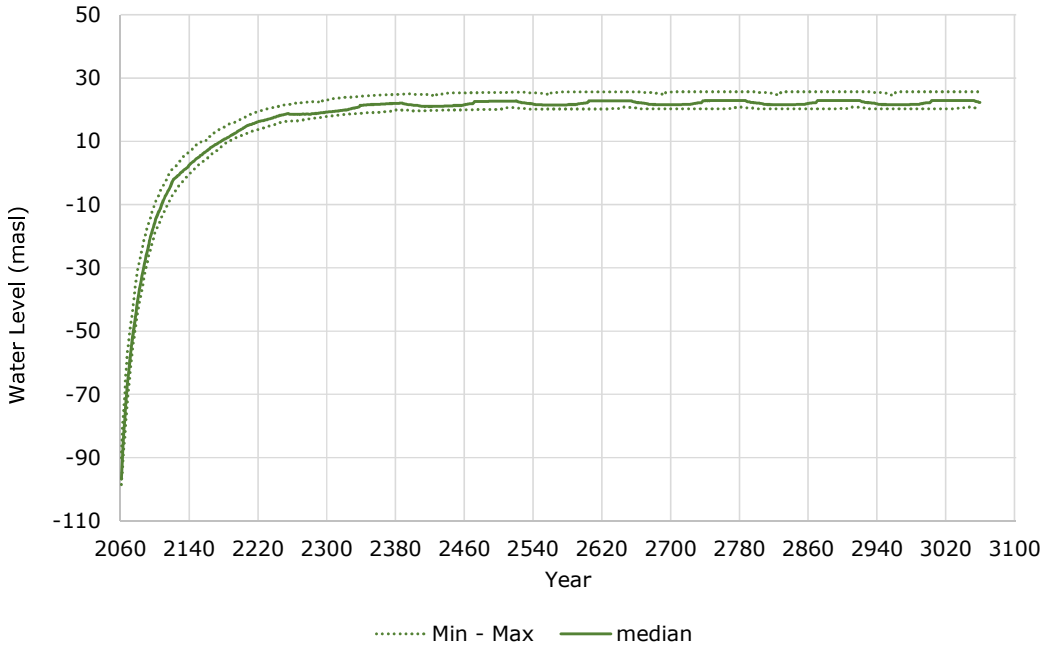


FIGURE C 3.3: PREDICTED WATER LEVEL FOR PIT 3-12 - SCENARIO3

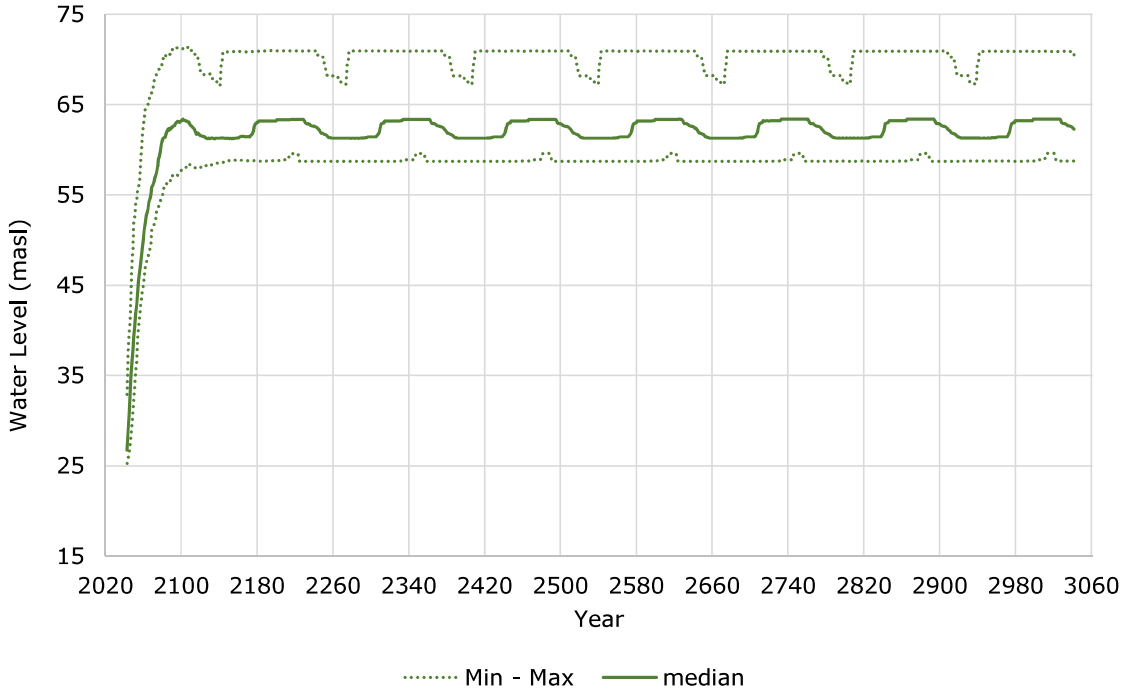


FIGURE C 3.4: PREDICTED WATER LEVEL FOR PIT 13 - SCENARIO3

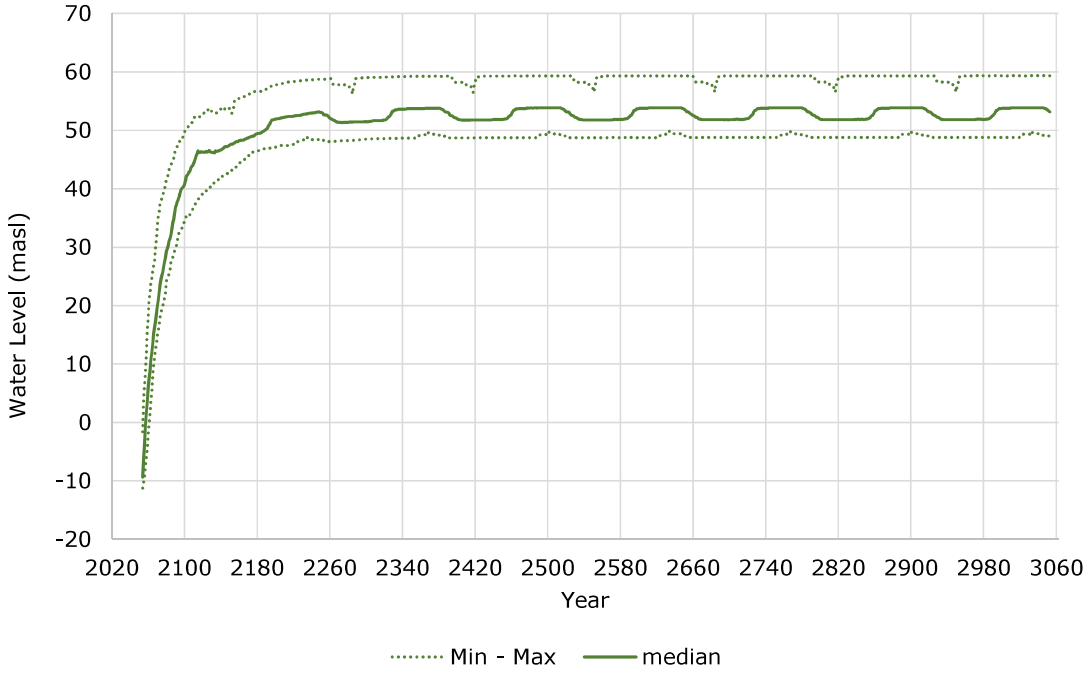


FIGURE C 3.5: PREDICTED WATER LEVEL FOR PIT 19 - SCENARIO3

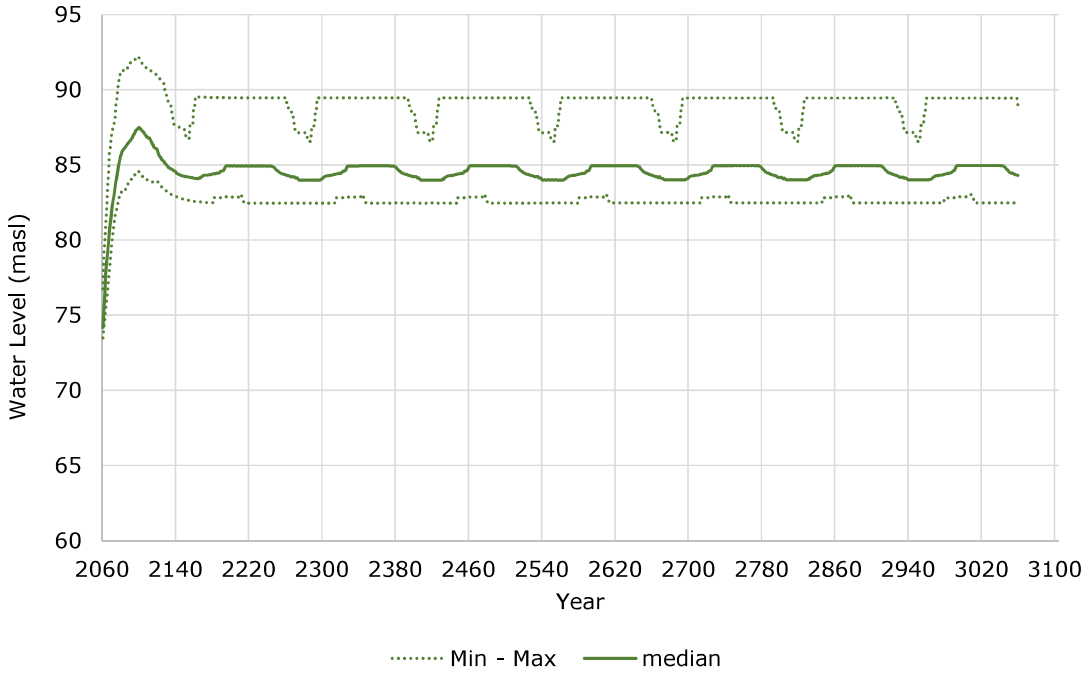


FIGURE C 3.6: PREDICTED WATER LEVEL FOR PIT 24 - SCENARIO3

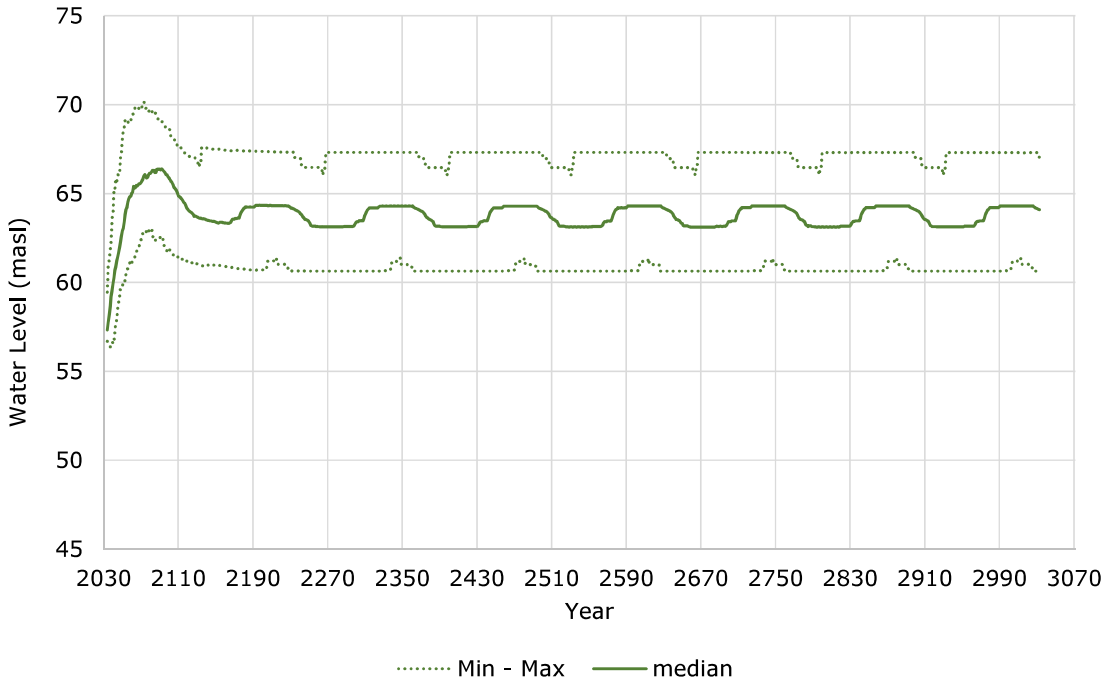


FIGURE C 3.7: PREDICTED WATER LEVEL FOR PIT 25 - SCENARIO3

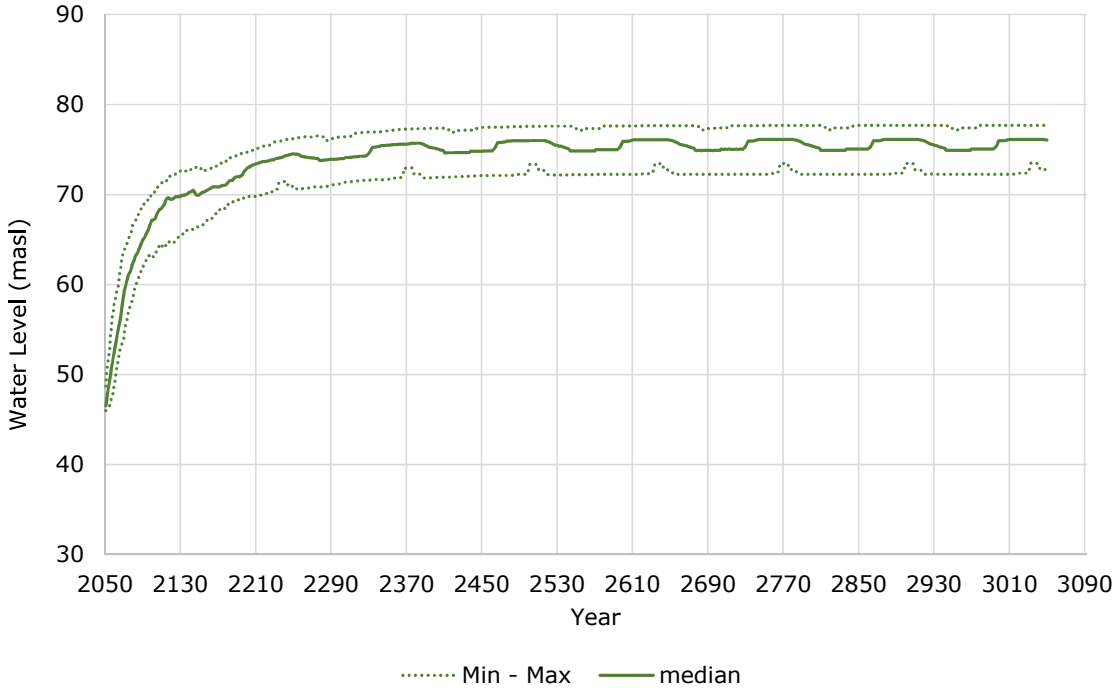


FIGURE C 3.8: PREDICTED WATER LEVEL FOR PIT 28 - SCENARIO3

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Appendix 4.7 Spontaneous Combustion Report

SPONTANEOUS COMBUSTION TECHNICAL REPORT

SPONTANEOUS COMBUSTION HAZARD ASSESSMENT OF COAL SAMPLES FROM DAWSON MINE

B3 MINING SERVICES TECHNICAL REPORT – 2023/TR110

PREPARED FOR DAWSON MINE

DECEMBER, 2023

Prepared by Dr B Basil Beamish MAusIMM CP(Min) RPEQ No.12621
and
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COMMERCIAL IN CONFIDENCE

EXECUTIVE SUMMARY

This report contains the results and analysis of coal spontaneous combustion testing of coal samples from Dawson Mine, Queensland.

Previous spontaneous combustion studies using an adiabatic oven have measured the self-heating rate index (R_{70}) of coals being mined around the world, including many Queensland mining operations. Therefore, comparisons between this study and the previous studies can be used to obtain a relative indication of the intrinsic spontaneous combustion propensity of the coal samples. In addition, spontaneous combustion indices (minimum self-heating temperature and crossing point temperature) have been derived from coal quality data of the samples. These derived indices are also used to obtain a relative indication of the intrinsic propensity of the coal for spontaneous combustion.

The R_{70} self-heating rate values measured for coal samples from Dawson Mine range from 0.81 °C/h to 4.00 °C/h, which rates the samples as having a Low-Medium to Very High intrinsic spontaneous combustion propensity. These values are consistent with the rank and type of coal. It should be noted that the R_{70} test is performed on a dry basis and as such it does not provide any indication of the time taken to reach thermal runaway. Calculated spontaneous combustion index values for crossing point temperature indicate the samples have a Low to Medium spontaneous combustion propensity rating. The measured relative ignition temperatures for the samples are in agreement with the R_{70} results.

A spontaneous combustion hazard likelihood chart has been developed for the samples to help identify those samples that are able to achieve thermal runaway under ideal conditions. The criticalities needed to create ideal conditions should be evaluated as part of the risk assessment process as it is apparent that several of these will not be met in the context of the Dawson Mine. For example, the presence of moisture in the coal has a strong moderating influence on the likelihood of self-heating generating a hot spot. In addition, if the coal is present in a fugitive state mixed with inert overburden materials the heat sink effect of the rock also strongly moderates self-heating by lowering the coal reactivity.

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1.0 INTRODUCTION

1.1 Spontaneous combustion testing

There are a number of spontaneous combustion tests documented in the literature that produce indices for rating the propensity of coal to spontaneously combust (Nelson and Chen, 2007). The more common ones that have gained wider use in the Australian and New Zealand coal industries are R_{70} self-heating rate, crossing point temperature (CPT), relative ignition temperature (RIT) and minimum self-heating temperature (SHT). The first three of these are available from laboratory testing that is offered in Australia. However, SHT is a calculated value from coal quality data using the original equation developed by Smith and Lazzara (1987) based on US coals, as this test is no longer offered by any laboratory.

All of the existing index parameters provide an indication of the intrinsic spontaneous combustion propensity of a particular coal using a classification scheme, but they do not provide any indication of the timeframe taken for coal spontaneous combustion issues to occur (incubation period). They also do not provide a proper hazard evaluation of coal self-heating that takes into consideration the effects of extrinsic factors (Beamish and Theiler, 2017a). The moderating influences of extrinsic factors such as in-mine ambient temperature and moisture (both in the coal and the surrounding environment) have been recognised and studied by Hodges and Hinsley (1964), Guney (1971) and Smith and Lazzara (1987) using adiabatic oven testing. From these early studies it is clear that the entire coal self-heating behaviour from low ambient temperature to thermal runaway can only be fully assessed by replicating in-mine conditions.

Recent investigations by Beamish and Beamish (2011, 2012) have shown how spontaneous combustion hazard assessment can be improved by benchmarking against known coal self-heating experience from operating mines and built stockpiles using an Incubation test method. Beamish *et al* (2012) and Beamish and Theiler (2015) provide working examples of the success of this new technique. In addition, earlier efforts to identify and quantify any accelerating effects from the presence of reactive pyrite in coal and non-coal strata were not successful (Miron, Lazzara and Smith, 1992), but the new incubation test method has overcome this problem (Beamish and Theiler, 2017b).

1.2 Scope of the work

ERM sought to establish the spontaneous combustion hazard likelihood of coal samples from Dawson Mine on behalf of Anglo American. To achieve the spontaneous combustion hazard assessment of these samples the following scope of testing was developed and performed:

1. R_{70} testing of each sample to establish their Intrinsic Spontaneous Combustion Propensity rating. In addition, this test also produced a value for the Relative Ignition Temperature of the sample.
2. Incubation testing of the coal samples to establish the minimum incubation period (time to thermal runaway if it occurred) and to compare against previous results for benchmark coals under ambient mine conditions.
3. Coal quality analysis (proximate, total sulphur and calorific value) of the samples to be used to assist with interpretation of testing results and to calculate values for crossing point temperature (CPT), where applicable.
4. Development of a spontaneous combustion hazard likelihood chart for the samples tested.

2.0 METHODOLOGY

2.1 Samples

The sample reference numbers and corresponding sample details supplied are contained in Table 1. As soon as possible after receiving the samples, they were prepared for spontaneous combustion testing.

Table 1
Coal samples supplied from Dawson Mine for spontaneous combustion testing

Location/ Sample ID	Seam	Sample Type	Test Reference Number
GS000936	A seam	Bulk grab	AAMDAW1R AAMDAW1ISV
GS000937	CL seam	Bulk grab	AAMDAW2R AAMDAW2ISV
GS000938	B seam	Bulk grab	AAMDAW3R AAMDAW3ISV
GS000939	AU seam	Bulk grab	AAMDAW4R AAMDAW4ISV

R = R_{70} self-heating rate test;
ISV = Incubation testing conducted under sluggish ventilation flow rate conditions

2.2 Adiabatic oven R_{70} test procedure

Full details of the adiabatic oven are given in Beamish, Barakat and St George (2000). Prior to each R_{70} test, the sample to be tested is removed from the freezer, crushed and sieved to <212 μm in as short a time as possible to minimise the effects of oxidation on fresh surfaces created by the grinding of the coal. A 150 g sample is placed in a 750 mL volumetric flask and a unidirectional flow of nitrogen at 250 mL/min applied to the flask inside a drying oven. Precautions are taken to ensure the exclusion of oxygen from the vessel prior to heating the coal for drying. Hence, the air is flushed from the system at room temperature for a period of one hour. After one hour, the oven is ramped up to 110 °C and the coal is dried under nitrogen for at least 16 h to ensure complete drying of the sample. All R_{70} tests are performed on a dry basis to standardise the test results.

At the completion of drying, the coal is transferred into the reaction vessel and left to stabilise at 40 °C in the adiabatic oven with nitrogen passing through it. The reaction vessel is a

450 mL thermos flask inner. When the sample temperature has stabilised, the oven is switched to remote monitoring mode. This enables the oven to track and match the coal temperature rise due to oxidation. The gas selection switch is turned to oxygen with a constant flow rate of 50 mL/min. The temperature change of the coal with time is recorded by a datalogging system for later analysis. The oven limit switch is set at 160 °C to cut off the power to the oven, and stop the oxygen flowing when the sample reaches this temperature. When the oven cools down, the sample is removed from the reaction vessel, which is then cleaned in preparation for the next test.

For coals with a low self-heating rate, a step-heat procedure is used, since these coals can take over 100 hours to reach test completion. The decision to step-heat the sample is based on the sample temperature not reaching 90 ºC after approximately 20 hours. For these samples the coal temperature is step-heated to between 100 ºC to 130 ºC (depending on the temperature the coal has reached in the first 20 hours) using the oven heaters and then returned to adiabatic tracking mode to allow the coal to continue to thermal runaway adiabatically. This enables a value for the relative ignition temperature of the coal to be determined and the test to be completed in two days, inclusive of drying.

2.3 Adiabatic oven incubation test procedure

This test is designed to replicate the true coal self-heating behaviour from low ambient temperature. As such, the normal in-mine temperature is used as the starting point for the test. The nature of the test also assumes that in the real operational situation there is a critical coal pile thickness present that minimises any heat dissipation (represented by the adiabatic oven testing environment) and there is a sufficient supply of oxygen present to maintain the oxidation reaction. A larger sample mass and lower oxygen flow rate is used, compared to the R_{70} test method, to produce conditions that more closely match reality. The coal sample either reaches thermal runaway, or begins to lose heat due to insufficient coal intrinsic reactivity to overcome heat loss from moisture release/evaporation and/or heat sink effects from non-reactive mineral matter. As the coal is tested with its as-received moisture content, for some coals this may produce a prolonged temperature shoulder on the way to thermal runaway. This feature of the coal self-heating is not identified by the older R_{70} test, which only measures the coal intrinsic spontaneous combustion propensity on a dry basis. For coals with a low self-heating rate, a proprietary step-heat procedure is used to establish the self-heating behaviour of the coal from low ambient mine temperature through to thermal

runaway or to record the coal self-heating behaviour when exposed to an additional heat source.

2.4 Coal rank analysis procedure

Suggate (2000, 1998) demonstrated the applicability of the Suggate rank parameter to both New Zealand and Australian coals. This parameter is determined from either the calorific value and volatile matter of the coal expressed on a dry mineral matter and sulphur free basis (dmmsf), or the atomic O/C and H/C of the coal expressed on a mineral matter free basis. The simpler of these two approaches is to use the calorific value and volatile matter data. This is normally done using a purpose-built spreadsheet to generate the Suggate rank plots. In addition, the ASTM rank is calculated using equations contained in the COALAP computer program developed by Sykes and Suggate (1990).

2.5 Intrinsic spontaneous combustion propensity analysis procedure

The R_{70} self-heating rate value was first reported by Humphreys, Rowlands and Cudmore (1981), who used an adiabatic oven to assess the propensity of Queensland coals for spontaneous combustion. They defined a self-heating rate value R_{70}, which equated to the time taken for dry, crushed coal to increase in temperature from 40 ºC to 70 ºC due to oxidation under adiabatic conditions. For coals with a low self-heating rate, which are tested using a step-heat procedure, the R_{70} is calculated based on the non-Arrhenius kinetics theory proposed by Beamish and Arisoy (2008a) and Arisoy and Beamish (2015). This kinetic model is applicable to all coals and enables interpolation of the missing data between the initial self-heating up to 20 hours and the higher temperature self-heating rate data after the step-heating to the oven trip temperature.

Moreby (1997) reports that a coal with an R_{70} value below 0.5 ºC/h is considered to be low propensity, 0.5-0.8 ºC/h medium propensity, while coals with an R_{70} value higher than 0.8 ºC/h are considered to be highly prone to spontaneous combustion. Beamish, Barakat and St George (2001), Beamish (2005) and Beamish *et al* (2005) and Beamish and Arisoy (2008) have published R_{70} values for New Zealand, Australian, Indonesian and American coals using the same adiabatic oven at The University of Auckland and The University of Queensland, which clearly shows a distinct rank relationship. High rank bituminous coals have R_{70} values less than 0.8 ºC/h, whereas low rank subbituminous coals have R_{70} values in excess of 16 ºC/h.

More recent testing has recorded values in excess of 32°C/h for sub-bituminous C coals and a value of 99°C/h has been recorded for a lignite sample. Consequently, the majority of coals currently being mined around the World would fit the high propensity category based on the three tier rating system, which suggests there is a need to review the way in which the R_{70} value is used in hazard assessment.

As the R_{70} test procedure is performed on a dry basis, the value obtained is actually a true measure of the intrinsic coal reactivity to oxygen. Hence, Beamish and Beamish (2011) proposed an appropriate intrinsic spontaneous combustion propensity rating classification based on R_{70} values for Queensland and New South Wales conditions (Table 2), which takes into consideration the different start temperatures that exist in both settings. Also, the boundary for each class takes into account that the rank relationship with R_{70} values is non-linear.

Table 2
Intrinsic spontaneous combustion propensity classification (ISCP)
(based on Queensland and New South Wales coal conditions)

ISCP Class	Propensity rating	Queensland R_{70} value (°C/h)	New South Wales R_{70} value (°C/h)
I	Low (L)	$R_{70} < 0.5$	$R_{70} < 1$
II	Low-Medium (LM)	$0.5 \leq R_{70} < 1$	$1 \leq R_{70} < 2$
III	Medium (M)	$1 \leq R_{70} < 2$	$2 \leq R_{70} < 4$
IV	High (H)	$2 \leq R_{70} < 4$	$4 \leq R_{70} < 8$
V	Very High (VH)	$4 \leq R_{70} < 8$	$8 \leq R_{70} < 16$
VI	Ultra-High (UH)	$8 \leq R_{70} < 16$	$16 \leq R_{70} < 32$
VII	Extremely High (EH)	$R_{70} \geq 16$	$R_{70} \geq 32$

Beamish and Beamish (2011)

2.6 Minimum self-heating temperature analysis procedure

In the 1980s the US Bureau of Mines had an active research team working on coal spontaneous combustion issues. A test method was developed that produced an index parameter for spontaneous combustion propensity called Minimum Self-heating Temperature

(SHT). This index parameter was found to be related to the coal oxygen content (O, % dry, ash-free basis) according to the following equation (Smith and Lazzara, 1987):

$$SHT\ (^{o}C) = 139.74 - 6.57 \times O$$

To account for the increased (or decreased) reactivity of a coal due to ambient in-mine temperatures, the value for the minimum SHT determined from the equation can be adjusted based on the ambient in-mine temperature of the coal. A value of 12.8 ºC (55 ºF) is used as the baseline in-mine temperature (Smith, Rumancik and Lazzara, 1996):

$$SHT_{adj}\ (^{o}C) = [SHT - (T_{ambient} - 12.8)]$$

According to Smith, Rumancik and Lazzara (1996) coals with adjusted SHT's <70 ºC are rated as having a high spontaneous combustion propensity, while those with adjusted SHT's > 100 ºC are rated as having a low spontaneous combustion propensity. Coals with adjusted SHT's between 70 and 100 ºC are rated as having a medium spontaneous combustion propensity.

Beamish and Beamish (2011) found that for a range of Australian coals the high intrinsic spontaneous combustion propensity boundary should be increased to 80 ºC using the original Smith and Lazzara equation for SHT. Therefore, the Smith and Lazzara (1987) equation and the modified boundary are applied to the samples in this report.

2.7 Crossing point temperature and relative ignition temperature analysis procedure

The determination of crossing point and relative ignition temperatures (CPT and RIT) follows a similar methodology (Banerjee, 1985). Both tests use an oven heated at a fixed rate (usually 2 ºC/min) to drive the temperature of the coal to a point where the coal crosses over the oven temperature and rapidly progresses towards thermal runaway. This is substantially different to the adiabatic oven testing where the oven tracks the coal temperature as it reacts with oxygen. The lower the CPT or RIT value the higher the spontaneous combustion propensity of the coal.

Barve and Mahadevan (1994) established that CPT values can be calculated from coal quality data based on the moisture content (M, air-dried basis) and the ash content (A, dry

basis) of the coal. They proposed a separate equation for bituminous coals in general and a more specific equation for high volatile bituminous coals:

General CPT equation for bituminous coals

$$CPT\ (^{o}C) = 168.8 - 10.3 \times M + 0.12 \times A + 0.69 \times M^2 - 0.06 \times M \times A + 0.01 \times A^2$$

CPT equation for high volatile bituminous coals

$$CPT\ (^{o}C) = 170 - 5.16 \times M - 2.8 \times A - 0.005 \times M^2 + 0.28 \times M \times A + 0.02 \times A^2$$

Banerjee *et al* (1972) determined that coals with CPT values less than 140 ºC are generally considered to have a high intrinsic spontaneous combustion propensity, those within the range of 140 ºC to 160 ºC have a medium intrinsic spontaneous combustion propensity, and coals with CPT values greater than 160 ºC have a low intrinsic spontaneous combustion propensity. However, more recent checks of each of the CPT equations for a range of Australian coals suggests that the boundaries should be set at 130 ºC for high propensity and 150 ºC for low propensity.

The adiabatic R_{70} self-heating rate test also provides a value for RIT, which is defined as the temperature where the rate of coal self-heating reaches 2 ºC/min. Subsequently, the coal temperature rapidly rises beyond this point on its way to thermal runaway. This value is obtained from the R_{70} self-heating rate data and can be compared against the R_{70} value to provide a confirmation of the relative intrinsic spontaneous combustion propensity of the coal. The lower the RIT value the higher the intrinsic propensity of the coal for spontaneous combustion.

2.8 Incubation period analysis procedure

The self-heating behaviour of the coal recorded by the incubation test is compared against the documented self-heating performance of a range of coals with known spontaneous combustion histories (incubation periods). Due to the nature of the moisture evolution that occurs during the coal self-heating, where some coals develop a prolonged temperature shoulder on the way to thermal runaway, the time taken for the coal temperature to reach 120ºC is used as the key indicator of the coal to reach thermal runaway (t_{TR}). This value is obtained in laboratory hours and is converted to site days using the comparison with coals of known behaviour. The site days are expressed as a range rather than an exact value as it is

impossible to project the outcome of a real event in exact terms. It should be noted that this analysis is for loosely piled coal such as that found in mine goaf Areas, mine roof falls, loosely formed coal benches or temporary stockpiles that have not been compacted. A recent pillar heating case study (Chalmers *et al*, 2012) also provides a known reference point for benchmarking such occurrences.

3.0 ANALYSIS OF RESULTS AND INTERPRETATION

3.1 Coal quality analysis and rank

Proximate analysis, ultimate analysis and calorific value determination was performed on duplicates of the test samples. A summary of the results obtained for each sample are contained in Table 3. The ASTM rank classification of the A, CL and B seam samples is high volatile A bituminous, based on the volatile matter content and calorific value of the coal, although the CL and B seam samples have low volatile matter contents due to their low-medium vitrinite content as shown on a Suggate rank plot (Figure 1). The AU seam has a lower ASTM rank classification of high volatile B bituminous and it plots within the low-medium vitrinite coal band as shown in Figure 1. All samples have a low sulphur content, which indicates the presence of pyrite is minimal.

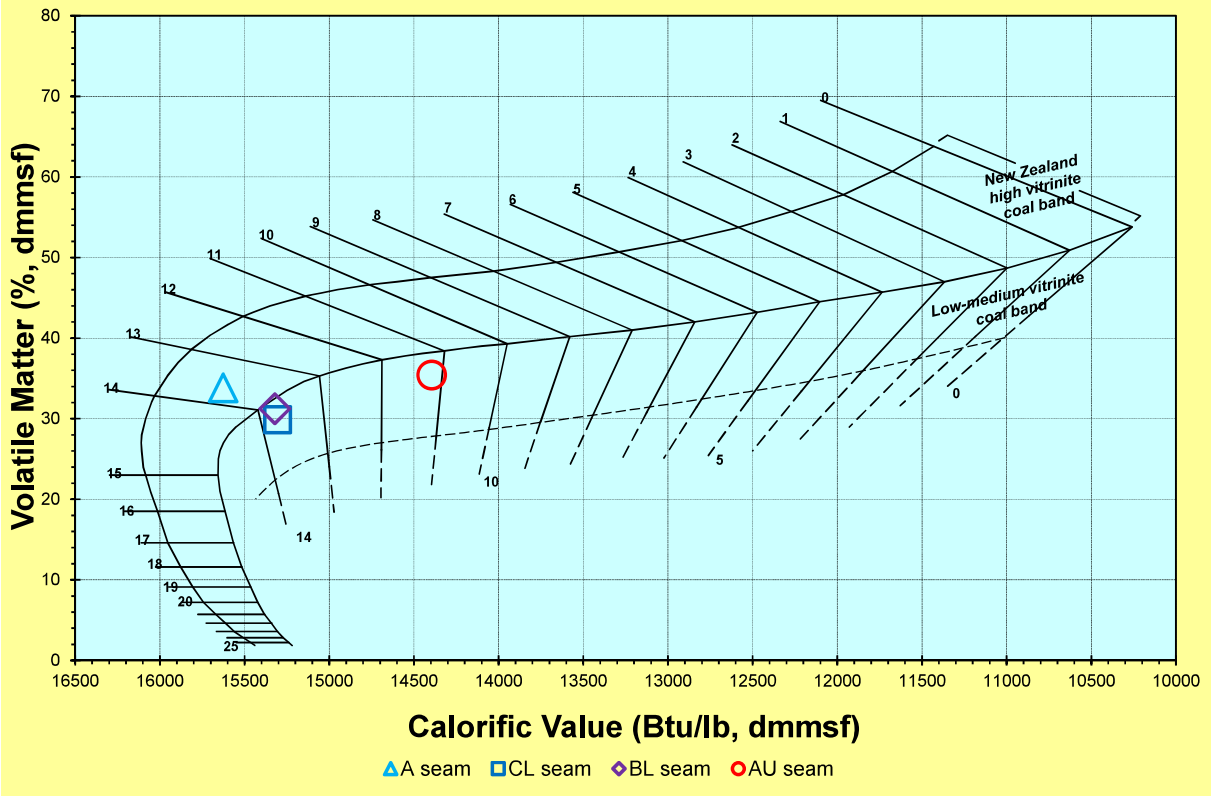


Figure 1. Suggate rank plot for coal samples from Dawson Mine.

Table 3
Analytical and rank data for coal samples from Dawson Mine

	A seam	CL seam	B seam	AU seam
PROXIMATE ANALYSIS (air-dried basis)				
Moisture (%)	2.4	2.4	2.1	4.1
Ash (%)	23.1	9.1	6.9	8.3
Volatile Matter (%)	27.0	27.3	29.2	32.0
Fixed Carbon (%)	47.5	61.2	61.8	55.6
Total Sulphur (%)	0.41	0.35	0.44	0.71
Calorific Value (MJ/kg, raw)	26.13	31.09	32.07	28.88
ULTIMATE ANALYSIS (dry ash-free basis)				
Carbon (%)	84.0	86.2	86.4	80.9
Hydrogen (%)	5.61	5.12	5.16	4.93
Nitrogen (%)	2.04	1.92	1.89	1.85
Sulphur (%)	0.55	0.40	0.48	0.81
Oxygen (%)	7.8	6.4	6.1	11.5
COAL RANK PARAMETERS				
VM (%, dmmsf)	33.8	29.8	31.2	35.4
CV (Btu/lb, dmmsf)	15627	15304	15321	14394
Suggate rank	13.6	13.7	13.7	11.2
VM (%, dmmf)	34.5	30.2	31.6	35.9
CV (Btu/lb, mmmf)	14921	14782	14867	13574
ASTM rank	hvAb	hvAb	hvAb	hvBb

3.2 Intrinsic spontaneous combustion propensity analysis

A copy of the temperature data recorded for the R_{70} self-heating rate tests, which were conducted on the samples from Dawson Mine is contained in Appendix 1. A summary of the results is contained in Table 4, and shows the R_{70} values range from 0.81 °C/h to 4.00 °C/h. The RIT values for the samples are consistent with the R_{70} values and are indicative of a medium to high reactivity towards oxygen.

Table 4
R_{70} and RIT values for coal samples from Dawson Mine with their corresponding Intrinsic Spontaneous Combustion Propensity (ISCP) rating

Sample	Ash content (%, db)	R_{70} (°C/h)	RIT (°C)	ISCP QLD rating
A seam	23.7	0.81	148.3	Low-Medium
CL seam	9.3	1.13	146.7	Medium
B seam	7.0	1.00	147.5	Medium
AU seam	8.7	4.00	129.4	Very High

When interpreting R_{70} values it is important to realise that the value is not only rank dependent (Beamish, 2005; Beamish and Arisoy, 2008b), it is also affected by coal type (Beamish and Clarkson, 2006; Beamish and Arisoy, 2008b) and mineral matter constituents (Beamish and Blazak, 2005; Beamish and Arisoy, 2008b; Beamish and Sainsbury, 2008). As such, a true comparison between samples can be obtained by plotting R_{70} against the ash content (acting as an indicator parameter of mineral matter content) of the coal on a dry basis as shown in Figure 2. The intrinsic spontaneous combustion propensity rating based on Queensland conditions for the current coal samples tested from Dawson Mine is Low-Medium to Very High. This rating is consistent with the rank and type of each coal and is consistent with previous results obtained for Dawson Mine of coal samples with equivalent rank and type. For example, the GS000939 AU seam sample overlaps the samples from borehole B26240, which were also high volatile B bituminous in rank.

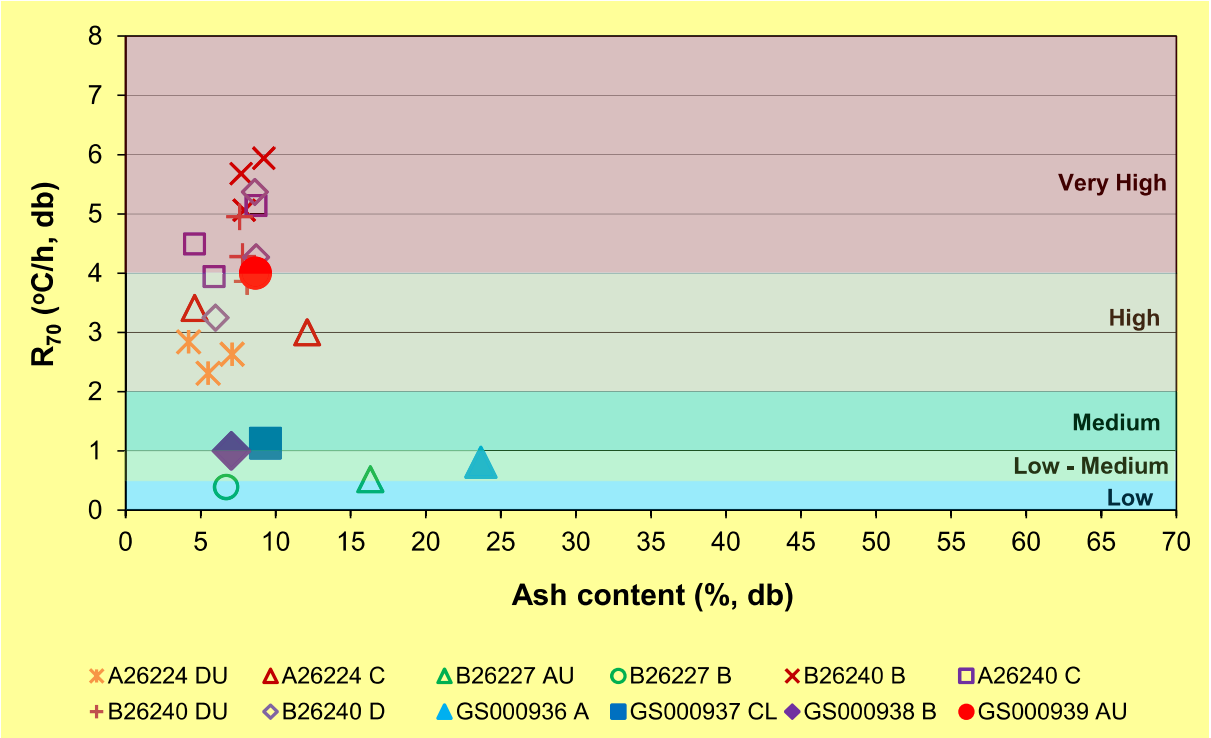


Figure 2. R_{70} self-heating rate relationship with ash content for coal samples from Dawson Mine, showing intrinsic spontaneous combustion propensity classes based on Queensland conditions.

3.3 Minimum self-heating temperature and crossing point temperature analysis

The calculated minimum self-heating temperature and crossing point temperature values for the coal samples from Dawson Mine are contained in Table 5 with their respective propensity ratings. The SHT values produce ratings that are consistent with the rank and type of the coal samples. The CPT values for the samples generally indicate a Low to Medium spontaneous combustion propensity rating.

Table 5
SHT and CPT values for coal samples from Dawson Mine with their corresponding spontaneous combustion propensity rating

Seam/Ply	SHT (°C)	Propensity rating	CPT (°C)	Propensity rating
A seam	88	Medium	153	Low
CL seam	98	Medium	149	Medium
B seam	100	Low	151	Low
AU seam	64	High	138	Medium

3.4 Incubation period analysis

Beamish and Beamish (2010, 2011a,b and 2012) showed that the time taken for coal to reach thermal runaway under loosely piled conditions (incubation period) can be determined using a laboratory adiabatic testing technique that is benchmarked against known coal performance on site. This analysis has been applied to the coal samples from Dawson Mine. All Incubation test results are contained in Appendix 1. The initial conditions for the test and the inferred minimum incubation periods for both loosely piled coal and fractured in-situ coal are contained in Table 6. The corresponding incubation self-heating curves for the coal samples are shown in Figures 4 and 5 for both a loose pile state and fractured in-situ state respectively. These results are consistent with the intrinsic reactivity of the sample and the moisture content in the coal that acts as a moderator of coal self-heating.

Table 6
Incubation test conditions and minimum incubation period for coal samples from Dawson Mine

Sample	Moisture content (%)	Ash Content (%)	Initial temperature (°C)	Minimum Incubation Period Loosely Piled Coal (days)	Minimum Incubation Period Fractured In-situ Coal (years)
A seam	1.8	23.3	35.0	108-127	~12.2
CL seam	4.1	8.9	35.0	58-71	~8.1
B seam	3.5	6.8	35.0	53-65	~7.6
AU seam	5.5	8.2	35.0	23.-29	~4.0

It should be noted that the longer the coal is exposed to a cooler temperature, the longer it takes to reach thermal runaway (incubate) due to heat dissipation effects to the surroundings. Conversely, if the coal is exposed to an additional external heat source, this will reduce the time to reach thermal runaway due to the temperature dependence of the oxidation reaction rate. For coals with a low intrinsic reactivity an additional heat source (either internal such as the presence of reactive pyrite or external such as contact with Polyurethane Resin (PUR)) can often be the root cause of developing a spontaneous combustion event (Theiler and Beamish, 2019). A delay in thermal runaway (longer incubation period) is also created by an oxygen deficient atmosphere. It should be noted that when the coal reaches thermal runaway (temperatures in excess of 120ºC), the rate of temperature increase will be greater than shown by the incubation testing results as a

hotspot present in a critical thickness of coal has the ability to migrate toward the air source with greater access to oxygen as it approaches the free surface.

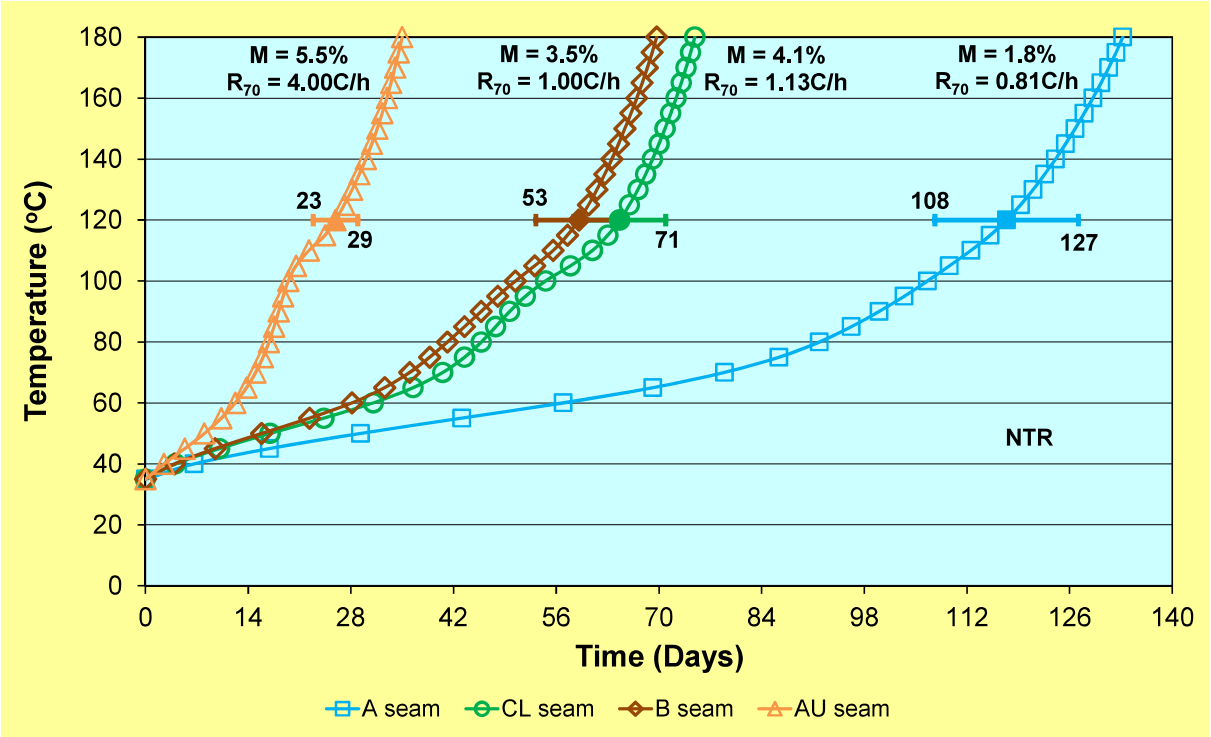


Figure 3. Incubation test results for the coal samples from Dawson Mine with incubation period shown for a loosely piled state under ideal conditions.

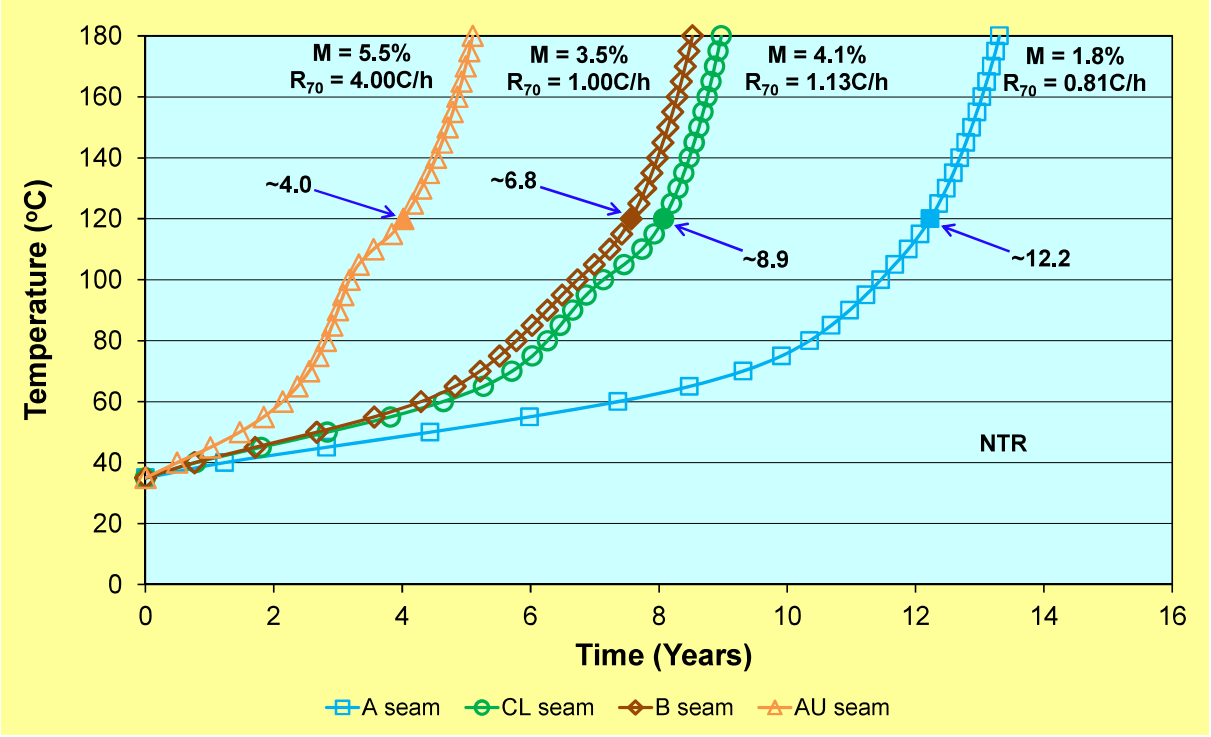


Figure 4. Incubation test results for the coal samples from Dawson Mine with incubation period shown for a fractured in-situ state under ideal conditions.

4.0 EVALUATION OF SPONTANEOUS COMBUSTION HAZARD LIKELIHOOD

4.1 Introduction

The intrinsic spontaneous combustion propensity of coal samples from Dawson Mine has been determined from laboratory testing to be Low-Medium to High. However, to establish an overall site-specific hazard assessment of spontaneous combustion likelihood it is necessary to take into consideration the physical properties of the coal, as well as the mine site factors. This is emphasised by way of stockpile examples in Figures 5 and 6 that show loosely formed coal piles with steep sides and coarse coal near the base, which is a poor combination in terms of spontaneous combustion management where the surrounding environmental conditions favour heat gain over heat dissipation.



Figure 5. Enclosed stockpile storage of Kideco coal showing no compaction except from the weight of the stockpile and steep sides at angle of repose with coarse coal fraction accumulated at the base of the stockpile allowing pathways for air to enter the stockpile and create a chimney effect. Note the moisture condensation lines within the rectangular zone arising from hot spot development inside the pile. Thermal runaway reached in 10-13 days.



Figure 6. Coal heating developed in uncompacted stockpile with steep sides (angle of repose) and coarse coal fraction accumulated at the base of the stockpile allowing pathways for air to enter the stockpile and create a chimney effect. The hotspot has migrated from inside the stockpile to daylight on the surface and reach ignition.

4.2 Coal physical properties and site factors

Production of coal fines will enhance the reactivity of the coal through greater access of air to oxidation sites as a result of the increased surface Area available for reaction to take place. The ease of fines production is a property of the coal, which is best measured by the Hardgrove Grindability Index (HGI) value. Also, care must be taken in identifying Areas of crushed coal that may be associated with faulting or other geological features, as these will provide greater fines production and pathways for air access into the seam.

Moisture effects on coal self-heating in a pile of broken coal (whether naturally formed underground by roof falls, or as part of goaf formation or surface built stockpiles) are two-fold. In the case of low-moisture content coals, the maximum temperature increases steadily with time. In the case of high-moisture coals, temperature increases rapidly initially before evaporation dominates and the temperature reaches a plateau value (generally around 80-90 °C). Once the coal becomes dry locally the temperature will increase rapidly towards

thermal runaway. However, if the coal pile has been in a prolonged drying phase that is interrupted by a wetting or rain event and the water penetrates into the coal pile then additional heat can be generated from the "heat of wetting" effect as the coal re-adsorbs the moisture available to it. A similar effect is created by an increase in humidity, which can also lead to premature thermal runaway in the coal pile.

The coal ambient temperature also plays a major role in determining the initial coal self-heating rate. The R_{70} test is performed at 40 °C to compare all coals on a standard basis. This temperature is more closely aligned with Queensland coals for which the test was originally developed (Humphreys, Rowlands and Cudmore, 1981) and is indicative of underground or summer temperatures in the Bowen Basin. For coal ambient temperatures at least 10 °C lower than this, the initial self-heating rate of the coal will be greatly diminished (approximately halved). This increases the timeframe for any hot spot to develop assuming ideal conditions exist to allow heat to accumulate in broken coal. The converse is also true.

Arisoy and Akgun (2000) showed that for different coal reactivities there was a critical pile thickness necessary for coal self-heating to develop to a stage where spontaneous combustion was inevitable after three months. This thickness varied between 0.85 and 1.8m for coals with high reactivities and medium reactivities respectively. More recent work by Akgun and Essenhigh (2001) also showed that where coal pile heights exceeded 2 m, given sufficient time and other favourable conditions, coal self-heating leading to thermal runaway was inevitable. This aspect of coal self-heating is often overlooked in underground mining and must be considered if coal is to be left in the goaf from using a coal roof, or falls into the goaf from adjacent seams, or significant floor coal is left in the goaf.

There are two very important parameters that determine the rate at which a hot spot will develop in a broken coal pile. These are pile porosity and slope angle of the pile sides. Compaction decreases the pile porosity and thus increases the resistance to the airflow into the pile, which results in suppressing the oxidation reaction due to air starvation (Akgun and Essenhigh, 2001). As the slope of the coal pile sides decreases, the time to thermal runaway increases. Akgun and Essenhigh (2001) found that reducing the coal pile slope from 63° to 34° increased the time to thermal runaway by 100%. Hence, steep-sided coal piles create the biggest problem for coal self-heating, which normally initiates about 2 m in from the sides.

Air supply to broken coal is also a pre-requisite for self-heating to generate. In a goaf environment, exclusion of air removes the issue. However, often some air leakage will occur. As a standard risk mitigation strategy, gas monitoring of the goaf environment will normally provide confirmation of this, with any hot spot development showing as a change in goaf gas composition (for example abnormal increases in carbon monoxide or other spontaneous combustion indicators above the background trends).

Winmill (1915) performed a definitive study of the effect of varying the percentage of oxygen in air on the rate of oxygen absorption by crushed coal (<250 µm) at 30 °C and hence the rate at which reaction can take place. The results of this study (Figure 7) showed that the rate of oxygen absorption was proportional to the square-root of the oxygen percentage in the air. As such the rate of oxygen absorption dropped to just over half when the oxygen concentration decreased from 100% to 20.9% (normal air concentration) and when the oxygen concentration decreased to 5% the rate of oxygen absorption halved again. These findings emphasise the importance of keeping goaf Areas airtight. Winmill (1915) also stated that "So long as the oxygen is below 2 per cent, it would seem that no coal has a sufficiently high rate of oxidation to cause any serious rise in temperature".

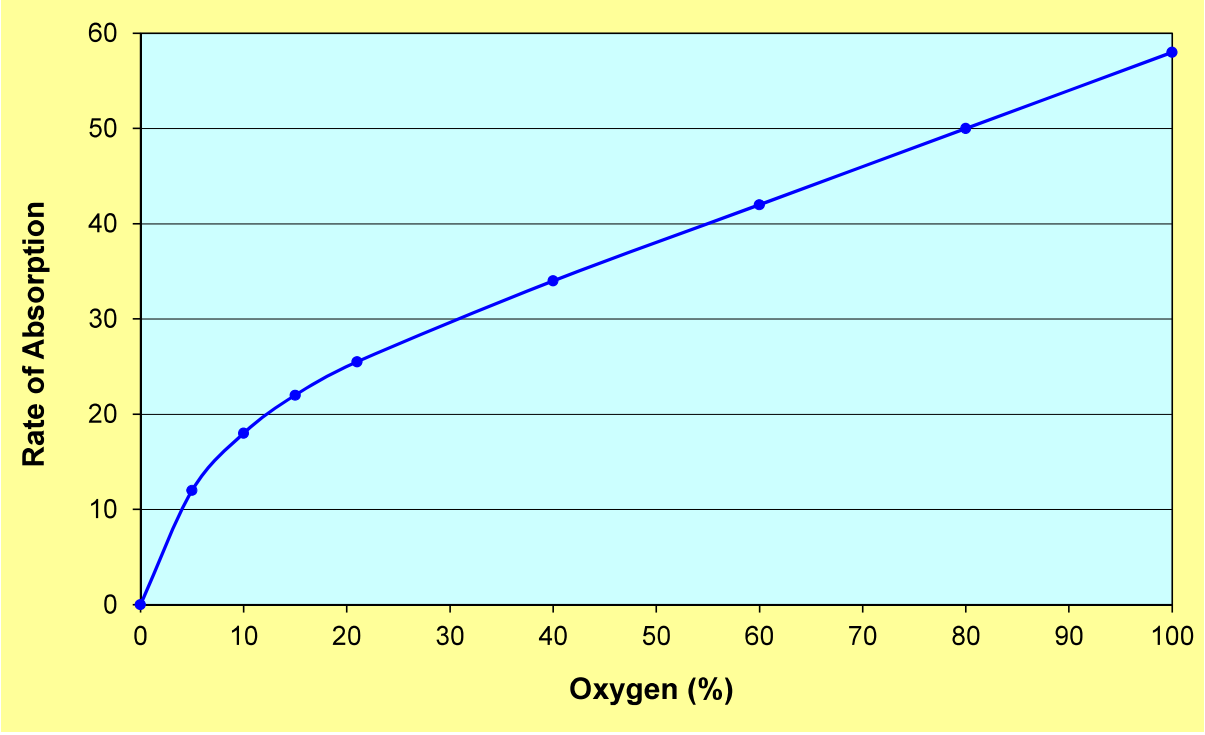


Figure 7. Relationship between oxygen concentration in air and oxygen absorption rate (note the rates of absorption are expressed in arbitrary units, since comparative figures only are required).

4.3 Spontaneous combustion hazard likelihood

4.3.1 General hazard assessment methodology

Risk assessment is routinely used in the coal industry to develop plans that are appropriate to the management of hazards. Leading practice at all coal mines requires the implementation of a Principal Hazard Management Plan for Spontaneous Combustion. The initial step in developing this plan should be to identify the root causes of an unwanted spontaneous combustion event. This can be achieved using the Fault Tree Analysis (FTA) risk assessment method. A generic example of the initial branches of a spontaneous combustion fault tree is shown in Figure 8. The self-heating behaviour of the coal can be assessed in the context of the Dawson Mine to enable the likelihood of developing a spontaneous combustion event to be evaluated.

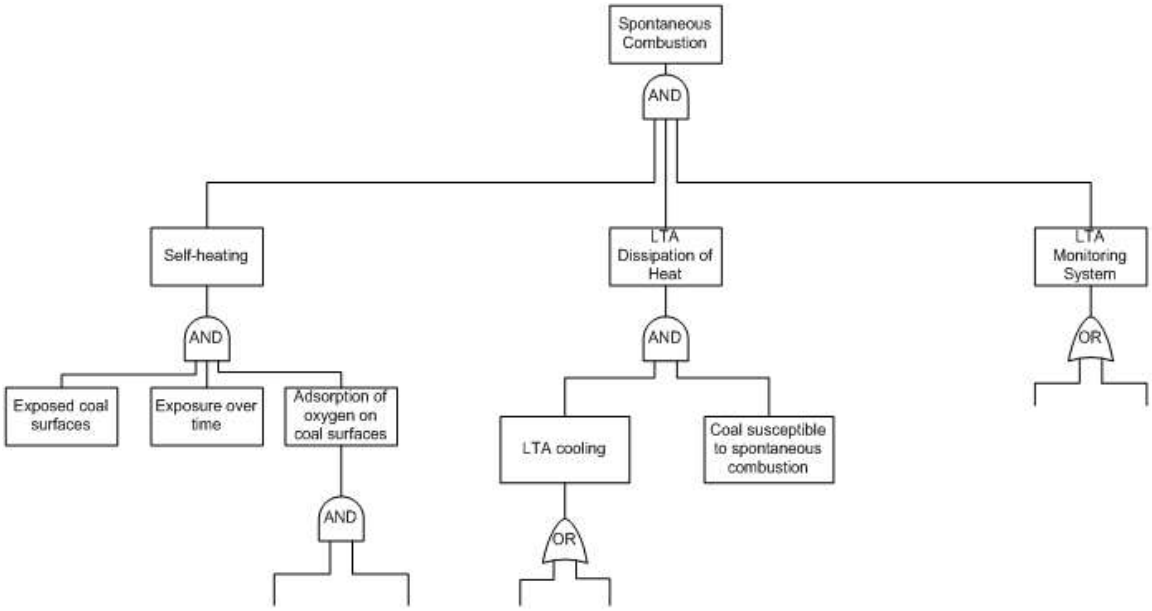


Figure 8. Partial spontaneous combustion fault tree showing possible causes leading to an unwanted event (modified from Beamish *et al*, 2010). Note: LTA = Less Than Adequate

4.3.2 Spontaneous combustion hazard likelihood assessment

The data obtained to date for Dawson mine coal samples provides a solid database for establishing whether the intrinsic reactivity/moisture heat balance of the samples favours reaching Thermal Runaway (TR) or No Thermal Runaway (NTR). Consequently, a boundary line can be drawn between the two possible outcomes for the site-specific situation. This is

shown in Figure 9 by plotting the total moisture content of each sample against the R_{70} self-heating rate value. The importance of the moisture state of the coal is emphasised by the red arrows. In addition, for ideal conditions there are several criticalities that need to be present. These are:

- There is a critical thickness present. For coals with an R_{70} value less than 2 the critical thickness required is generally greater than 1.5 m. For coals with an R_{70} value between 2-4 the thickness needs to be greater than 1.0 m. For coals with an R_{70} value between 4-8 the thickness needs to be greater than 0.5 m. For coals with a higher reactivity a thickness less than 0.5 m can be sufficient depending on the moisture state of the coal.
- There is a sufficient and continuous supply of oxygen due to airflow. In a loose pile this is normally created by ventilation flow underground or wind flow in a surface environment, particularly during high wind conditions. For fractured material in-situ there needs to be a considerable pressure differential present to enable the air to penetrate through the fracture system. This often occurs around faulted ground in underground mines where there is a substantial pressure differential between intake and return airways. In a surface mine exposure, the air penetration is more difficult as it is controlled mainly by barometric pumping, which is minimal compared to an underground mine situation.
- In a surface environment there would need to be no moisture accumulation from surface ponding or groundwater penetration that either excludes ingress of oxygen or creates a large evaporative heat loss mechanism.

It should also be noted that in a surface environment the material will oxidise over time to a point of deactivation if no heat is accumulated.

The higher rank A, CL and B seam samples would be reclassified as NTR with either additional moisture being present or if fugitive coal from these seams was mixed with minor amounts of inert overburden material (>10%) since this would act as a heat sink and lower the R_{70} value of the mix below the TR/NTR boundary. Fugitive coal from the lower rank AU seam would need to be mixed with 75% inert overburden material to lower the R_{70} value to approximately 1, which would then classify the mix as NTR.

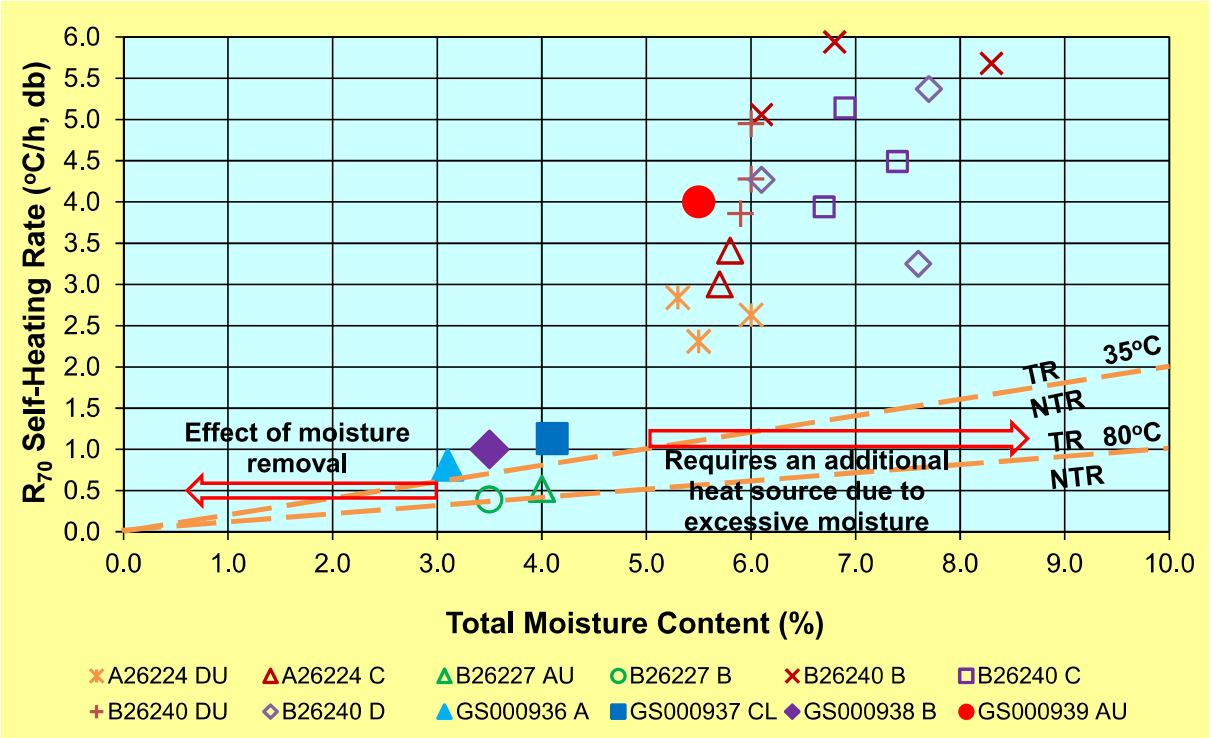


Figure 9. Spontaneous combustion hazard likelihood chart based on total moisture content and R_{70} self-heating rate value. TR – Thermal Runaway; NTR – No Thermal Runaway in a practical timeframe without the presence of an additional heat source.

The presence of reactive pyrite can also initiate a spontaneous combustion event in a sample that may plot in the NTR category. This is because the R_{70} test does not identify the effects of reactive pyrite due to it being conducted on a dry basis. An initial indication of the presence of pyrite can be obtained by analysing the sample for sulphur content. If pyrite is indicated then the test sample should be subjected to an Incubation test with the coal moisture present to quantify any effects of accelerated self-heating if the pyrite proves to be reactive.

There is another possible situation that could lead to a spontaneous combustion event for a coal that plots in the NTR category. This is when the coal comes into contact with an external heat source, such as a curing compound used in an underground environment (for example PUR (Cliff, Beamish and Cuddihy, 2009) or other products that produce an exothermic reaction). Embers from a bushfire could also act as an external heat source in a surface environment. Under these circumstances the temperature of the coal may be artificially raised and a short incubation period ensues. A lightning strike initiated event would be extremely rare since the heat from the lightning strike would be of short duration and it would easily dissipate to the surroundings.

5.0 CONCLUSIONS

Adiabatic testing of coal samples from Dawson Mine has resulted in R_{70} values ranging from 0.81 °C/h to 4.00 °C/h. These R_{70} values indicate that the intrinsic spontaneous combustion propensity rating for the samples is Low-Medium to Very High based on Queensland conditions. The R_{70} values are consistent with the rank and type of coal. Calculated spontaneous combustion index values for crossing point temperature indicate a Low to Medium spontaneous combustion propensity rating. The relative ignition temperature values measured for the samples confirm the intrinsic spontaneous combustion propensity rating obtained from the R_{70} values.

The likelihood of self-heating generating a hot spot that leads to a spontaneous ignition event is moderated by various coal physical properties and mine site-specific factors. Under ideal conditions incubation to thermal runaway is possible for all of the samples, however as a fugitive coal mix in overburden spoilpiles the spontaneous combustion hazard likelihood can be reclassified as NTR (No Thermal Runaway without an additional heat source) as the percentage of inert overburden increases and the moisture content of the pile increases.

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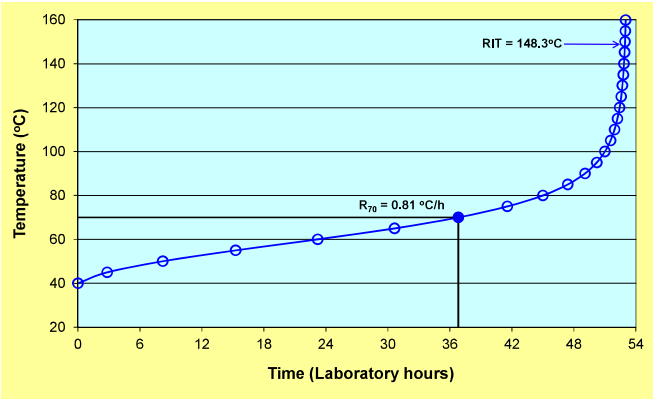
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APPENDIX 1
ADIABATIC TESTING RESULTS FOR
COAL SAMPLES FROM DAWSON MINE

Dawson Mine

A seam	GS000936	
AAMDAW1R		
Date prepared	26/10/2023	
Date on test	31/10/2023	
Adiabatic self-heating test R_{70}	0.81	°C/h
Relative ignition temperature (RIT)	148.3	°C
Moisture content (as-received)	3.1	%

Coal Temp (°C)	Time (min)	Time (h)
40.0	0	0.000
45.0	170.00	2.833
50.0	492.83	8.214
55.0	916.33	15.272
60.0	1392.33	23.205
65.0	1838.27	30.638
70.0	2209.47	36.824
75.0	2493.86	41.564
80.0	2700.08	45.001
85.0	2844.70	47.412
90.0	2944.43	49.074
95.0	3012.90	50.215
100.0	3060.12	51.002
105.0	3093.04	51.551
110.0	3116.34	51.939
115.0	3133.11	52.218
120.0	3145.40	52.423
125.0	3154.57	52.576
130.1	3161.57	52.693
135.0	3166.90	52.782
140.0	3171.07	52.851
145.2	3174.40	52.907
150.0	3176.90	52.948
154.9	3178.90	52.982
159.9	3180.57	53.010



Dawson Mine

A seam	GS000936	
AAMDAW1ISV		
Date prepared	26/10/2023	
Date on test	26/10/2023	
Moisture content	1.8	%

Time to thermal runaway (t_{TR})

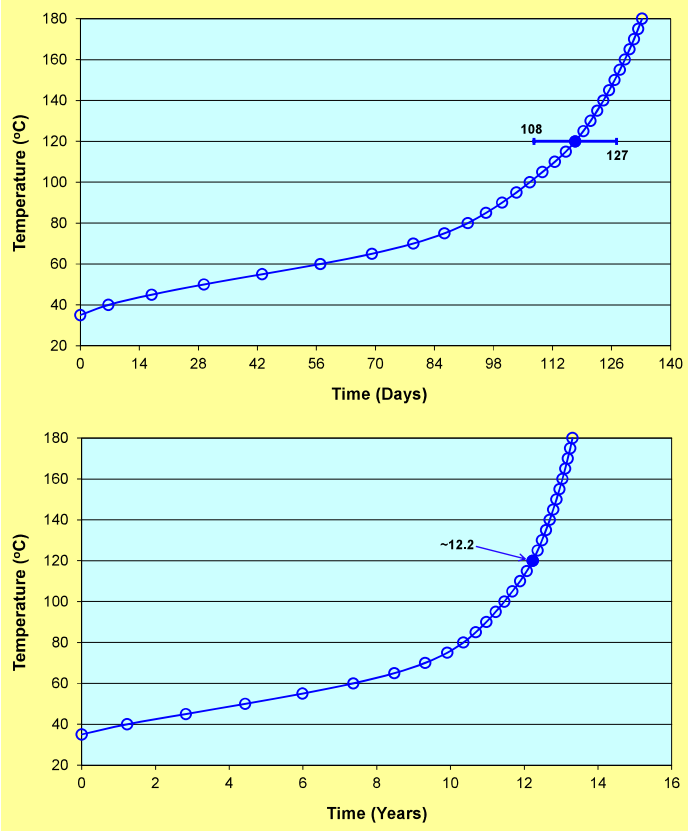
Loosely Piled Coal

Minimum incubation period lower limit	108	days
Minimum incubation period upper limit	127	days

Fractured In-situ State

Minimum incubation period	~12.2	years

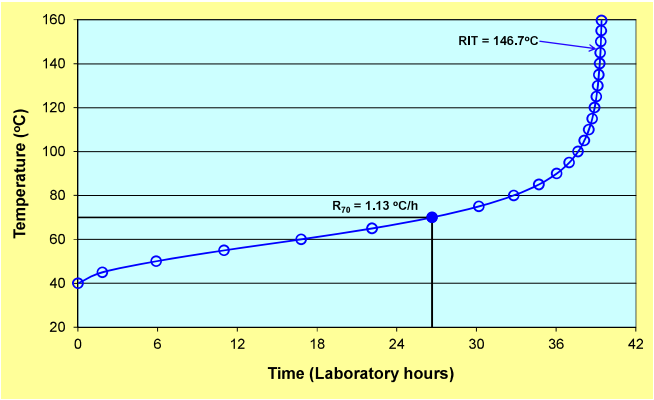
Coal Temp (°C)	Loose Time (days)	In-situ Time (years)
35.0	0.00	0.00
40.0	6.63	1.23
45.0	16.92	2.82
50.0	29.30	4.43
55.0	43.13	5.99
60.0	56.95	7.36
65.0	69.18	8.48
70.0	78.98	9.31
75.0	86.37	9.91
80.0	91.90	10.35
85.0	96.24	10.68
90.0	100.05	10.97
95.0	103.46	11.23
100.0	106.63	11.46
105.0	109.63	11.68
110.0	112.56	11.89
115.0	115.18	12.07
120.0	117.41	12.23
125.0	119.33	12.36
130.0	121.05	12.48
135.0	122.62	12.59
140.0	124.08	12.69
145.0	125.46	12.78
150.0	126.76	12.87
155.0	128.01	12.96
160.0	129.19	13.04
165.0	130.30	13.11
170.0	131.35	13.18
175.0	132.35	13.25
180.0	133.27	13.31



Dawson Mine

CL seam	GS000937	
AAMDAW2R		
Date prepared	31/10/2023	
Date on test	01/11/2023	
Adiabatic self-heating test R_{70}	1.13	°C/h
Relative ignition temperature (RIT)	146.7	°C
Moisture content (as-received)	4.1	%

Coal Temp (°C)	Time (min)	Time (h)
40.0	0	0.000
45.0	110.33	1.839
50.0	353.33	5.889
55.0	659.67	10.994
60.0	1007.83	16.797
65.0	1328.66	22.144
70.0	1599.27	26.654
75.0	1811.01	30.183
80.0	1968.49	32.808
85.0	2081.97	34.699
90.0	2162.34	36.039
95.0	2218.91	36.982
100.0	2258.81	37.647
105.0	2287.16	38.119
110.0	2307.54	38.459
115.0	2322.38	38.706
120.0	2333.35	38.889
125.0	2341.57	39.026
130.0	2347.73	39.129
135.0	2352.57	39.209
140.1	2356.40	39.273
145.0	2359.23	39.321
150.1	2361.57	39.359
155.1	2363.40	39.390
159.7	2364.73	39.412



Dawson Mine

CL seam	GS000937	
AAMDAW2ISV		
Date prepared	31/10/2023	
Date on test	31/10/2023	
Moisture content	4.1	%

Time to thermal runaway (t_{TR})

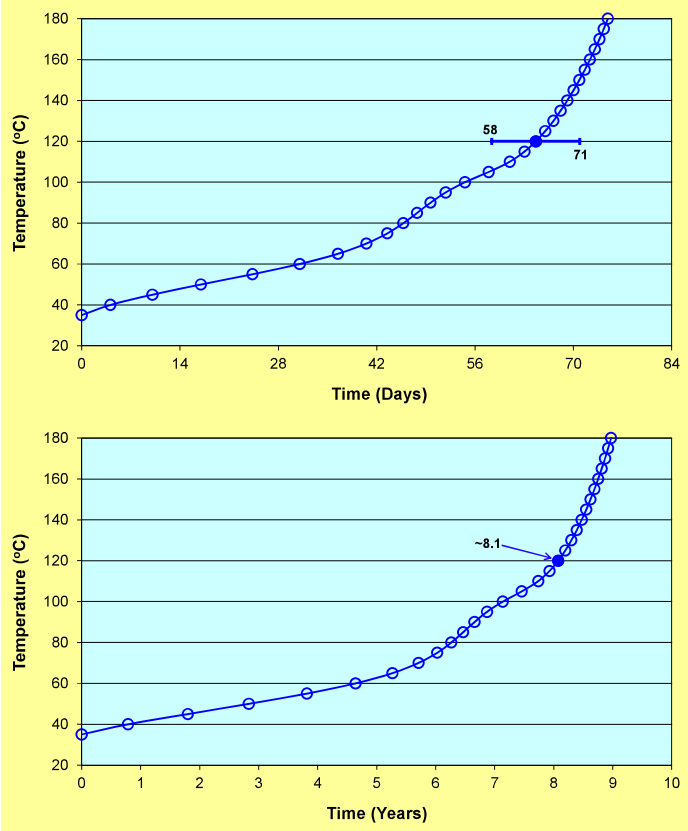
Loosely Piled Coal

Minimum incubation period lower limit	58	days
Minimum incubation period upper limit	71	days

Fractured In-situ State

Minimum incubation period	~8.1	years

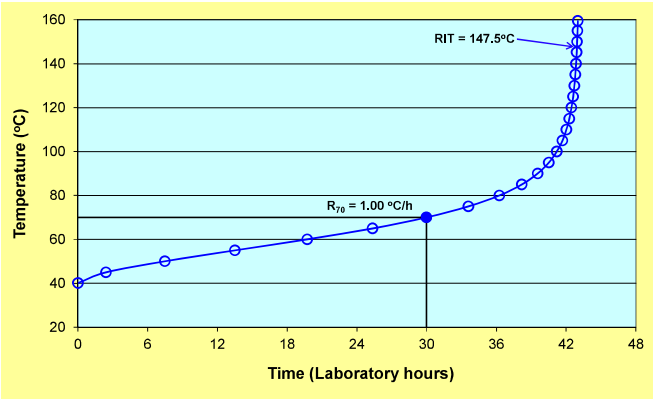
Coal Temp (°C)	Loose Time (days)	In-situ Time (years)
35.0	0.00	0.00
40.0	4.09	0.79
45.0	10.08	1.80
50.0	16.98	2.83
55.0	24.32	3.82
60.0	31.05	4.64
65.0	36.48	5.27
70.0	40.53	5.71
75.0	43.50	6.03
80.0	45.79	6.26
85.0	47.75	6.46
90.0	49.66	6.66
95.0	51.81	6.87
100.0	54.55	7.14
105.0	57.95	7.46
110.0	60.94	7.74
115.0	63.04	7.93
120.0	64.65	8.08
125.0	65.99	8.20
130.0	67.15	8.30
135.0	68.19	8.39
140.0	69.13	8.47
145.0	70.01	8.55
150.0	70.84	8.62
155.0	71.62	8.69
160.0	72.35	8.75
165.0	73.05	8.81
170.0	73.71	8.87
175.0	74.33	8.92
180.0	74.91	8.97



Dawson Mine

B seam	GS000938	
AAMDAW3R		
Date prepared	03/11/2023	
Date on test	06/11/2023	
Adiabatic self-heating test R_{70}	1.00	°C/h
Relative ignition temperature (RIT)	147.5	°C
Moisture content (as-received)	3.5	%

Coal Temp (°C)	Time (min)	Time (h)
40.1	0	0.000
45.0	144.83	2.414
50.0	449.00	7.483
55.0	809.67	13.494
60.0	1183.33	19.722
65.0	1520.42	25.340
70.0	1799.20	29.987
75.0	2015.31	33.588
80.0	2175.53	36.259
85.0	2291.00	38.183
90.0	2372.90	39.548
95.0	2430.64	40.511
100.0	2471.39	41.190
105.0	2500.36	41.673
110.0	2521.16	42.019
115.0	2536.30	42.272
120.0	2547.47	42.458
125.0	2555.85	42.598
130.0	2562.19	42.703
135.1	2567.19	42.786
140.0	2571.02	42.850
145.2	2574.19	42.903
150.0	2576.52	42.942
155.0	2578.52	42.975
159.5	2580.02	43.000



Dawson Mine

B Seam	GS000938	
AAMDAW3ISV		
Date prepared	03/11/2023	
Date on test	03/11/2023	
Moisture content	3.5	%

Time to thermal runaway (t_{TR})

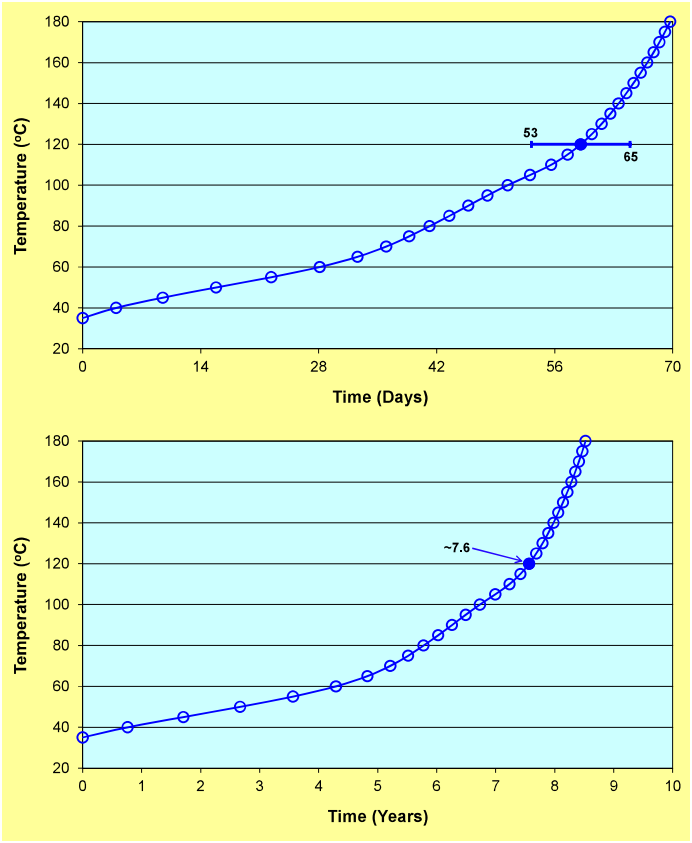
Loosely Piled Coal

Minimum incubation period lower limit	53	days
Minimum incubation period upper limit	65	days

Fractured In-situ State

Minimum incubation period	~7.6	years

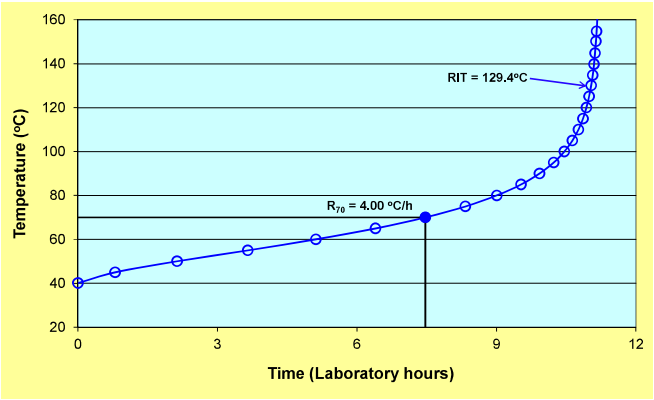
Coal Temp (°C)	Loose Time (days)	In-situ Time (years)
35.0	0.00	0.00
40.0	3.96	0.76
45.0	9.50	1.71
50.0	15.83	2.67
55.0	22.37	3.57
60.0	28.13	4.29
65.0	32.61	4.83
70.0	36.01	5.21
75.0	38.74	5.52
80.0	41.16	5.78
85.0	43.49	6.02
90.0	45.75	6.26
95.0	48.02	6.49
100.0	50.42	6.73
105.0	53.08	6.99
110.0	55.58	7.23
115.0	57.53	7.42
120.0	59.09	7.57
125.0	60.40	7.69
130.0	61.56	7.79
135.0	62.60	7.89
140.0	63.58	7.98
145.0	64.49	8.06
150.0	65.36	8.14
155.0	66.19	8.21
160.0	66.98	8.28
165.0	67.72	8.35
170.0	68.42	8.41
175.0	69.07	8.47
180.0	69.69	8.52



Dawson Mine

AU seam	GS000939	
AAMDAW4R		
Date prepared	07/11/2023	
Date on test	08/11/2023	
Adiabatic self-heating test R_{70}	4.00	°C/h
Relative ignition temperature (RIT)	129.4	°C
Moisture content (as-received)	5.5	%

Coal Temp (°C)	Time (min)	Time (h)
40.1	0	0.000
45.0	48.00	0.800
50.0	128.00	2.133
55.0	219.17	3.653
60.0	307.00	5.117
65.0	384.00	6.400
70.0	448.33	7.472
75.0	499.83	8.331
80.0	540.50	9.008
85.0	571.83	9.531
90.0	595.67	9.928
95.0	613.83	10.231
100.0	627.67	10.461
105.0	638.00	10.633
110.0	645.83	10.764
115.0	651.67	10.861
120.0	656.17	10.936
125.1	659.67	10.994
130.1	662.33	11.039
134.8	664.33	11.072
139.8	666.00	11.100
144.8	667.33	11.122
150.2	668.50	11.142
154.8	669.33	11.156
160.1	670.17	11.169



Dawson Mine

AU seam	GS000939	
AAMDAW4ISV		
Date prepared	07/11/2023	
Date on test	07/11/2023	
Moisture content	5.5	%

Time to thermal runaway (t_{TR})

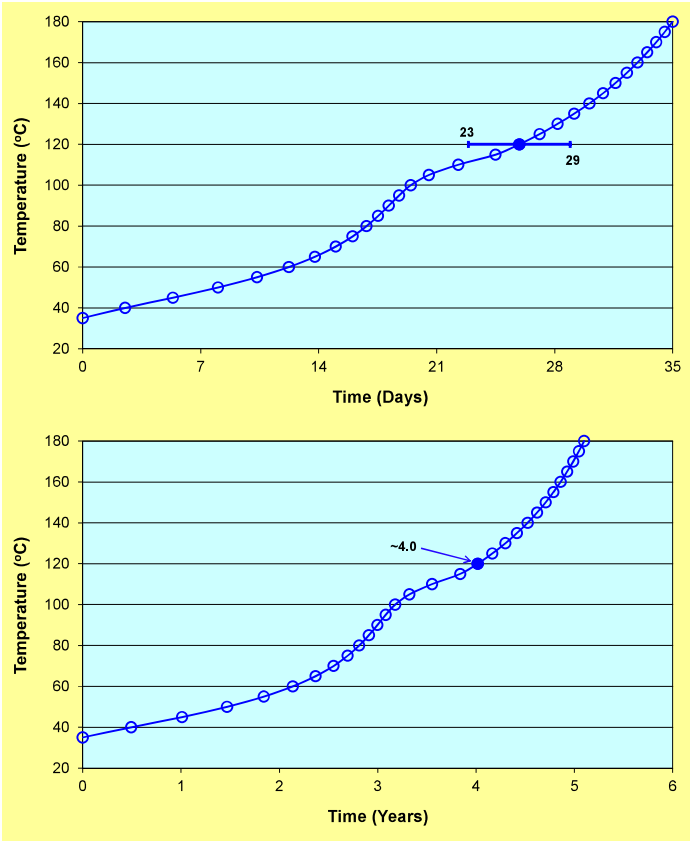
Loosely Piled Coal

Minimum incubation period lower limit	23	days
Minimum incubation period upper limit	29	days

Fractured In-situ State

Minimum incubation period	~4.0	years

Coal Temp (°C)	Loose Time (days)	In-situ Time (years)
35.0	0.00	0.00
40.0	2.52	0.49
45.0	5.35	1.01
50.0	8.03	1.47
55.0	10.34	1.84
60.0	12.24	2.14
65.0	13.77	2.37
70.0	15.01	2.55
75.0	16.01	2.70
80.0	16.83	2.81
85.0	17.53	2.91
90.0	18.15	3.00
95.0	18.77	3.08
100.0	19.46	3.18
105.0	20.53	3.32
110.0	22.28	3.55
115.0	24.49	3.84
120.0	25.90	4.02
125.0	27.10	4.17
130.0	28.17	4.30
135.0	29.15	4.42
140.0	30.05	4.52
145.0	30.87	4.62
150.0	31.61	4.71
155.0	32.28	4.79
160.0	32.91	4.86
165.0	33.49	4.93
170.0	34.02	4.99
175.0	34.53	5.05
180.0	34.99	5.10



Appendix 4.8 Landform Evolution Model Results

Aquaterra
International Pty Ltd

Landform Evolution Modelling for Anglo American Dawson mine PRCP assessment

Greg Hancock



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Revision History

Revision Number	Date	Prepared by
Rev 1	25/3/2024	Greg Hancock

Project overview

Aquaterra International has been requested to provide a Landform Evolution Model (LEM) assessment of existing and proposed landforms at the Anglo American Dawson coal mine.

A landform review and design update is required as a key input towards development of a compliant Progressive Rehabilitation and Closure Plan (PRCP).

The assessment uses the industry accepted Landform Evolution Model (i.e. SIBERIA) appropriate to the risk and scale of the landform of the site to determine the long-term landscape erosion behaviour.

The model used incorporates the following:

1) a digital elevation model (DEM) using a resolution appropriate for the level of detail in the existing and/or proposed landform.

2) erosion characteristics representative of the materials used in the rehabilitated landform.

3) an assessment of the landscape erosion behaviour across a range of time intervals. At a minimum, outputs for 10, 100, and 300 years.

4) consideration of erosion rates for both successful revegetation and reduced revegetation.

Modelling of the landform

1) allows erosion rates, erosion type and erosion location to be determined, and

2) allows designs to be modified once the strengths and weaknesses are known.

Model parameters

SIBERIA parameters were determined from sites as outlined in Sheridan et al. (2000) and flume and rainfall simulator studies which developed the Queensland Coal Association Version 1.0 erosion database (Gyasi-Agyei and Willgoose, 1997) from the Dawson (then Moura) site. These were site specific parameters.

The project determined erodibilities for a range of different mine wastes and different surface materials from an extensive field campaign with a rainfall simulator over a three-year period. Data was available for plots with slope of 20% and different discharges using rainfall applied for 30 minutes. This rainfall, runoff, infiltration characteristics and sediment transport data were scaled using local pluviograph records to extend the plot data and generate a long runoff and erosion series from which the input parameters were derived. This process resulted in SIBERIA parameters of b_1 =0.0003, m_1=1.5, n_1=2, b_3=1 and m_3=1. Details of this process can be found in Gyasi-Agyei and Willgoose (1997), Sheridan et al. (2000) and Willgoose (2005).

The parameters derived from this process are for Dawson (Moura) topsoil which is assumed as the cover for the landscape with no vegetation. There are no parameters available for the highwall materials. Therefore, the erosion patterns particularly for the highwall are conservative and likely to be an overestimate.

For hillslopes with significant planned vegetation cover such as Dawson, there will be a significant reduction in both erosion rate and gullying. To accommodate this reduction, the RUSLE vegetation cover C-factor can be used to estimate the likely reduction in erosion (Wischmeier and Smith, 1978; Rosewell, 1993). C-factors are available from a range of sources (Wischmeier and Smith, 1978; Blanco and Lal, 2008). Assuming the vegetation cover is moderate, a C-factor of 0.1 has been selected based on the table for vegetation in Blanco and Lal (2008) and refined from the C-factor map of Australia in Teng et al. (2016). The SIBERIA β_1 value is then approximated by multiplying the K-factor and C-factor values.

Landforms assessed

The SIBERIA model requires a Digital Elevation Model (DEM) as landscape input for each site. This DEM needs to contain sufficient coordinates to correctly represent the landscape and capture hillslope shape and curvature as well as any other features such as drainage control structures.

DEM data was supplied by ERM.

Five landscapes were examined. These were

- Dawson North
- Dawson South
- PIT02
- PIT0312
- PIT0319

A summary of the data and its source is provided in Table 1.

Table 1. Landscapes, DEM source and general characteristics

Landscape	Source	Area (ha)	Elevation (relief) (m)
Dawson North	ERM supplied DEM	2480	381
Dawson South	ERM supplied DEM	6196	198
PIT02	ERM supplied DEM	1487	281
PIT0312	ERM supplied DEM	5180	398
PIT0319	ERM supplied DEM	7145	263

Model and model setup

All modelling was performed using the SIBERIA landscape evolution model (Willgoose, 2005a,b).

The SIBERIA model was run for 300 years with outputs at 10, 100 and 300 years.

The model assessed each landscape listed in Table 1 using the parameters described above.

Results

An LEM assessment has been conducted for each of the 5 sites, with both vegetated and reduced vegetation scenarios, for 10, 100 and 300 years.

Digital files of results have been supplied to ERM externally to this report. The files contain a table of erosion rates and LEM images at each time interval. The files are as follows:

Dawson North - No vegetation

Dawson North - Vegetation

Dawson South - No vegetation

Dawson South - Vegetation

PIT02 - No vegetation

PIT02 - Vegetation

PIT0312 - No vegetation

PIT0312 - Vegetation

PIT0319 - No vegetation

PIT0319 - Vegetation

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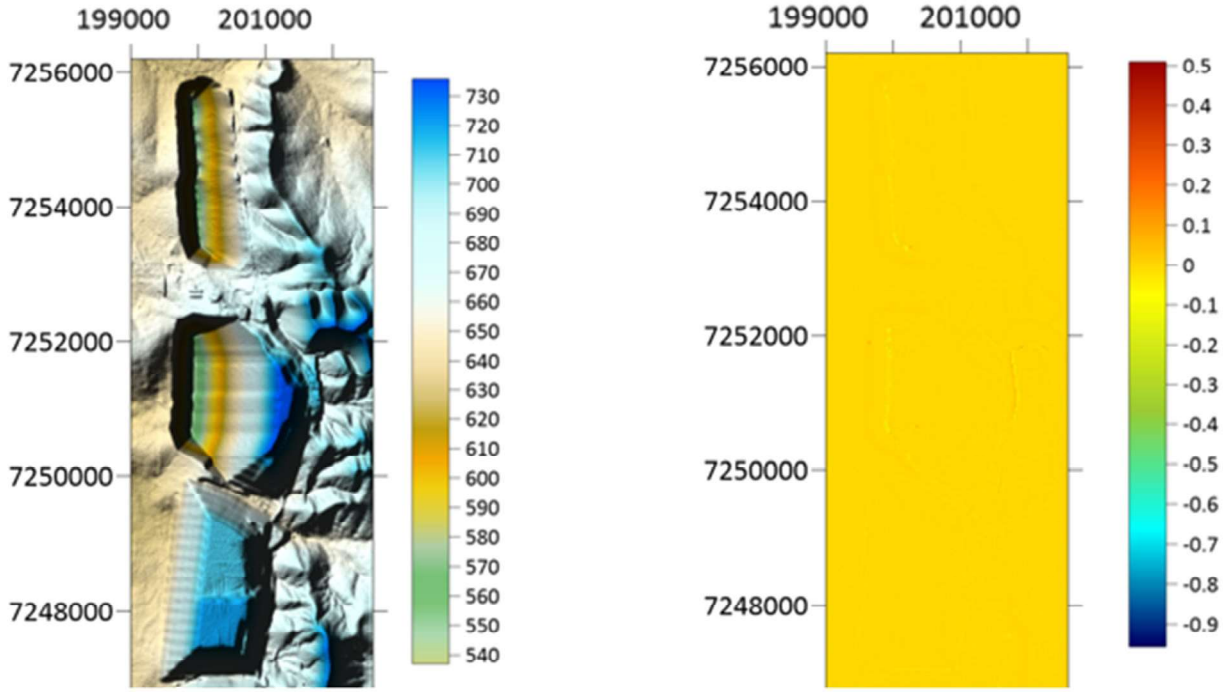
Summary of Landform Erosion Modelling Results

	Closure Surface	Vegetation			Non-Vegetated		
Time (years)		10	100	300	10	100	300
Erosion Rate (t/ha/yr)	Dawson South	6.63	5.51	4.1	31.9	24.2	21.1
Max Erosion (gully depth – m)		0.51	2.6	13.42	5.91	28.62	35.44
Max deposition (m)		0.95	3.77	6.93	4.23	15.5	24.67

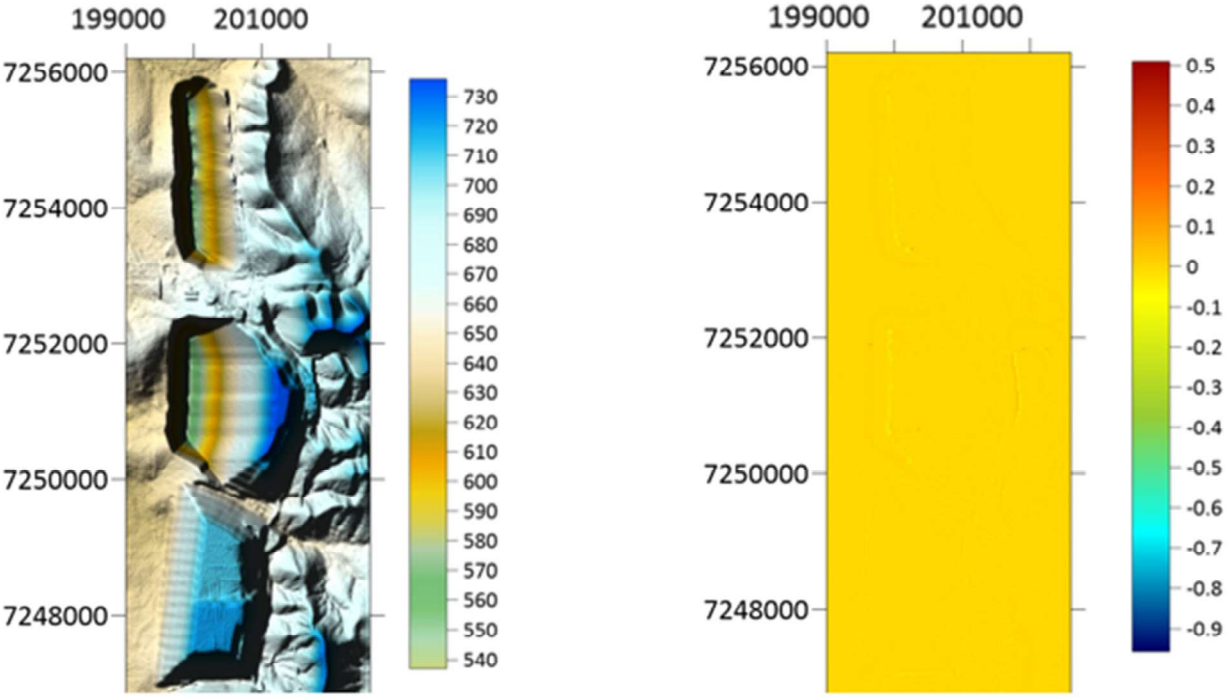
Note: In the figures below, units are elevation in metres for the erosion plots, and erosion depth in metres for the deposition plots.

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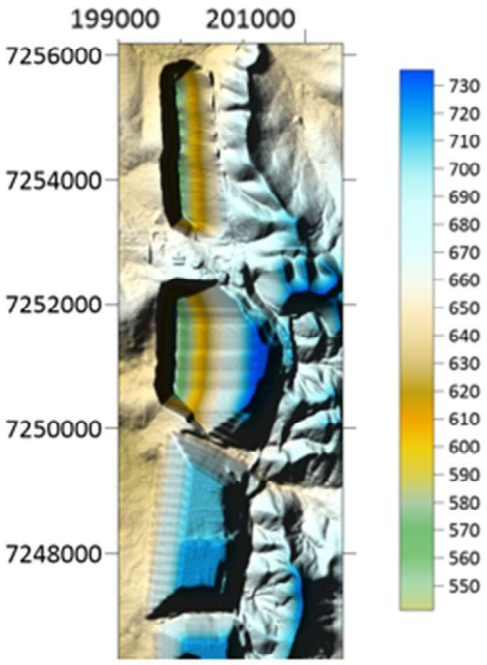
Figures

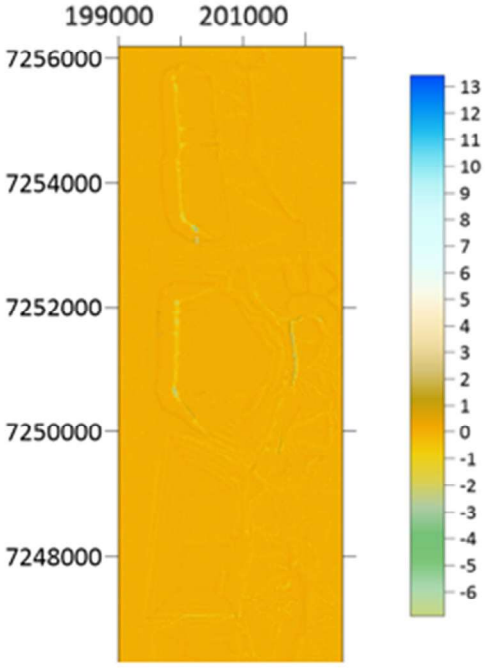


Dawson South 10 years – Vegetation. Plan view (left) with erosion and deposition plot (right)

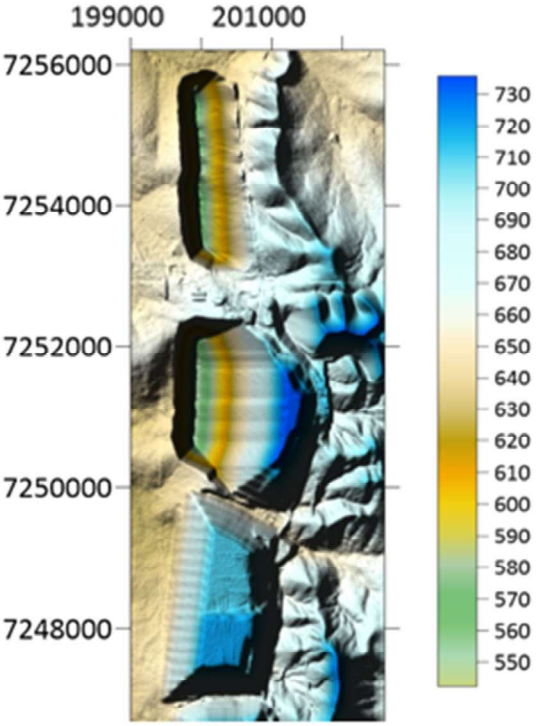


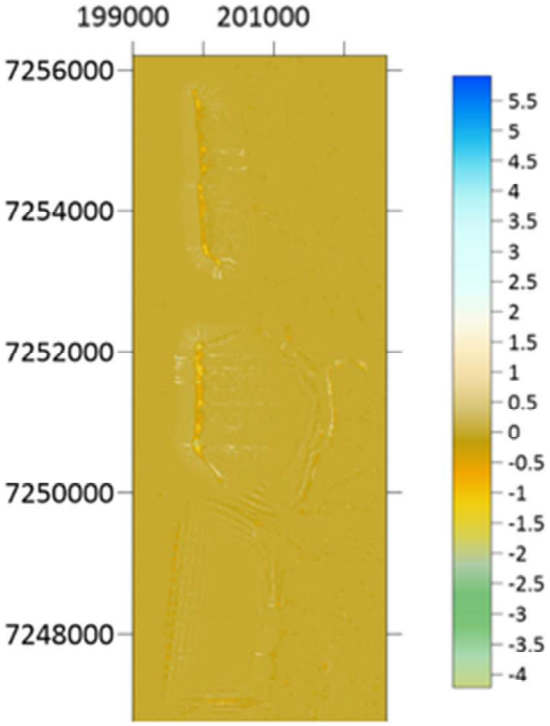
Dawson South 100 years – Vegetation. Plan view (left) with erosion and deposition plot (right)



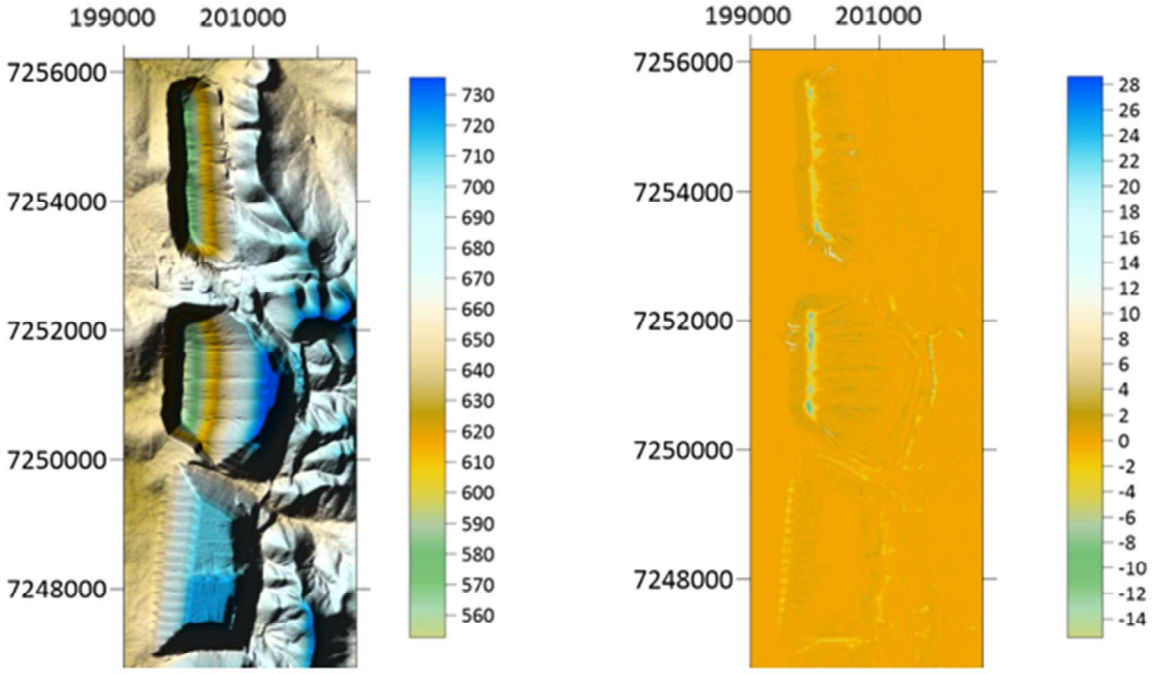


Dawson South. 300 years – Vegetation. Plan view (left) with erosion and deposition plot (right)

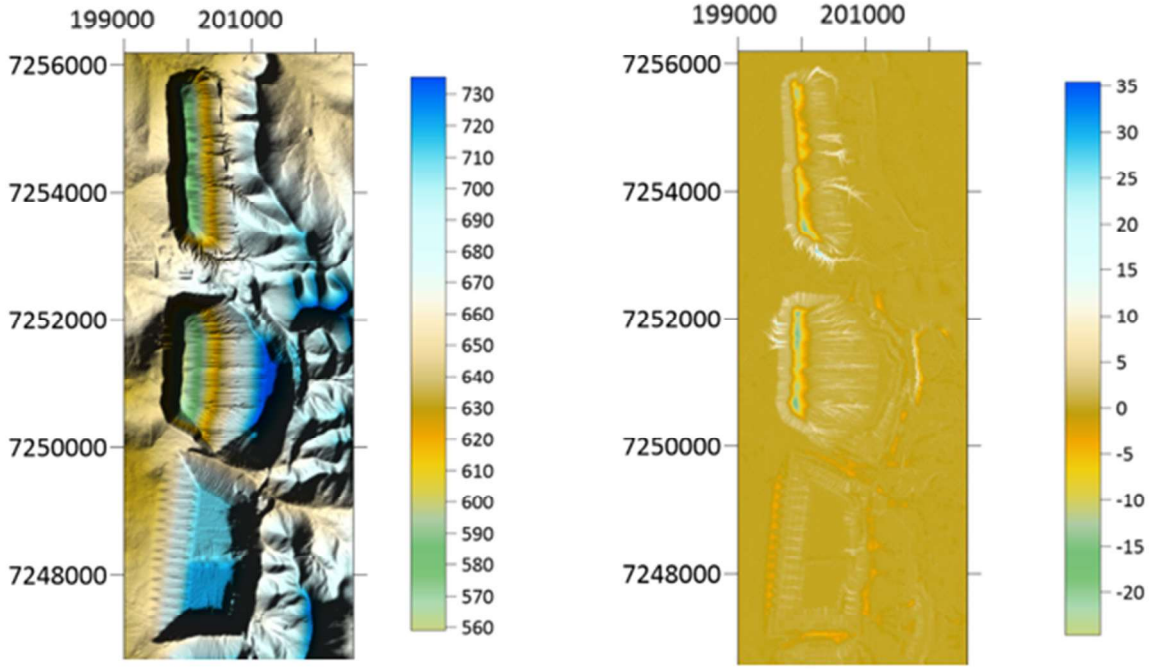




Dawson South. 10 years – No Vegetation. Plan view (left) with erosion and deposition plot (right)



Dawson South. 100 years – No Vegetation. Plan view (left) with erosion and deposition plot (right)



Dawson South. 300 years – No Vegetation. Plan view (left) with erosion and deposition plot (right)

Appendix 4.9 Underground Assessment

GEOTECHNICAL ASSESSMENT OF THE UNDERGROUND EXCAVATIONS AT DAWSON MINE

Prepared for ERM Australia

Report No: Dawson24 - R1 FEBRUARY 2024

Mobile: 0428 186 255
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EXECUTIVE SUMMARY

The overarching issue for the PRCP in the Dawson area is to ensure that the surface above the underground excavations is safe and stable after closure. This includes that there is no failure of the pillars and roadways in the underground excavations that could lead to surface disturbance that could be a hazard to people and animals on the surface.

Surface subsidence is likely to have occurred over parts of the underground mines where higher extraction ratio mining methods have been used and in places above the highwall excavations where pillar failures have occurred. The analysis of the magnitude of the subsidence above the underground excavations is however restricted by the lack of accurate extraction heights and in some areas reliable survey control, particularly in the highwall mining and augering excavations.

It is anticipated that future dumping of spoil above the underground excavations could lead to further pillar failures due to the increase in the load on the coal pillars. Conversely, the mining of deeper open cut pits may reduce the depth of cover to <50 m where there is the potential of sinkhole subsidence occurring, depending on the competency of the overburden strata.

The available piezometric data indicates that the majority of the underground excavations are currently flooded, which provides a buoyancy effect to reduce the load on the coal pillars. This flooding also reduces the potential for spontaneous combustion events to occur.

In terms of sealing, there is minimal detail on how the shafts and portals have been sealed. The portals and highwall drives appear to have been sealed with loose material and not engineered seals/bulkheads and some level of water leakage is anticipated.

Spontaneous combustion and heating events have previously been encountered in the Dawson area and the potential for these occurring again during the excavation of some of the highwall mining drives in future open cut pits should be managed using the Highwall Auger Mining SOP.

To assist in the management of the surface above the underground excavations a number of controls are recommended. These include:

- Inspection of potential subsidence areas and rehabilitate if required.
- Continue monitoring of the ground water levels to determine the groundwater levels with respect to the underground excavations. This includes the installation of additional piezometers.
- Implement a monitoring program of LiDAR surveys to allow comparison with previous surveys and identify any areas of significant ground movement.

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Glossary

CHPP	Coal Handling and Preparation Plant.
EA	Environmental Approval.
EP Act	Environmental Protection Act.
First Workings	The process of developing roadways to delineate larger blocks of coal to be extracted by other means.
Goaf	The void from which all the coal in a seam has been

	extracted and where the roof is allowed to collapse in a controlled manner.
NUMA	Non-use management area.
PMLU	Post-mining land use.
Second Workings	The process of mining large blocks of coal between areas of first workings.

1 INTRODUCTION

Gordon Geotechniques Pty Ltd (GGPL) has been requested by ERM Australia to prepare a geotechnical assessment of the underground excavations at Dawson Mine, as part of the Progressive Rehabilitation and Closure Plans (PRCP) for Dawson North, Central and South.

These underground excavations include the Moura No. 1, No. 2, No. 3 and No. 4 and Kianga No. 1 bord and pillar mines (**Figure 1 and Figure 2**). There are also a large number of highwall mining and augering excavations, in a number of different seams, around the Dawson mine site that need to be considered (**Figure 1 and Figure 2**).

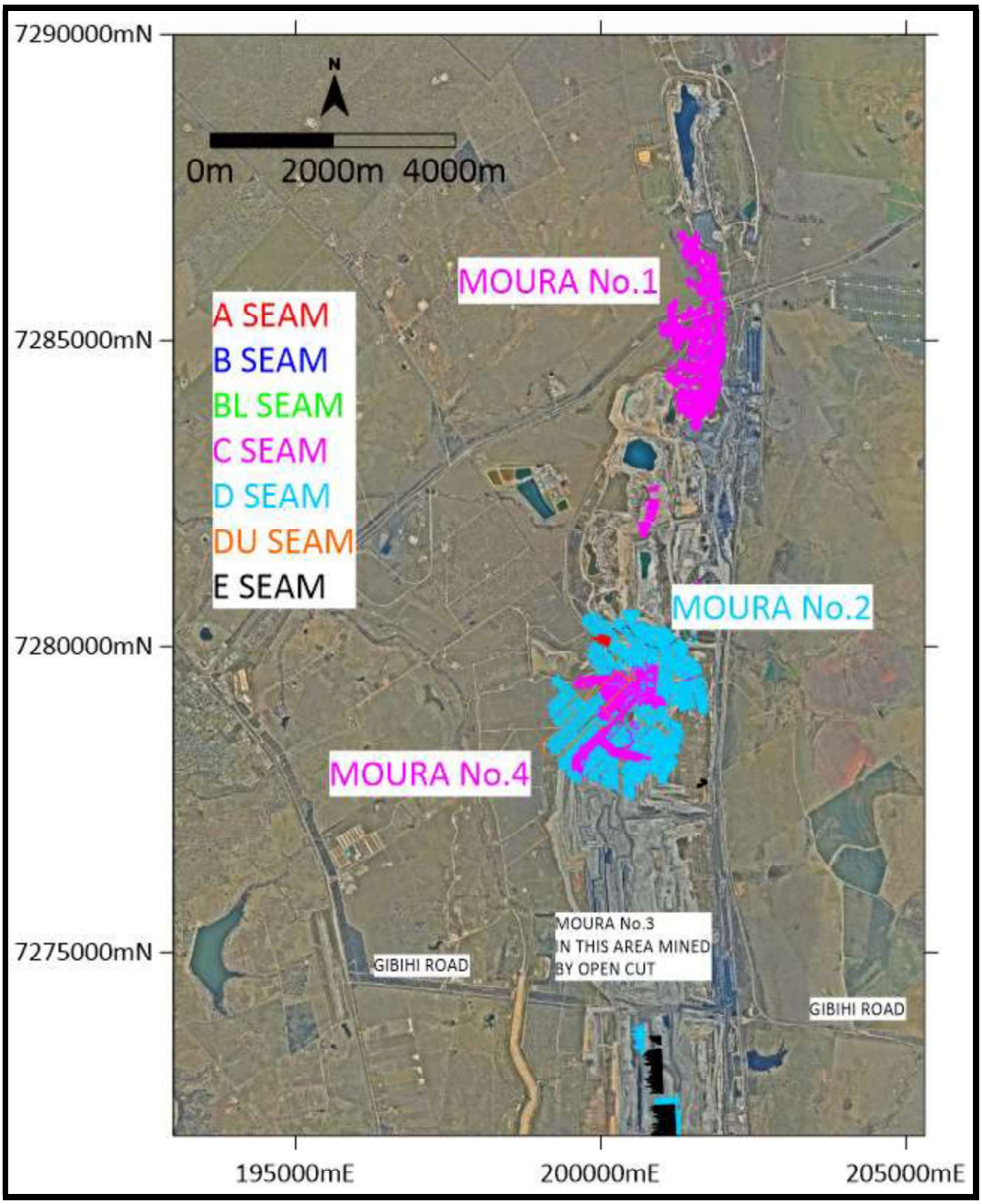


Figure 1. Location of Underground Excavations (North of Gibihi Road).

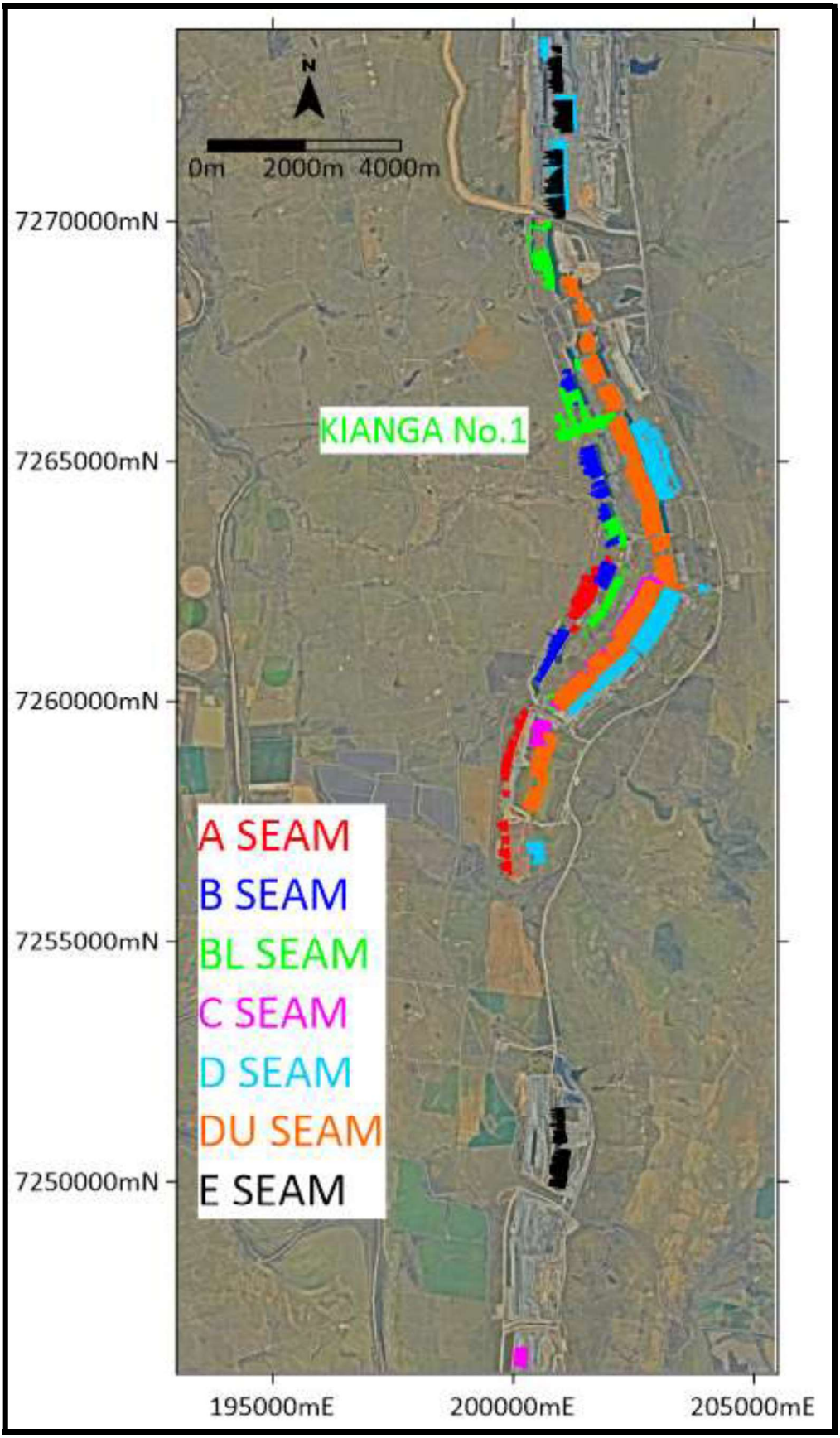


Figure 2. Location of Underground Excavations (South of Gibihi Road).

1.1 Progressive Rehabilitation and Closure Plans (PRCP)

The Department of Environment, Science and Innovation (DESI) has prepared a guideline to assist mining companies with Progressive Rehabilitation and Closure Plans (PRCP), as part of their legal obligations. Version 3 of this guideline was reviewed in 2023[1].

The main purpose of the PRCP is to:

- Require the holder of an EA to plan for how and where activities will be carried out on land, in a way that maximises the progressive rehabilitation of the land to a stable condition.
- Provide for the condition to which the holder must rehabilitate the land before the EA may be surrendered.

The EP Act requires that all areas disturbed within the relevant mining tenure must be rehabilitated to a post-mining land use (PMLU), or managed as a non-use management area (NUMA).

As detailed by DESI (2023), the PRCP requires analysis and justification of PMLUs and NUMAs. For the Dawson mine, this includes subsidence and groundwater impacts due to underground mining.

At this stage, a range of PMLUs are being considered. Some of the open cut voids are also planned to be filled, with the remaining voids to be considered NUMAs, subject to approval. The Dawson South and Dawson Central areas are planned to be non-use management areas (NUMA).

1.2 Closure Process

The PRCP guideline (DESI, 2023) also requires the rehabilitation and management strategy must include in the construction and decommissioning phase of rehabilitation, confirmation that underground workings and surface impacts have been decommissioned or remediated as planned.

A monitoring regime should be developed for areas subject to subsidence to monitor the effects of subsidence, as detailed in section 3.8 of the PRCP guideline (DESI, 2023):

1. Schedule of monitoring, reporting and review for each milestone.
2. Description of methodologies and standards, which could include field-based assessments and the application of new remote sensing, GIS and other relevant emerging technologies.

[1] Department of Environment, Science and Innovation (2023). Guideline – Progressive rehabilitation and closure plans (PRC plans). Report No. ESR/2019/4964 - Version 3.00.

3. Monitoring that enables the repeatable collection of relevant statistically valid data.
4. Monitoring using appropriate quality assurance and data management processes and systems.
5. Regular analysis of site data including multi-year comparison trends and bench-marking against analogue/reference sites.
6. Contingency strategies if monitoring data indicates milestone criteria are not being met.
7. Post-closure monitoring to ensure milestone criteria has been demonstrated.
8. Intent of monitoring reports, such as provision of results and key findings.

1.3 Assessments and Studies Required

Specifically for underground mining, the PRCP guideline (Section 3.6) requires the following aspects to be addressed in the closure rehabilitation plan (DESI, 2023):

1. A geotechnical study.
2. An assessment of groundwater interactions and potential lowering of groundwater levels that includes:
    a. Consideration of the potential exposure of previously saturated geological formations to air, leading to AMD generation.
    b. Consideration of measures to avoid or minimise groundwater discharges to the surface through appropriate mine access planning, including post mining sealing off of tunnels, shafts, adits, boreholes, and other openings.
3. The development of a hydrogeological conceptual model.
4. Subsidence analysis and modelling and a subsidence vegetation/habitat impact assessment.
5. Consideration of how potential entries to underground workings will be sealed i.e. through some form of capping or back filling.
6. How surface ponding and cracking will be mitigated.
7. Identification of post-closure stabilisation of underground workings in order to manage the potential for unplanned surface subsidence and unplanned ground collapse such as sinkholes and pot holing.

1.3.1 Geotechnical Study

As detailed in Section 3.6.4 of the PRCP guideline (DESI, 2023), the geotechnical study must include an assessment of:

1. **Post-closure stabilisation of underground workings** - including geotechnical assessments of the stability of the underground openings, assessment of groundwater conditions and groundwater impacts on the design of stabilisation methods.
2. **The requirements for sealing off surface openings to underground workings** - including geotechnical assessments of bulkhead materials,

competency and stability of the ground containing the bulkhead, the need if any for additional ground support and reinforcement including grouting, and assessment of groundwater conditions and groundwater impacts on the design of bulkheads.

3. **The magnitude and spatial extent of post-closure residual subsidence of underground workings** - this would include but not be limited to geotechnical assessments of the stability of the underground openings and overburden, assessment of adverse surface effects, and assessment of surface water and groundwater conditions and groundwater impacts on subsidence.

Aspects that need to be specifically addressed in this post-closure geotechnical study for the underground excavations in the Dawson area include:

- The stability of the bord and pillar workings at the four underground mines.
- The stability of the highwall mining and augering entries in a number of seams from A to E.
- Method of sealing the portals and ventilation shafts of the underground mines.
- Review of the surface effects above the underground excavations such as cracking and the potential for unplanned surface subsidence and unplanned ground collapse such as sinkholes and pot holing.
- The height of the recovered groundwater table with respect to the portal locations and other parts of the underground excavations.
- Review the impact of groundwater conditions such as flooding, on the stability of the underground workings and stabilisation methods.

These aspects need to consider the proposed post-mining land use (PMLU).

In summary, this geotechnical assessment needs to determine if the land that has been disturbed by underground mining activities is considered to be rehabilitated when it can be demonstrated it is safe, stable and does not cause environmental harm. The rehabilitated land also needs to be able to sustain the PMLU approved in the PRCP.

1.3.2 Subsidence

With regard to subsidence, the PRCP guideline (DESI, 2023) states that subsidence modelling must be carried out to predict potential subsidence, surface strain and tilt resulting from the underground mining operations and be used to inform implications for the rehabilitation strategies.

The guideline also details that an underground mining method should be adopted that provides for planned subsidence of the ground surface in a predictable and controlled manner (DESI, 2023). Planned subsidence means lowering the ground surface above the underground operation within predictable limits as to spatial extent, magnitude and surface distortion.

Alternatively, prevention or minimisation of planned subsidence is more appropriate and this is best achieved through the adoption of a mining method that allows for permanent post-closure support (DESI, 2023).

The stability of the bord and pillar and highwall mining/augering entries therefore needs to be calculated to allow an assessment of potential subsidence impacts.

The guideline also details that the subsidence analysis and modelling, which will inform rehabilitation strategies, must address potential management issues including (DESI, 2023):

1. Vegetation/habitat impacts such as:
    a. Damage to vegetation in the vicinity of surface cracks.
    b. Impacts associated with changed hydrogeological characteristics.
2. Community, wildlife and livestock safety and access issues associated with changes to topography and large surface cracking.
3. Potential impacts to surface infrastructure including houses, roads and power lines, etc.
4. Changes to hydrological regimes.
5. Changes to pre-existing surface water characteristics due to cracks in the bed and banks of waterways.
6. Destabilisation of waterway bed and banks as a result of the new, post-mining trough and ridge profile along the waterway, which may be geomorphologically unstable.
7. Changes to the hydrogeological regime as a result of new cracks in the rock mass which can provide new flow paths in what could have previously been impermeable rock.
8. Potential for vertical connections between previously separated aquifers.
9. Changes in surface topography and local drainage characteristics. This may result in some areas becoming more free-draining while runoff may be reduced in other areas, resulting in the ponding of water in areas where previously no ponding occurred.
10. Changes in surface drainage, leading to changes in the composition of vegetation communities and distribution of flora and fauna species.

1.3.3 Groundwater

The PRCP guideline states that the hydrogeology of the site and all connected strata should be assessed and a conceptual model of the groundwater systems should be developed. This information must be integrated into the design of rehabilitation strategies and choice of PMLU or NUMA (DESI, 2023). The hydrogeological assessment should include the following steps:

- Determining the groundwater occurrence including the existence of and depth to aquifers and aquitards.
- Locating groundwater recharge and discharge locations locally and regionally.

- Groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs).
- Current and potential future uses of groundwater including existing groundwater extraction bores.
- Groundwater flow direction and velocity, including field tests to determine hydraulic conductivity.
- The development of potentiometric mapping and hydro stratigraphic cross sections.
- Groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage.

The prediction of water quality impacts from mining activities is necessary to determine appropriate measures for the containment and management of contaminants and the potential impacts on environmental values should they be released.

Specific items in the guideline for underground mining operations related to groundwater include:

1. An assessment of groundwater interactions and potential lowering of groundwater levels.
2. The development of a conceptual model including the hydrological processes that would occur post-closure. A numerical model must also be developed and included in the rehabilitation planning part to enable analytical assessment of the hydrological evolution within the underground workings post-closure. This model should include groundwater and surface water interaction and would utilise the hydrogeological model developed for the site.

1.4 Scope of Work

The scope of work for this geotechnical assessment of the underground excavations in the Dawson area is as follows:

- Review all available information, in particular, relating to mining method, location and extent, including the underground disasters and sealing response.
- Conduct a site visit to understand the current performance of the undergrounds, including the state of any residual surface openings, and subsidence/surface cracking etc.
- Develop a report which provides:
    - A summary of the known/previous closure of the undergrounds.
    - An assessment of post-closure stability using current performance as an indication.
    - An outline of the sealing requirements for any remaining shafts, drifts, vents, adits etc.

- A summary of any remaining or continuing surface impacts/issues such as subsidence and surface cracking, and recommendations for management.

1.5 Site Inspection

A site inspection was carried out on 7th November 2023 in the company of Martha Jimenez (ERM) and assisted on site by Chris Mann (Dawson Sustainable Development Superintendent). Unfortunately, due to prior wet weather, the surface inspection was restricted to the surface above the Moura No. 2 and No. 4 underground mines.

Whilst on site, discussions were held with site personnel including:

- Andy Margot (Open Cut Examiner).
- Gary Turner (Mine Surveyor).
- Andrew Brunker (Pump Supervisor).
- Val Garret (Geologist).
- Daniel Martin (Technical Services Manager).

Borehole data was also collected from the geological team on site.

1.6 Borehole Data

A large database of exploration boreholes is available in the Dawson area to allow the analysis of the depth of cover above the underground excavations at the time of closure (**Figure 3**). The structure roof levels for each seam mined were gridded in SURFER and subtracted from the final landform surface provided by ERM on the 13th December 2023 to calculate the depth of cover at closure.

Where spoil is planned to be dumped, a saturated spoil density of 2 t/m^3 was assumed in order to determine the effective depth of cover used in the stability calculations.

The seam thickness data from these boreholes has also been contoured to allow an assessment of the likely extracted mining heights.

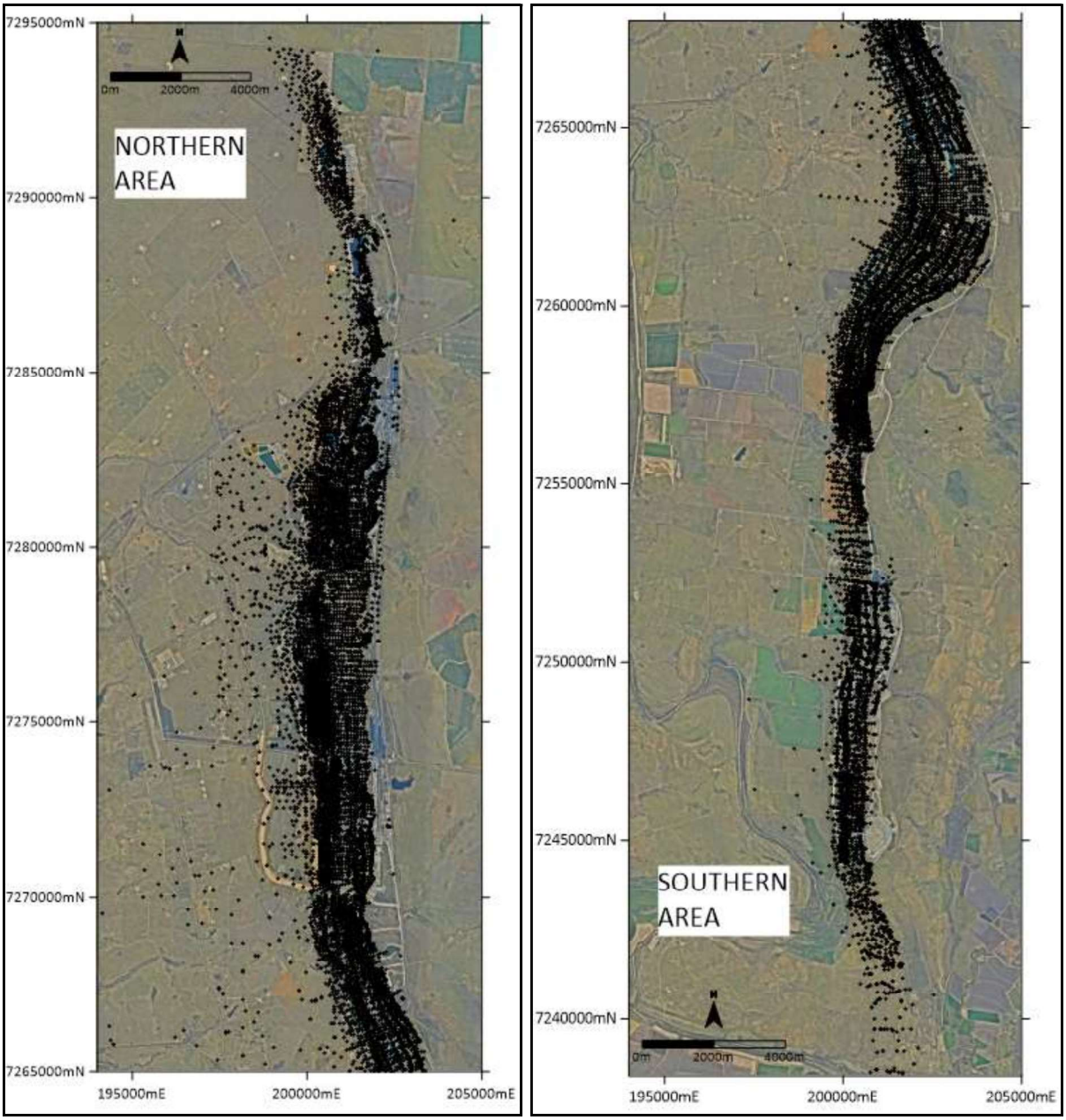


Figure 3. Location of Exploration Boreholes.

1.7 Relevant Underground Mining Experience

Nick Gordon of GGPL previously carried out consulting studies for ACIRL in the late 1980's at a number of underground bord and pillar mines in NSW. Nick then moved to the South Blackwater mine, where he was the geotechnical engineer at the Laleham bord and pillar mine and Kenmare longwall mine from 1993-1999. GGPL has also prepared highwall mining designs for Ensham mine.

This experience provides a greater understanding of the mining methodologies used in the Dawson mining area since the start of underground mining more than fifty years ago.

2 OVERVIEW OF THE BORD AND PILLAR MINING

2.1 Introduction

This section of the report provides an overview of the mining methodology and history of the underground bord and pillar mines in the Dawson mining area. Discussion on the groundwater levels with respect to the excavations, as well as potential surface disturbance effects are also included.

The depth of cover above each mine has also been reviewed, highlighting areas of spoil dumping as well as the mining of deeper open cut pits. Finally, the available knowledge on the sealing of the excavations is also included.

These bord and pillar mines include Moura No. 1, No. 2 and No. 4, as well as Kianga No. 1 (**Figure 1 and Figure 2**). The Moura No. 3 mine, located just to the north of the Gibihi Road, is understood to have been previously mined out by the open cut (**Figure 1**).

2.2 Moura No. 1

2.2.1 Introduction

Moura No. 1 mine in the northern part of the Dawson area extracted the C Seam, at depths down to 220 m (**Figure 4**). The C Seam in this area is 5-6.5 m thick.

The time span of mining at Moura No. 1 mine is unknown, however the Kianga No. 1 mining disaster report (Warden's Inquiry, 1975[2]) indicates that Moura No. 1 was operational in 1974.

The southern part of Moura No. 1 is located below several tailings dam cells and to the west of the Dawson CHPP (**Figure 9**).

2.2.2 Mining Methodology and History

The mine plan indicates that the majority of the Moura No. 1 underground workings were carried out as first workings i.e. the development of coal pillars only (**Figure 4**). Whether additional floor coal was mined in these roadways is not known.

As is typical of older bord and pillar mines, Moura No. 1 mine is characterised by an irregular layout of pillars and panels, including the development of angled roadways to assist in the loading out of the mined coal. This configuration however makes the analytical assessment of the stability of the pillars more difficult.

[2] Warden's Inquiry (1975). Report on an Accident at Kianga No. 1. Underground Mine on Saturday, 20th September, 1975.

There are localised areas of secondary extraction where the pillars are shown to have been mined out, particularly in the shallow panels to the north and south of the portals (**Figure 4**). In this area, splitting and pocketing of the development pillars has been carried out

As detailed above, the C Seam in this area is up to 6.5 m thick, however no detail is available on the extracted thickness to assess the stability of the remnant coal pillars.

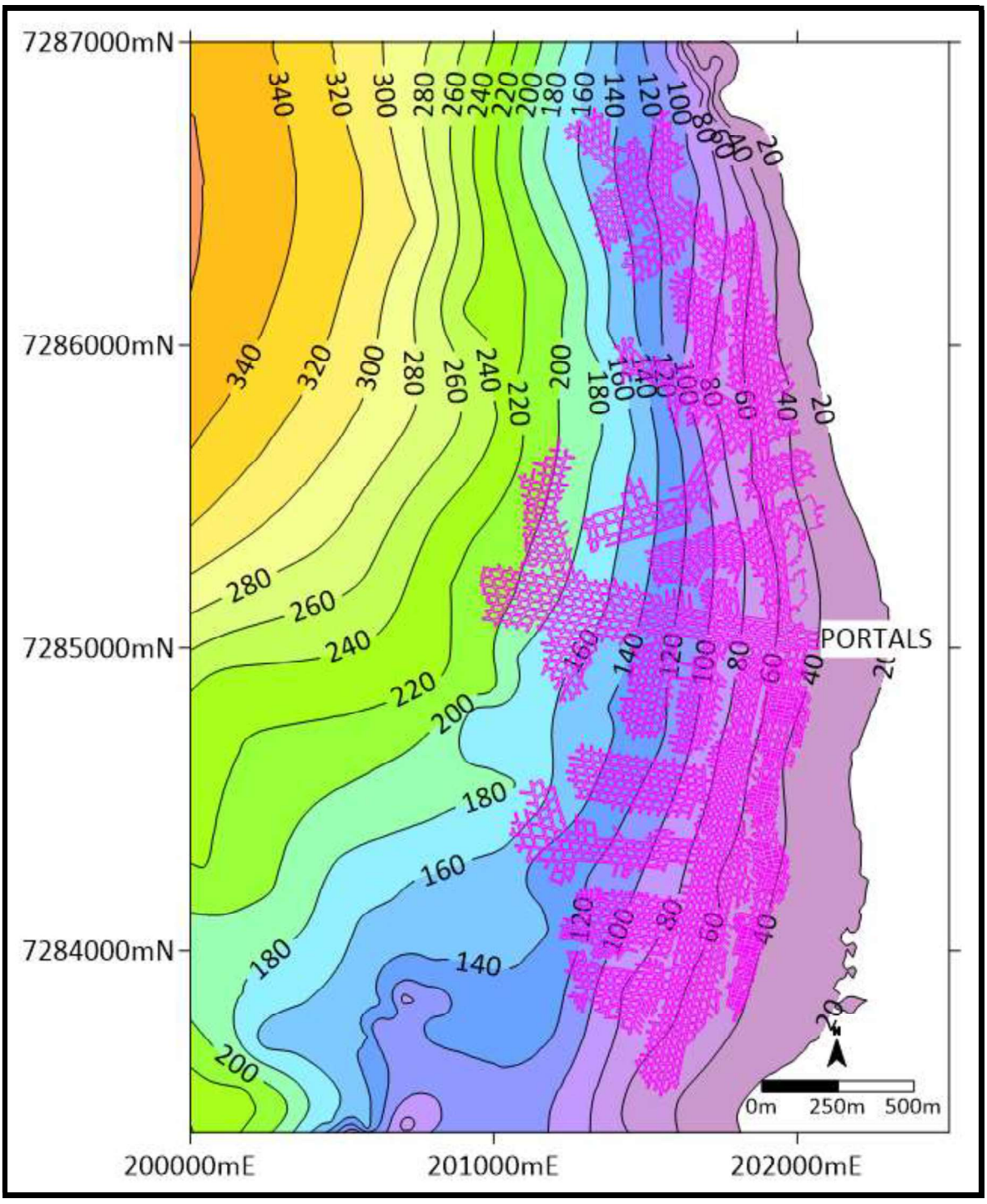


Figure 4. Underground Mine Plan and Depth of Cover – Moura No. 1 Mine (m).

2.2.3 Final Landform

At the time of closure, minimal change to the surface topography is planned above the Moura No. 1 underground workings (**Figure 5**). An open cut pit extracting down to the C Seam is planned to the southwest of the underground workings (**Figure 5**). This reduces the depth of cover above some of the underground panels from 140-180 m to 80-120 m adjacent to the pit (**Figure 6**).

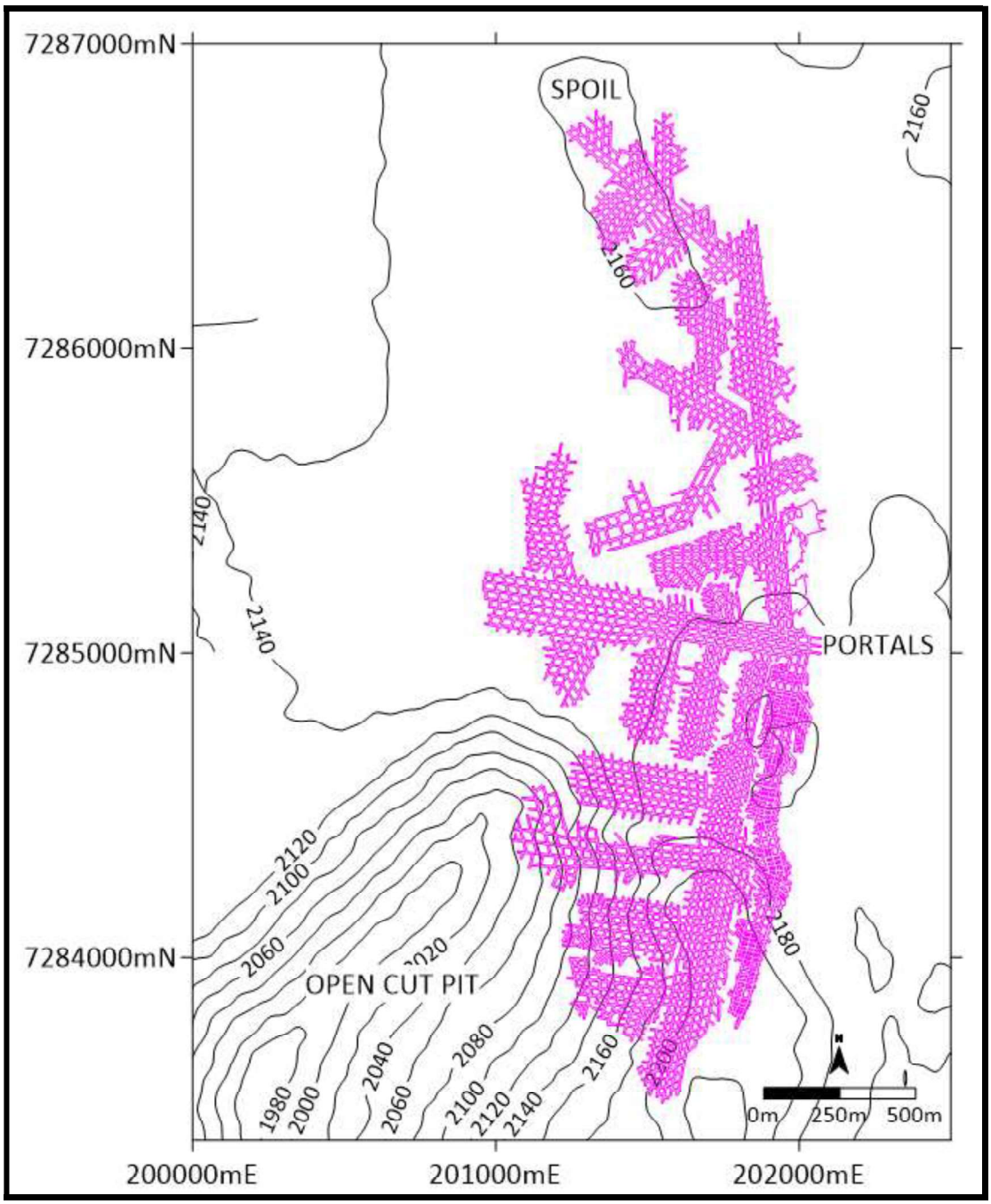


Figure 5. Final Landform at Closure – Moura No. 1 Mine (m ASL - 2000).

In the northern part of the area, a small spoil dump is planned, which increases the depth of cover by up to 20 m above the northern panels in this area (**Figure 6**).

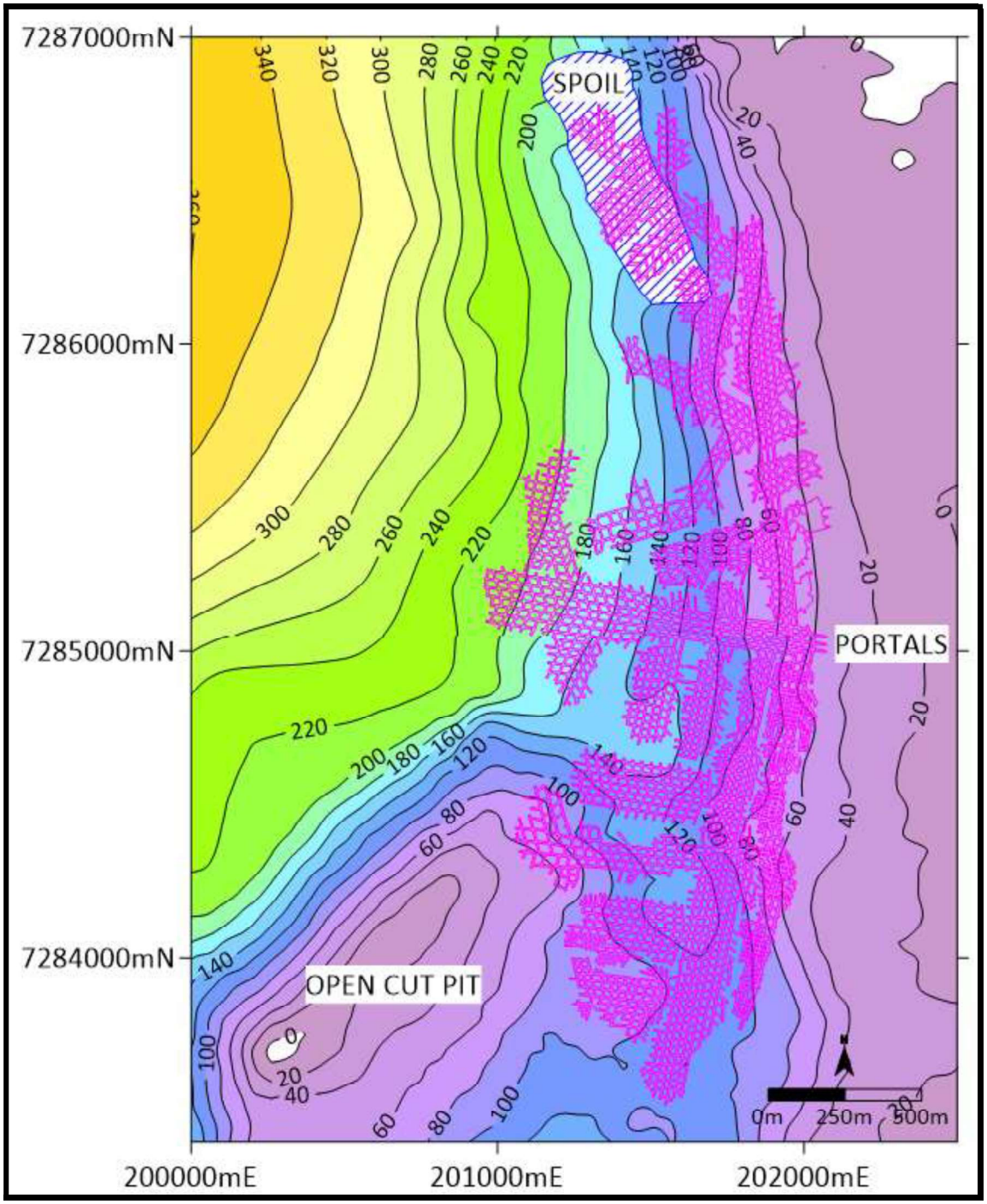


Figure 6. Depth of Cover at Closure – Moura No. 1 Mine (m).

2.2.4 Water Level

There are two piezometers that are regularly monitored in the Moura No. 1 mine area, namely P10 and P11B (**Figure 7**). Based on **Figure 8**, the water level in P10 in mid-2023 was around 116 m ASL and 121 m ASL in P11B. Site personnel indicated that there may also be another monitoring borehole approximately 250 m northwest of the portals. At the time of this geotechnical investigation, no data had been provided for this borehole.

Based on the structure roof level for the C Seam of around 115 m ASL at the portals, these piezometric water levels indicate that the Moura No. 1 underground mine is currently full of water (**Figure 7**). Site personnel also indicated that during periods of heavy rainfall, water is seen to flow out of the portal area, consistent with these measured water levels (**Figure 10**). It is not known if water flows back through these portals into the underground.

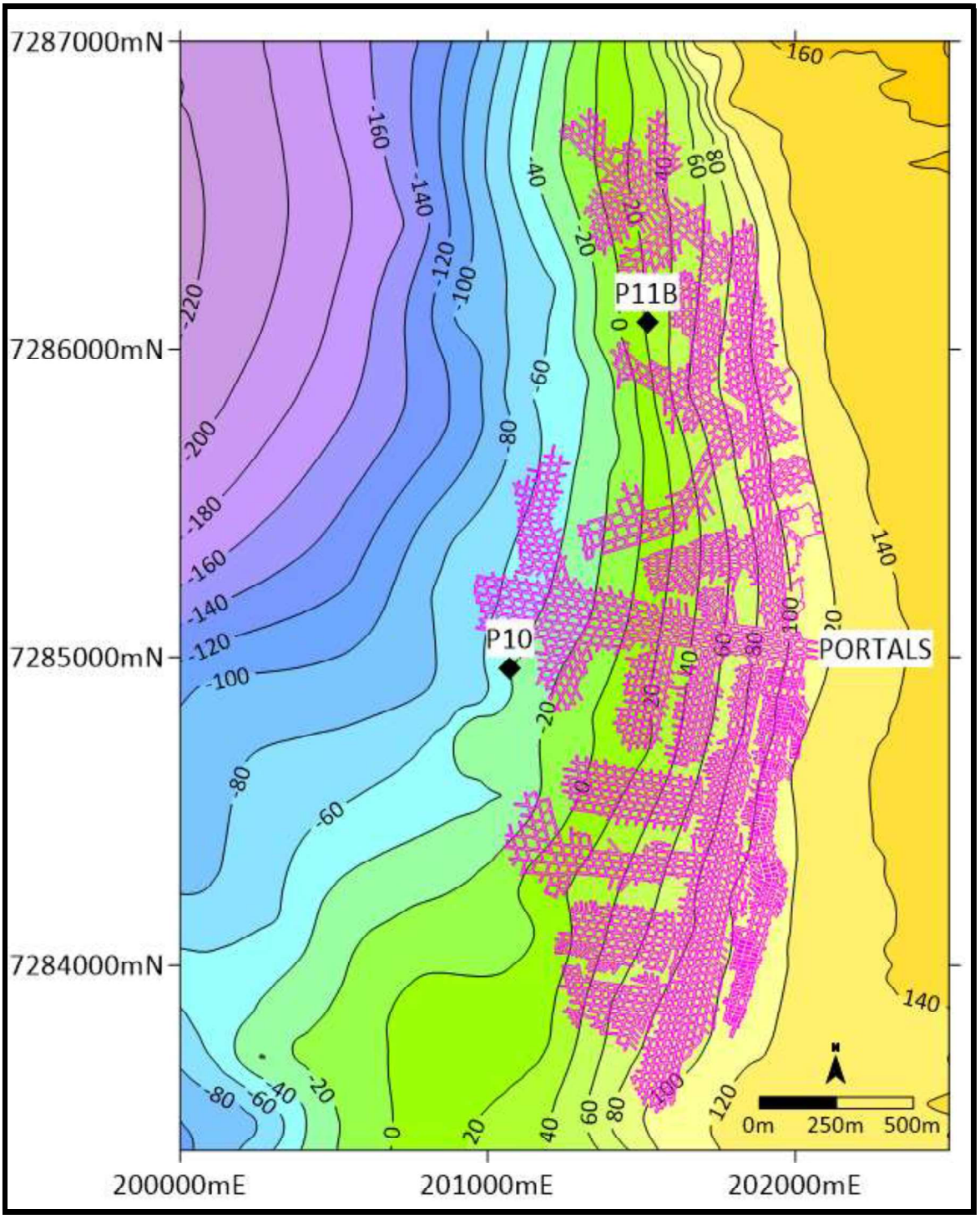


Figure 7. Structure Roof Level C Seam – Moura No. 1 Mine (m ASL).

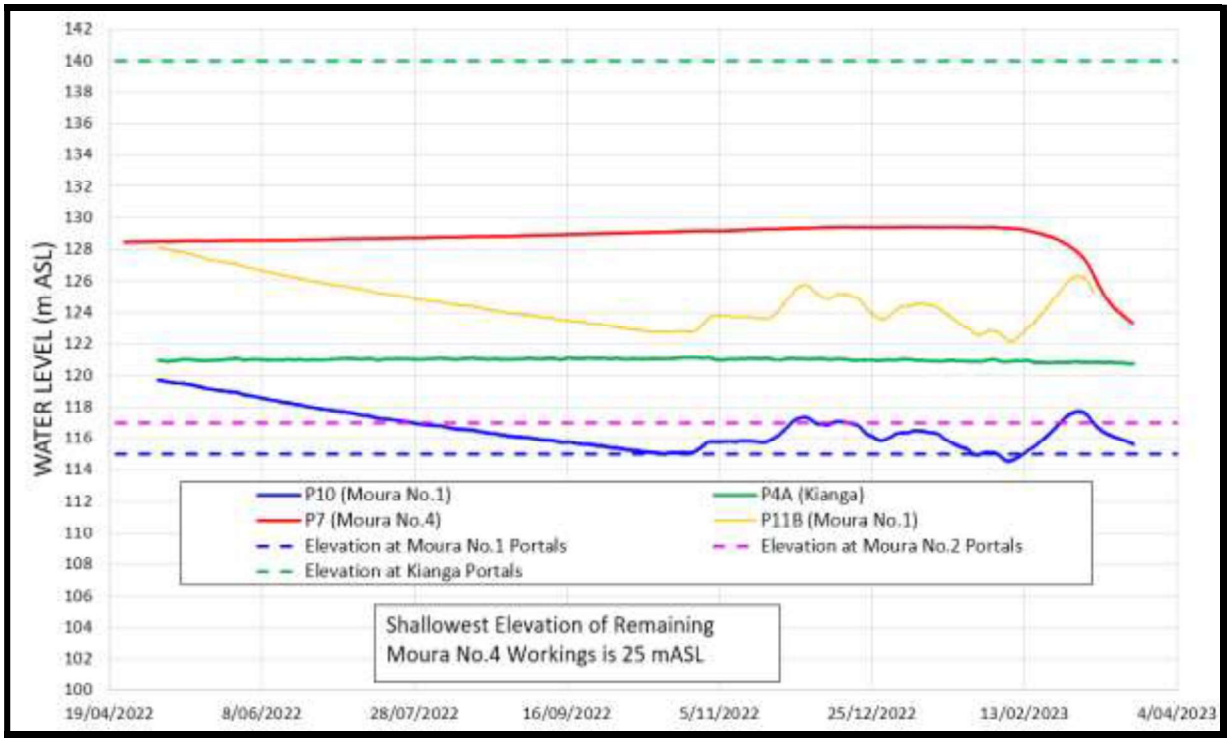


Figure 8. Piezometer Data near the Bord and Pillar Mines.

There is also a borehole used to pump out water from the underground workings for the CHPP. This borehole is located around 450 m down dip of portals, where the depth of cover to the C Seam is approximately 110 m.

2.2.5 Surface Disturbance

Based on a review of the mine layout and the pillar extraction methodology carried out, potential areas of previous subsidence above the Moura No. 1 underground workings are shown in **Figure 9**. These areas were mined more than fifty years ago and experience at other bord and pillar mines indicates subsidence would most likely have occurred soon after mining was completed.

As indicated earlier, the extraction height is unknown to allow a confident assessment of the stability of the coal pillars and also the magnitude and extent of the surface subsidence at Moura No. 1 mine.

It is also highlighted that the Dawson Highway is located above the Moura No.1 mine, however the workings are not extensive in this area (**Figure 9**). In the shallower part of the area, the mine appears to have been planned to have purposely only mined three roadways in two locations below the highway to maintain stability (**Figure 9**).

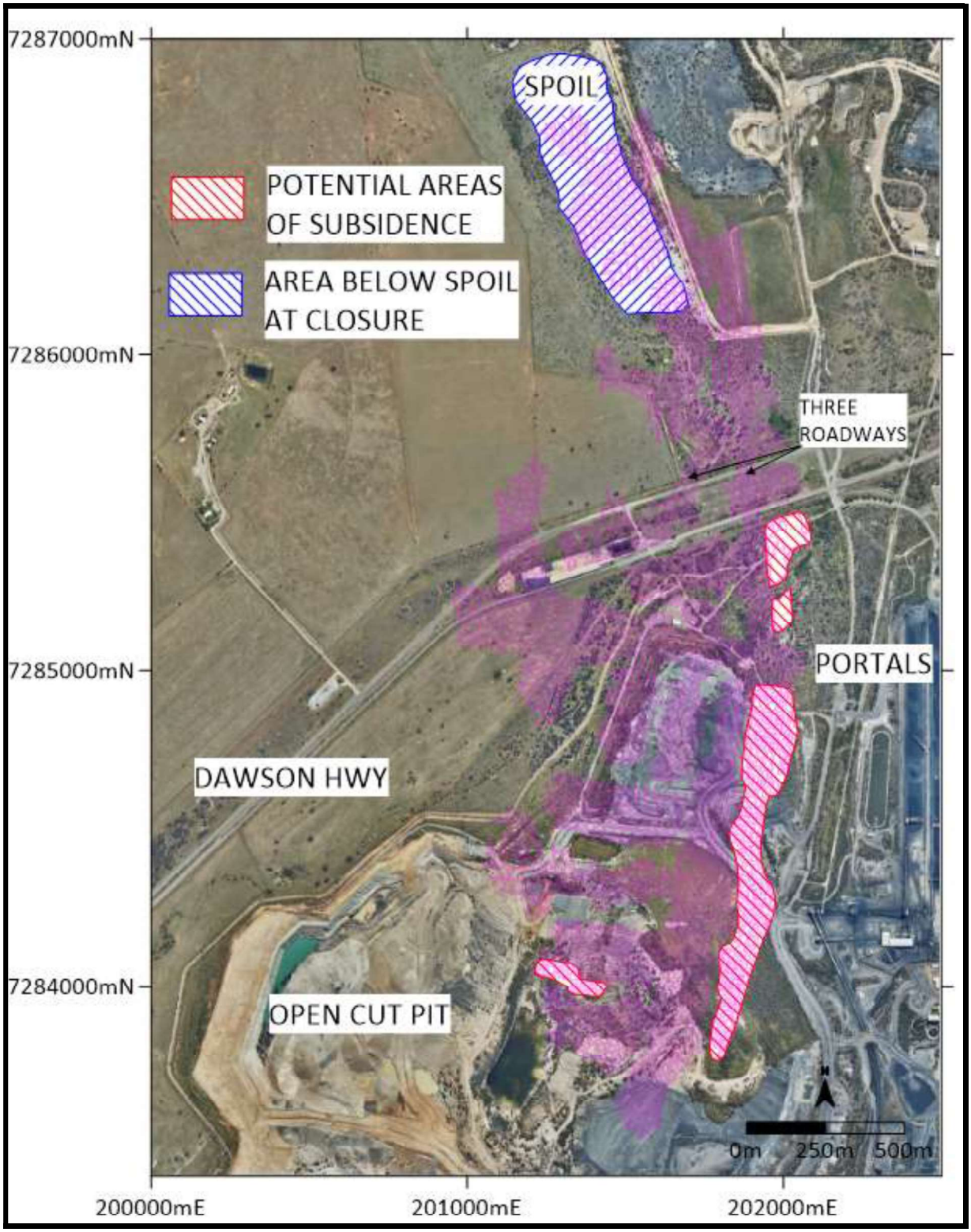


Figure 9. Potential Areas of Surface Disturbance – Moura No. 1 Mine.

The surface around the portals and a possible shaft site adjacent to the portals, shows minimal disturbance on the LiDAR photograph in October 2023 (**Figure 10**). It is understood that on closer inspection the portals are covered over by rocks.

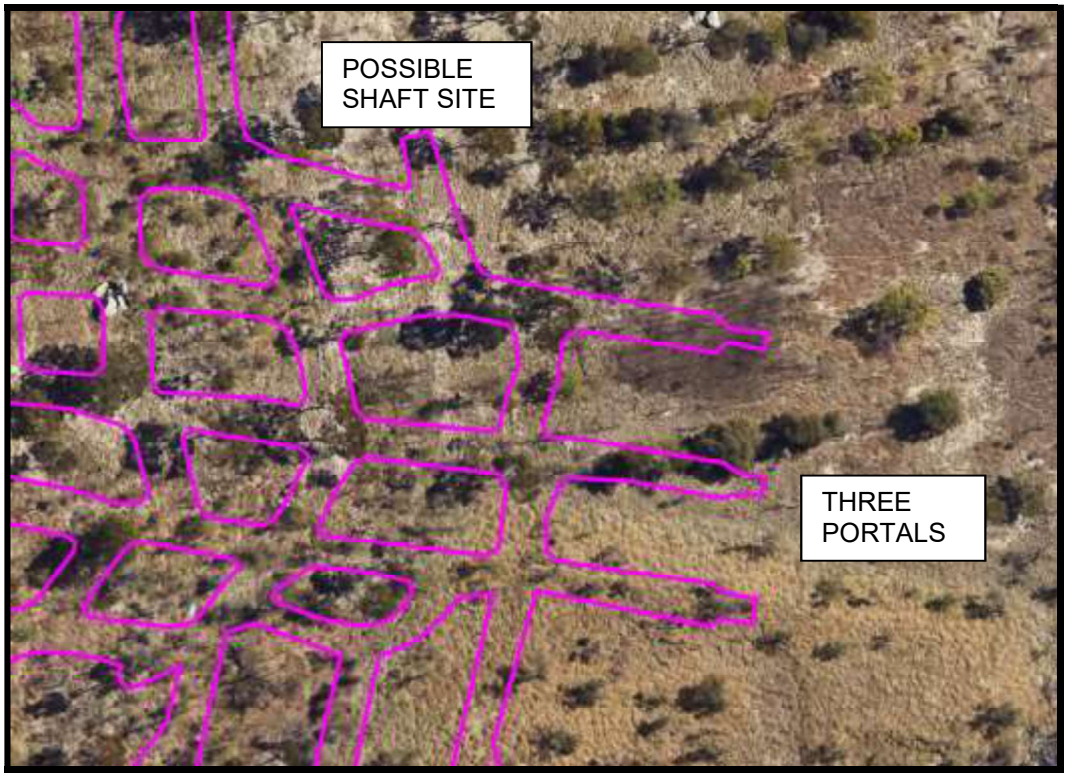


Figure 10. Moura No. 1 Mine - Portal Area (October 2023).

2.2.6 Sealing of the Mine

The details of the sealing of the portals and possible shaft at Moura No. 1 mine are unknown, however the observation by site personnel of water flow from the portals after heavy rainfall indicates leakage is occurring.

2.3 Moura No. 2

2.3.1 Introduction

Moura No. 2 underground mine extracted the D Seam approximately 40 m below the Moura No. 4 mine (**Figure 11**). The D Seam in this area is 2.5-4 m thick, at depths exceeding 260 m (**Figure 11**).

The Moura No. 2 underground workings, unlike the shallower C Seam workings at Moura No. 4 mine, have not been mined out by the open cut.

2.3.2 Mining Methodology and History

On 7 August 1994, eleven miners died as a result of an explosion at Moura No. 2 (Warden's Inquiry, 1994[3]). After the second explosion on the 9th August, the shaft and four portals were sealed and the bodies were never recovered. In the western

[3] Warden's Inquiry (1994). Report on an Accident at Moura No. 2 Underground Mine.

part of the area, there is an exclusion around the area where the men are still buried (**Figure 11**).

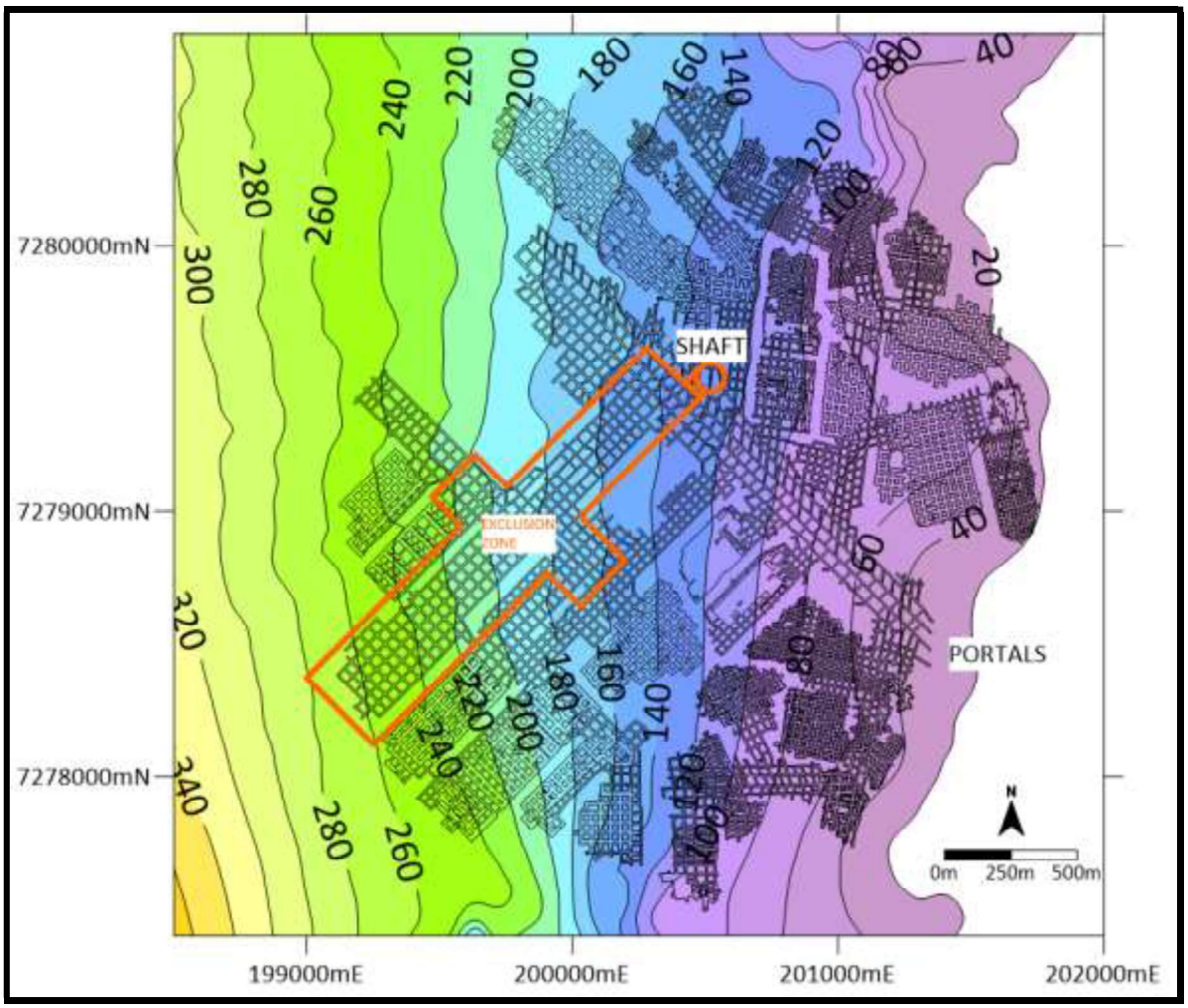


Figure 11. Underground Mine Plan and Depth of Cover – Moura No. 2 Mine (m).

As detailed in the Warden's Report, Moura No 2 underground mine started operations in 1970 and a total of 28 bord and pillar panels were mined before closure (**Figure 11**). The design of the panels was variable in the seam thickness mined and also the overall panel dimensions and size of the pillars (**Figure 11**). This led to a range of extraction ratios as shown in **Figure 11**.

Typically, panels were developed by forming solid coal pillars on the advance, which was the first phase of the coal extraction process called first workings (Warden's Report, 1994). Once fully developed, the second phase of the operation were for the goaf to remain open and be supported by leaving selected pillars either totally or partially in place called second workings or secondary extraction.

On completing the extraction, panels were isolated from the rest of the mine by the erection of brick and cement rendered seals across all entries to the panel.

The panel layout in the older panels at Moura No. 2 mine is less regular compared to the more recent panels, such as in the exclusion zone (**Figure 11**). These regular pillar dimensions are more amenable to a pillar stability analysis as detailed in Section 4.

Prior to 1986, panels at Moura No. 2 mine had been designed for the goaf to collapse during the pillar extraction phase. Panel design had been evolving over several years with the objectives of improving productivity and coal recovery by mining to the full seam height and seeking to inhibit spontaneous combustion by ventilating an open goaf (Warden's Report, 1994).

2.3.3 Final Landform

As shown in **Figure 12**, extensive dumping of spoil, up to 120 m high, is planned over the Moura No. 2 underground workings. This spoil dump will increase the depth of cover above the portals to 160 m (**Figure 13**).

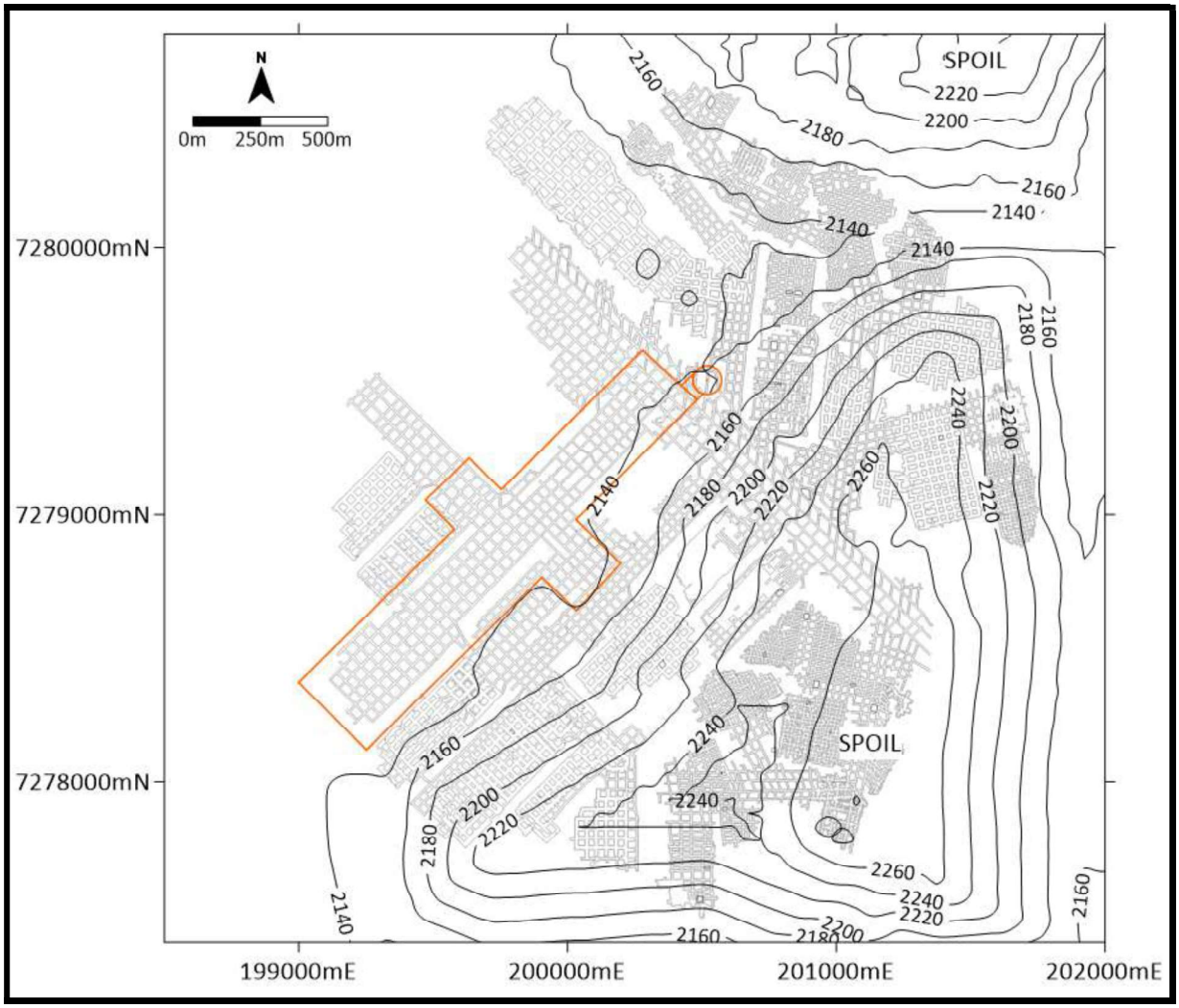


Figure 12. Final Landform at Closure – Moura No. 2 Mine (m ASL - 2000).

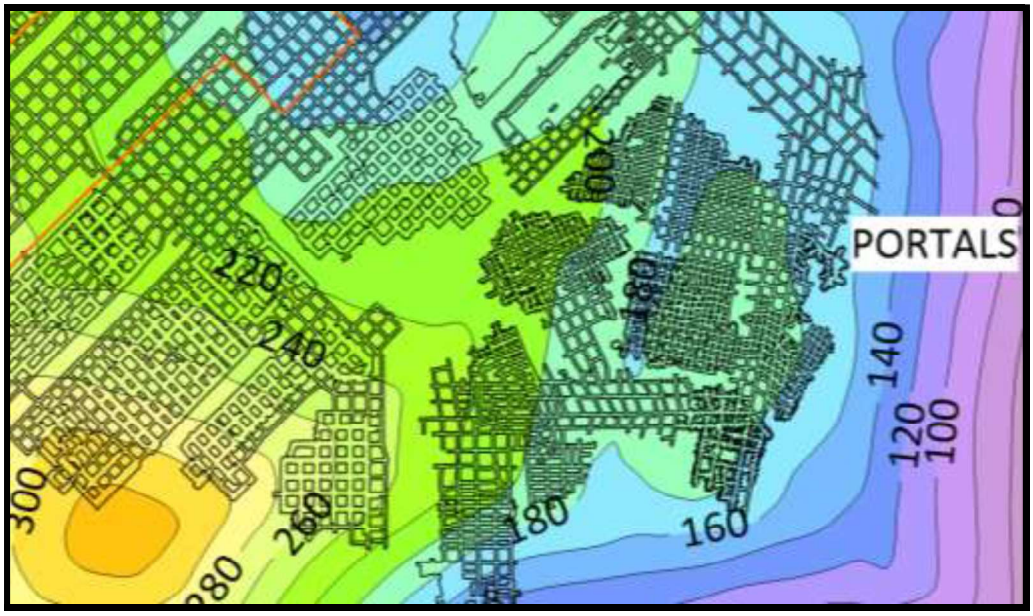


Figure 13. Depth of Cover at Closure – Moura No. 2 Mine (m).

2.3.4 Water Level

The piezometer P7, indicates that the water level in mid-2023 was around 124 m ASL, having fallen in February 2023 from a more constant 128 m ASL (**Figure 8**).

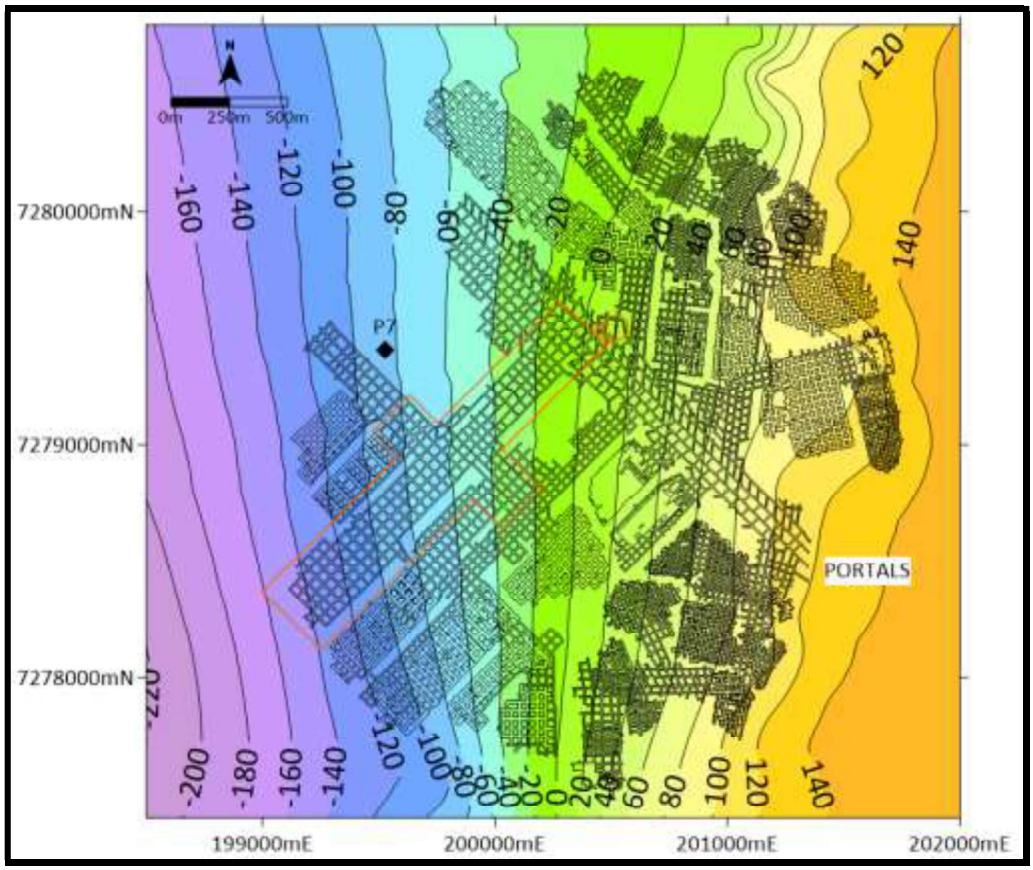


Figure 14. Structure Roof Level D Seam – Moura No. 2 Mine (m ASL).

This water level indicates that the Moura No. 2 underground mine is currently full of water based on the elevation at the portals of around 120 m ASL (**Figure 7 and Figure 14**). This is also consistent with reports by site personnel that water was pumped into the mine for about 8 years.

2.3.5 Surface Disturbance

As shown in **Figure 15**, the collar of the Moura No. 2 ventilation shaft is still exposed at the surface.



Figure 15. Moura No. 2 Mine - Shaft Area (October 2023).

The undisturbed surface above the underground workings in the exclusion zone is shown in **Figure 16 and Figure 17**.



Figure 16. Moura No. 2 Mine – Exclusion Zone (October 2023).



Figure 17. Moura No. 2 – Exclusion Zone (7th November, 2023).

Where the highwall mining drives have extracted the A Seam above the Moura No. 2 D Seam underground workings, it is understood that surface cracking up to 200 mm wide was observed (**Figure 18**). The drives in this area were 3.6 m wide and 3.6 m apart (**Figure 18**).

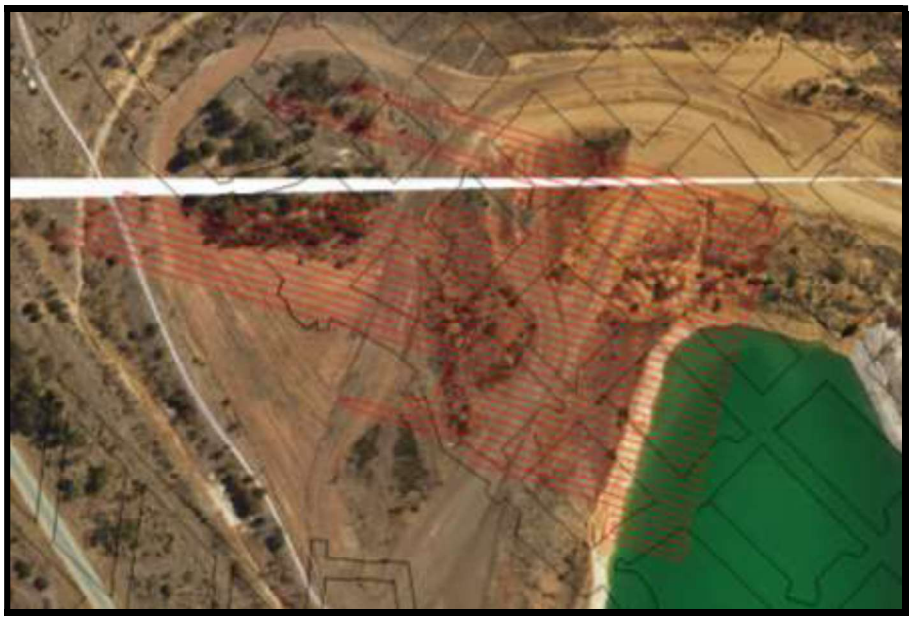


Figure 18. Moura No. 2 – Overlying A Seam Highwall Drives (October 2023).

Discussions with site personnel indicated surface cracking has also occurred at the south-western end of Moura No. 2 mine. As shown in **Figure 19**, secondary extraction was carried out in a number of panels in this area. As detailed earlier, these panels are planned to be covered by extensive spoil, increasing the depth of cover at closure to 160-320 m (**Figure 13 and Figure 19**).

As shown in **Figure 19**, there are extensive areas of secondary extraction where subsidence is predicted soon after mining. This is consistent with reports of cracking on the Three Chain Road over areas of secondary extraction (**Figure 20**). Some of these secondary extraction areas are already covered by spoil (**Figure 19**).

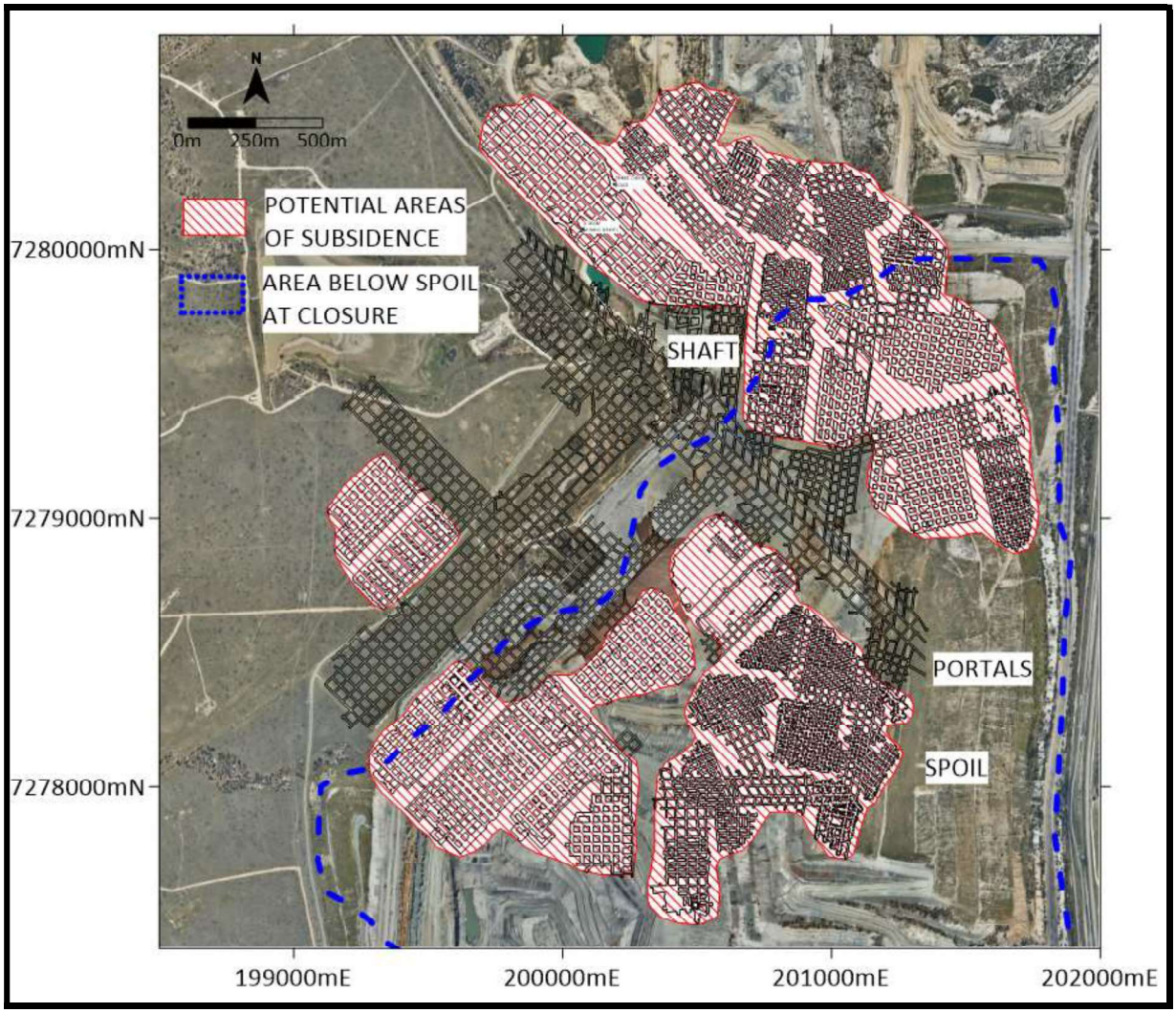


Figure 19. Potential Areas of Surface Disturbance – Moura No. 2 Mine.



Figure 20. Reports of Cracking over Moura No. 2 Mine.

2.3.6 Sealing of the Mine

The specific details on how the Moura No. 2 shaft was sealed is unknown. After the second explosion, material was pushed over the highwall to seal the portals. It is understood that permanent bulkheads/seals were not built due to the risk of further explosions.

2.4 Moura No. 4

2.4.1 Introduction

Moura No. 4 mine extracted the C Seam approximately 40 m above the Moura No. 4 underground workings, at depths of 40-200 m (**Figure 21**). The C Seam in this area was typically 6.5-7 m thick.

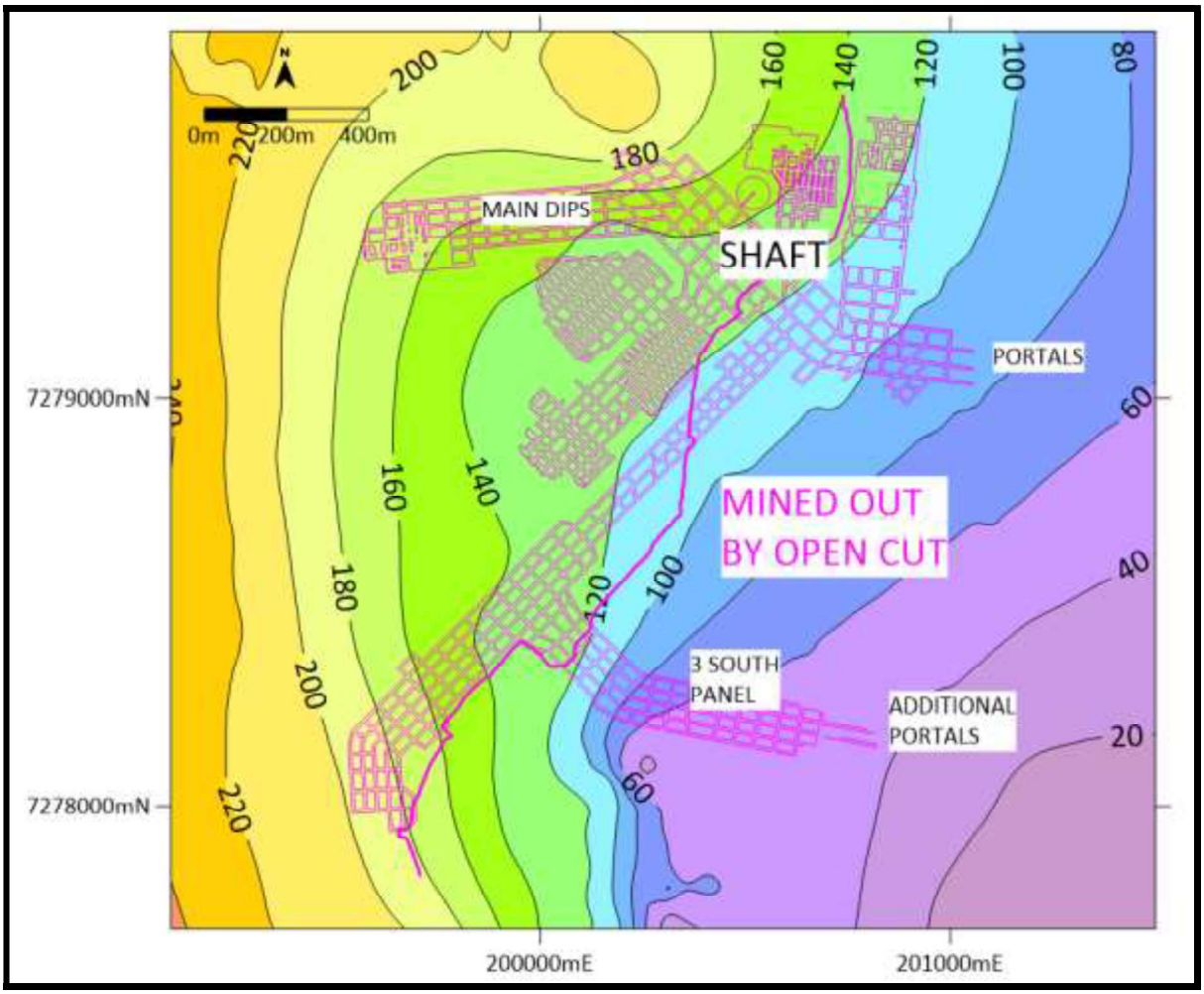


Figure 21. Underground Mine Plan and Depth of Cover – Moura No. 4 Mine (m).

As shown on **Figure 22**, the shallower part of the Moura No. 4, C Seam workings were mined out by the open cut with approximately 35% of the total mined workings

was removed. This mined out area has been covered in part by spoil and in some areas this has been rehabilitated (**Figure 22**).

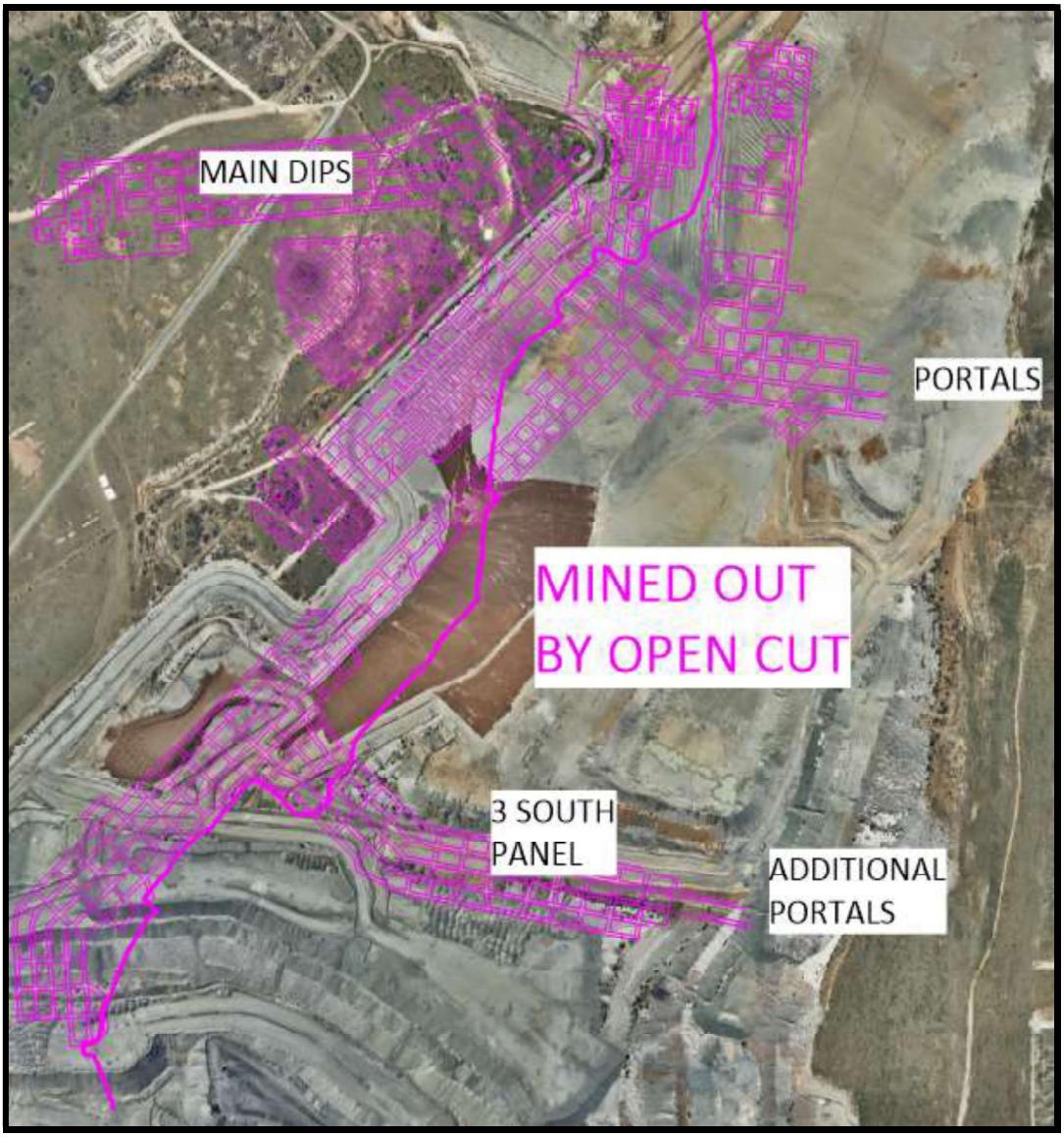


Figure 22. Open Cut Mining above Moura No. 4 Mine.

2.4.2 Mining Methodology and History

Moura No. 4 mine commenced in February 1978 with the driveage of three portals from the toe of an abandoned highwall in the top 3 m of the seam in the northern part of the area (**Figure 21**). The layout of roadways and pillars at Moura No. 4 mine was more regular than the Moura No .1 mine plan (**Figure 4 and Figure 21**).

As detailed in the Wardens Report (1986[4]), the C Seam consists of upper and lower sections of good quality coal, both around 3 m thick, separated by a middle split of up to 1 m of poor quality coal.

[4] Warden's Inquiry (1986). Report on an Accident at Moura No. 4 Underground Mine.

A further set of entries were developed to improve access to the southern section of the mine along the 3 South Panel (**Figure 21**).

Mining was carried out using continuous miners and shuttle cars and a number of panels were formed and extracted. Both total extraction of the good quality upper section and partial extraction of the total seam involving lifting of bottoms was carried out (**Figure 21**).

At about 11:05 am on 16th July, 1986 an explosion occurred in the Moura No. 4 underground mine. The twelve miners who were extracting pillars in the Main Dips panel were killed (Warden's Report, 1986) (**Figure 21**). At the time of the explosion, the upper part of the 7 m thick C Seam was being mined.

2.4.3 Final Landform

As shown in **Figure 23**, extensive dumping of spoil is planned over the Moura No. 4 underground workings, with an additional 140-160 m of spoil above the two portal areas at closure (**Figure 24**).

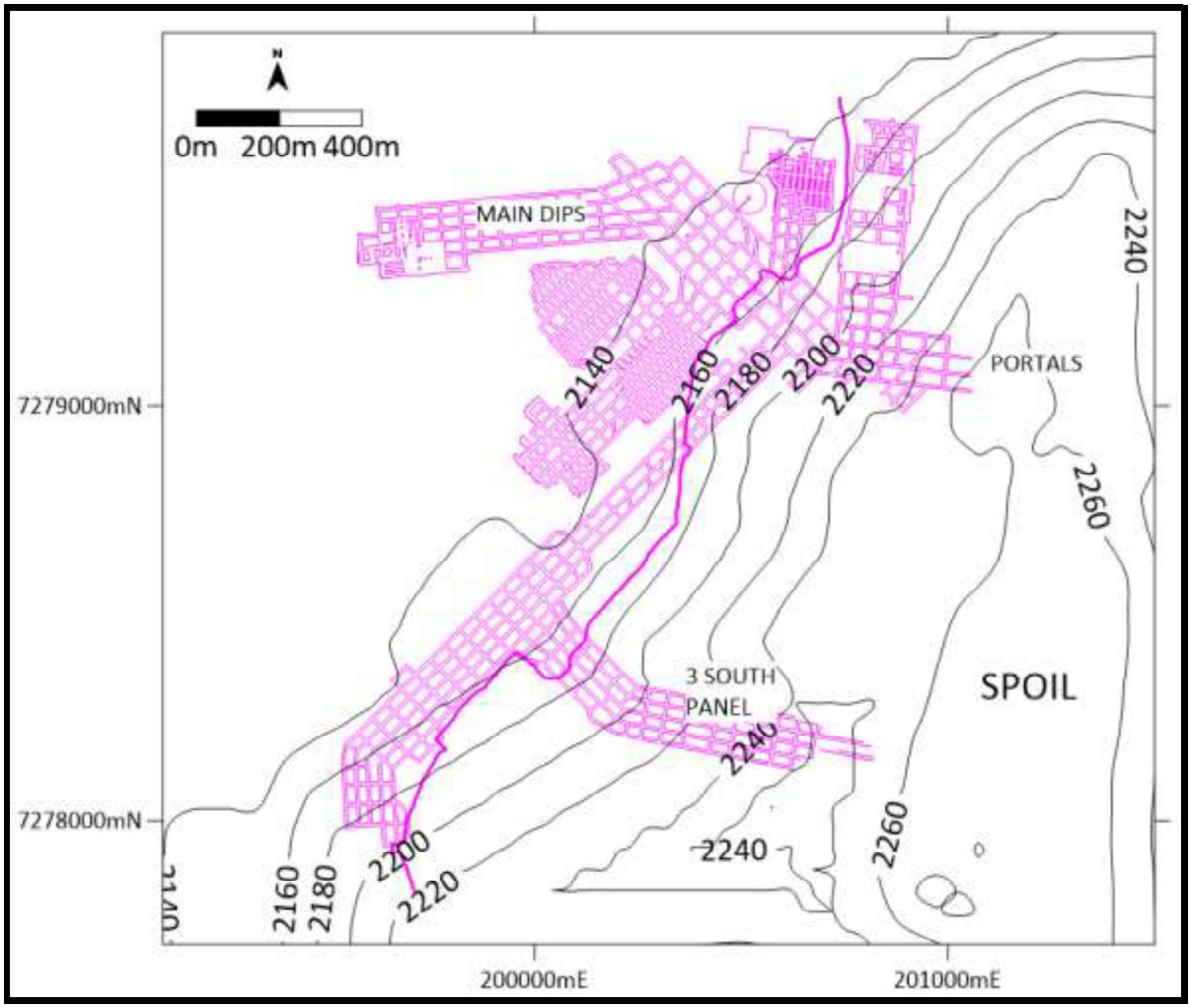


Figure 23. Final Landform at Closure – Moura No. 4 Mine (m ASL - 2000).

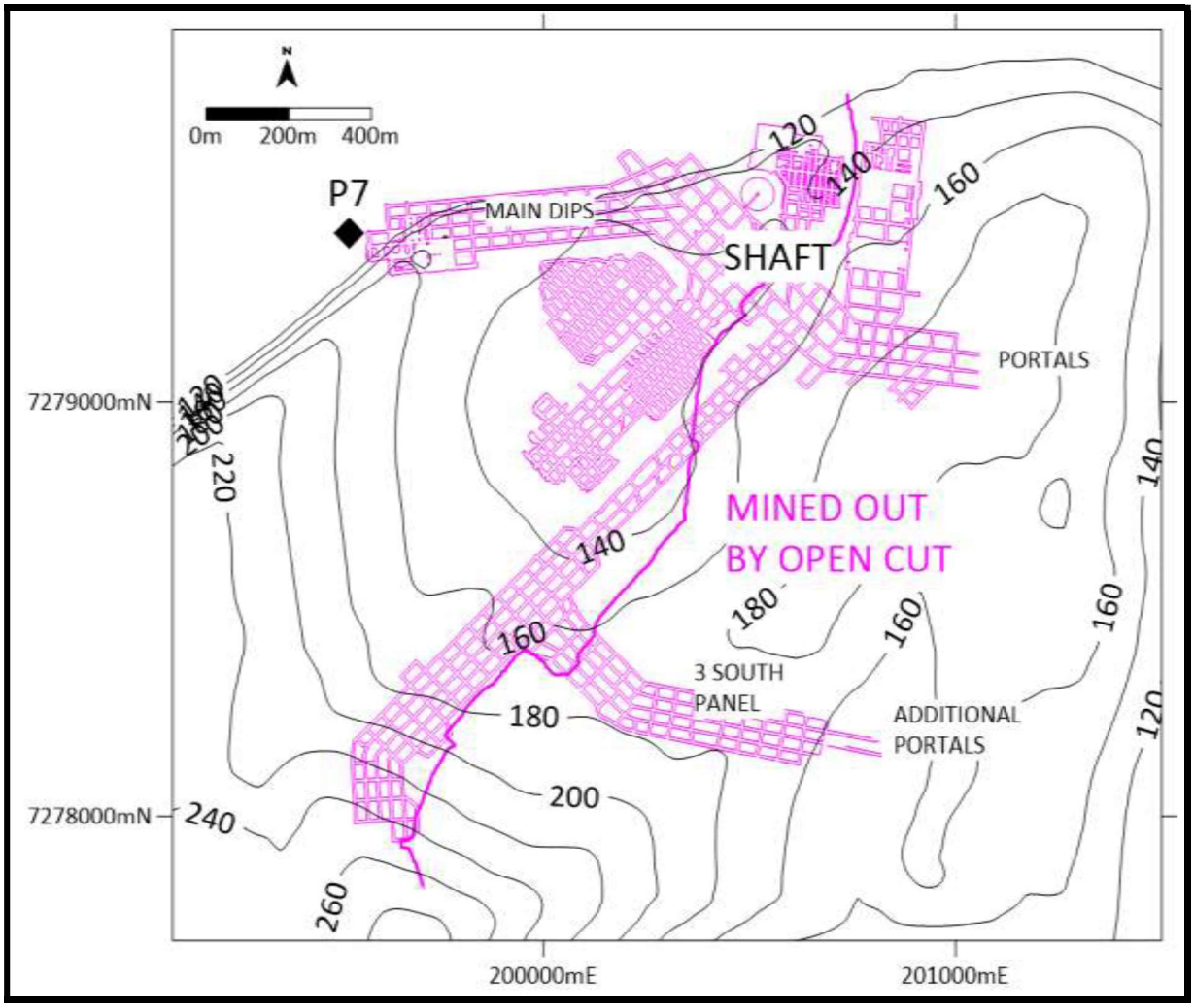


Figure 24. Depth of Cover at Closure – Moura No. 4 Mine (m).

2.4.4 Water Level

The piezometer P7 in the Moura No. 4 mining area, indicates that the water level in mid-2023 was around 124 m ASL, having fallen in February 2023 from a more constant 128 m ASL (**Figure 8**). This indicates that the Moura No. 4 mine is currently full of water due to location of the northern and southern portals at 60 m ASL and 100 m ASL respectively (**Figure 25**).

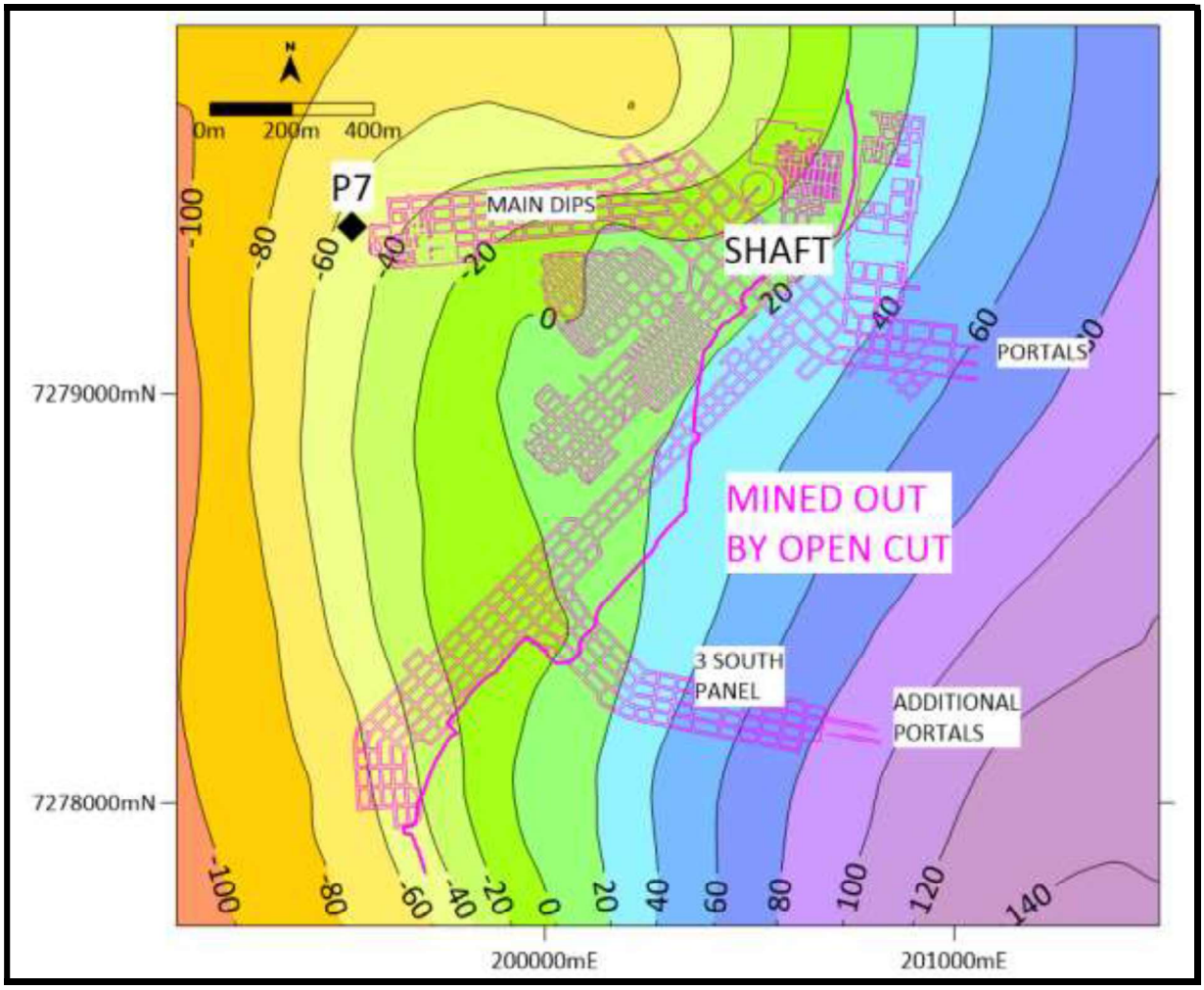


Figure 25. Structure Roof Level C Seam – Moura No. 4 Mine (m ASL).

2.4.5 Surface Disturbance

Based on the extraction methodology carried out, including pillar splitting (partial extraction) and lifting of pillars (total extraction), potential areas where surface subsidence above the Moura No. 4 underground workings is likely to have occurred are shown in **Figure 26**. Due to the uncertainty in the extraction thickness, the magnitude of the subsidence is unknown.

2.4.6 Sealing of the Mine

Where the open cut mined out the shallower part of the Moura No. 4 workings, it is anticipated the exposed roadways were sealed with backfill material (**Figure 22**). As detailed earlier, the method used for sealing the shaft is unknown.

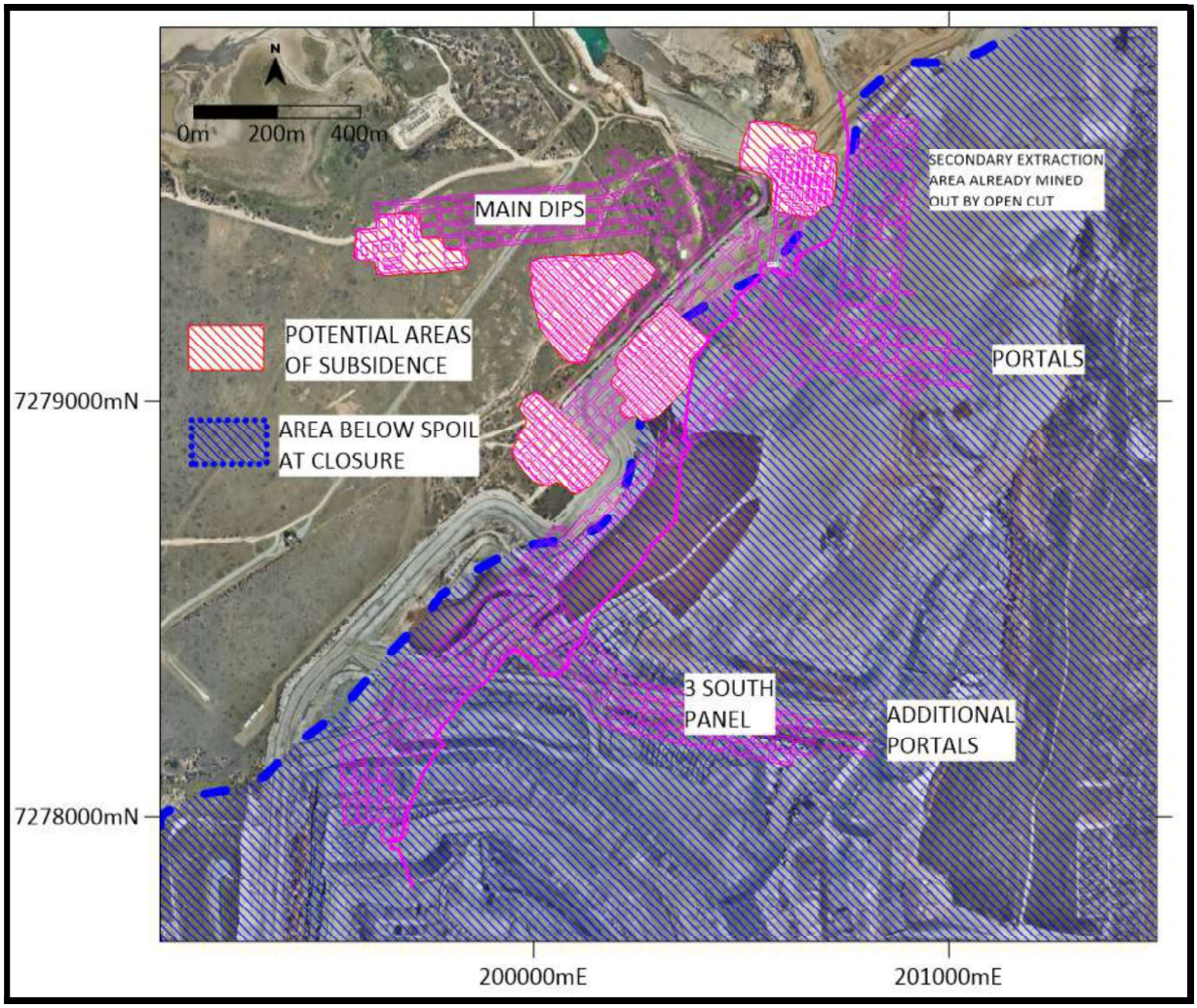


Figure 26. Potential Areas of Surface Disturbance – Moura No. 4 Mine.

2.5 Kianga No. 1

2.5.1 Introduction

The Kianga No. 1 underground mine extracted the B Lower Seam in the central part of the Dawson mining area (**Figure 2**). This mine was located at depths ranging from around 20 m at the portal, increasing to around 180 m at the western extent of the underground workings (**Figure 27**).

The B Lower Seam in this area was 3.5-5 m thick. The method of mining involved the extraction of the bottom 3 metres of the seam by the use of continuous miner-shuttle car combinations (Warden's Inquiry, 1975). The remaining top coal was left against the roof.

As shown in **Figure 27**, despite the age of the underground workings, the pillars and roadways at Kianga No. 1 mine were developed in a more regular pattern than Moura No. 1 mine.

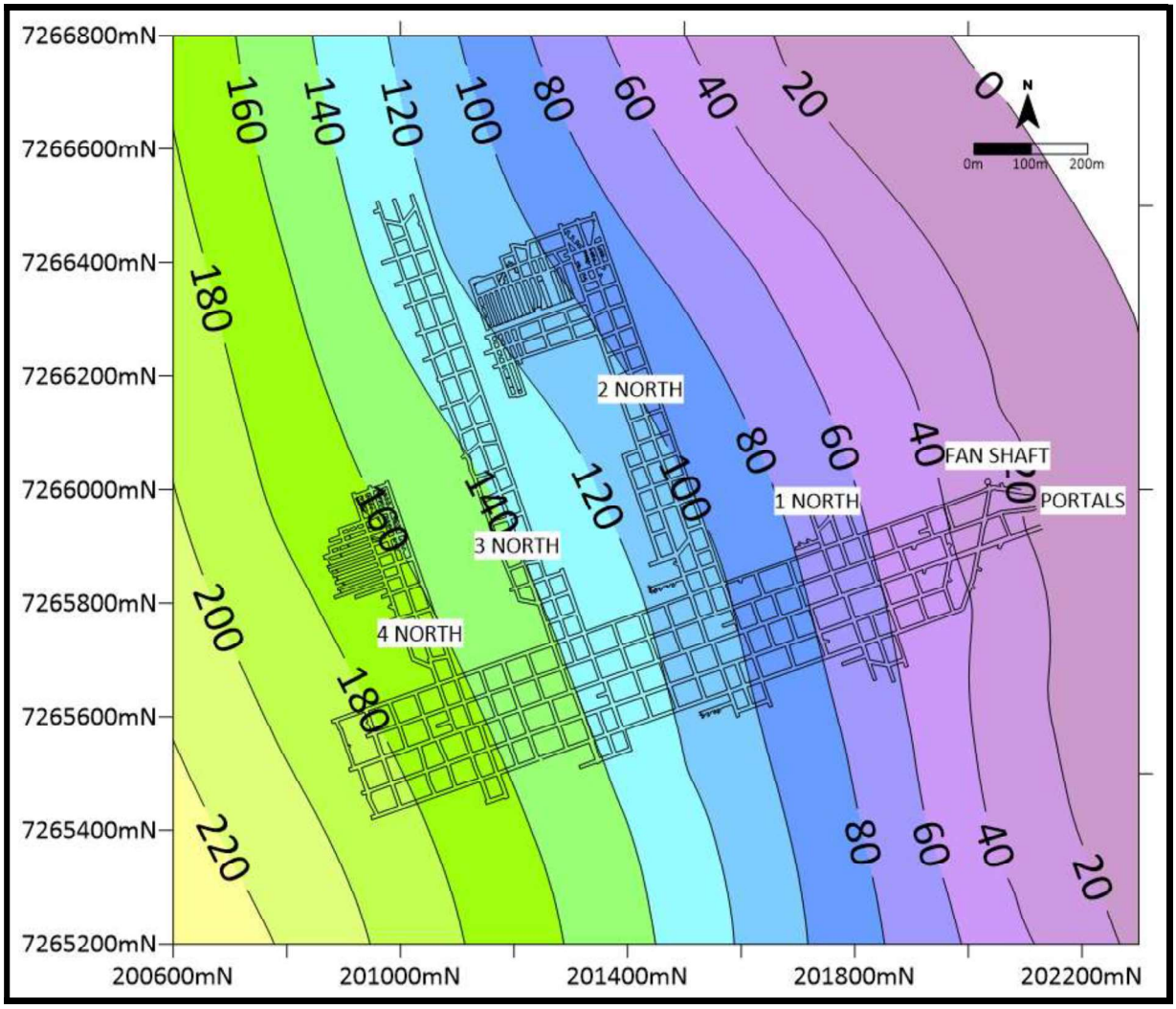


Figure 27. Underground Mine Plan and Depth of Cover – Kianga No. 1 Mine (m).

2.5.2 Mining Methodology and History

As detailed in the Mining Wardens report, at about 5.10 pm on September 20, 1975, an explosion occurred in the underground workings of the Kianga No. 1 mine. The thirteen men who were underground at the time attempting to seal off a heating caused by spontaneous combustion of in-situ coal in the 4 North panel were killed (**Figure 27**).

4 North was the most remote panel from the surface, located about 1500 m from the portal entry (**Figure 27**). The Warden's report documents that the roof conditions were poor in this area and following a fall off ground it was decided not to develop 4 North panel any further and extract coal on the retreat (**Figure 27**).

As shown on **Figure 27**, secondary extraction of the coal was carried out in the 2 North and 4 North panels. This mining methodology increases the extraction ratio of

the coal. For example the typical first workings pillars shown in **Figure 27**, remove approximately 30% of the coal leaving 70% in the ground.

Whereas in the secondary extraction areas of 2 North and 4 North, up to around 80-90% may have been removed and some level of surface subsidence would be anticipated soon after mining.

Based on the width of the extraction areas and a 3 m extraction height, surface subsidence of around 1.8 m is anticipated based on experience elsewhere in the Bowen Basin and a subsidence factor of 60%.

2.5.3 Final Landform

The proposed final landform is anticipated to have minimal effect on the current surface above the Kianga No. 1 underground mine (**Figure 27 and Figure 28**). There is planned to be some dumping of spoil over the portal and shaft area, increasing the final depth of cover in this area to 30-40 m (**Figure 28**).

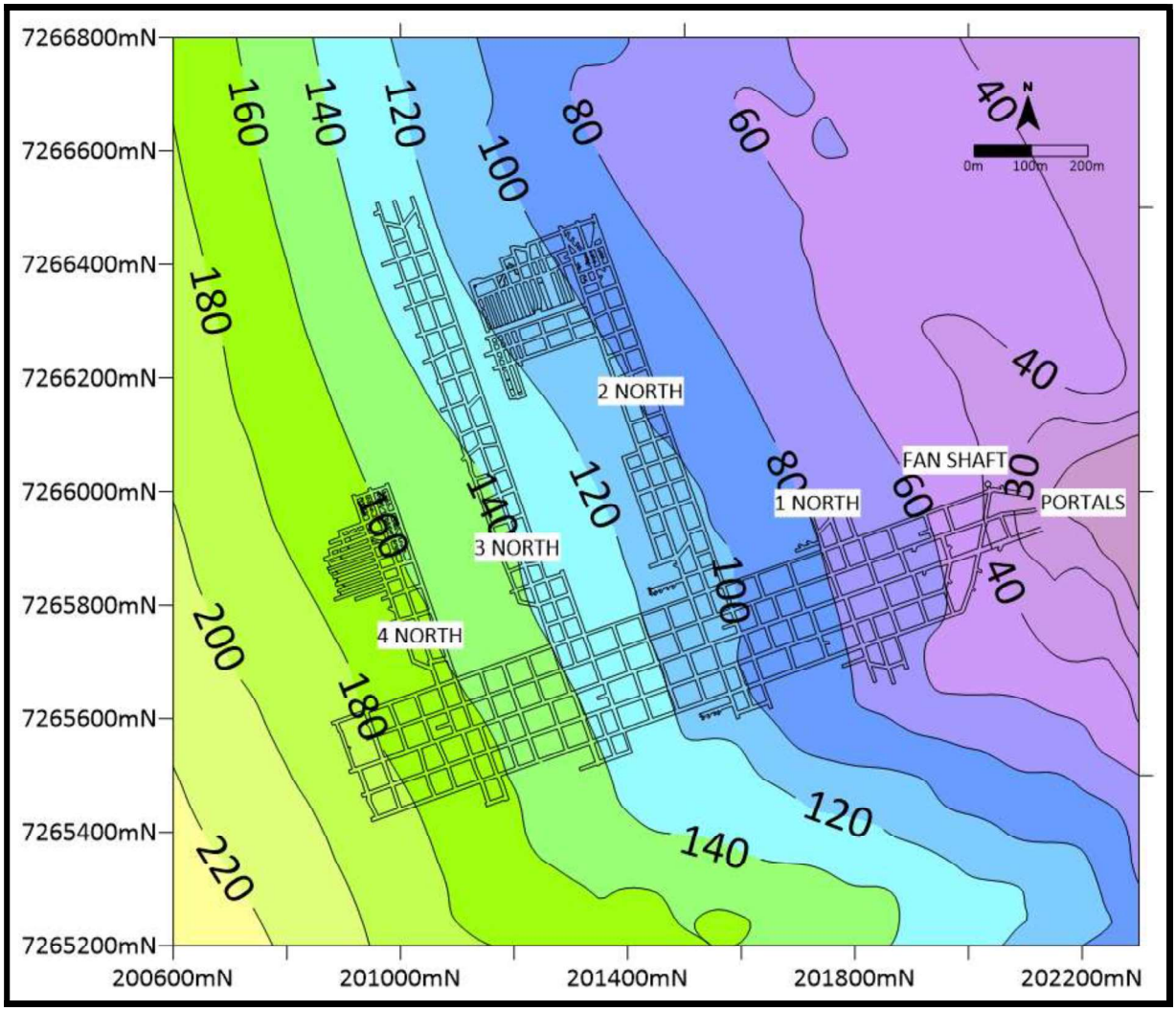


Figure 28. Depth of Cover at Closure – Kianga No. 1 Mine (m).

2.5.4 Water Level

The piezometer P4A adjacent to the Kianga No. 1 underground mine area, indicates that the water level in mid-2023 was around 121 m ASL (**Figure 8**). This indicates that the Kianga No. 1 mine is almost full of water based on a level at the portals of 140 m ASL (**Figure 29**).

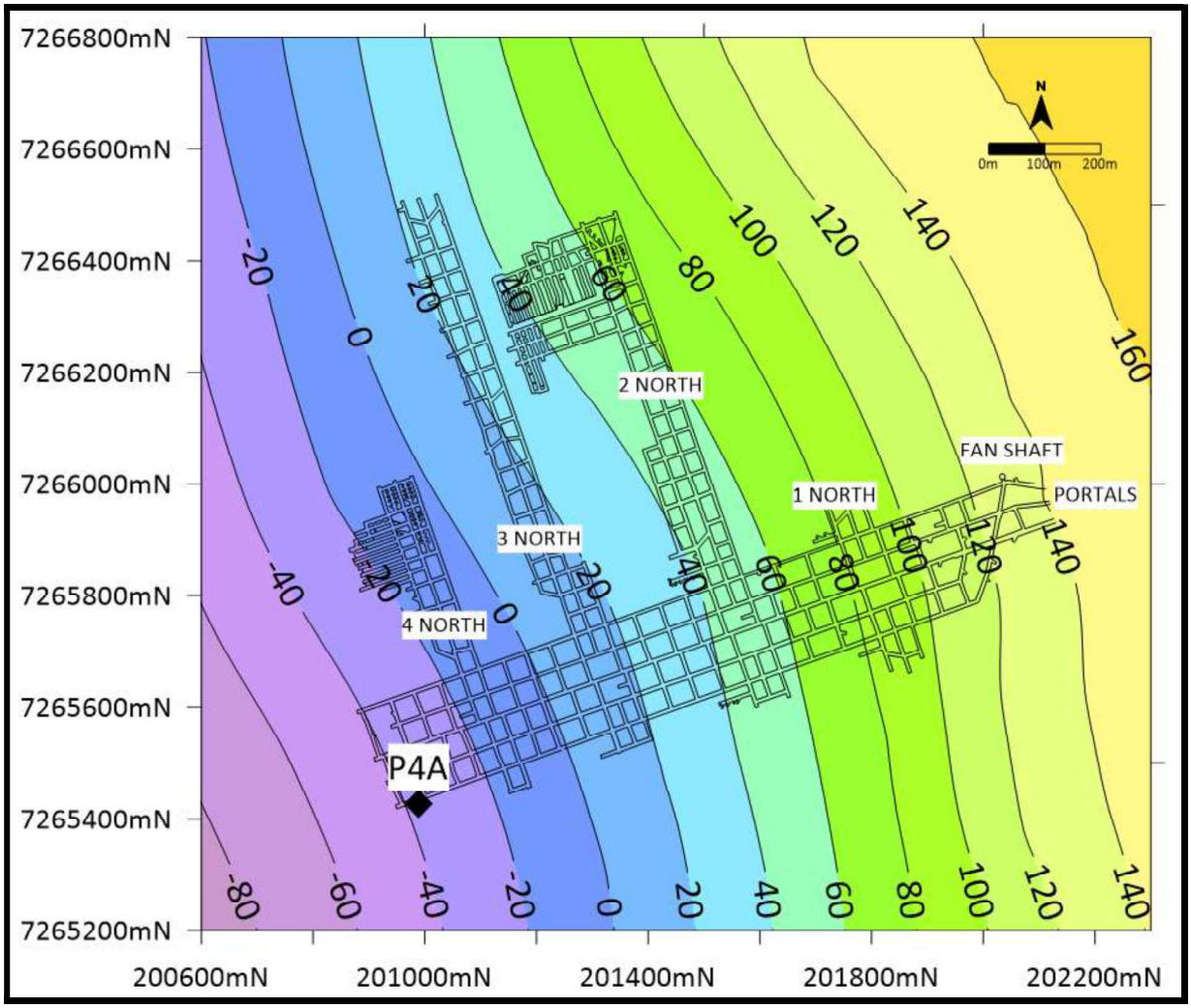


Figure 29. Structure Roof Level BL Seam – Kianga No.1 Mine (m ASL).

2.5.5 Surface Disturbance

Based on the extraction methodology shown on the mine plan, potential areas of previous subsidence above the 2 North and 4 North panels are shown in **Figure 30**.

Recent LiDAR photography indicates that surface disturbance is not discernible in these two areas (**Figure 31 and Figure 32**).

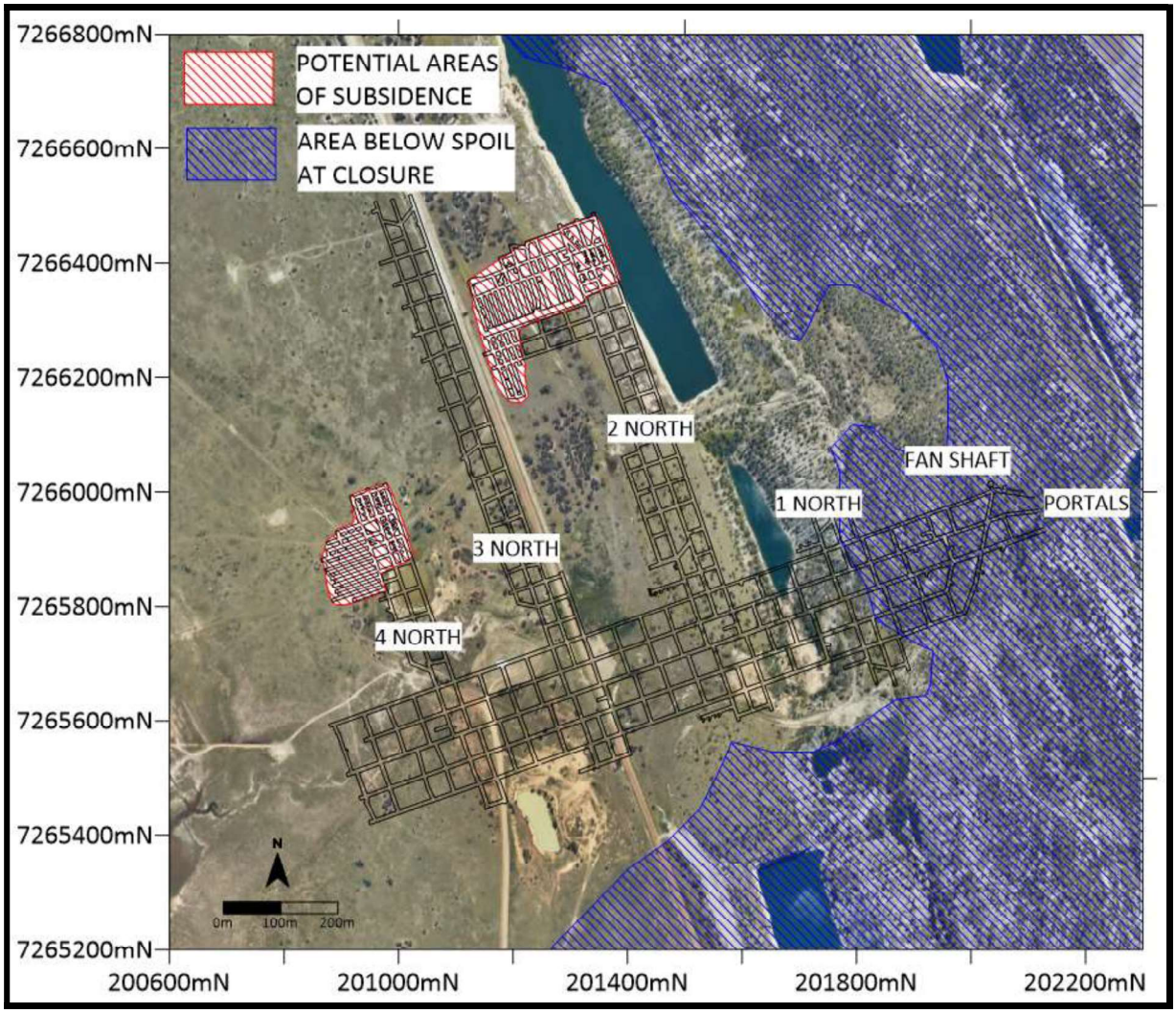


Figure 30. Potential Areas of Surface Disturbance – Kianga No. 1 Mine.

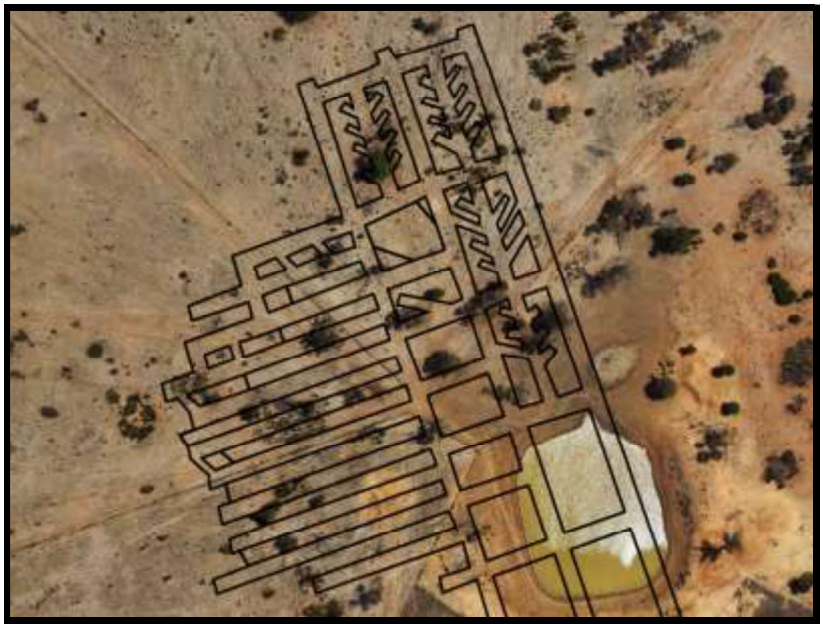


Figure 31. Kianga No. 1 Mine - 4 North Extraction Area (October 2023).



Figure 32. Kianga No. 1 Mine - 2 North Extraction Area (October 2023).

2.5.6 Sealing of the Mine

The Warden's report documents that on 22nd September 1975, the fan shaft and three portals were covered, with further material pushed over the portals for another ten hours to improve the seal efficiency (Warden's Report, 1975).

The LiDAR taken in October 2023 shows little apparent disturbance in this area, almost 50 years after the area was sealed (**Figure 33**).

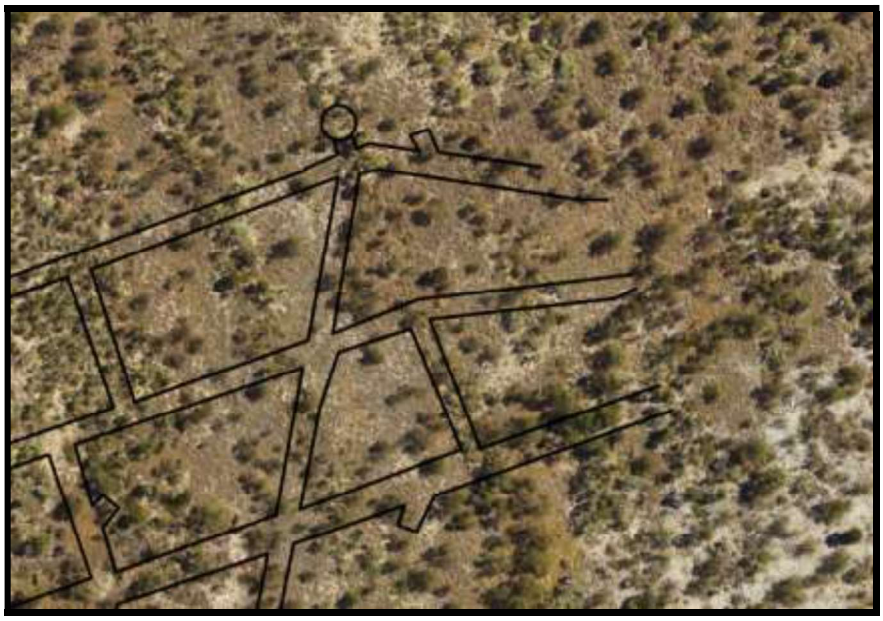


Figure 33. Kianga No. 1 Mine - Portal and Shaft Area (October 2023).

3 OVERVIEW OF THE HIGHWALL MINING AND AUGERING

3.1 Introduction

As well as the underground bord and pillar mines, a significant amount of mining from the toe of the highwall has been carried out in the Dawson area. This mining has dominantly used remote continuous miner machines with rectangular entry widths of 3.5-3.6 m. This has been carried out in a number of seams including the A, B, BL, C, D, DU and E seams.

Highwall augering using 1.5-1.9 m diameter circular holes has also been carried out to a lesser extent in all seams apart from the B Seam.

Augering is currently being carried out in pits 6-8 (**Figure 34**). The continuation of highwall mining/augering at Dawson in the future is highly dependent on the economic climate.



Figure 34. Highwall Augering Operations in Pits 6-8 (October, 2023).

Due to the complexity and extent of the highwall mining/augering excavations, each seam is discussed separately in the sections below.

3.2 A Seam

3.2.1 Discussion

The majority of highwall mining in the A Seam has been carried out south of the Kianga No. 1 underground mine (**Figure 2**). Highwall mining was also carried out in a localised area above the northern part of the Moura No. 2 mine D Seam workings (**Figure 1**). In this area, the continuous miner cutting machine became stuck and was left in the drive as shown on the statutory survey plans provided by the Dawson survey department.

These A Seam highwall mining drivages are typically 4.1-4.2 m apart but do range from as low as 3 m and up to 5.4 m (**Figure 35**). The drive width varies from 3.5-3.6 m. In the pit 18 area, 1.9 m diameter auger holes were mined in two locations. These holes were typically 1.1-1.4 m apart.

3.2.2 Final Landform

At closure, the surface above the southern highwall mining drives in the pit 21-23 area is left relatively unchanged (**Figure 35**). The open cut in pit 19 is anticipated to remove some of the A Seam highwall drives in this area (**Figure 35**) Sealing of the exposed entries in this area needs to be considered. As detailed in the Highwall Auger Mining SOP (2023[5]), completed auger holes are sealed off from exposed coal by stacking waste material against the highwall within 28 days after the mining has been completed.

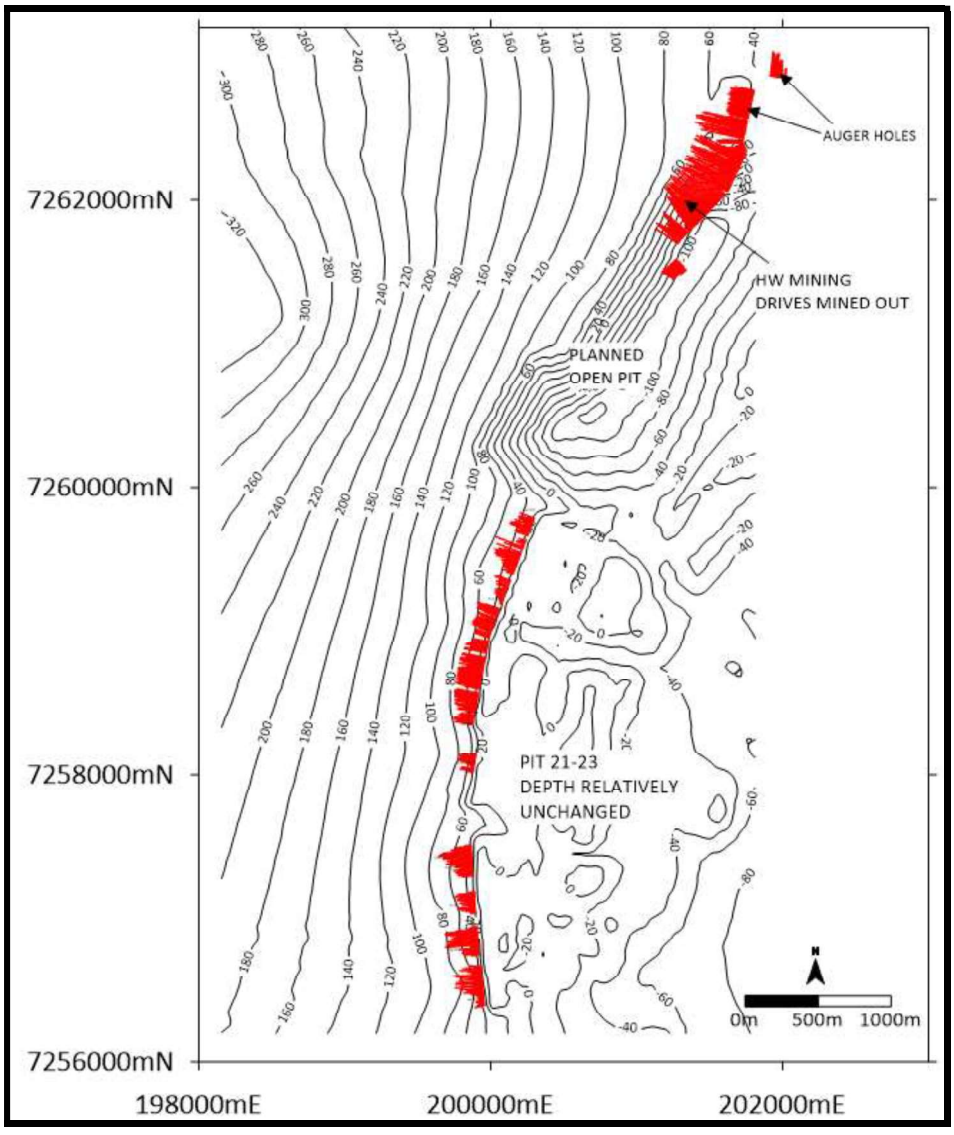


Figure 35. Depth of Cover at Closure – A Seam Highwall Mining Drives (m).

[5] Coal Augering Services (2023). SOP0125 – Highwall Auger Mining, 31st August 2023.

3.2.3 Water Level

Piezometer P2A, located downdip of the A Seam entries in the pit 21 area, indicates that the water level in mid-2023 was around 104 m ASL (**Figure 37**).

This indicates that the A Seam drives in the pit 21 to 23 area are likely to be almost full of water (**Figure 36**). It is highlighted that pit 18-19 A Seam drives are up to 4 km from piezometer P2A (**Figure 36**). Further north, piezometer P4A near the Kianga underground mine indicates a higher water level of 121 m ASL (**Figure 37**). Again this piezometer is located 3-4 km north of the pit 18-19 drives.

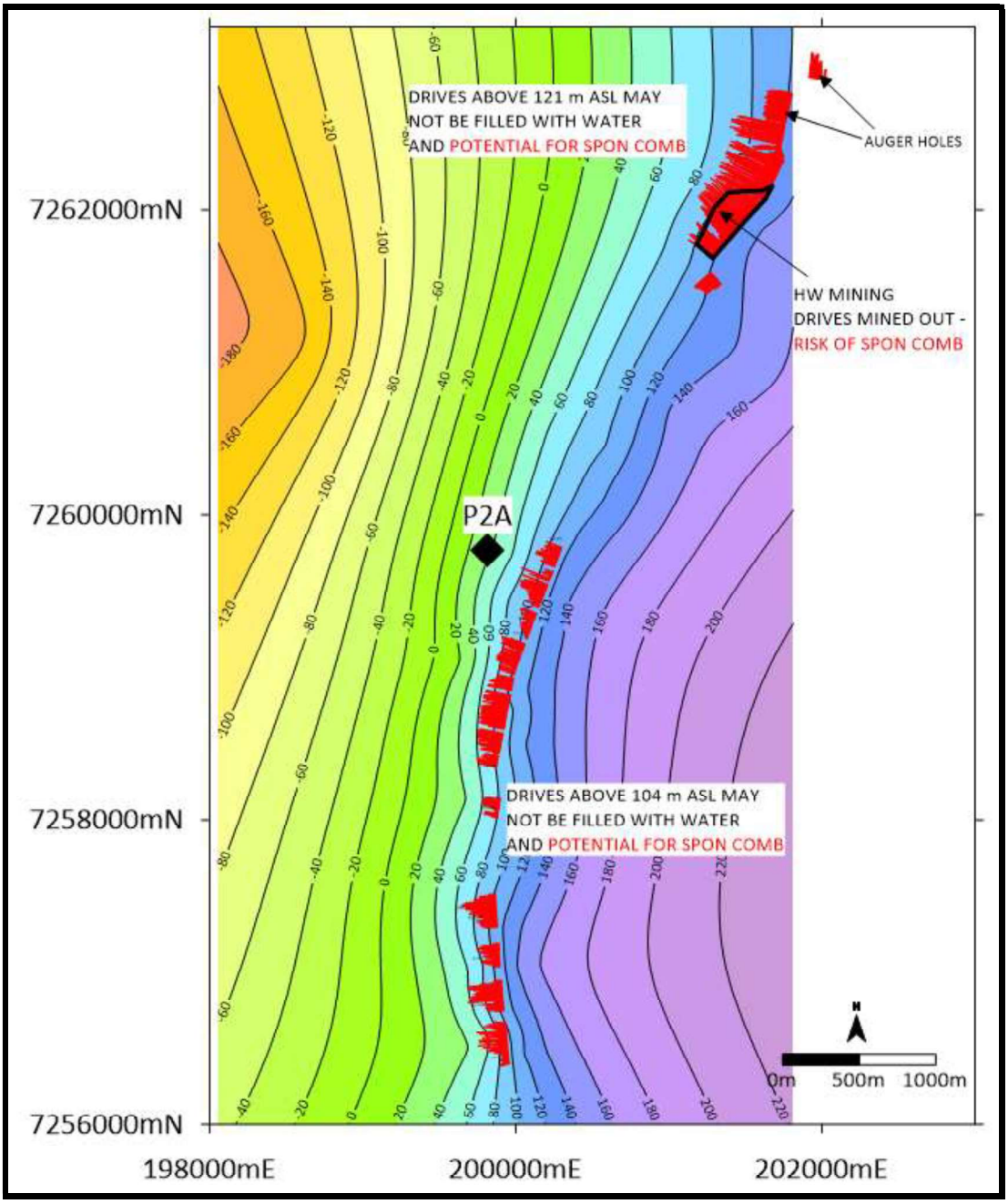


Figure 36. Structure Roof Level - A Seam Highwall Mining Area (m ASL).

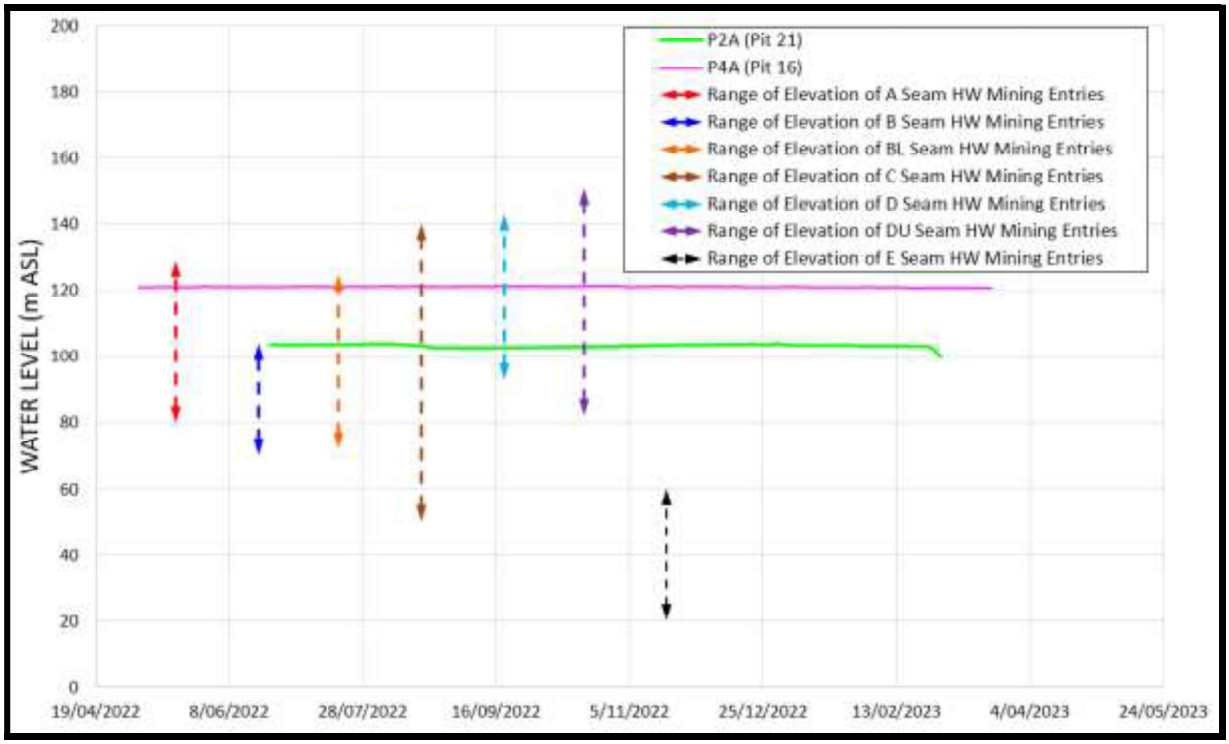


Figure 37. Piezometer Data near the Highwall Mining/Augering Drives.

3.3 B Seam

3.3.1 Mining Dimensions

At this stage, there has been no augering in the B Seam in the Dawson area, however highwall mining has been carried out in pits 15-21. The rectangular highwall mining drives have been 3.5-3.6 m wide and are typically 3-4.2 m apart (**Figure 38**).

3.3.2 Final Landform

It is noted that at closure in the southern part of the area in pit 20-21, the drives will be partially mined out and the entries may be exposed in the final highwall increasing the potential for spontaneous combustion of the coal due to the ingress of oxygen (**Figure 38**).

Elsewhere, the surface above the B Seam highwall mining drives located downdip of the final highwall remains relatively unchanged (**Figure 38**).

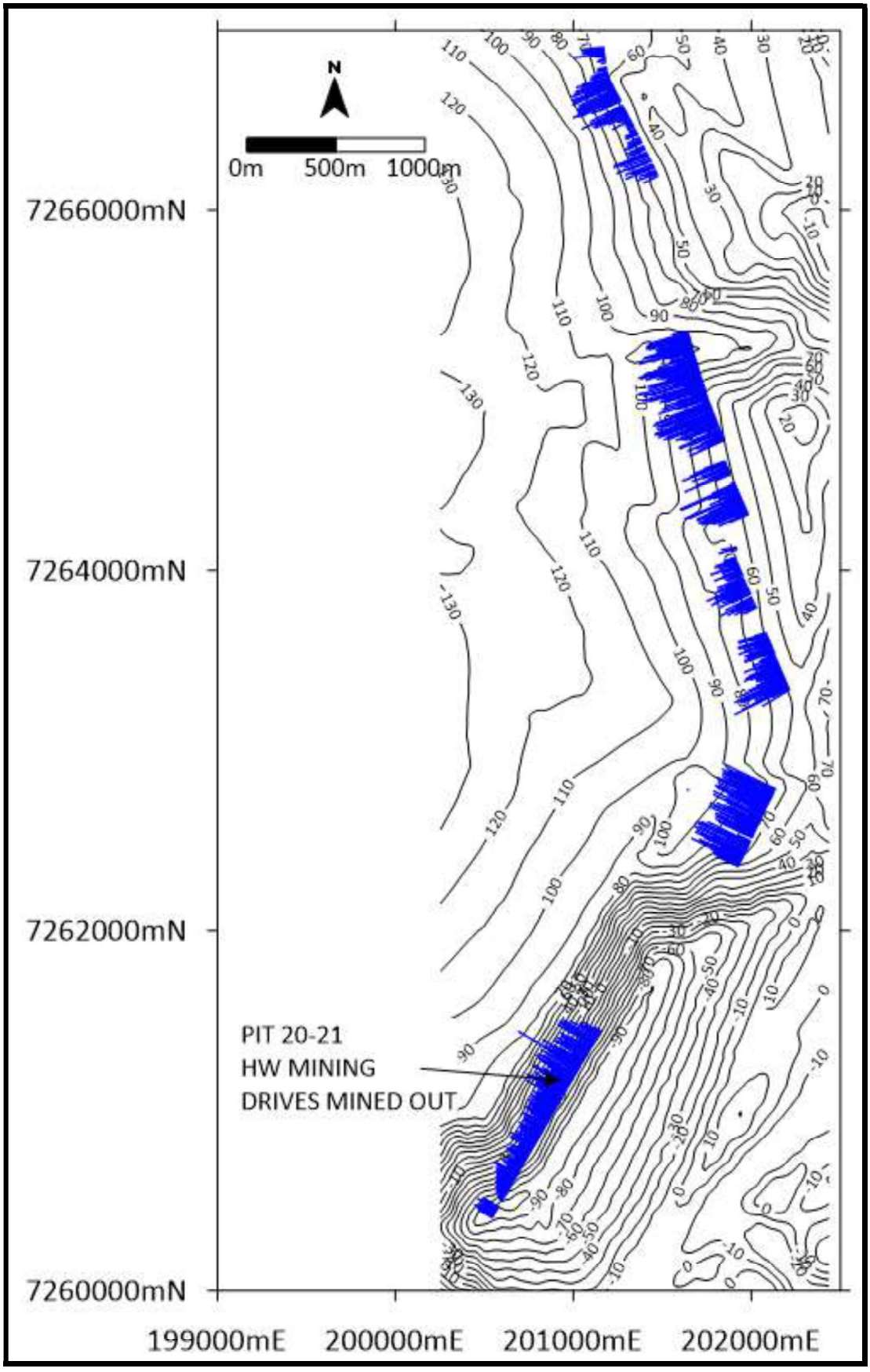


Figure 38. Depth of Cover at Closure – B Seam Highwall Mining Drives (m).

3.3.3 Water Level

Piezometer P4A, located downdip of the B Seam entries in the pit 16 area, indicates that the water level in mid-2023 was around 121 m ASL (**Figure 37**). This indicates that the B Seam drives in this area are likely to be full of water based on a level of around 80-100 m ASL at the up-dip end of the drives (**Figure 39**).

Similarly, the 104 m ASL in the P2A piezometer in the pit 20-21 area indicates that the drives in this area, located below 80 m ASL, are anticipated to be full of water (**Figure 39**).

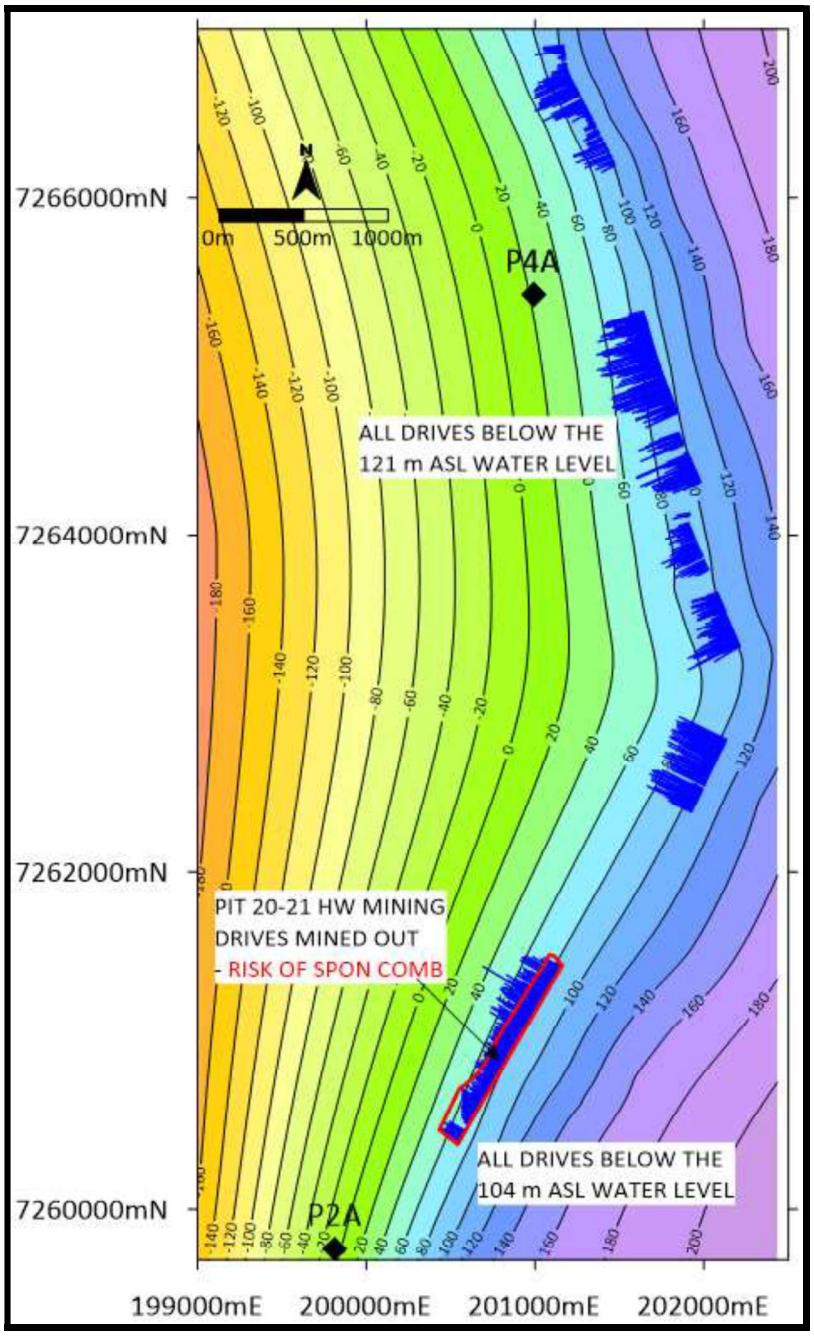


Figure 39. Structure Roof Level - B Seam Highwall Mining Area.

3.4 BL Seam

3.4.1 Mining Dimensions

The highwall mining entries in the BL Seam are between 3.5 m and 5.2 m apart. The drive width is 3.5-3.6 m and mining extends from pit 13 south towards pit 21 (**Figure 40**).

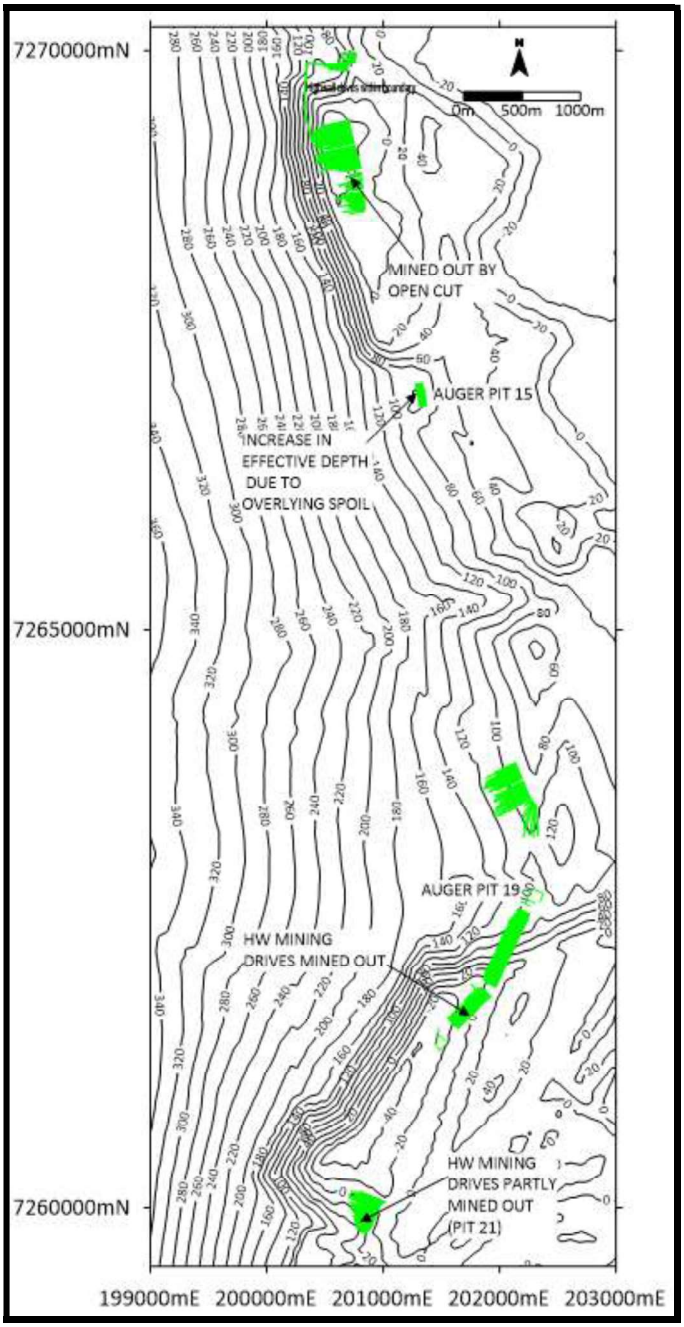


Figure 40. Depth of Cover at Closure – BL Seam Highwall Mining Drives (m).

Augering has been carried out in two locations in pit 15 and pit 19 (**Figure 40**). The auger holes are 1.9 m diameter and typically 1.5 m apart in the pit 15 area, whereas they are up to 5.4 m apart and 1.8 m diameter in the pit 19 area.

3.4.2 Final Landform

As shown in **Figure 40**, at closure a number of the highwall mining drives are planned to be mined out by the open cut. In the pit 15 auger area, dumping will also increase the effective depth of cover (**Figure 40**).

3.4.3 Water Level

The current levels in piezometers P2A and P4A located downdip of the BL Seam indicates that the majority of the BL Seam highwall mining excavations would be currently full of water (**Figure 36, Figure 37 and Figure 41**).

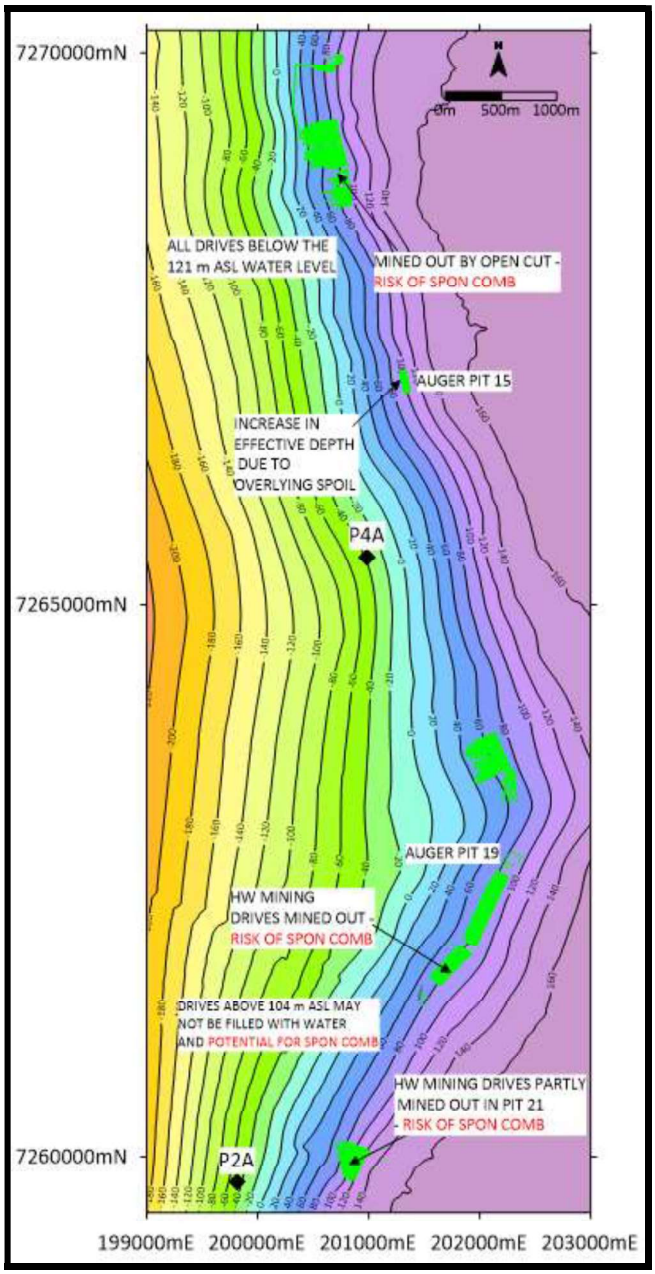


Figure 41. Structure Roof Level - BL Seam Highwall Mining Area (m ASL).

3.5 C Seam

3.5.1 Mining Dimensions

Highwall mining has been carried out in the C Seam from pit 2 all the way along strike down to Dawson South. The highwall mining entries are 3.5-3.6 m wide and have been mined at a wide range of distances apart from 2-6.5 m.

1.9 m diameter auger holes have been mined near the Moura No. 2 underground mine and also in pit 3 (**Figure 42**). The holes are typically 1.1-1.4 m apart but were mined as close as 0.5 m in the pit 3 area.

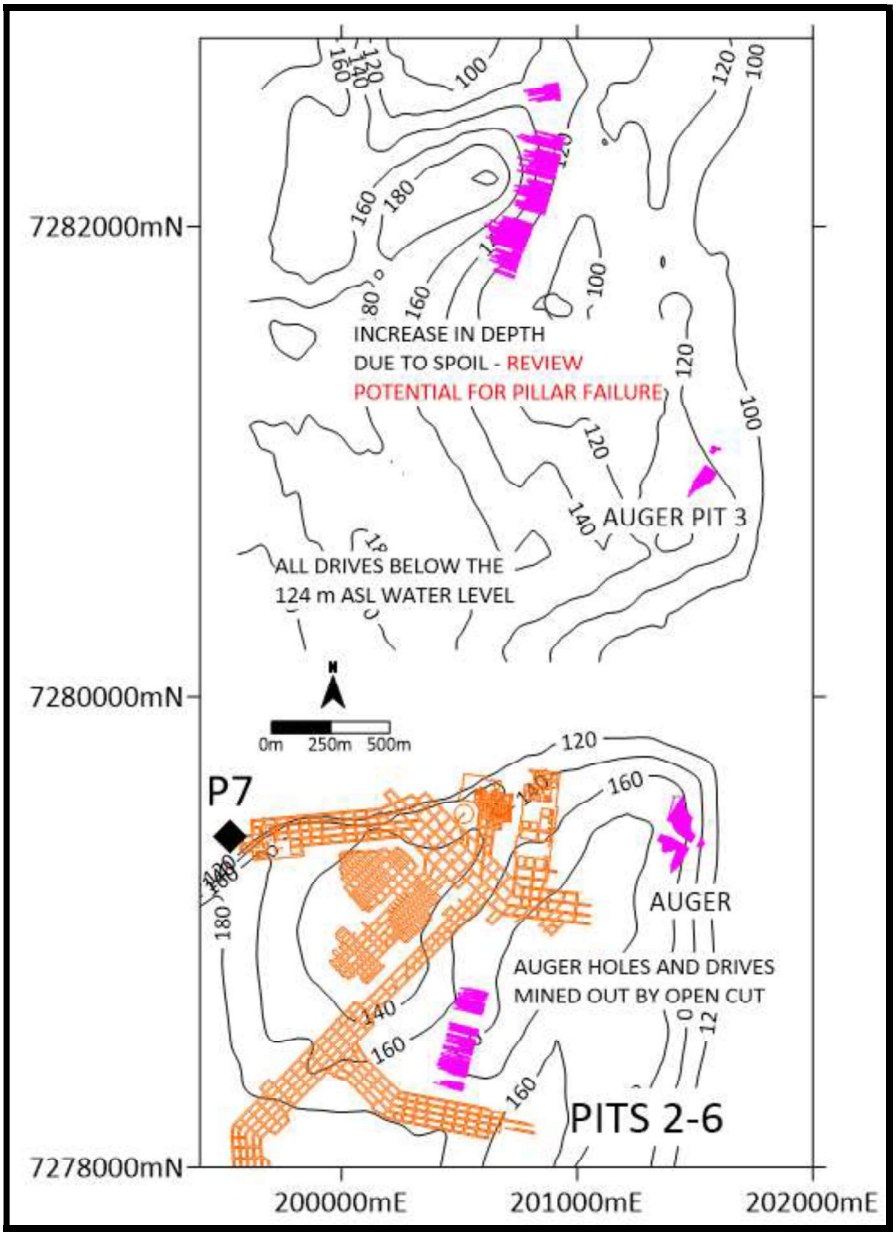


Figure 42. Depth of Cover at Closure – C Seam Highwall Mining Drives – Pits 2-6 (m).

In the pit 19 area, the C Seam as well as the D and DU Seam were mined along strike (**Figure 43**). In these conditions, it was difficult to mine the drives to design due to movement of the continuous miner across the seam dip.

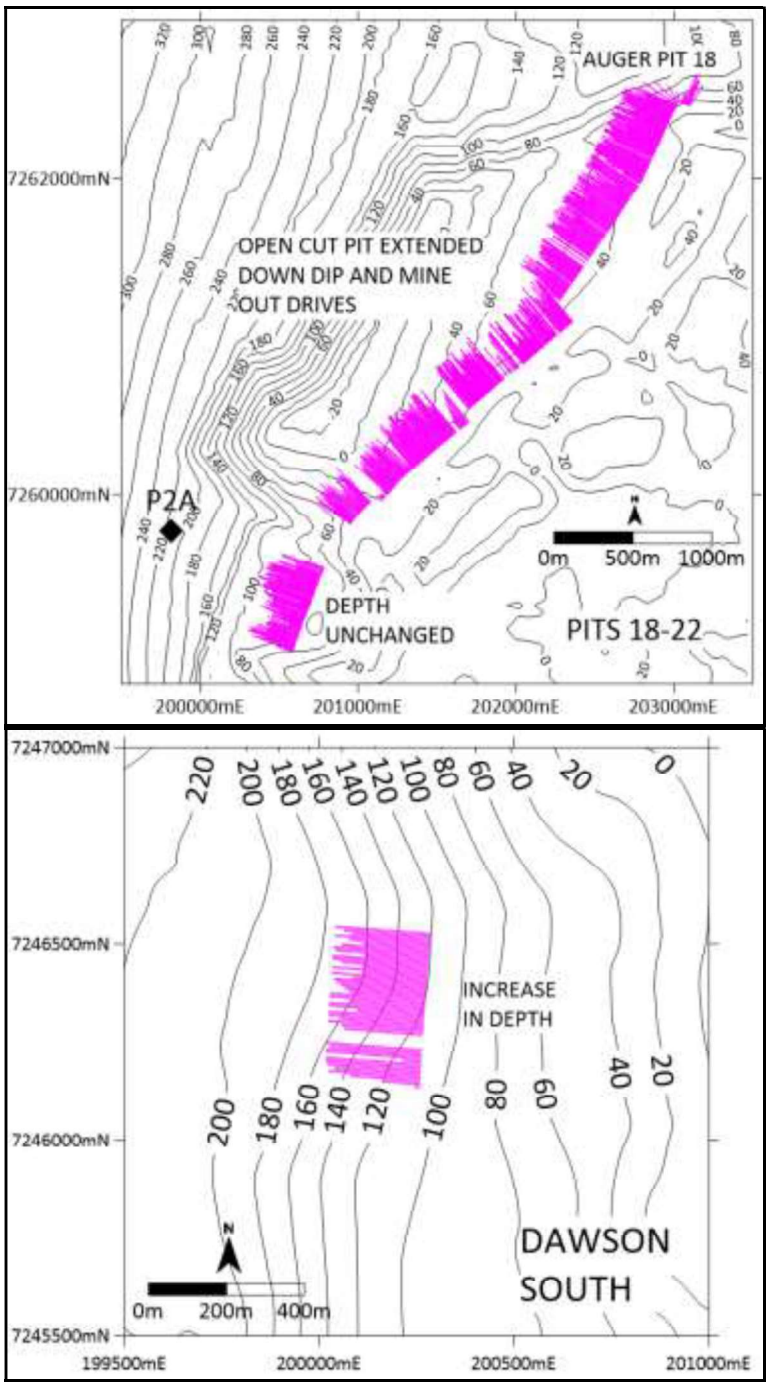


Figure 43. Depth of Cover at Closure – C Seam Highwall Mining Drives – Pits 19-22 and Dawson South (m).

3.5.2 Final Landform

In the pit 2-3 area, the dumping of spoil increases the final depth of cover above the highwall mining and auger holes in the C Seam (**Figure 42**). Similarly in the Dawson

South area, the depth of cover is increased above the highwall mining drives at closure (**Figure 43**). The C Seam drives adjacent to the Moura No.4 mine have been mined out by the open cut (**Figure 42**).

In the majority of the pit 18-21 area, the C Seam drives are planned to be mined out by the open cut (**Figure 43**). In the pit 22 area, the depth of cover remains unchanged, as well in the pit 18 area where the auger holes appear to be left unmined (**Figure 43**).

3.5.3 Water Level

In the pit 2-3 area, the water level of 124 m ASL in piezometer P7 downdip of Moura No. 4 underground indicates that the highwall drives would be totally full of water (**Figure 8 and Figure 44**).

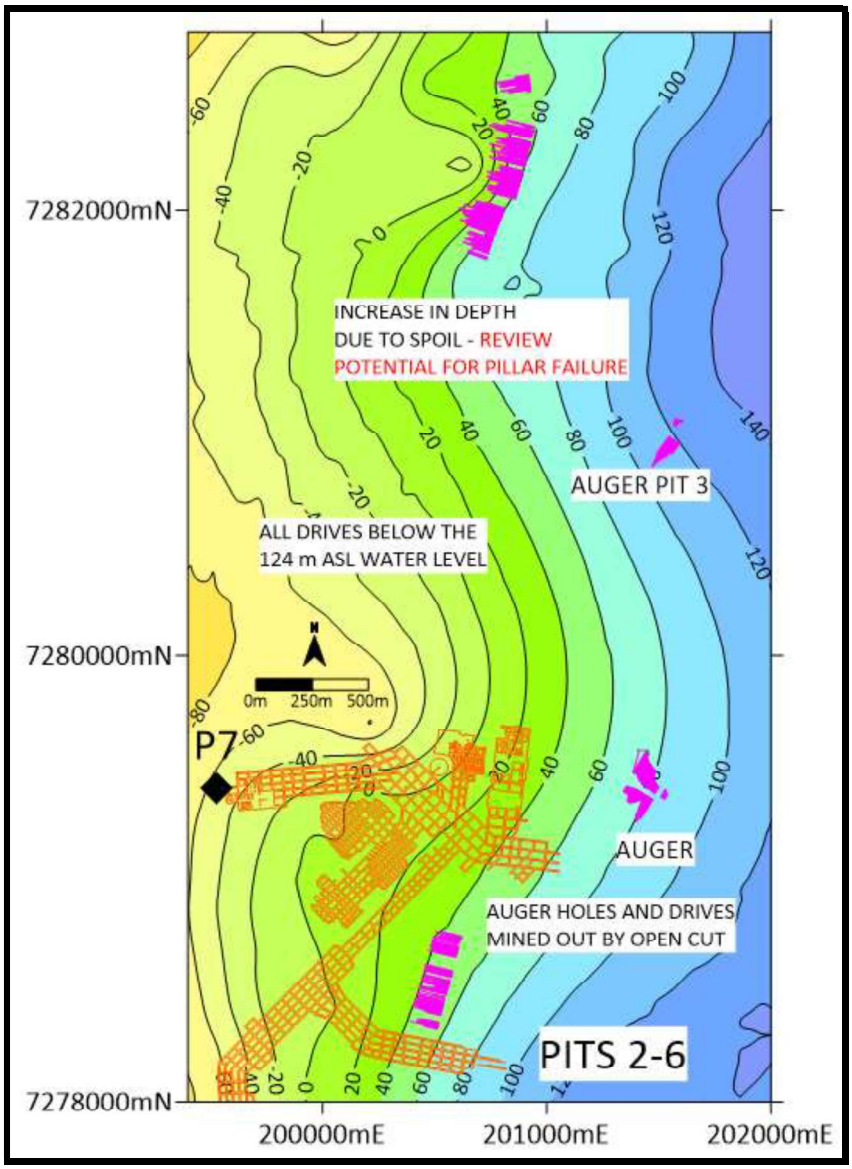


Figure 44. Structure Roof Level - C Seam Highwall Mining Area – Pits 2-5 (m ASL).

The current levels in piezometers P2A and P4A, of 104 m ASL and 121 m ASL respectively, indicates that the majority of the C Seam highwall mining excavations in the pit 18-22 area would be partially full of water (**Figure 37 and Figure 45**).

There are no piezometers available in the Dawson South area near the C Seam highwall mining drives in this area.

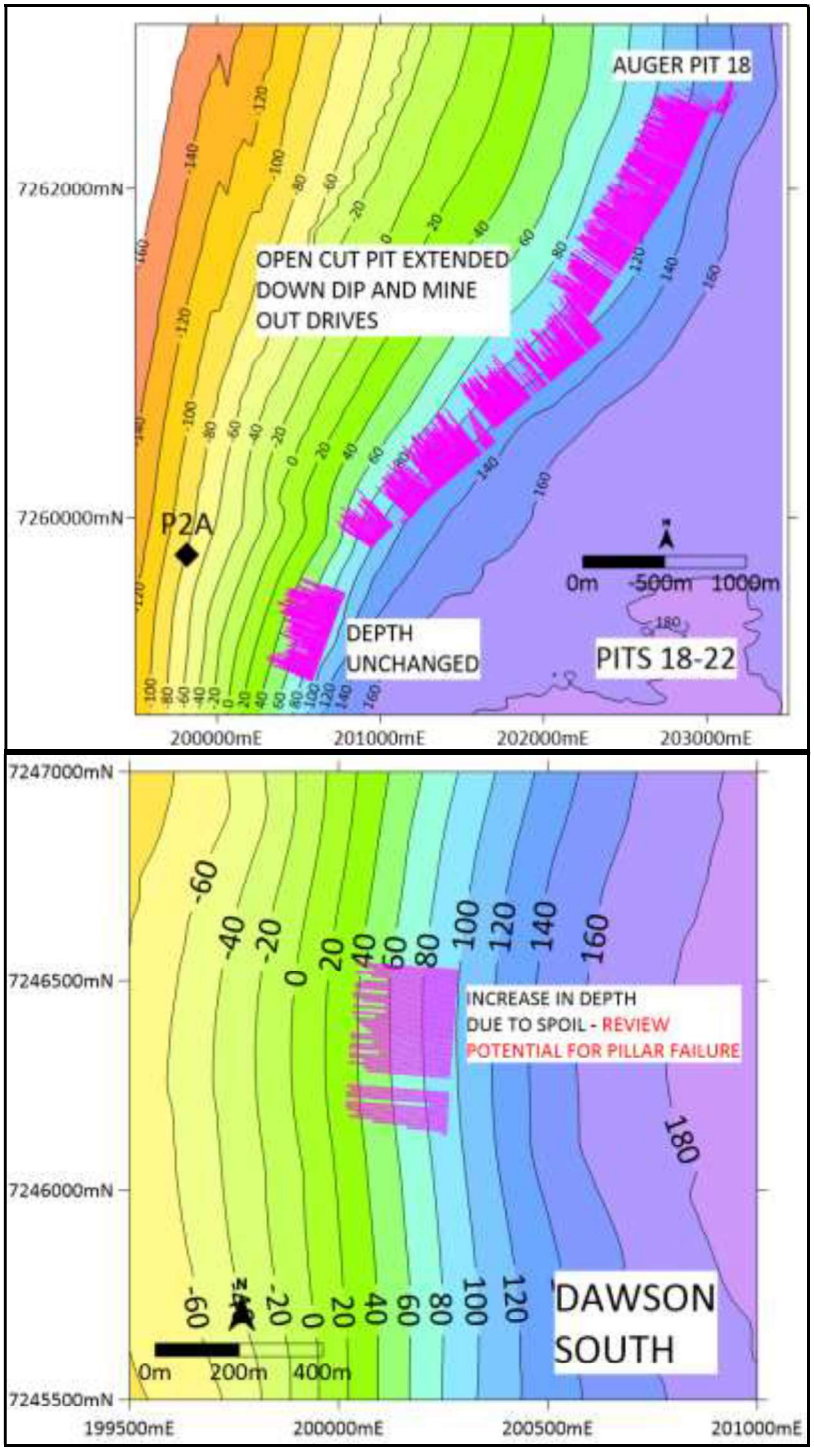


Figure 45. Structure Roof Level - C Seam Highwall Mining Area – Pits 18-22 and Dawson South (m ASL).

3.6 D Seam

3.6.1 Mining Dimensions

Highwall mining in the D Seam using continuous miner machines has been carried out from pit 4 to pit 24. Some augering has also been carried out in pit 4 and pit 19.

The rectangular highwall mining entries range from 2.8-4.8 m apart and between 3.5-3.6 m wide. The circular auger holes are 1.5 m diameter and typically 2 m apart.

3.6.2 Final Landform

Dumping of spoil is planned above the pit 4 auger holes increasing the depth of cover from 40-60 m up to 130-160 m and the potential for pillar failure should be reviewed. Increased depth of cover is also planned in pits 10-12 and 16-17 (**Figure 46**). Some of the D Seam drives in pit 18-19 area may be mined out as the open cut is extended downdip (**Figure 46**).

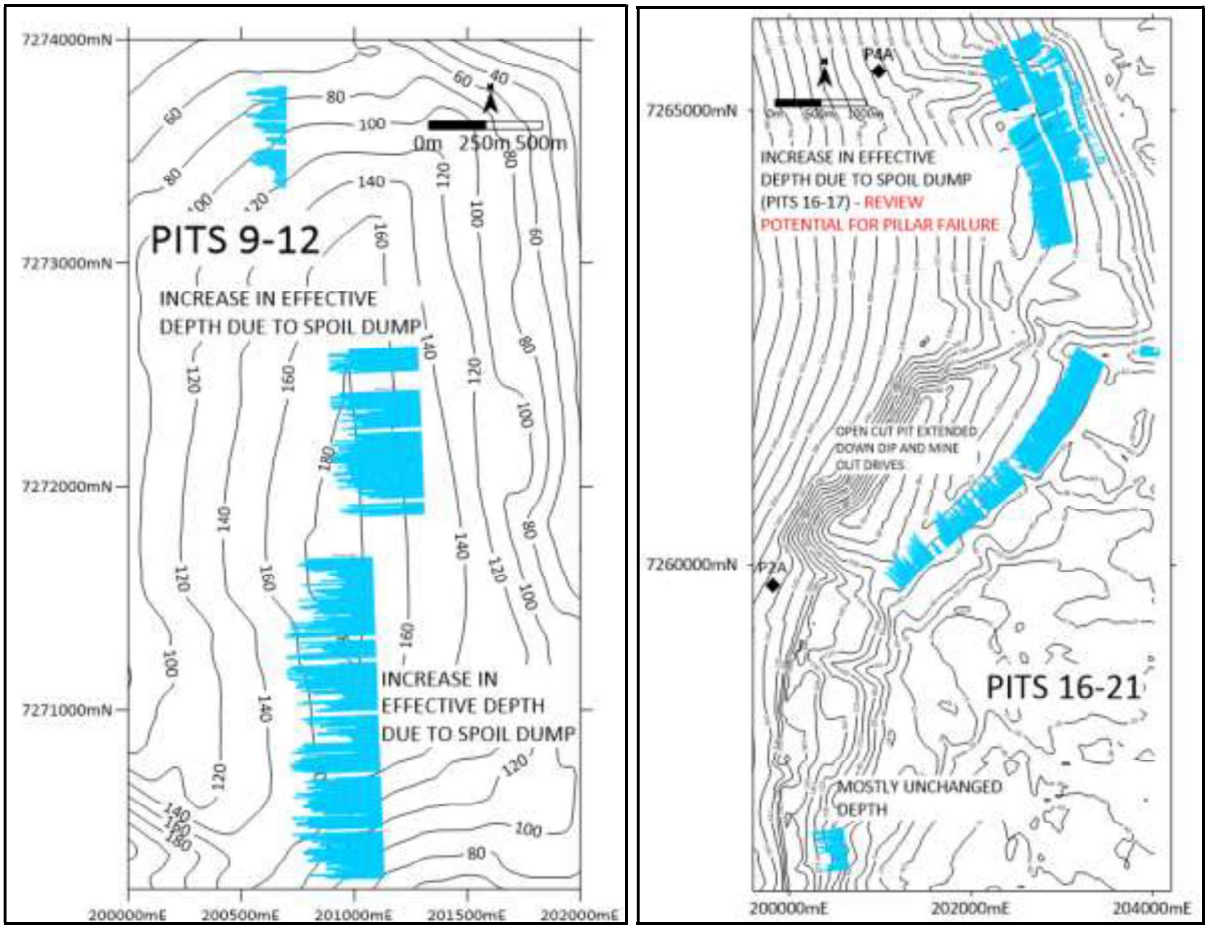


Figure 46. Depth of Cover at Closure – D Seam Highwall Mining Drives (m).

3.6.3 Water Level

The current level of 121 m ASL in piezometer P4A indicates that the majority of the D Seam highwall mining excavations in the pit 9-17 area would be totally full of water (**Figure 37 and Figure 47**).

Similarly, the 104 m ASL level in piezometer P2A indicates the D Seam drives in pits 19-21 are also close to being full of water (**Figure 37 and Figure 47**).

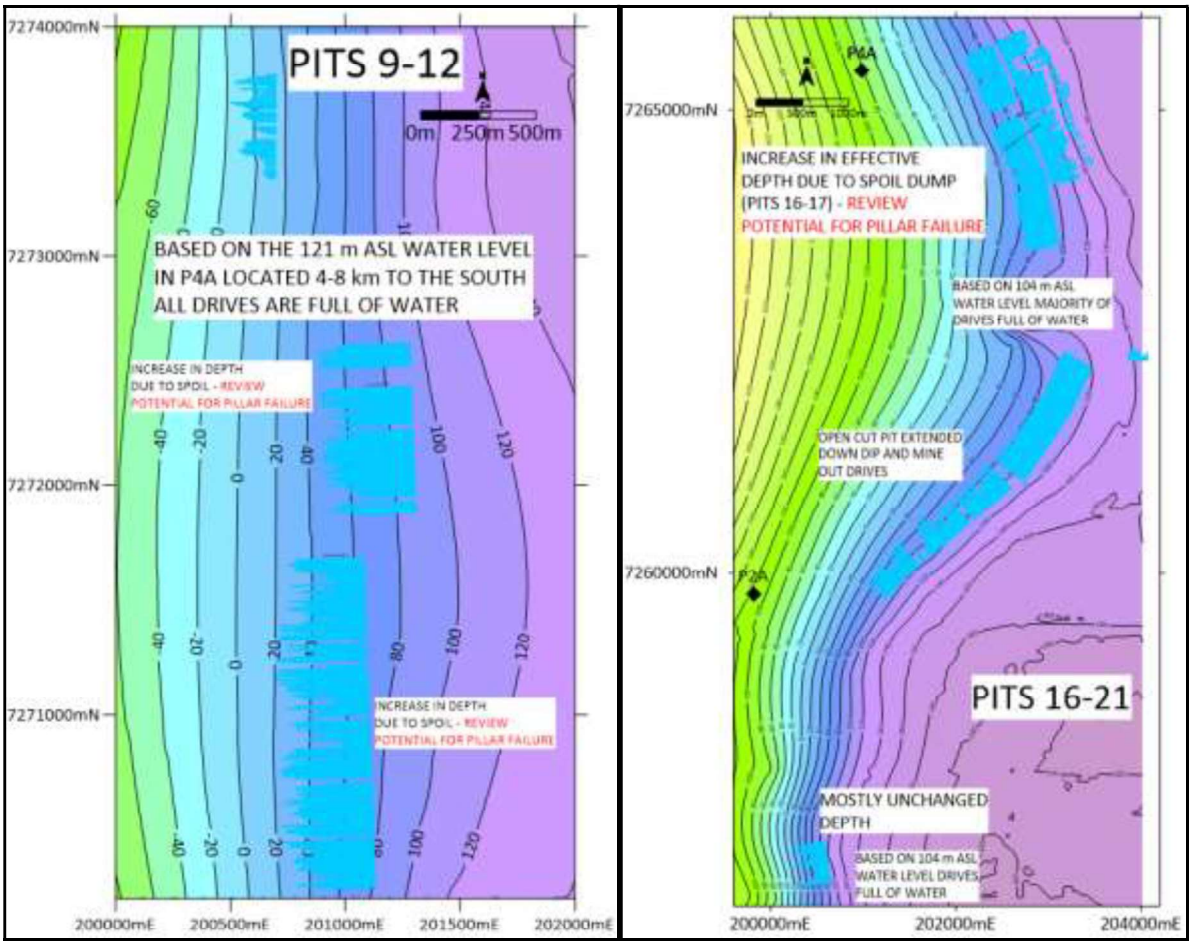


Figure 47. Structure Roof Level - D Seam Highwall Mining Area

3.7 DU Seam

3.7.1 Mining Dimensions

The majority of excavations in the DU Seam are highwall mining entries and are typically 3-4.2 m apart but do range down to as low as 2.2 m in the pit 23 area. The drive width is 3.5-3.6 m.

The circular auger holes in the pit 18 area are 1.9 m diameter and typically 1.1-1.2 m apart.

3.7.2 Final Landform

In the pit 13 area some of the DU Seam drives may be excavated by the open cut, whereas in the pit 16 area the dumping of spoil may increase the effective depth of cover (**Figure 48**). In the pit 18-19 area, the majority of the drives are planned to be mined by the open cut (**Figure 48**).

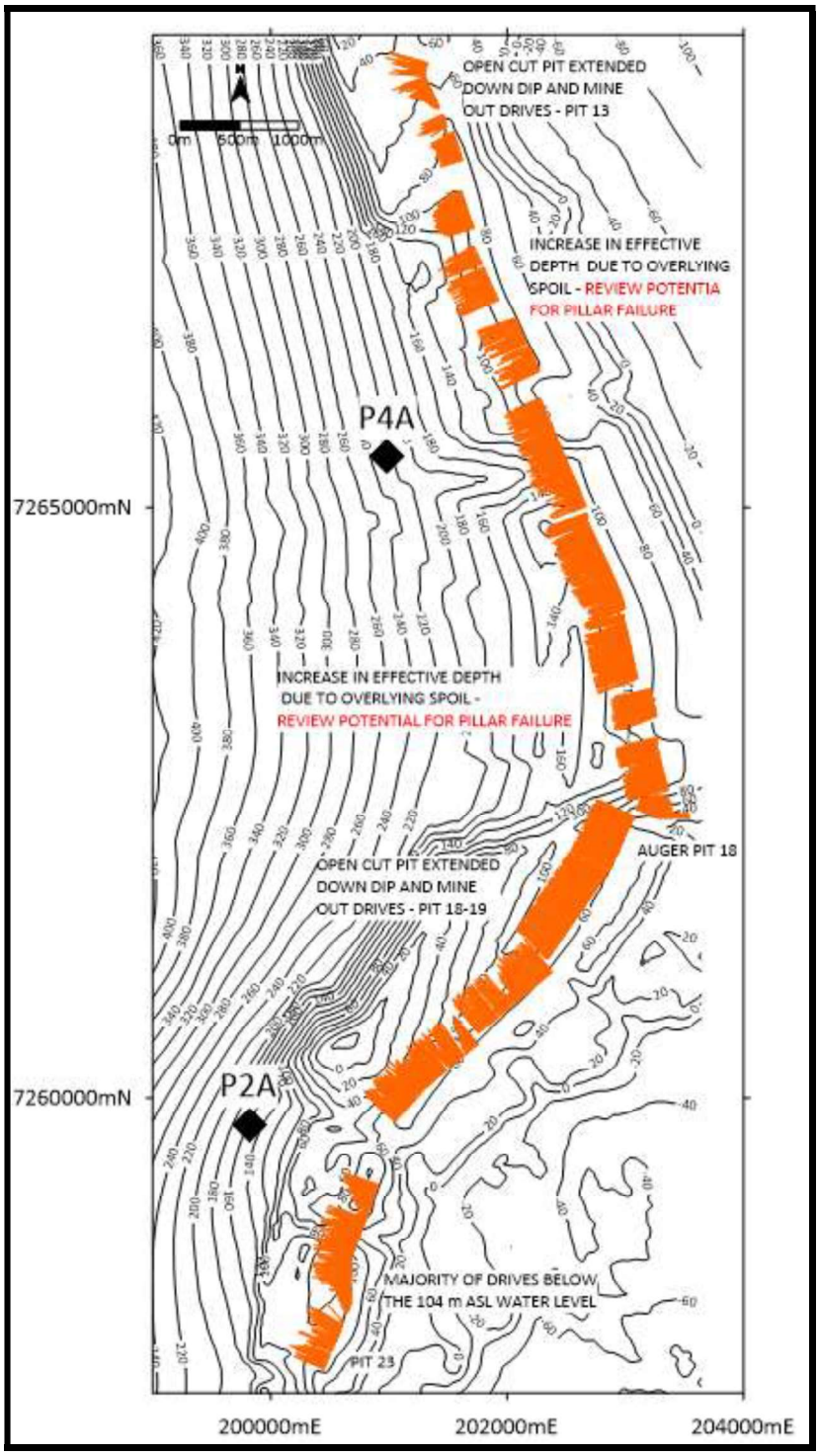


Figure 48. Depth of Cover at Closure – DU Seam Highwall Mining Drives (m).

3.7.3 Water Level

The current levels in piezometers P2A and P4A located downdip of the entries indicates that the majority of the DU Seam highwall mining excavations in the pit 13-23 area would also be totally full of water (**Figure 37 and Figure 47**).

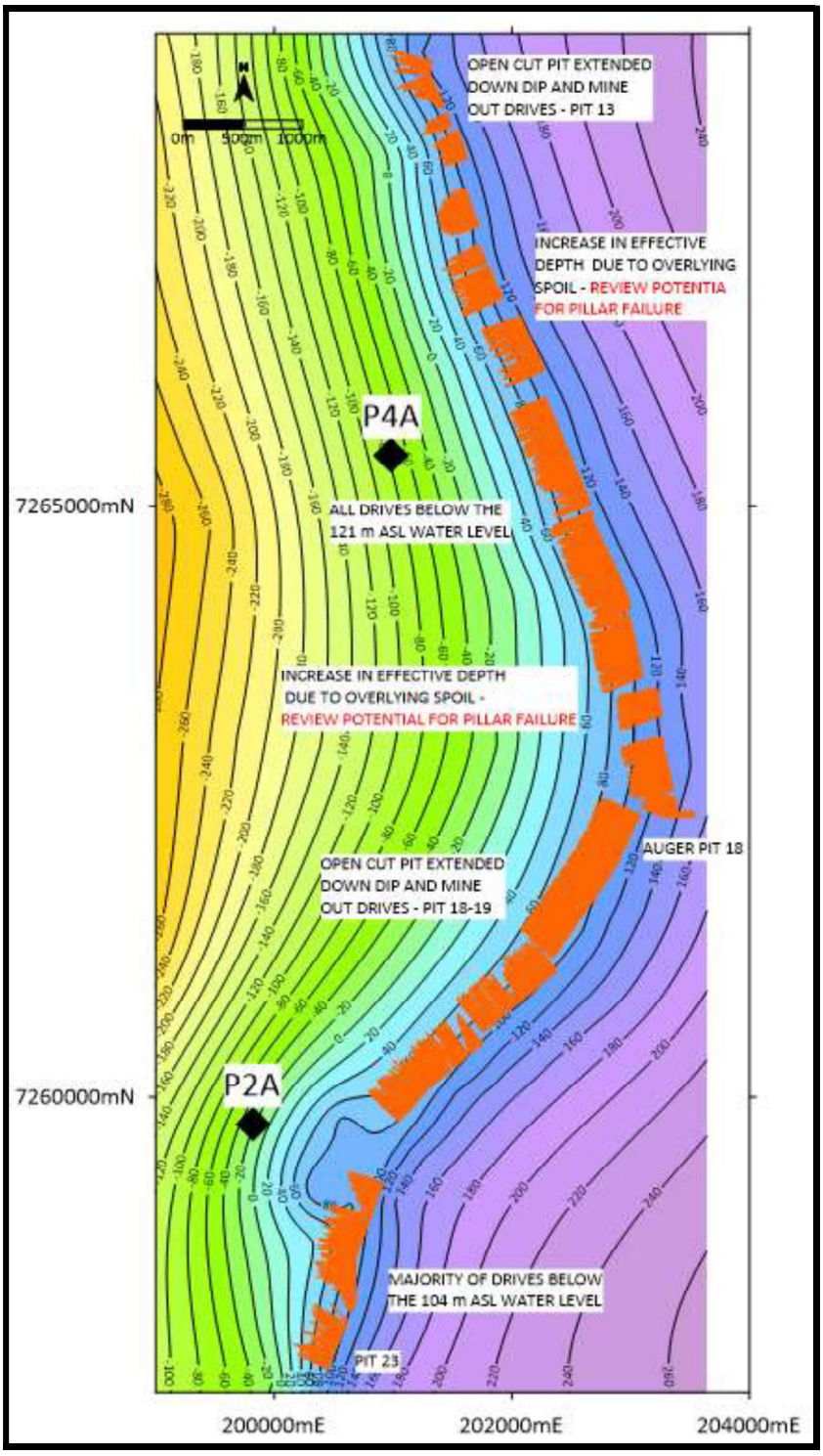


Figure 49. Structure Roof Level - DU Seam Highwall Mining Area (m ASL).

3.8 E Seam

3.8.1 Mining Dimensions

The highwall mining entries in the E Seam are typically 4.2-5.8 m apart with a width between 3.5-3.6 m (**Figure 50**).

There is a small area of 1.5 m diameter auger holes in the pit 6 area where the holes are typically 1 m apart.

3.8.2 Final Landform

In the pit 9-12 area, the planned spoil dump increases the depth above the E Seam highwall mining entries from a maximum of 140 m, up to over 220 m (**Figure 50**). There is also an increase in the effective depth in the Dawson South area (**Figure 50**).

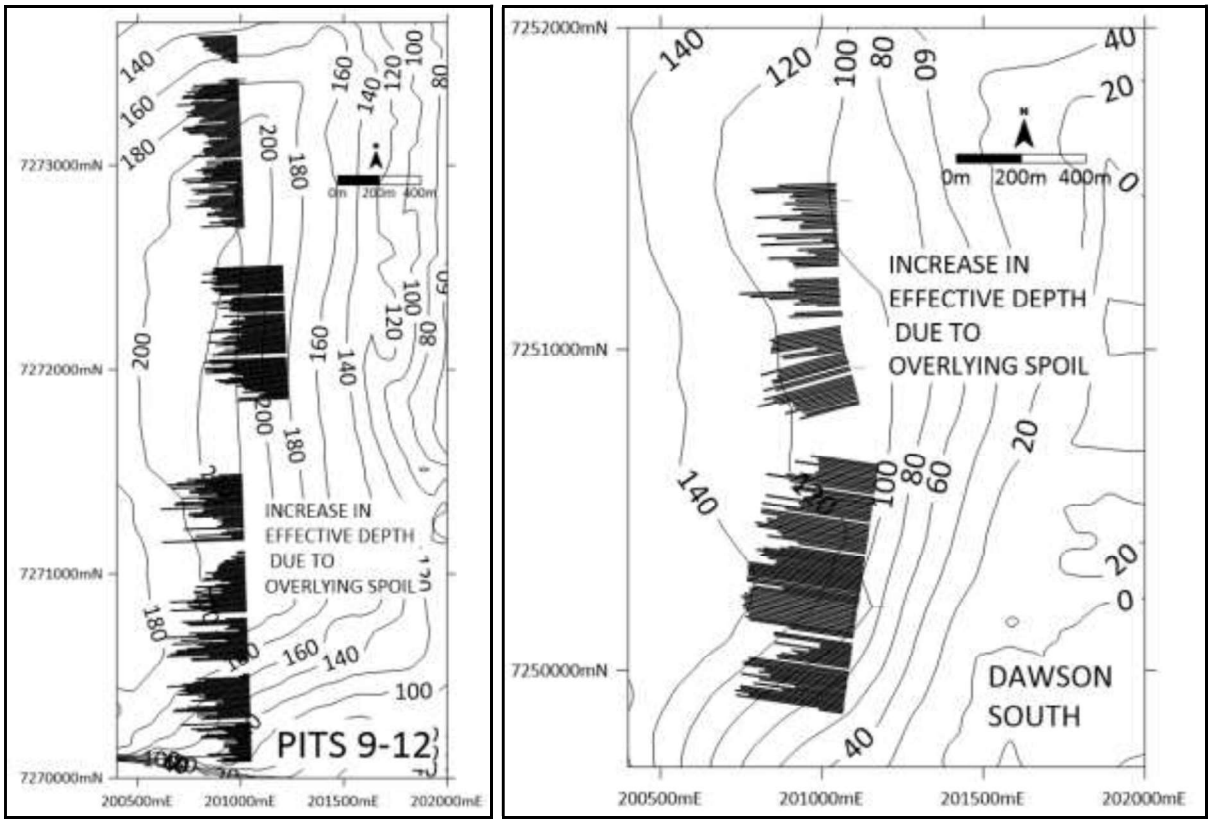


Figure 50. Depth of Cover at Closure – E Seam Highwall Mining Drives (m).

3.8.3 Water Level

The current level of 121 m ASL in piezometer P4A located 4.5-8 km south of the entries indicates that the E Seam highwall mining excavations in pits 9-12 area would be totally full of water (**Figure 37 and Figure 51**). Additional piezometers are therefore required in this area to confirm the groundwater levels.

There are no piezometers available in the Dawson South area near the E Seam highwall mining drives in this area.

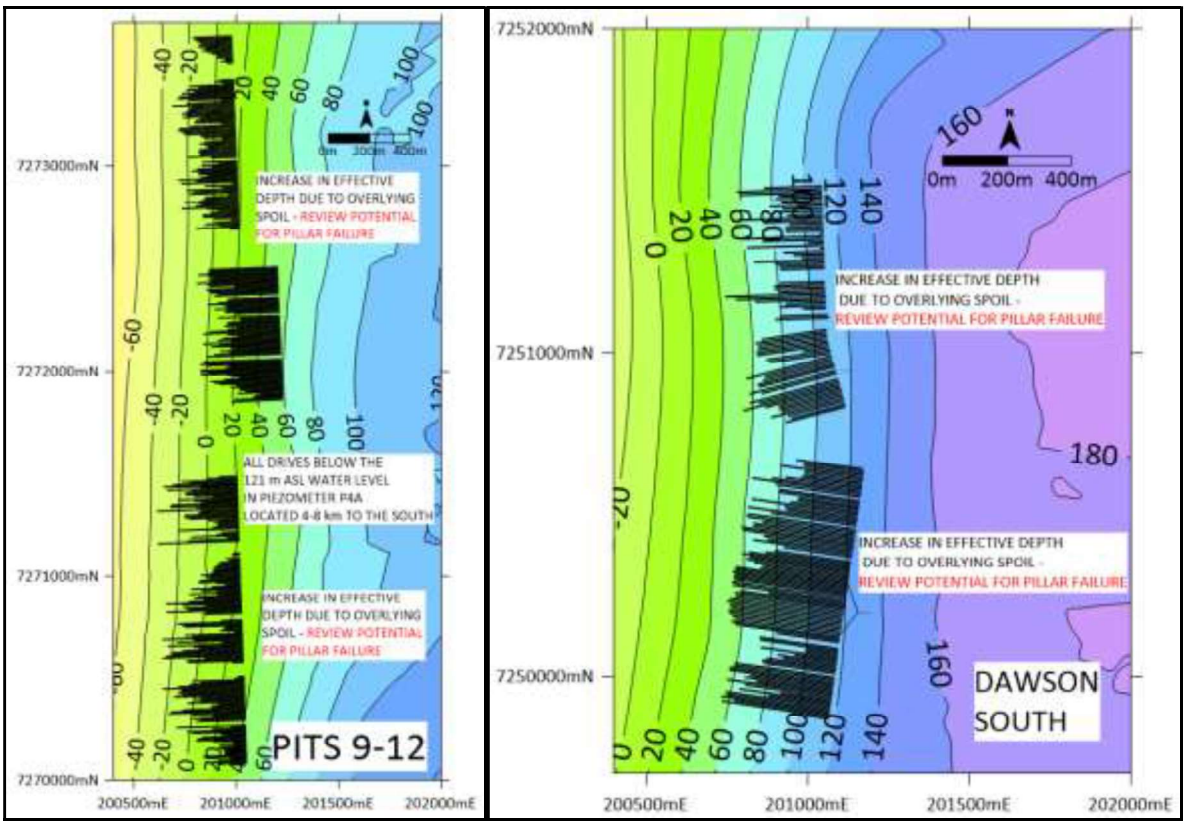


Figure 51. Structure Roof Level - E Seam Highwall Mining Area.

3.9 Surface Disturbance

Discussions with site personnel also indicated that there have been occurrences of heating's such as the one in the highwall mining area around pit 19 in the southernmost part of central area.

Similarly, the highwall mining area between pits 17 and 18 in 2009, was burning for a number of years. The seams that caught on fire are not known.

Heating's are also understood to have occurred in rehabilitated areas such as the pit 17-18 area where a coal stockpile from highwall mining activities was not cleaned up.

Another heating occurrence was experienced in pit 19 where the auger holes were white hot and burnt through to the surface. The piezometric water levels indicate that the majority of the highwall excavations are currently flooded. There are however some areas where the highwall excavations are located above the current groundwater levels and potentially exposed to oxidation. Additional piezometers would assist in providing greater confidence in the water levels across the site.

3.10 Sealing of the Drives

It is understood that all the highwall mining entries have been sealed over to varying degrees by dumping material over the entries (Highwall Auger Mining SOP, 2023).

4 STABILITY OF THE BORD AND PILLAR WORKINGS

4.1 Introduction

The stability of pillars in Australian underground coal mines is normally assessed using the industry accepted University of New South Wales Pillar Design Procedure to determine the Probability of Failure according to the design Factor of Safety (Galvin et al, 1998[6]).

4.2 Factor of Safety

The factor of safety is defined as:

FoS = Strength of Pillar/Load on Pillar

The industry standard for long term stable pillars is a Factor of Safety of >2.11, equating to a Probability of Failure > 1 in 1,000,000.

4.2.1 Pillar Strength

The UNSW Pillar Power Strength Formulae can be used to calculate the strength of the pillars. For pillars with w/h ratios <5, the strength is defined as:

$$\sigma_p = 8.6 \frac{(w_p \theta)^{0.51}}{h^{0.84}}$$

For pillars with w/h ratios ≥5, the strength is:

$$\sigma_p = \frac{27.63\theta^{0.51}}{w_p{}^{0.22} h^{0.11}} \left\{ 0.29 \left[\left(\frac{w_p}{5h} \right)^{2.5} - 1 \right] + 1 \right\}$$

Where: w_p = pillar width (m)
h = mining height
σ_p = pillar strength (MPa)
θ = dimensionless aspect ratio factor

The dimensionless aspect ratio is derived from Wagner's (1980[7]) hydraulic radius concept (effective pillar width) as follows:

When w/h <3:

$$\theta = 1$$

[6] Galvin, J., Hebblewhite, B., Salamon, M. and Lin, B. (1998). Establishing the Strength of Rectangular and Irregular Pillars. Final Report, ACARP Project C5024.

[7] Wagner, H. (1980). Pillar Design in Coal Mines. Journal of South African Institute of Mining and Metallurgy, 80 (1), 37-45.

When 3≤ w/h ≤6:

$$\theta = \left[\frac{2l_p}{w_{p+l_p}}\right]^{\frac{\frac{w}{h}-3}{3}}$$

When w/h >6

$$\theta = \left[\frac{2l_p}{w_{p+l_p}}\right]$$

Where: l_p = pillar length (m)

4.2.2 Pillar Load

Tributary area loading can be used to calculate the load carried by the pillars as follows:

$$Load\ (MPa) = \frac{0.025 \cdot H \cdot C^2}{w^2}$$

Where: C = pillar width (centre to centre) (m)
H = depth of cover (m)
w = pillar width (solid dimension) (m)

4.3 Flooding Workings

In the longer term, the flooding of underground excavations in the Dawson area needs to be considered. Current water levels indicate that the majority of the underground excavations in the Dawson area are full of water.

Galvin (2008[8]) discusses this aspect in more detail and suggested that flooding of mine workings could influence the pillar load in two ways.

1. The water pressure acting on the roof of the workings would function as a hydraulic jack to unload the pillars or
2. The overburden may be fully saturated over the full water head, effectively reducing the density, resulting in lower loads on the pillars.

Both these mechanisms have a positive impact on the long-term stability of old workings.

The other aspect that needs to be considered is the effect of water on the strength of the pillar system. Galvin (2008) details that water can reduce friction on fracture

[8] Galvin, J. (2008). Geotechnical Engineering in Underground Coal Mining – Basic Principles of Pillar Behaviour and Design. ACARP Report.

planes and roof/floor interfaces. The water can also accelerate the degradation of clay rich minerals in the roof, floor and coal seam.

The buoyancy effect of water will reduce the vertical load on the pillars by up to 40% and hence increase the factor of safety. This effect is calculated using the formula:

Effective Stress on Pillar = Total stress on Pillar – Pore Pressure due to Flooding

The effective stress on the pillar is therefore 1.5 (2.5-1) or 60% (1.5/2.5) of the total stress. The extent of the increase in stability will depend on any strength loss in the coal and the surrounding strata, which may be up to 10-15% due to the occurrence of puggy or water sensitive material in the coal seams and immediate roof and floor strata that could degrade over time.

A conservative 25% reduction in load would significantly increase the FoS of the coal pillars in the bord and pillar and highwall mining areas at Dawson.

There is a case of a pillar collapse in a flooded bord and pillar iron ore mine in France. Conversely, many of the mines in the Newcastle Coalfield of NSW have been flooded for years without adverse effect on stability.

Galvin cautions that careful consideration needs to be given to the possible adverse effects on stability by dewatering the workings, as there is a history of pillar collapses soon after being dewatered.

4.4 Potential For Sinkhole Subsidence

In addition to overall pillar stability, the risk of roadway (intersection) collapse such that sinkholes develop at the surface should be considered in the Dawson underground area. Significantly, it is reported in the technical literature that sinkholes are restricted to shallow mining areas and generally only reach the surface at depths **less than 50 m**[9,10,11].

4.4.1 Mechanism of Sinkhole Development

Whittaker and Reddish (1989) devote an entire chapter to sinkhole subsidence above bord and pillar mines. They present various analyses examining the development and propagation of sinkholes and also review the published literature, supplemented with some case examples.

[9] Mahar, J.W. and Marino, G.G. (1982). Building response and mitigation measures for building damage in Illinois. Proceedings of Workshop on Surface Subsidence due to Underground Mining, Morgantown, West Virginia University, pp. 238-252.

[10] Whittaker, B.N. and Reddish, D.J. (1989). Subsidence: Occurrence, prediction and control, Elsevier, Amsterdam, 528p.

[11] Nielen Van Der Merwe, J and Madden, BV.J. (2002). Rock Engineering for Underground Coal Mining. South African Institute of Mining and Metallurgy. Special Publications Serries 7.

Whittaker and Reddish concluded that the local geology and the natural strength of the immediate roof are important factors in assessing the potential for sinkhole development. The mining dimensions and geometry of workings are also of equal importance and should be considered in making an assessment of subsidence risks above bord and pillar mines and highwall mining/augering drives.

One of the key issues in regards to sinkhole development through fresh rock material is the extent by which the upwards progression of a roof cavity is truncated by either lithology or natural arching (**Figure 52**). **Figure 52** shows that sinkholes develop with vertical sides rather than any form of natural arching, which will cause the effective span to decrease higher into the cavity.

This failure mechanism is commonly observed in underground coal mines and along with roof lithology acts to restrict the height of roadway roof fall cavities to typically only a few metres, rather than propagating higher as shown in **Figure 52**.

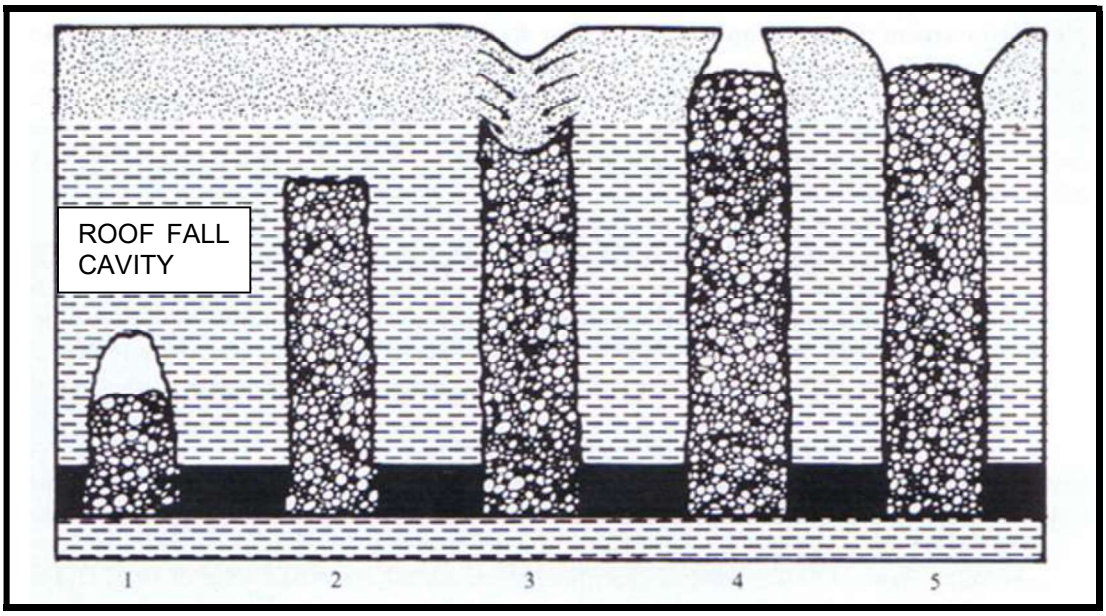


Figure 52. Illustration of Suggested Sinkhole Development Mechanism (Whittaker and Reddish, 1989).

4.5 Stability Calculations

4.5.1 Moura No. 1

As detailed above, the extracted thickness in the Moura No. 1 workings was not available for this assessment, however there have been no reports of surface cracking. There is also no significant increase in the effective depth of cover planned above the workings at closure that would increase the load (**Figure 6**).

Analysis of the 20 m x 30 m (solid) pillars in the main east/west development panel at Moura No. 1 mine, at 200 m depth developed with 3 m high by 6.5 m wide roadways, indicates a FoS of 2.3.

Similarly, in the southern part of the Moura No. 1 workings, analysis of the 16 m x 25 m (solid) pillars at 150 m depth with 6.5 m wide roadways at 3 m high indicates a FoS of 2.49.

4.5.2 Moura No. 2

As detailed earlier, extensive dumping of spoil is planned over the Moura No. 2 workings (**Figure 12**). A good example of the impact of increasing the depth of cover by dumping and modifying the Factor of Safety is detailed below for the panel in the southern part of the Moura No. 2 workings (**Figure 53**).

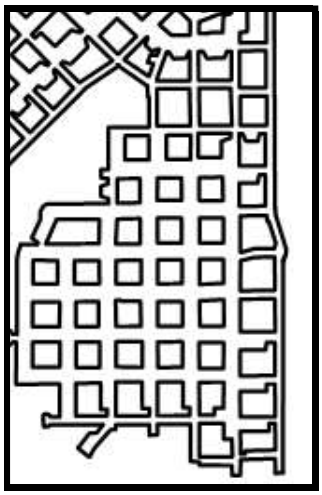


Figure 53. Pillar Panel – Moura No. 2.

Prior to dumping, the depth of cover above this panel was 160 m. For the 20 m x 20 m solid pillars and 15.5 m roadways (formed by pillar stripping) and a seam thickness of 2.5 m, the FoS is 1.73.

After the dump is complete the final depth of cover is 260 m (**Figure 13**). To account for the spoil material, a density of 2 t/m^3 has been assumed reducing the 100 m increase in depth to an effective depth of 240 m (160 m + 80 m). This reduces the FoS from 1.73 to 1.15 and failure of the pillars is anticipated at some stage during the dumping process, which would manifest as surface cracking and the formation of a depression.

Whereas in the exclusion zone, analysis of the 36 m x 36 m (solid) pillars at 240 m depth with 8.5 m wide roadways at a typical 3 m development height indicates a FoS of 4.09. Even increasing the extraction height to 4 m still maintains the FoS at 2.37.

4.5.3 Moura No. 4

Analysis of the 22 m x 42 m (solid) pillars in the south western development panel at Moura No. 4 mine, at 200 m depth developed with 3 m high by 7 m wide roadways indicates a FoS of 2.77. Dumping of spoil in this area is planned to marginally increase the effective depth by around 15 m (**Figure 24**). The FoS at a 215 m effective depth is still 2.58.

The same pillar size in the Main Dips panel at 160 m depth has a FoS of 3.46 at 3 m high. The dumping of spoil is not planned above the Main Dips panel (**Figure 26**).

4.5.4 Kianga No. 1

The Kianga No. 1 mine plan indicates that the roadways are 6.5 m wide and the standard pillar size is 40 m x 40 m (solid). Using the UNSW pillar design method, even at 180 m depth the Factor of Safety of these pillars at 3 m high is 7.44. Assuming deterioration of the 1.2 m of coal tops, which would increase the height of the pillar to 4.2 m, the FoS is 3.8. There is more certainty on the mining height at Kianga No. 1 compared to the other underground mines.

Review of the mine plan indicates some smaller 25 m x 40 m (solid) pillars which at 180 m depth and 4.2 m high have a FoS of 2.31. Limited spoil dumping is also planned over these workings (**Figure 30**).

4.6 Synopsis

This section of the report provides some FoS calculations within the underground bord and pillar workings. Due to the variability and complexity of the underground layouts and also some uncertainty in the extraction heights, an analysis of every pillar is not warranted.

It is suggested that any failures below the spoil dumps can be managed during the rehabilitation process and reshaping/contouring process. Long term monitoring using LiDAR could be used to compare the surface deformations such as that employed to monitor the highwalls at Anglo's Aquila mine (**Figure 54**).

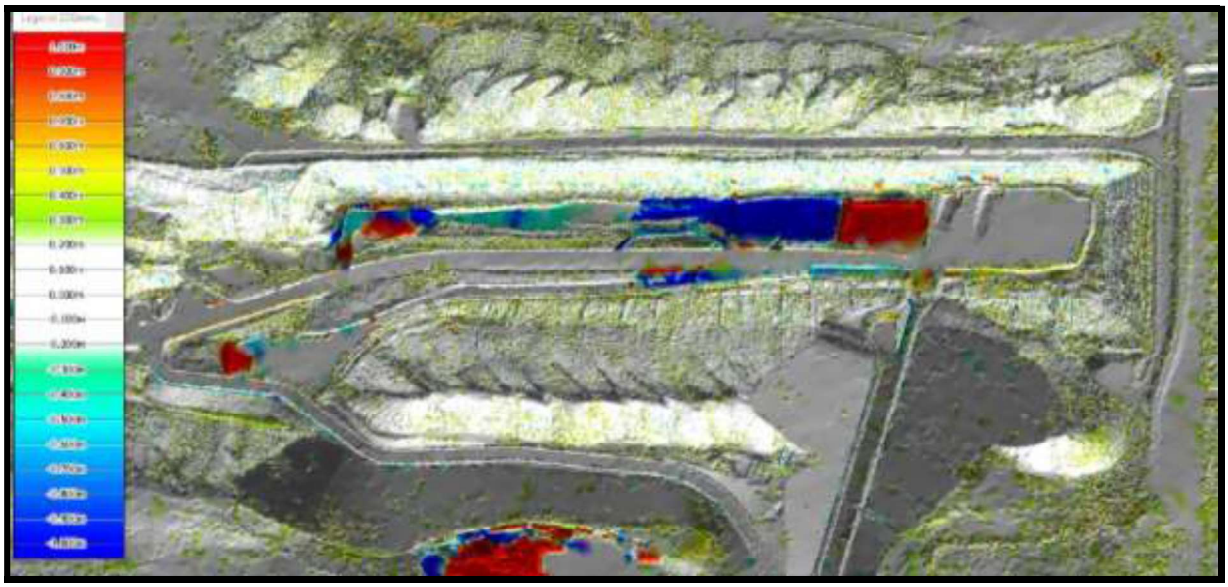


Figure 54. Aerial LiDAR Comparison (January 2022 to April 2023).

5 STABILITY OF THE HIGHWALL MINING/AUGER EXCAVATIONS

5.1 Pillar Design Formulae

Similar to the pillars in the bord and pillar mines, the stability of the highwall mining/auger pillars between the drives can be assessed using the ARMPS-HWM software from NIOSH.

5.1.1 ARMPS-HWM

The pillar strength in ARMPS-HWM is determined using the Mark-Bieniawski rectangular pillar formula that considers the effect of pillar length as follows:

$$\text{Pillar Strength} = S1\,[0.64 + (0.54\ w/h - 0.18\ (w*w/hL))]$$

Where: S1 = in situ coal strength,
w = pillar width,
h = pillar height, and
L = pillar length.

This formula including pillar length is used in the ARMPS software was derived from analysis of the pillar stress distributions implied by empirical pillar strength formulas. The formula is equivalent to the original Bieniawski formula when pillars are square.

For highwall mining pillars (both webs and barriers), the pillar length is infinite, and the equation becomes:

$$\text{Pillar Strength} = S1\,[0.64 + (0.54\ w/h)]$$

5.2 Documented Failures

ACARP project C5007 (1999[12]) details two highwall mining panel failures at Dawson as follows:

1. **Pit 17, DU Seam**.
    a. Cover Depth = 45-80 m.
    b. Panel width >130 m.
    c. Panel failure was first noticed 10 months after mining, hence it was not known exactly when failure occurred.

2. **Pit 16, BL Seam**.

    a. Cover Depth = 90-105 m.
    b. Panel width = 150 m.

[12] ACARP (1999). Geomechanical Factors Affecting Highwall Mining. Project No. C5007.

c. The original layout design was based on a cutting height of 3.7 m. During mining, coal falls of about 1.0 m were reported to be extensive. These roof falls heightened the pillars from 3.7 m to 4.8 m and the Factor of Safety of the panel was significantly reduced.
d. A panel failure of 26 entries occurred.

5.3 Stability Calculations

As detailed above, failure of the highwall mining entries has previously occurred at Dawson prior to increasing the effective depth of cover by the dumping of spoil. Some stability calculations from each seam are documented below using extraction heights estimated from the seam thickness.

5.3.1 A Seam

For 3.6 m wide drives in the A Seam mined 4 m apart at 3.6 m high, the FoS at 80 m depth is 2.03.

The FoS of the 1.9 m diameter auger holes in the A Seam at around 40 m depth and 1.1 m apart the FoS is 2.17.

5.3.2 B Seam

For typical 3.6 m wide drives in the B Seam at 3 m apart and 4 m high, the FoS at a maximum 100 m depth after closure is 1.18 indicating some potential for failure. This is the worst-case scenario as the FoS improves significantly to 1.47 at 80 m depth of cover.

5.3.3 BL Seam

The majority of the BL Seam mining drives are either mined out or the cover depth is reduced increasing the FoS (**Figure 40**).

The auger holes in the north are 1.9 m diameter and 1.5 m wide. At the increased 120 m depth (106 m effective depth) the FoS is 1.1 and there is the potential for failure as the spoil dump height increases.

5.3.4 C Seam

In the Dawson South area, the FoS for the drives mining the 3 m thick C Seam, in 3.6 m wide drives at 3.8 m apart and at 120 m depth is 1.41. The planned closure depth is 170 m, which equates to an effective depth of 160 m. The FoS is now 1.06 and failure is anticipated as the spoil dump height increases.

Similarly, in pit 2, for a conservative 4 m cutting height using 3.5 m wide drives at 4 m apart and 100 m depth the FoS is 1.56. The planned closure depth is 160 m, which

equates to an effective depth of 148 m. The FoS is also now 1.06 and again failure is anticipated.

5.3.5 D Seam

In the pit 4 area, the FoS of the 1.5 m wide auger holes in the D Seam at 2 m apart and at 60 m depth is 3.22. The planned closure depth in this area is 160 m which equates to an effective depth of 140 m. The FoS is now 1.38.

Similarly in the pit 9-12 area, the depth is increased up to 180 m from around 80 m, decreasing the FoS of the 3.6 m wide drives at 3.5 m apart at 3 m high from 1.94 to 0.97. Failure of the pillars is anticipated.

It is noted that there is also an extensive area of augering in pit 4 that has not been surveyed accurately.

5.3.6 DU Seam

For 3.6 m wide drives in the DU Seam mined 3.6 m apart at 3.5 m high, the FoS at 80 m depth is 1.86. The FoS of the 1.9 m diameter auger holes in the DU Seam at around 60 m depth and 1.1 m apart the FoS is 1.45.

5.3.7 E Seam

For 3.6 m wide drives in the E Seam mined 4 m apart at 2.5 m high, the FoS at 100 m depth is 1.97. The FoS of the 1.9 m diameter auger holes in the E Seam at around 40 m depth and 1.1 m apart the FoS is 2.17.

5.4 Synopsis

At closure some of the drives may be mined out, whereas others located below spoil may fail due to the increased load as detailed in the examples above. The situation is complicated by potential failure of roof coal which can increase the effective mining height such as occurred in the BL Seam pit 16 failure. The uncertainty in the extraction height, as well as potential errors in survey control in some areas adds further complexity.

There are documented occurrences of panel failures in the highwall mining drives and subsidence in the 2000s was reported by site personnel above the entries south of Kianga No. 1. The magnitude of this subsidence is not known.

This is a complex situation but rehabilitation of the spoil, supplemented with monitoring program and regular LiDAR surveys, should assist in managing any failures.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The overarching issue for the PRCP in the Dawson area is to ensure that the surface above the underground excavations is safe and stable after closure. This includes that there is no failure of the pillars and roadways in the underground excavations that could lead to surface disturbance that could be a hazard to people and animals on the surface.

6.1.1 Pillar/Roadway Stability

Due to a lack of knowledge regarding the extraction height of the underground excavations, a confident analysis of the stability of the coal pillars is not possible. The survey accuracy of some of the highwall excavations may also be inadequate to base a credible analysis.

There have previously been failures of the highwall mining excavations and increasing the load on the coal pillars in both the bord and pillar mines and highwall mining/auger excavations could lead to further failures.

Conversely, areas have been identified in the Dawson area where the depth of cover above the underground excavations may be reduced to <50 m due to further mining in the open cut. This could potentially lead to sinkhole subsidence above mined roadways, particularly at intersections where the span is greatest. This failure mode is highly dependent on the competency of the overburden strata.

After mining is completed and the workings are allowed to flood with groundwater, the buoyancy effect of the groundwater will reduce the vertical load on the pillars by up to 40%. This has a positive effect on the long-term stability of the pillars but depending on the FoS values may not restrict further failures. Based on the current water levels, most of the underground excavations are currently full of water.

6.1.2 Sealing

In terms of sealing, there is little detail on how the shafts have been sealed and even if shafts were used at the Moura No. 1 and Kianga No. 1 mines. The location of potential shafts at these two mines have been inferred from the mine plans provided. Site personnel have indicated that the Moura No. 2/4 shaft is probably filled with concrete but this needs to be confirmed.

The portals and highwall drives appear to have been sealed with loose material and not engineered seals/bulkheads. Further dumping is planned above the Moura No. 2 and No.4 and Kianga No. 1 portals. Based on the groundwater levels some leakage of water is therefore anticipated. It is also not practical to access the existing portals/drifts of the underground mines to install engineered seals. Similarly, the

unsupported ground in the highwall drives would not be safe to access to allow the installation of permanent engineered seals.

With further excavation of the open cut, there are areas identified where the highwall excavations may be exposed. Sealing of these excavations is required, particularly as heating's have been an issue previously with the underground excavations in the Dawson area.

6.1.3 Subsidence

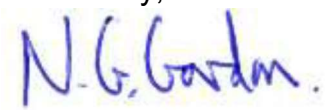
Due to the uncertainty in the extracted thickness, the accuracy of detailed subsidence modelling is limited. Areas of potential subsidence as determined from the mine plans should be inspected and any cracks identified should be rehabilitated.

6.2 Recommendations

Based on these conclusions, a number of recommendations are suggested, including

- Inspection of all areas of predicted subsidence for evidence of cracking and rehabilitate if required. The compilation of a subsidence risk map could be carried out to assist in targeting potential failure areas.
- Ensure all portal areas are sealed, particularly Moura No. 1 mine. Some form of grout/foam injection through boreholes may be required to reduce the leakage in this area.
- Monitoring of piezometers to determine the groundwater levels with respect to the underground excavations. This includes the installation of additional piezometers.
- Regrading and contouring of spoil dumps to reduce surface disturbance due to potential failure of underlying underground excavations.
- Implement a monitoring program of LiDAR surveys to allow comparison with previous surveys and identify any areas of significant ground movement.

Yours truly,



Nick Gordon
RPEQ No. 9855

Appendix 4.10 Flora and Fauna Monitoring

DAWSON MINE
2018 FLORA & FAUNA MONITORING

Anglo American Coal (Dawson Mine)

March 2019

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1 Introduction

Dawson Mine is owned by the Moura Joint Venture, comprising Anglo American Coal Pty Ltd (AAC) (51%) and Mitsui Coal Holdings Pty Ltd (49%). The mine is operated by AAC and exports coking, soft coking and thermal coal to markets throughout Asia. The mine is located in the Dawson Valley at the southern part of the Bowen Basin, approximately 10 km east of Moura in Central Queensland.

The mine has been in operations since 1960 and combines three adjacent areas that stretch for approximately 60 kilometres. The Dawson Mine currently utilises open cut and high wall mining methods to produce its Coal.

Dawson Mine has an environmental duty of care to manage and therefore reduce any negative impacts the operation has or may have on the environment. A three yearly Flora and Fauna survey was established in 2005 to monitor both the impacts of the mine on the natural environment and the condition of mine rehabilitation. In addition, a Biodiversity Action Plan (BAP) was developed in 2007 to actively manage biodiversity across the operation. The BAP identifies seven Biodiversity Management Units (BMUs) across the Dawson operation. These are:

BMU 1 – Mining impact unit:

This unit represents lands that are currently being mined or have been mined and are not yet rehabilitated. This includes infrastructure, sediment dams and old voids. It is anticipated BMU 3 will largely replace this BMU by the end of mine life.

BMU 2 - Peripheral lands unit:

These areas represent highly fragmented vegetation types, which have resulted from previous land disturbances such as broadscale clearing to enable grazing and/or cultivation and logging.

BMU 3 – Rehabilitation unit:

This unit represents areas that have been rehabilitated post mining.

BMU 4 – Willawa Nature Refuge:

The Nature Refuge was established under the *Nature Conservation Act 1992* in consultation with the Queensland Parks and Wildlife Services (QPWS). The refuge was a condition of approval of the Dawson South section of the Dawson Mine, which was administered under the Environmental Protection Agency. The Nature Refuge occurs as two separate sections. BMU4a is the area described as a potential Nature Refuge expansion area.

BMU 5 – Corridor/waterways unit:

This unit represents areas of high conservation value for wildlife habitat and movement opportunities. BMU 5 comprises waterways as well as associated riparian vegetation and large water bodies including the Dawson River. BMU5a consists of future corridors/waterways outside of the current mining area.

BMU 6 – Social amenity unit:

This unit comprises areas of social importance and includes the towns of Theodore, Woolthorpe, Bindaree, Banana and Harcourt. Contains residential areas, homesteads, major roads, recreation areas, commercial enterprises and areas of high visibility vantage points and aesthetic value.

BMU 7 – Heritage unit:

This unit comprises areas of heritage importance, consisting of Kianga Homestead, a scar tree at Kotti Doon and areas of land with Native Title Claim.

Flora and fauna monitoring has been conducted in 2005, 2008, 2011 and 2014. Ecological Survey & Management was engaged to conduct the 2018 fauna and flora monitoring at Dawson Mine and this report outlines the finding of these surveys.

1.1 Specific objectives of flora and fauna monitoring at Dawson Mine

The Dawson Mine Flora and Fauna Monitoring Survey aimed to achieve the following objectives:

- obtain data on the performance of vegetation cover, species diversity and growth to use in the assessment of rehabilitation success and to determine whether recruitment is occurring
- obtain data on fauna across the BMUs to compare the suitability of rehabilitated and non-rehabilitated mining areas as fauna habitat in comparison to the surrounding environment
- gain an understanding of the impact of mining on the flora and fauna populations in areas surrounding the Dawson Mine
- gain an understanding of the biodiversity status of each BMU which can be used to develop recommendations and action plans for improvement
- obtain data relating to erosion and its impacts.

1.2 Description of flora and fauna monitoring sites at Dawson

Dawson Mine has a total of 27 monitoring sites spread across six of the seven BMUs. The 2018 monitoring program revisited ten sites across four of the BMUs where flora and fauna surveys were undertaken at each site. Five of the monitoring sites were situated in rehabilitated areas in BMU 3 while the remaining sites were situated in areas that have not been mined but may have been subjected to historic disturbance or considered to be representative of remnant vegetation. Two sites were in BMU 2, two sites in BMU 5 and one site in BMU 4.

These ten sites were the focus of monitoring in 2011 and 2014.

The location of monitoring sites is shown on Figures 1a and 1b.



Legend

- Mining Lease
- Road
- Railway
- Waterway
- Kianga Creek Diversion
- Survey plot (flora and fauna – 2018)

Figure 1a : Location of Survey Plots

Dawson Mine Flora and Fauna Monitoring

Map Number: 18057_01a_A
Date: 14 February 2019
Map Projection: GDA 1994 MGA Zone 56
Imagery: DigitIa Globe
Data: Roads, Railway, Waterway, Cadastral Boundary - (c) DNRM 2019

0 .5 1 2 3 4 5
Kilometres

N

ecological survey & management



Legend

- Mining Lease
- Road
- Railway
- Waterway
- Survey plot (flora and fauna – 2018)

Figure 1b : Location of Survey Plots

Dawson Mine Flora and Fauna Monitoring

Map Number: 18057_01b_b
Date: 14 February 2019
Map Projection: GDA 1994 MGA Zone 56
Imagery: Digital Globe
Data: Roads, Railway, Waterway, Cadastral Boundary - (c) DNRM 2019

0 .5 1 2 3 4 5
Kilometres

N

ecological survey & management

1.3 Purpose of this report

Ecological Survey and Management was engaged to conduct the 2018 flora and fauna surveys at Dawson Mine. As established in Section 1.2, the surveys were performed at ten previously established monitoring plots in a mixture of rehabilitation areas and remnant vegetation. The purpose of the monitoring program is to provide an empirical means of assessing the biodiversity values within lands rehabilitated and managed by Dawson Mine. This report provides the results of the 2018 monitoring surveys and discusses any trends or differences from previous monitoring surveys.

This report:

- provides a short review of relevant literature, mapping and database information
- describes the methodology of the survey
- details the results of the monitoring survey, including comprehensive species lists, monitoring site descriptions that include vegetation and fauna habitat elements
- compares current data to data collected previously and discusses any trends or differences
- provides recommendations for future rehabilitation and monitoring.

2 Methodology

2.1 Timing of monitoring surveys

The 2018 flora and fauna monitoring survey was undertaken over a four day/four night period between the 11 and 14 December 2018. This was the fifth round of flora and fauna monitoring at the mine, with previous monitoring being completed in 2005, 2008, 2011 and 2014.

The 2018 surveys were conducted in early summer with the weather during the surveys being characterised by warm to hot days (30.6°C to 34.9°C) and mild nights (16.7°C to 22.8°C) (BOM weather station 039089; (BOM 2019)). The region had experienced a significantly drier than average summer, with no rainfall received in the 10 days before the surveys (BOM 2019). The region had also experienced below average rainfall for the spring period. The 2018 monitoring surveys were conducted during dry conditions.

The relatively cool overnight conditions during the survey may have reduced the detectability of amphibians and reptiles during spotlighting. The drier conditions are also likely to have reduced the detectability of some grass and herb species.

2.2 Plot selection

The Dawson Mine Environment Team selected 10 monitoring sites from a total of 27 available monitoring sites for the 2018 monitoring surveys. These 10 sites were the same 10 sites that were assessed in 2011 and 2014. The 10 monitoring sites along with their associated BMU are presented in Table 1.

A flora and fauna survey was performed at each of the ten sites. The co-ordinates represent the start and end points of the 100 m transect (see Section 2.4)

Table 1: Monitoring sites surveyed during the 2018 Flora and Fauna Survey

Site no.	BMU	Latitude (WGS84)	Longitude (WGS84)	Previous survey year			
				2005	2008	2011	2014
1	3	-24.659602	150.048001	X		X	X
		-24.659382	150.04899				
8	3	-24.686077	150.05947	-	X	X	X
		-24.686835	150.060066				
10	2	-24.741807	150.068794	X	-	X	X
		-24.742713	150.068585				
11	3	-24.74159	150.060274	X	X	X	X
		-24.741942	150.059381				
16_D	3	-24.705955	150.062598	-	-	X[#]	X
		-24.705103	150.062777				
17	3	-24.488813	150.062628	-	-	X[#]	X
		-24.487925	150.062398				

Site no.	BMU	Latitude (WGS84)	Longitude (WGS84)	Previous survey year			
				2005	2008	2011	2014
18	4	-24.85103	150.047961	-	-	X	X
		-24.850738	150.047033				
19	5	-24.656193	150.052302	X	-	X	X
		-24.656209	150.052828				
22	5	-24.843001	150.005374	-	-	X	X
		-24.84392	150.005285				
23	2	-24.622305	150.037208	-	-	X	X
		-24.623222	150.037107				

[#] - No fauna survey.

2.3 Vegetation assessment

An assessment of the vegetation at each site was conducted using a proforma that was developed to incorporate features of the methodologies described in the "*BioCondition: A terrestrial Condition Assessment Tool for Biodiversity in Queensland*. *Field Assessment Manual Version 2.1.*" (Eyre et al. 2011a), "*Methodology for the establishment and survey of reference sites for BioCondition – Version 2.0"* (Eyre et al. 2011b) and "*Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland; Version 4.0*" (Neldner et al. 2017) . This proforma allowed for the collation of a wide array of BioCondition parameters, including several which are not currently recognised in the Department of Environment and Science (DES) produced BioCondition benchmarks. Refer to Eyre *et al.* (2011a, b) and Neldner *et al.* (2017) for a detailed description of the below-mentioned parameters.

The BioCondition assessment proforma allowed for the collation of data relating to the parameters outlined below. The assessment of these parameters was conducted within a 100 m by 20 m plot, which was marked out based on the existing plot delineation stakes. Where permanent plot delineation stakes were absent, efforts were made to place the plot where the previous assessments took place through the use of co-ordinates and a handheld GPS. The plots were laid out using 100 m and 50 m measuring tapes and demarcated with surveyor's tape. An internal plot of 50 m x 10 m was also marked out using surveyor's tape. This internal plot was representative of the plot used in the previous monitoring surveys.

The following data was recorded within the 100 m by 20 m plot:

- orientation of the plot
- date and precise location (with reference to handheld GPS)
- soils, slope, aspect and landform observations
- ground-layer, mid-stratum and canopy species composition and relative abundance
- structural characteristics

- tree/shrub cover intercept (i.e. vertical projection of the canopies of all woody vegetation across the 100m centreline of the plot)
- groundcover parameters were recorded in ten 1 m by 1 m quadrats were installed at the 5, 15, 25, 35, 45, 55, 65, 75, 85 and 95 m marks along the central transect
- condition and disturbance (including distribution of weed species)
- quantity of recruitment
- patch size
- photographs of the community (taken at the start and end of the 100 m transect and in a north, east, south, west direction at the 50 m mark or centre of the original plot)
- photographs of the groundcover, surface soils and three soil core samples

The following data was recorded within the 50 m by 10 m plot:

- prevalence of rill erosion (categorised by depth)
- species richness (collated as a complete floral inventory describing stratum position and relative abundance using the Hurst and Allen (2007) interpretation of the Braun-Blanquet technique
- total length of fallen woody debris that is greater than 0.5 m in length and 100 mm in diameter and in contact with the ground
- hollows of less than 100 mm diameter and greater than 100 mm in diameter
- diameter at breast height (DBH), height, cover and number of all woody vegetation distribution by breaking the internal plot into five 10 x 10 m squares.

The data collated is presented in Appendix A.

The 2014 monitoring surveys used a modified version of the BioCondition parent methodologies (Eyre et al. 2011 a, b) to assess the number of large trees present (i.e. trees with diameter at breast height or DBH above 30 cm for eucalypts and 20 cm for non-eucalypts). The modified methodology involved measuring all woody vegetation within the BioCondition plot in terms of species, DBH and height. For the 2018 surveys, this approach was re-assessed and the "large trees" BioCondition parameter was omitted from the surveys. Based on data from 2014, the mean DBH of trees within the monitoring sites was well below the threshold DBH in the BioCondition Benchmark for the corresponding regional ecosystems (REs). It was also considered unlikely that woody vegetation within the plots would have reached or exceeded the benchmark DBH threshold for these REs during the four year period between monitoring surveys. Subsequently, the BioCondition parameters regarding height and cover within each stratum are considered to be more useful in terms of assessing the vegetation community structure, as well as providing the opportunity to monitor particular aspects of the regeneration process including natural attrition within the canopy and mid-stratum layers.

By conducting this style of monitoring, the overall condition and success of the rehabilitation can be more easily compared with remnant vegetation that is sampled using a similar methodology. BioCondition scores for all plots will be determined through reference to corresponding BioCondition benchmarks, which have been attached in Appendix B.

2.4 Terrestrial fauna assessment

Survey techniques employed for the terrestrial fauna assessment included active searching, spotlighting, Anabat acoustic sensors and infrared cameras. All survey techniques were standardised across each of the fauna monitoring sites. Each fauna survey site comprised the following:

- One 60 minute (2 persons for 30 minutes) morning bird census survey
- One 60 minute (2 persons for 30 minutes) diurnal active searching session conducted concurrently with the bird survey
- One 60 minute (2 persons for 30 minutes) nocturnal spotlight and active search session
- Anabat recorded for one full night
- One infrared camera for a minimum of four nights

This methodology is consistent with the 2014 monitoring surveys. However, as noted in the 2014 monitoring report (EcoSM 2014) this methodology was altered slightly in comparison to the 2011 survey. In 2011, bird surveys and active searches were conducted over two mornings for 30 minutes. Due to logistical constraints with access to operational areas of the mine, this was not feasible in 2014 so one 60 minute bird survey and active search was conducted at each monitoring site.

In line with the 2014 surveys, anabats and infrared cameras were used at each monitoring site in increase the ability to make comparisons between monitoring sites over time.

2.5 Nomenclature

Application of flora scientific names in this report follows Bostock and Holland (2018). In the first occurrence in the text, common names (if one exists) will be followed by its scientific name. Common names for flora were derived from Harden et al. (2006), Brooker and Kleinig (2008), Maslin (2001), Hacker (1990), Tothill and Hacker (1996) , Sharp and Simon (2002), and Auld and Medd (2002). Use of an asterisk (*) indicates the species is not native to Queensland, e.g. Spiked Malvastrum (**Malvastrum americanum*). Following the first in-text reference, species will be referred to by common name only, where one exists.

Faunal Taxonomy within this report follows the following references:

- amphibians – Tyler and Knight (2011)
- reptiles – Wilson (2005)
- birds – Pizzey and Knight (2012)
- mammals (except bats) – Menkhorst and Knight (2011)

- bats – Churchill (2009).

Common names for fauna are used where a species has an accepted common name with the scientific name provided at the first instance of the name appearing in the text. Common names are sourced from the references listed above or where no common name is provided searches are made for other widely accepted common names. The use of an asterisk (*) indicates the species is not native to Queensland.

2.6 Co-ordinate system and map datum

Locations were recorded using the UTM coordinate system. All locations presented in this report are within zone 56J. The map datum used was GDA1994.

2.7 Survey limitations

2.7.1 Terrestrial flora assessment

The poor wet season at the beginning of 2018, coupled with a very dry winter has significantly reduced the species richness and overall biomass of the groundcover layer.

2.7.2 Terrestrial fauna assessment

Where possible the same methodology utilised in the previous fauna monitoring surveys was followed (refer Section 2.4). The relatively cool overnight temperatures and lack of rainfall preceding the survey may have reduced the detectability of some fauna particularly amphibians and reptiles during spotlighting.

3 Results

3.1 Flora assessment

The Dawson Mine is located in a region that has primarily been cleared for cultivation, cattle grazing and mining. Remnant vegetation to the west of the mine has been largely removed from the broad clay plains and at present is primarily restricted to narrow bands in road reserves. Remnant vegetation fringing the Dawson River persists. To the east of the mine the topography tends to gently undulated low rises with sandy clay to clayey sand soils This rises have been largely cleared but remnant vegetation, where retained, ranges from eucalypt grassy woodland to Brigalow (*Acacia harpophylla*) open forest to semi-evergreen vine thicket scrubs.

The vegetation communities that most commonly occur within the broader region include the regional ecosystems (REs) that are presented in Table 2. The selection of these REs is based on the regulated vegetation mapping which is available from DNRME (DNRME 2018). The non-remnant communities are most commonly dominated by Buffel Grass (**Cenchrus ciliaris*).

Table 2: Common remnant regional ecosystems in the broader region

Regional Ecosystem	Short description[1]	VM Act status
11.3.1	*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains	Endangered
11.3.2	*Eucalyptus populnea* woodland on alluvial plains	Of Concern
11.3.3	*Eucalyptus coolabah* woodland on alluvial plains	Of Concern
11.3.4	*Eucalyptus tereticornis* and/or *Eucalyptus spp*. tall woodland on alluvial plains	Of Concern
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	Least Concern
11.3.25d	Riverine wetland or fringing riverine wetland. *Melaleuca bracteata* woodland to open-forest.	Least Concern
11.3.37	*Eucalyptus coolabah* fringing woodland on alluvial plains	Least Concern
11.9.1	*Acacia harpophylla-Eucalyptus cambageana* open forest to woodland on fine-grained sedimentary rocks	Endangered
11.9.2	*Eucalyptus melanophloia* ± *E. orgadophila* woodland on fine-grained sedimentary rocks	Least Concern
11.9.4a	Semi-evergreen vine thicket, generally dominated by a low tree layer which is floristically diverse and variable. Emergents are usually present. Vines are frequent.	Of Concern
11.9.5	*Acacia harpophylla* and/or *Casuarina cristata* open forest on fine-grained sedimentary rocks	Endangered
11.9.7	*Eucalyptus populnea, Eremophila mitchellii* shrubby woodland on fine-grained sedimentary rocks	Of Concern
11.9.9	*Eucalyptus crebra* woodland on fine-grained sedimentary rocks	Least Concern

[1] Short description sourced from Regional Ecosystem Description Database, version 11 (Queensland Herbarium 2018).

Previous and current rehabilitation efforts at Dawson Mine appear to have utilised a commonly prescribed palette of species that are frequently introduced to re-contoured WRD in mines throughout central Queensland. However, the most commonly encountered species was Sally Wattle (*Acacia salicina*), which was found to clearly dominate some areas of rehabilitation. Commonly encountered eucalypt species included Spotted Gum (*Corymbia citriodora* subsp. *variegata*), River Red Gum, (*Eucalyptus camaldulensis*), Dawson River Gum (*Eucalyptus cambageana*) and Silver-leaved Ironbark (*Eucalyptus melanophloia*).

Although some of these species represent the dominant species listed for the REs in Table 2, these species in combination and/or in their present location (e.g. re-contoured WRD well removed from riverine influence) are not representative of a described RE. Ideally the REs described in Table 2 should be replicated on site but practical constraints such as major alteration to soil substrates, topography, aspect and hydrology make this difficult.

The long-term goal of rehabilitation should be to maximise local species and minimise the use or establishment of non-local species, particularly declared weeds. The REs shown in Table 2 provide a guide as to the ideal vegetation communities and species to be used in the rehabilitation areas at the Dawson Mine. However, those REs that do not occur on alluvial systems or broad clay plains (i.e. land zones 3 and 4) contain species more suitable for mine site rehabilitation. More specifically, these should include Ironbark and/or Lemon-scented Gum woodlands.

Monitoring for the successful establishment of these species and communities is an important aspect of the monitoring at Dawson Mine. This is balanced with other issues such as the shorter term needs to prevent erosion and offset weed invasion irrespective of the plant species composition.

3.1.1 Monitoring site descriptions

Monitoring of rehabilitation at Dawson has been occurring over a period 13 years. During this time some monitoring sites have been difficult to find, relocated or discounted due to access constraints. To improve consistency between monitoring surveys, the 2018 monitoring surveys conducted at the sites and locations set up during the 2014 monitoring event (refer EcoSM 2014).

3.1.1.1 Rehabilitation

Site 1 is the only advanced rehabilitation site that approximates remnant vegetation due to the presence of mid-mature Dawson River Gum, which is the dominant species of locally occurring RE 11.9.1. However, this vegetation is restricted to a very small patch of less than one hectare in size with the surrounding rehabilitation dominated by Sally Wattle shrubland with a Buffel Grass dominated groundcover layer. The area of the monitoring site also included planted specimens of Spotted Gum and Grey Gum (*Eucalyptus longirostrata*). A small copse of Belah was recorded to immediately east of the plot at the toe of slope. The ground

layer was dominated by Buffel Grass, with species richness and diversity being very low.

Sites 8 and **11** are situated on the crests or upper slopes of re-contoured spoil dumps that have not had any topsoil applied. Species richness is very low at both of these sites and it would appear that eucalypt seeds have either failed to germinate or omitted from the seed mix applied to these areas. This type of rehabilitation is typical and widespread across the Dawson Mine. Both sites are dominated by Sally Wattle shrubland to open shrubland with a ground layer of Buffel Grass. Although these species establish relatively easily, and in many cases do so spontaneously, the resulting ecosystem is dysfunctional and not representative of any RE. It has some grazing value but little to no habitat value for both fauna and flora because of the lack of timber, topsoil, larger trees and hollows. The absence of a productive substrate, i.e. topsoil, is considered likely to limit the ability of these areas to become more diverse over time.

Site 16_D was not represented by an established site that had been surveyed during monitoring events prior to 2014 and was only an opportunistic observation point. Prior to 2014, this site had flora, fauna and soil monitoring conducted at three different locations. In 2014, a new plot was established approximately 60 m to the west and downslope of the observation point to ensure that this and future monitoring is conducted consistently. This new plot was run at edge or transition between Sally Wattle (dominant vegetation on surrounding WRD) and eucalypt woodland in the gully. The intention of this location was to enable the eucalypt dominated vegetation to be monitored over time and determine if it colonises the surrounding area or contracts over time. This plot was monitored again in 2018.

The sampled community had a variable composition, with a sparse cover of Sally Wattle and/or Yellow Bells (**Tecoma stans*) on the slopes and eucalypts become more prevalent in the gully. Species such as Spotted Gum, Narrow-leaved Red Ironbark (*Eucalyptus crebra*), Silver-leaved Ironbark, Yellow Jacket (*Corymbia leichhardtii*), Coolabah (*Eucalyptus coolabah*) and River Red Gum were recorded in the gully. Buffel Grass and Butterfly Pea (**Clitoria ternatea*) were dominant groundcover species on the slopes and in the gully.

Site 17 occurs on a relatively stable benched WRD. Woody vegetation at this location was primarily limited to a narrow strip of regrowth confined to the toe of the batter with the balance of the bench and adjacent slopes primarily devoid of woody vegetation. Large logs have also been scattered along the toe of the batter. The narrow strip is approximately 5 m in width and dominated by Spotted Gum and Sally Wattle. The groundcover layer while dominated by Pale Pigeon Grass (**Setaria pumila*), also supported several native grass species. This is largely due to the re-instatement of clayey loam to a thickness in excess of 300 mm in depth.

The composition of the rehabilitation mix varies approximately 100 m to the north of the plot, wherein Sally Wattle is still present but Spotted Gum occurs less frequently and where present is generally stunted and performing poorly. Species such as *Acacia holosericea, Acacia ligulata, Eremophila maculata, Dodonaea viscosa, Senna spp., Erythrina vespertilio,*

Brachychiton populneus and **Vachellia farnesiana* occur commonly at this location.

3.1.1.2 Non-remnant and regrowth Brigalow

Monitoring Sites 18 and 23 are both representative of non-remnant Brigalow, despite current regulated vegetation mapping (DNRME 2018) mapping these areas as remnant vegetation.

Site 18 represents a small patch of mid-mature Brigalow woodland surrounded by Silver-leaved Ironbark and Mountain Coolabah open woodland (RE 11.9.2) tending to non-remnant to the north and remnant Poplar Box woodland (RE 11.9.7) to the west and north-west. The choice of the patch as a monitoring site is somewhat strange as it is a small patch within a much larger area of eucalypt dominated vegetation.

However, the patch of Brigalow had a relatively intact distribution of mid-mature Brigalow with several vine thicket generalists common within the shrub layer. The composition of the groundcover ranges from Brigalow Grass (*Paspalidium caespitosum*) within the patch to Buffel Grass at the periphery. This patch is characteristic of RE 11.9.5.

Site 23 is currently mapped as remnant but is instead representative of even-aged, regrowth Brigalow shrubland (RE 11.4.9), with the Brigalow within the patch having a consistent DBH, height and multi-leadered habit However, variable stages of recovery and/or remnant vegetation were recorded in the larger polygon of vegetation as a whole. The monitoring plot has been located in an area of the patch with a young cohort and generally lacks larger Brigalow trees or eucalypts (e.g. Dawson Ruiver Gum or *E. thozetiana*). The sampled cohort is separated from more mature patches by an access track/powerline easement in the east and a disused track in the west. This cohort is comprised of Brigalow with associated species including Turkey Bush (*Eremophila deserti*), Warrior Bush (*Apophyllum anomalum*) and Forest Grape (*Clematocissus opaca*).

The low shrub and groundcover layers are generally quite sparse. The latter is composed of Brigalow Grass. Other species include Twirly Windmill Grass (*Enteropogon ramosus*), Black Roly-poly (*Sclerolaena muricatus*) Soft Roly-poly (*Salsola kali*) and Purple Lovegrass (*Eragrostis lacunaria*). Weed infiltration within the patch is generally negligible, however Buffel Grass dominates the easement to the east. To the west, there is a taller stand of Brigalow in excellent condition, with a diverse understorey and diverse structure.

Of particular note, four flora species that are listed as Endangered under Queensland's *Nature Conservation Act 1992* (NC Act) were identified within this community, with one of the species being recorded within the plot. A total of 28 specimens of *Solanum elachophyllum* (no common name) (Plate 1) were recorded between the 34 and 37 m points of the transect and a further 14 specimens were recorded at the 10 m point in 2014. Specimens of this species were observed in 2018 but were not quantified due to the poor conditions. Additional specimens of this species were recorded throughout the community, as was *Solanum dissectum* (no common name)(Plate 2), *Solanum johnsonianum* (no common name) (Plate 3) and *Xerothamnella herbacea* (no common name). As required under scientific

permit conditions, samples of these species were collected and submitted to the Queensland Herbarium for inclusion in their records.



Plate 1: ***Solanum elachophyllum*** **in Plot 23**



Plate 2: *Solanum dissectum* in the vicinity of Plot 23



Plate 3: *Solanum johnsonianum* in the vicinity of Plot 23

3.1.1.3 Remnant Ironbark woodland

Site 10 is representative of remnant woodland of Narrow-leaved Red Ironbark (*Eucalyptus crebra*) and was found to be in moderate to good condition, with typical structure and diversity of RE 11.9.9. However the groundcover layer is dominated by Buffel Grass, which may be a function of the siting of this plot in close proximity to the north-western edge of the community, adjacent to several disturbance areas (e.g. detention basin, conveyor belt). It is worth noting that as per the 2014 surveys, the 50 x 10 m plot was started at the 0 m mark (as opposed to the 25 m mark of other sites) with the cover intercept plot extending a further 50 m past the 50 m point as a dam or detention basin was located approximately 10 m north of the 0 m point of the established plot.

3.1.1.4 Remnant riparian woodland

Site 19 is located adjacent to the upstream commencement of the Kianga Creek diversion. In 2014, this site was moved approximately 90 m to the west of original location in 2011, but no pegs were located. A 100 m cover intercept transect with a 50 x 10 m transect located centrally within (i.e. stakes at the 25 and 75 m mark) was not conducted at this site as the new site was located at the western edge of the vegetation type. To the west of the site woody vegetation is restricted to very sparsely scattered Sally Wattle within a broad, artificially created diversion channel.

Within the site woody vegetation is primarily restricted to the banks of Kianga Creek with the adjacent area dominated by a sparse to mid-dense cover of juvenile Sally Wattle. A levee bank is located approximately 50 m to south of the site. Significant levels of dieback were observed within the canopy layer (i.e. dead mature Queensland Blue Gum). This community was representative of non-remnant RE 11.3.25 and appears to be in decline.

Site 22 is representative of remnant Coolabah +/- Queensland Blue Gum fringing woodland (RE 11.3.25) on the steep banks and high flow terrace of the Dawson River. The canopy layer of this community is relatively intact with canopy, sub-canopy and juvenile trees present. However, the specimens of Queensland Blue Gum and River Tea Tree (*Melaleuca trichostachya*) are primarily restricted to the toe of the low flow bank. The groundcover layer was found to be heavily grazed and dominated by exotic species.

3.1.2 Summary of BioCondition parameters

Table 3 provides a summary of the BioCondition parameters that were collated during the 2108 monitoring period. The parameters measured are representative of those which are assessed when determining a BioCondition score and establishing 'best-on-offer' reference sites and benchmark sites. Refer to Appendix B for detailed site information and photos.

Table 3: Summary of BioCondition parameters[1]

Representative RE	Rehab	Rehab	Rehab	Rehab	Rehab	11.9.9	11.9.5 (n-r)	11.3.25 (n-r)	11.3.25	11.4.9
Monitoring sites surveyed	**BC001**	**BC008**	**BC011**	**BC016_D**	**BC017**	**BC010**	**BC018**	**BC019**	**BC022**	**BC023**
Structural composition										
Tree and/or canopy (T1) height (m)	16.10	-	6.40	9.88	8.23	16.40	11.10	20.0	20.87	-
Tree canopy (T1) cover (%)	43.95	-	15.00	40.55	30.30	17.70	11.00	<5	70.60	-
Sub-canopy (T2) height (m)	8.60	-	-	-	-	8.40	-	11.50	12.87	-
Sub-canopy (T2) Cover (%)	9.30	-	-	-	-	23.80	-	18.20	9.05	-
Shrub (S1) height (m)	3.60	3.00	2.20	3.40	3.71	3.30	5.70	3.50	-	4.25
Shrub (S1) cover (%)	8.00	38.90	9.35	5.00	15.50	20.70	13.46	9.10	-	53.35
Shrub (S2) height (m)	-	1.60	-	-	-	-	2.52	-	-	2.10
Shrub (S2) cover (%)	-	31.75	-	-	-	-	9.87	-	-	3.85
Recruitment of woody species	50%	100%	100%	43%	100%	100%	100%	100%	66%	100%
Coarse woody debris (50 x 10 m plot) [metres per ha)	62.5	0	0	0	1360*	567.5	350	150	217.5	10

Representative RE	**Rehab**	**Rehab**	**Rehab**	**Rehab**	**Rehab**	**11.9.9**	**11.9.5 (n-r)**	**11.3.25 (n-r)**	**11.3.25**	**11.4.9**
Monitoring sites surveyed	**BC001**	**BC008**	**BC011**	**BC016_D**	**BC017**	**BC010**	**BC018**	**BC019**	**BC022**	**BC023**
Groundcover parameters										
Native grass cover (%)	0.0	1.0	8.8	0.0	0.5	16.0	5.3	20.0	0.0	4.9
Native herb & forb cover (%)	0.0	0.0	0.0	0.0	0.0	1.9	1.4	40.2	0.9	1.3
Native shrubs (<1 m in height)	0.0	0.6	0.0	0.0	0.0	3.8	0.1	0.0	0.0	0.3
Non-native grass cover (%)	13.8	15.0	43.8	21.0	36.5	5.5	17.2	0.0	27.9	0.0
Non-native herbs & shrubs cover (%)	0.0	12.8	5.6	3.4	0.0	0.1	0.3	0.0	0.1	0.0
Aquatic vegetation (floating) cover (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aquatic vegetation (emergent) cover (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-aquatic sedges (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ferns (%)	0.0	0.0	0.0	0.0	0.0	0.8	0.0	10.7	0.5	0.0
Litter cover (%)	57.5	14.8	33.1	63.3	47.3	54.4	43.5	20.3	46.9	48.3
Bare ground (%)	9.6	15.0	6.8	7.8	1.3	13.5	24.6	0.2	13.3	44.2

Representative RE	**Rehab**	**Rehab**	**Rehab**	**Rehab**	**Rehab**	**11.9.9**	**11.9.5 (n-r)**	**11.3.25 (n-r)**	**11.3.25**	**11.4.9**
Monitoring sites surveyed	**BC001**	**BC008**	**BC011**	**BC016_D**	**BC017**	**BC010**	**BC018**	**BC019**	**BC022**	**BC023**
Rock (%)	18.2	40.5	2.0	3.4	0.1	0.9	2.8	0.0	0.0	0.0
Other (timber) (%)	0.7	0.3	0.6	1.0	12.4	0.2	3.6	8.6	5.7	1.0
Species richness										
Trees	4	0	0	7	3	3	1	1	4	2
Shrub (& exotic)	1(1)	9(3)	1(2)	3(1)	4(2)	20	16	5(1)	6(2)	8
Grasses (& exotic)	3(1)	1(7)	6(3)	1(3)	3(2)	14(4)	5(1)	3(2)	6(4)	5
Forbs and other (& exotic)	8(1)	4(5)	10(11)	7(4)	8(5)	24(1)	11(1)	22(9)	28(9)	20(1)
Total native species (& exotic)	15(3)	14(15)	17(16)	18(8)	18(9)	61(5)	33(2)	31(12)	44(15)	35(1)

* location and quantity of timber atypical with respect to the balance of the community (misleading)

Table 4 describes the BioCondition scores for each of the monitoring plots undertaken in native vegetation that supports remnant or non-remnant REs. These scores have are based on the corresponding BioCondition benchmarks available from DES (DES 2019) and provided in Appendix B.

Table 4: BioCondition scores for monitoring plots – native vegetation

BioCondition parameter	Representative Regional Ecosystem[1]				
	11.9.9	**11.9.5 (n-r)**	**11.3.25 (n-r)**	**11.3.25**	**11.4.9**
	Monitoring site number				
	10	**18**	**19**	**22**	**23**
Site-based condition attributes					
1. Recruitment of woody perennial species	5	5	5	3	5
2. Native plant species richness:					
- trees	5	2.5	2.5	5	2.5
- shrubs	5	5	5	5	2.5
- grasses	5	5	2.5	2.5	5
- forbs and other	5	5	5	5	5
3. Tree canopy height	5	3	5	5	3
4. Tree canopy cover	5	2	0	5	5
5. Shrub canopy cover	3	5	3	3	3
6. Native perennial grass cover	3	1	5	0	1
7. Organic litter	5	3	5	3	5
8. Coarse woody debris	2	5	3	5	0
9. Non-native cover	5	5	10	3	10
Landscape-scale attributes					
10. Size of patch (Fragmented)	5	0	0	7	5
11. Connectivity (Fragmented)	2	4	0	4	2
12. Context (Fragmented)	2	2	0	5	2
13. Distance from water (Intact)	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
2018 score	**62.0**	**52.5**	**51.0**	**57.5**	**56.0**
2014 score	**67.5**	**46.0**	**51.0**	**81.5**	**55.0**

[1]n-r, non-remnant

As anticipated, BioCondition scores for monitoring sites in native vegetation are highly variable due to the variety of influences affected each patch. The patch of fringing forest along the Dawson River (Site 22) scores highly in part, due to its relatively intact structure, connectivity and context in the landscape and moderate species richness, however the score is lessened by the dominance of exotic grass in groundcover layer and subsequent lack of native grass. The patch of Narrow-leaved Red Ironbark (Site 10) scores moderately due to a lack of connectivity and landscape context and moderate cover of weeds. The non-remnant areas score poorly due to the lack of connectivity and landscape context and lack of mature trees.

Table 5 describes the BioCondition scores for each of the monitoring sites conducted in rehabilitation areas. Given that the composition and structure

of the rehabilitation areas is not, or unlikely to ever be representative of a regional ecosystem, the benchmark used was for RE 11.9.9 (Narrow-leaved Red Ironbark woodland). The rationale for this approach is based primarily on the fact that this RE occurs in close proximity to a number of the sites and the seed mix is more indicative of a eucalypt woodland than Brigalow or riparian fringing forest.

Table 5: BioCondition scores for monitoring plots – rehabilitation

BioCondition parameter	Monitoring site number				
	1	**8**	**11**	**16_D**	**17**
Site-based condition attributes					
1. Recruitment of woody perennial species	3	5	5	3	5
2. Native plant species richness					
- trees	5	0	0	5	5
- shrubs	0	2.5	0	2.5	2.5
- grasses	2.5	0	2.5	0	2.5
- forbs and other	5	2.5	2.5	2.5	2.5
3. Tree canopy height	5	0	0	3	0
4. Tree canopy cover	3	0	0	3	0
5. Shrub canopy cover	5	3	5	5	3
6. Native perennial grass cover	0	0	1	0	0
7. Organic litter	5	3	3	3	3
8. Coarse woody debris	2	0	0	0	2
9. Weed cover	5	5	5	5	5
Landscape-scale attributes					
10. Size of patch (Fragmented)	0	0	0	0	0
11. Connectivity (Fragmented)	0	0	0	0	0
12. Context (Fragmented)	0	0	0	0	0
13. Distance from water (Intact)	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
2018 Score	**40.5**	**21.5**	**24.0**	**32.0**	**30.5**
2014 Score	**31.5**	**15.5**	**18.0**	**36.0**	**25.0**

The BioCondition scores for the rehabilitation sites are, as anticipated, low. This is largely due to a poor and generally non-representative structure, low species richness, high weed infiltration and absence of connectivity and landscape context. The three higher scores can be attributed to the presence of some eucalypt species. It is considered unlikely that these scores will significantly improve over time.

3.1.3 Time comparisons

The data collated from the 2018 survey was compared with the previous surveys undertaken in 2014, 2011, 2008 and 2005. The results are shown in Table 6.

Table 6: Comparison of vegetation structure of common plots over time

Site	Year				
	2005	**2008**	**2011**	**2014**	**2018**
Taxa (in 500 m² plot)					
1	12 (8)	12 (8)	8 (7)	10 (2)	15 (3)
8	18 (12)	16 (6)	6 (1)	11 (12)	14 (15)
10	*n/p*	*n/p*	33 (3)	49 (4)	61 (5)
11	11 (5)	18 (11)	15 (7)	10 (7)	17 (16)
16_D[1]	*n/a*	27 (19)	13 (9)	11 (6)	18 (8)
17	*n/a*	23 (15)	15 (10)	12 (6)	18 (9)
18	*n/a*	*n/a*	21 (1)	26 (2)	33 (2)
19	*n/a*	*n/a*	12 (8)	28 (11)	31 (12)
22	*n/a*	*n/a*	25 (10)	30 (11)	44 (15)
23	*n/a*	*n/a*	17 (2)	21 (2)	35 (1)
Average Cover (%)[1]					
1	17	59	67	76	75
8	10	64	88	55	100
10	*n/p*	*n/p*	152	93	90
11	13	75	58	55	83
16_D	n/a	87	103	82	70
17	n/a	94	92	116	83
18	n/a	n/a	122	89	59
19	n/a	n/a	93	132	88
22	n/a	n/a	72	98	109
23	n/a	n/a	102	84	64

[1] Of all vegetation (woody and non-woody) in 500 m² plot, which will include specimens in various layers overlapping (hence covers in excess of 100%)

The 2018 results, as was primarily the case in 2014, display a high variability across the triennial monitoring periods and a general absence of any discernible linear trends at certain sites (8, 19 and 23). This situation may in part be attributable to the methodology being altered and improved between monitoring events in response to the release of the BioCondition methodology and/or the site location being re-located.

3.2 Fauna assessment

3.2.1 Fauna habitat assessment

Fauna habitat assessments were completed for monitoring sites 1, 8, 10, 11, 16D, 17, 18, 19, 22 and 23. Descriptions for these sites are consistent with the 2014 monitoring surveys (EcoSM 2014). Table 10 presents a brief description of each fauna monitoring site visited during the 2018 surveys along with the key fauna habitat elements identified at each site. These descriptions are consistent with the 2014 and 2012 monitoring reports(EcoSM 2014; Footprints Environmental Consultants 2012). More detailed descriptions of the vegetation community at each monitoring site visited during the 2018 surveys along with representative photos are provided in Appendix A.

Table 7: Survey site descriptions and key fauna habitat characteristics

Site no.	Key fauna habitat characteristics
1	A mixed eucalypt and *Acacia* woodland to about 15 m (planted circa 1991). The trees did not support limb or trunk hollows and decorticating bark was scarce. Ground rocks up to 45 cm diameter were common. Tussock grass cover (principally Buffel Grass (**Cenchrus ciliare*)) was sparse on the upper and mid slopes of the site, whilst very dense at the foot of slope. Large ground logs were absent with only twigs and small branches (to about 3 cm) present though uncommon. The site was surrounded by rehabilitation (primarily Sally Wattle (*Acacia salicina*) and Buffel Grass). Kianga Creek diversion (and wetlands) and small remnants of native vegetation occur within close proximity of the site (Footprints Environmental Consultants 2012).
8	Stakes to mark this site could not be located so was re-established based on co-ordinates from the 2011 monitoring survey. This site was situated on the crest of mine spoil with no topsoil applied prior to rehabilitation. The site was very rocky with some very large boulders (up to 1 m in diameter) and deep crevices between groups of boulders. Sally Wattle dominated the shrub/small tree layer. No topsoil was present and ground cover was sparse and dominated by a variety of exotic grasses and herbs. There was no litter or ground timber present.
10	This terrestrial site supported an open woodland dominated by ironbarks (*Eucalyptus melanophloia* and *E. crebra*) with a shrubby and floristically diverse understorey and a grassy ground cover on a thin veneer of soils and sand stone. The relative dominance of native grasses was notable. Tree limb hollows were present, though not common and mainly small (e.g. <75 mm in diameter). Tree stags and fallen timber (including large ground logs) were abundant throughout the site. Ground rocks were also common. This site was located on the western side of a large bushland remnant (which also incorporates monitoring sites 15, 20 & 21). Silverton Creek, a small ephemeral watercourse, was located to the north of the site and a small, relatively permanent body of open water has been created by the impoundment of the creek. A coal conveyor was located to the immediate west of the site (Footprints Environmental Consultants 2012).
11	This site was situated on the upper slopes of rehabilitated mine spoil and was comprised of scattered, tall (to approximately 6 m) Sally Wattle with a low, sparse to moderately dense ground cover of Buffel Grass. In parts, ground rocks (to about 25 cm) were common. Several large depressions on the eastern side of the site are likely to support short-lived seasonal wetlands.
16D	This site was situated on the lower slope of rehabilitated mine spoil in the central portion of the Dawson Mine. Woody vegetation was dominated by Sally Wattle and Spotted Gum with Yellow Bells also prevalent. The relatively young age of the trees and shrubs meant tree hollows and decorticating bark were absent. The groundcover was dominated by patchy areas of Buffel Grass and litter. No large woody debris was present. Surface boulders and rubble supporting voids and cracks was also prevalent in some areas.
17	This site was situated on a mid-tier terrace of rehabilitated mine spoil in the Dawson North section of the Dawson Mine. Woody vegetation was arranged in two rows following the contour and was dominated by Sally Wattle and Spotted Gum. Due to the relatively young age of the vegetation no hollows or decorticating bark was present. The ground cover was dominated by a dense thatch of Pale Pigeon Grass and to a lesser extent native grasses. Felled trees have been placed about the terrace, particularly adjacent the planted trees, and support hollows and decorticating/decomposing bark. Boulders and

Site no.	Key fauna habitat characteristics
	surface rock supporting voids were also present. Little leaf litter development had occurred and the area is isolated from patches of remnant vegetation.
18	This site straddled two vegetation communities. One an open woodland of Narrow-leaved Red Ironbark and Silver-leaved Ironbark with Clarkson's Bloodwood present on a thin veneer of soils and sand stone. Native grasses, primarily barbed-wire grass (*Cymbopogon refractus*), dominated ground cover but Kangaroo Grass (*Themeda triandra*) was also common. Ground rocks were patchy, primarily restricted to bedrock outcropping and there was little to no ground timber present (Footprints Environmental Consultants 2012). Litter development tended to be patchy and shallow. The other community was a restricted patch of woodland dominated by Brigalow. This community supported stags with decorticating bark and had more ground timber.
19	The site was situated in regrowth vegetation dominated by River Red-gum and Sally Wattle. The mature River Red-gum were predominately dead and supported hollows of various sizes. The ground cover was dominated in places by Umbrella Canegrass (*Leptochloa digitata*) close to the creek edge and a variety of native and exotic grasses in more open areas. Moderate amounts of ground timber and litter were present.
22	This site was located on an alluvial terrace within the riparian zone of the Dawson River and supported an open woodland dominated by Coolabah and Queensland Blue Gum on alluvial soils. The mature trees and stags supported hollows of various sizes. Ground cover was very low due to grazing and dominated by exotic grasses. Ground timber was sparse and litter development, though present, was shallow.
23	The vegetation at this site was dominated by closed Brigalow woodland on grey cracking clay soils. Ground cover was comprised of native, low tussock grasses. Ground timber was scarce to absent and there were no ground rock resources (Footprints Environmental Consultants 2012). Deep cracks had emerged in the clay and deep litter development was present in places. There was also evidence of weak gilgai depressions through the site. It appears that this site may have been cleared and the resultant Brigalow vegetation is regrowth. Neighbouring vegetation communities support tall open woodlands of Dawson Gum and Brigalow with an understory of vine thicket generalist species (Footprints Environmental Consultants 2012).

3.2.2 Terrestrial vertebrate fauna survey

A total of 104 species of terrestrial vertebrates were recorded from across the ten sites surveyed during the 2018 fauna monitoring surveys. This includes 7 species of amphibian (including one introduced species), 61 species of bird, 21 species of mammal (including 12 species of microbat and 1 introduced species) and 15 species of reptile. A complete list of the terrestrial vertebrate fauna detected during the 2018 fauna monitoring survey is provided in Appendix C.

Table 8 presents a summary of the fauna data including the species richness of each faunal group along with relative abundance at each monitoring site.

Table 8: Species richness of each faunal group recorded from each monitoring site

Faunal group	Monitoring site number and type									
	S1	S8	S11	S16D	S17	S10	S18	S19	S22	S23
	BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
	Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Amphibians	0	1	1	0	0	1	1	5	4	0
Birds	6	8	11	12	17	17	11	19	20	25
Mammals	8	12	7	13	7	12	11	8	10	10
Reptiles	1	3	0	0	0	4	4	0	6	3
Total	15	24	19	25	24	34	27	32	40	38

Table 8 indicates that the observed species richness is greater in areas supporting native vegetation in comparison to areas of rehabilitation.

3.2.2.1 Conservation significant fauna

No conservation significant fauna were recorded at any of the monitoring sites during the 2018 surveys.

It is noted the Powerful Owl (*Ninox strenua*), listed as vulnerable under the NC Act, was recorded at site 22 during the 2014 surveys. This species was not detected again at this site in 2018.

3.2.2.2 New fauna

The 2018 fauna monitoring surveys identified 10 species that have not been recorded during previous monitoring events. The newly identified fauna consisted of 1 new species of amphibians, 7 new bird species, 1 new mammal species and 2 new reptile species. Table 9 presents a list of the newly identified faun species within the Dawson Mine area.

Table 9: New fauna species recorded during the 2018 fauna monitoring survey

Common name	Scientific name	Status[1]		Sites	BMU
		NC Act	EPBC Act		
Amphibians					
Green-striped Burrowing Frog	*Cyclorana alboguttata*	LC	NL	19, 22	5
Birds					
Australian Hobby	*Falco longipennis*	LC	NL	18	4
Collared Sparrowhawk	*Accipiter cirrocephalus*	LC	NL	19	5
Eastern Egret	*Ardea modesta*	LC	NL	10	2
Eastern Yellow Robin	*Eopsaltria australis*	LC	NL	23	2
Grey Butcherbird	*Cracticus torquatus*	LC	NL	18	4
Superb Fairy-wren	*Malurus cyaneus*	LC	NL	17	3

Common name	Scientific name	Status[1]		Sites	BMU
		NC Act	EPBC Act		
Mammals					
Squirrel Glider	*Petaurus norfolcensis*	LC	NL	22	5
Reptiles					
Prickly Knob-tailed Gecko	*Nephrurus asper*	LC	NL	10, 18	2, 4
Robust Velvet Gecko	*Nebulifera robusta*	LC	NL	22	5

[1]Status under the Queensland *Nature Conservation Act 1992* (NC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act): LC, Least concern; NL, Not listed; *, Introduced species.

Based on the fauna database complied as part of the 2011 Fauna Monitoring Report (Footprints Environmental Consultants 2012 Appendix D Tables 10 through 13) and the results of the 2014 monitoring event (EcoSM 2014) a total of 316 fauna species had been identified within the Dawson Mine. The total number of fauna species is now 326 and consists of 18 amphibians, 54 reptiles, 196 birds and 58 mammals after the 2018 fauna monitoring surveys.

3.2.2.3 Introduced fauna

Two species of introduced fauna were recorded during the 2018 fauna monitoring survey, namely Cane Toad (**Rhinella marina*) and Feral Cat (**Felis catus*). Both species were directly observed with Cane Toads recorded at sites 8, 10, 11, 19 and 22 during spotlighting and/or active searching. A single Feral Cat was recorded on the infrared camera set at site 19.

The Feral Cat is a restricted invasive animal under the *Biosecurity Act 2014*. Under the Act, restricted invasive animals must not be moved, fed, given away, sold, or released into the environment without a permit. The Act also requires everyone to have a general biosecurity obligation (GBO), which means all reasonable and practical steps to minimise the risks associated with invasive animals under their control must be taken.

A total of 11 introduced fauna have been recorded from the Dawson Mine Area during previous fauna monitoring surveys. Table 10 presents a list of introduced species compiled from previous surveys with those species recorded during the 2018 survey indicated.

In addition, the Feral Cat, Dog, Fox and Pig are considered to be key threating processes for a variety of conservation significant fauna.

Table 10: Introduced fauna recorded in the Dawson Mine area

Common name	Scientific name	Biosecurity Act status[1]	Present 2018
Cane Toad	*Rhinella marinus*	I	X
House Sparrow	*Passer domesticus*	I	-
House Mouse	*Mus musculus*	I	-

Common name	Scientific name	Biosecurity Act status[1]	Present 2018
Dog	*Canis familiaris*	RI, Category 3, 4 and 6	-
Dingo	*Canis lupus dingo*	RI, Category 3, 4, 5 and 6	-
European Red Fox	*Vulpes vulpes*	RI, Category 3, 4, 5 and 6	-
Feral Cat	*Felis catus*	RI, Category 3, 4 and 6	X
European Brown Hare	*Lepus capensis*	I	-
European Rabbit	*Oryctolagus cuniculus*	RI, Category 3, 4, 5 and 6	-
Feral Pig	*Sus scrofa*	RI, Category 3, 4 and 6	-
Cattle	*Bos taurus*	I	-

[1]Biosecuity Act Status: RI, Restricted invasive animal; I, Invasive animal. Category numbers are assigned to restricted matters under the Act to assist with regulation of activities such as reporting, disposal, movement and keeping of restricted matters.

X – Species recorded during the 2018 fauna monitoring survey

4 Discussion

4.1 Vegetation assessment

As anticipated, the general condition of the rehabilitation areas was found to be poor in comparison to native vegetation communities within or surrounding the Dawson Mine. Notwithstanding the lack of structure, species richness and diversity, poor habitat value and poor soil structure, the rehabilitation areas have shown some value in stabilising the re-contoured WRD.

General trends in relation to woody vegetation height, cover, richness and stem count were difficult to determine given the variability of the surveys. These differences include:

1. variability of survey methodology
2. re-establishing the monitoring plot at an alternative location
3. four different assessment teams

Seasonality also plays an important role wherein by conducting the flora survey at the end of the dry season the survey runs the risk of sampling an atypical representation of growth. That is, generally grasses and annual herbs are difficult to identify at the end of the dry season, but if the region was subjected to a late wet season, atypical winter rains or scattered spring storms, the representation of these species would be highly variable and potentially over-represented. This compares with BioCondition monitoring that usually occurs post-wet season when all plants that naturally occur at any given location are likely to be present and easily identifiable.

In 2014, the scope of works was modified to align with BioCondition monitoring methodologies that have been designed by the Queensland Herbarium. This methodology, which was used again in 2018, has been used in the ecological assessment industry over the last twelve years and has undergone several revisions to ensure ease of use and repeatability. Further, the herbarium has over the last twelve years compiled a broad database of BioCondition benchmarks and continues to add new and refine existing benchmarks.

The application of this methodology in future monitoring surveys will enable a qualitative and quantitative approach to assessing the failings or improvements of not only the rehabilitation areas but also native vegetation within and fringing the Dawson Mine. This will also minimise subjectivity in assessing covers and tree heights.

In relation to the actual BioCondition of the surveyed areas, the current rehabilitation sites generally show limited signs of progress toward a self-sustaining functional ecosystem. The primary eucalypt species, where present, include Spotted Gum, Dawson Gum and to a lesser extent Narrow-leaved Red Ironbark, Silver-leaved Ironbark, Queensland Blue Gum and Rusty Jacket. It should be noted that a number of these species do not occur in or within close proximity of the Dawson Mine. Further, these species generally do not occur in the composition that has been recorded in the mine. It is therefore difficult to assess the BioCondition and overall value of these areas, as a local, regional or even bioregional equivalent vegetation

type does not exist. Notwithstanding this limitation, it was observed that the aforementioned eucalypt species have successfully established on re-contoured mine spoil and, in many cases, in the absence of re-instated topsoil.

An issue of concern is the tendency for the majority of rehabilitation at Dawson Mine to be dominated by Sally Wattle above a sparse to mid-dense cover of Buffel Grass. In addition, the establishment of Butterfly Pea and the expansion of Yellow Bells are considered a significant threat to the long-term value and viability of the rehabilitation areas.

The discovery of four threatened flora species in relatively intact Brigalow regrowth (Site 23) is considered to be positive outcome for the survey. Monitoring of the population of these species in this area should be incorporated into future monitoring surveys.

4.2 Fauna assessment

In line with previous surveys, the 2018 fauna monitoring surveys found a greater diversity of species from monitoring sites located in the remnant or non-mined (BMUs 2, 4 and 5) (Table 11). This result follows the widely held ecological principle that fauna species richness increases with habitat heterogeneity (Stein et al. 2014). The theory suggests that heterogeneous habitats offer more niche space, provision of refuges and opportunities for isolation and divergent adaptation are thought to enhance species coexistence, persistence and diversification (Stein et al. 2014). There were higher levels of floristic diversity and structural complexity found within the remnant and non-mined monitoring sites when compared to rehabilitated monitoring sites.

The rehabilitated monitoring sites surveyed were structurally and floristically simple with woody vegetation tending to be dominated by a few hardy species such as Sally Wattle and the introduced Yellow Bells. At rehabilitated monitoring sites, where eucalypts had been planted, they tended to occurred in linear rows and were still relatively young. The immature eucalypts lacked important fauna habitat features such as hollows and decorticating bark. They also do not provide course woody debris which mature eucalypts provide as their limbs senesce or are removed by strong winds. In addition, the ground covers in rehabilitated areas tended to be dominated by dense exotic grasses particularly Buffel Grass and lacked significant leaf litter development. All these elements in combination provide the variety of habitat resources to support a variety of fauna species. These habitat features were more commonly found to be present at the remnant/non-mined monitoring sites.

The species encountered within the rehabilitated monitoring sites tended to be hardy generalists that were typically adaptive, highly mobile or disturbance tolerant. Highly mobile species (birds, bats and larger mammals) are able to forage across larger areas and retreat to more suitable areas of habitat for refuge and potentially breeding.

The previous surveys have grouped the fauna assemblages into those detected in rehabilitated lands and those detected in remnant or non-mined lands. In the interest of consistency the same grouping has been applied to the 2018 fauna data and it is presented in Table 11 and Figure 2. The table

and figure also includes data from the 2005, 2008, 2011 and 2014 surveys to allow comparison. It should be noted that a different number of sites have been surveyed during monitoring events making direct comparison between monitoring events difficult.

During the 2018 and 2014 monitoring 10 sites (5 remnant and 5 rehabilitated) were surveyed while 13 sites (4 remnant and 9 rehabilitated) were surveyed in 2005 and 17 sites (8 remnant and 9 rehabilitated) were surveyed in 2011. Unfortunately the fauna data set for the 2008 monitoring surveys was incomplete and the data presented here is sourced from the 2011 survey report (Footprints Environmental Consultants 2012).

Table 11: Comparison of the fauna recorded in rehabilitated and remnant lands at Dawson Mine across four monitoring years

Lifeform	2005		2008		2011		2014		2018	
	Rem	Rehab	Rem	Rehab	Rem	Rehab	Rem	Rehab	Rem	Rehab
Amphibians	8	7	8	11	6	6	5	2	7	1
Birds	105	87	105	97	54	120	47	25	56	28
Mammals	27	20	27	20	22	28	19	11	20	16
Reptiles	15	7	15	13	15	13	15	4	14	3
Total	**155**	**121**	**155**	**141**	**97**	**167**	**86**	**42**	**97**	**45**

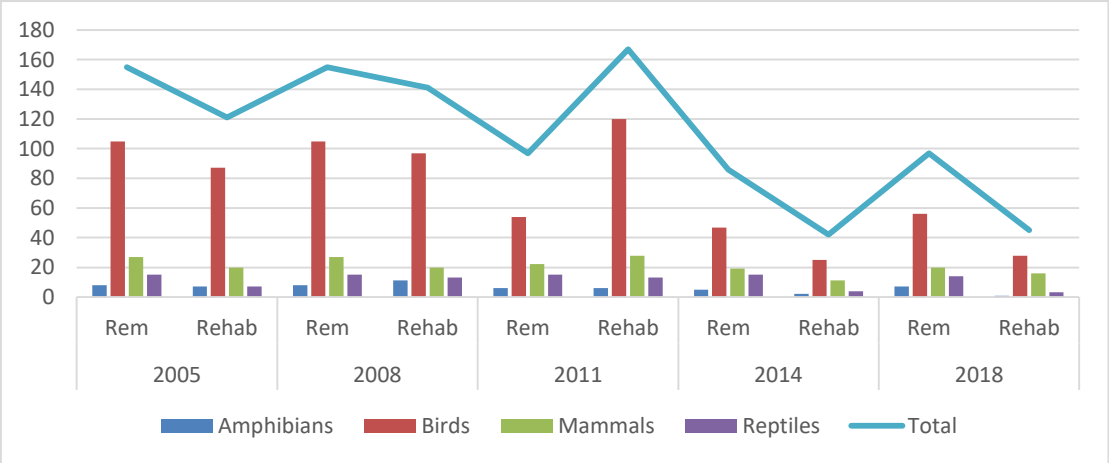


Figure 2: Fauna species richness at Dawson Mine across five monitoring events

The 2018 monitoring surveys found a further reduction in fauna species richness in both remnant and rehabilitated lands. However, with the exception of the 2011 surveys, remnant lands continue to support a greater species richness across the majority of faunal groups. The most significant reduction in species richness occurred with the bird fauna. This may be a result of the minor differences in methodology, the very dry conditions prior to the 2018 monitoring event and/or the reduced number of monitoring sites surveyed. Previous monitoring years have also conducted dedicated

water bird surveys on dams and other impoundments were bird diversity tends to be high.

The species richness of the other faunal groups recorded during the 2018 fauna monitoring survey was not significantly different to previous years.

4.2.1 Threatened fauna

Previous surveys have recorded a variety of species of conservation significance within the Dawson Mine area. Species recorded include one bird, three reptiles and one mammal (Footprints Environmental Consultants 2012). In addition, eight species of migratory bird have also been recorded.

A review of the records for these species found that the monitoring sites where the reptiles and Koala (*Phascolarctos cinereus*) were identified were not part of the 2018 monitoring survey and the birds were all recorded through incidental observations rather than through bird census at monitoring sites.

The Powerful Owl was also recorded from Site 22 during the 2014 along the Dawson River. Although only one call was heard meaning that this species' presence could not be absolutely confirmed. This species was not recorded at this site in the 2018 survey.

5 Recommendations

The current rehabilitation approach has delivered a variable distribution of native woody species that in general terms fails to resemble native ecosystems that are comparable to vegetation communities in the vicinity of the active mining area. However, in some areas the eucalypts have become well established, but are also prone to falling over due to the rockiness of the underlying substrate and in some respects unsuitability of the substrate for particular species.

The following recommendations are presented for consideration of the Dawson Mine Environmental team.

5.1 Current rehabilitation monitoring

The rehabilitation monitoring program has been conducted over a number years by a variety of technical professionals. This has in many instances, and for reasons that remain unclear, led to changes in methodology and the locations of monitoring sites. These changes have ultimately led to a less rigorous approach data comparison and trends over time. One trend that is clear from the monitoring data collected in 2005, 2008, 2011, 2014 and 2018 is that the mine site rehabilitation areas surveyed are not consistent with the 'desired states and transitions' for creation of a native ecosystem outlined in the Dawson Three-year Rehabilitation Plan 2017-2019 (Rehabilitation Strategy). Further, the rehabilitation areas are displaying traits more consistent with the 'undesired transition' states identified in the Rehabilitation Strategy in that the majority of monitoring sites were found to:

- have a low rate of native trees and shrubs establishment
- have a simple structure, which lacks a distinct canopy, sub-canopy, shrub and ground layer
- support a low diversity of tree and shrubs species, with Sally Wattle being particularly prevalent
- support moderate to high levels of Yellow Bells, Buffel Grass, Butterfly Pea and/or , Feral Leucaena (**Leucaena leucocephala*) infestations
- have encroaching populations of WONS, e.g. Rubber Vine (**Cryptostegia grandiflora*).

Given the above, it is recommended that the focus on existing areas of mine site rehabilitation shifts from monitoring the condition of the vegetation, to identifying and implementing appropriate 'management manipulations' as outlined in the Rehabilitation Strategy.

Of particular concern is the extent of Yellow Bells infestations throughout some areas of rehabilitation. Yellow Bells is a restricted invasive plant under Queensland's *Biosecurity Act 2014* and there is a requirement for landholders and managers to take all reasonable and practical steps to minimise the risks associated with invasive plants under their control. This is called a general biosecurity obligation (GBO). Moreover, effective management of Yellow Bells across the mine site rehabilitation will be critical to achieving the broader goal of creating a 'non-polluting'

environment. Specifically, the extensive infestations of this species are currently providing a significant source of seed (which is wind-blown) and vegetative propagules for ongoing persistence in the rehabilitation areas, as well as colonisation of surrounding environments.

The following management manipulations should be considered in relation to control of Yellow Bells infestations.

- M1 - Chemical removal of grass and weed species and/ or a controlled burn.
- M4 - Spot spraying of weed species and grasses, controlled burn and/ or introduced grazing.

It is highly recommended that the Dawson Environmental Team liaises with Biosecurity Queensland and/or Banana Shire Council with regards to the developing an effective management program for Yellow Bells. Given this species is a disturbance specialist that can reproduce via seed and root suckers, there is a risk in using fire (i.e. a disturbance event) to manage populations. At present, the Queensland Government recognises physical removal and chemical control as appropriate control measures for this species. However, these approaches may not be cost-effective over a broad area.

Other management manipulations that warrant consideration involve measures to establish a more diverse and structurally complex community. This will ultimately assist with the control of Yellow Bells infestations through competitive exclusion and creation of a more shaded environment that this species is less likely to colonise or persist in.

- M1 – Re-seeding with native tree/shrub seed mix
- M2 – Direct return of high quality topsoil with viable understory seed bank
- M3 – Re-seed with higher diversity seed mix of non-*Acacia* species.
- M6 – Addition of fresh topsoil, spreading of organic material including seed containing litter. Translocation of juvenile understory and shrub species.

With regard to the above, in some areas of rehabilitation it would be worth considering changing the objective from creating a native ecosystem to creating a semi-evergreen vine thicket (SEVT) in line with the Rehabilitation Strategy. In particular, the establishment of SEVT is more likely to be successful on the steep and rocky slopes of former mine voids and spoil dumps, due to the normal tendency of this community to persist in skeletal soils on rocky scree slopes. The establishment of eucalypt woodlands on this landform is less likely to be successful given the underlying substrate is not compatible with the establishment of large, deep-rooted trees. It is understood that trials for the establishment of SEVT have been factored into the Rehabilitation Strategy. A preliminary trial was visited in December 2018 as part of the current monitoring program. Preliminary assessment of this trial ascertained that in essence, this trial had been poorly planned and implemented. It appeared that tube-stock had been planted in widely spaced rows at approximately 5 m centres and that these plants had been irrigated by hand during their establishment. This approach is incredibly

cost-intensive and moreover has failed to achieve the primary intent of this planting, which is to establish a dense cover of vegetation to minimise weed infiltration but more importantly erosion.

Follow-up monitoring should then be specifically designed to gauge the success of management manipulations in correcting the trajectory of the rehabilitation towards achieving desired states and transitions. It is recommended that the implemented monitoring program is staged and performances objectives are developed that assess the parameters specific to each desired state. Table 12 provides some recommended parameters and approaches to monitoring for each desired state listed in the Rehabilitation Strategy.

Table 12: Recommended performance objectives for desired states

Desired state[1]	Years[2]	Recommended parameters	Suggested approach
S1	<5 yrs	Weed control, particularly Yellow Bells: ▪ rate of mortality following initial and subsequent control measures ▪ rate of regeneration via seed and/or rootstock following initial and subsequent control measures ▪ % cover of infestations ▪ % flowering and fruit set. Re-establishment of structural complexity and species richness: ▪ appropriate locally endemic species used in seed mix (if M1 is applied) ▪ rates of germination and establishment of canopy, sub-canopy, shrub and groundstorey species (if M1 – M3 applied) ▪ rates of transplant survival and establishment (if M6 applied) ▪ cover of weed species.	▪ Permanent replicate plots – for consistency with later stages where the BioCondition methodology is appropriate, a 50 x 100 m plot is recommended. ▪ Parameter specific methodology to be developed that is repeatable and measurable against a set performance objective (e.g. 90% mortality of Yellow Bells infestations following initial treatment, minimum number of trees and shrub species establishing - with reference to BioCondition benchmarks). ▪ Monitoring should be more frequent following implementation of management manipulation, becoming less-frequent over time. ▪ Preparation of a Trigger Action Response Plan (TARP) will assist in identifying and appropriately responding to areas where set performance objectives are not being met and the trajectory of rehabilitation works has shifted towards undesired states and transitions are occurring.
S2	5-10	Weed control, particularly Yellow Bells: ▪ % cover of infestations ▪ % flowering and fruit set. Re-establishment of structural complexity and species richness:	▪ Established permanent replicate plots. ▪ Parameter specific methodology to be developed that is repeatable and measurable against a set

Desired state[1]	Years[2]	Recommended parameters	Suggested approach
		▪ height, cover and DBH of canopy species ▪ cover of native sub-canopy, shrub and groundstorey species ▪ species richness in each stratum ▪ cover of weed species.	performance objective for weed control parameters ▪ BioCondition methodology for: - tree height and cover - sub-canopy, shrub and groundstorey cover - species richness - weed species cover ▪ modified BioCondition methodology to measure tree DBH – measure all trees within 20 x 50 m plot ▪ Two-yearly monitoring is recommended. ▪ Follow TARP as required.
S3	10-20	Weed control, particularly Yellow Bells: ▪ % cover of infestations ▪ % flowering and fruit set Re-establishment of structural complexity and species richness: ▪ height, cover and DBH of canopy species ▪ cover of native sub-canopy, shrub and groundstorey species ▪ cover of weed species ▪ cover of organic litter ▪ coarse woody debris.	▪ Established permanent replicate plots. ▪ Parameter specific methodology to be developed that is repeatable and measurable against a set of performance objectives for weed control parameters ▪ BioCondition methodology for: - tree height and cover - sub-canopy, shrub and groundstorey cover - species richness - weed species cover - coarse woody debris ▪ modified BioCondition methodology to measure tree DBH – measure all trees within 20 x 50 m plot ▪ Five-yearly monitoring is recommended. ▪ Follow TARP as required.
S4	5	Weed control, particularly Yellow Bells: ▪ % cover of infestations ▪ % flowering and fruit set Re-establishment of structural complexity and species richness: ▪ Height and cover of canopy species ▪ cover of native sub-canopy, shrub and groundstorey species ▪ large trees	▪ Established permanent replicate plots. ▪ Parameter specific methodology to be developed that is repeatable and measurable against a set of performance objectives for weed control parameters ▪ BioCondition methodology for: - tree height and cover - sub-canopy, shrub and groundstorey cover - large trees

Desired state[1]	Years[2]	Recommended parameters	Suggested approach
		▪ cover of weed species ▪ cover of organic litter ▪ coarse woody debris.	- species richness - weed species cover - coarse woody debris ▪ ten-yearly monitoring is recommended. Follow TARP as required.

[1] Desired states taken from the Rehabilitation Strategy

[2] Years since management manipulation

The following additional measures are also recommended for the rehabilitation program:

1. expand the scope of future monitoring surveys to include monitoring of the populations of the four threatened flora species at Site 23
2. establish or bolster top of batter rills to divert/prevent excessive run-off
3. introduce logs into rehabilitation areas when available from vegetation clearing on the site.

5.2 Future rehabilitation monitoring

The success of future rehabilitation programs in achieving the objectives set out in the Rehabilitation Strategy will be dependent on a number of factors, including:

- appropriate treatment and re-contouring of the post-mining landform - avoid deep ripping of rehabilitation areas that results in large rocks being brought to the surface and only lightly rip the reinstated topsoil, where applied, with smaller and more closely spaced tynes (depending on whether top-soil is being applied)
- identification of target vegetation communities appropriate to the post-mining landform (i.e. refer discussion of eucalypt woodland versus SEVT in Section 5.1)
- use of appropriate locally endemic species in seed mixes (where applicable)
- development of fit-for-purpose performance objectives that are measurable, repeatable and relevant to the 'desired states and transitions' outlined in the Rehabilitation strategy (refer Table 12)
- development of a monitoring program and methodology that measures the success of rehabilitation in achieving the set performance objectives (refer Table 12)
- development of a TARP to provide a framework for responding to non-compliance of rehabilitation areas with the set performance objectives.

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Appendix A

Flora - Monitoring site data

BIO-CONDITION ASSESSMENT									
Date: 12/12/2018			**Collector:**	Chris Hansen and Monica Campbell			**SITE:** BC001		
Time: 11:45			**Job No.**	18057					
Mapped RE:	nil								
Field RE:	nil					**Lot on Plan**: Lot 78 on DW485 (ML 5630)			
Structure:	mixed species rehabilitation (planted)								
Slope : 12 %	**Aspect:** E		**Landform (local):** upper slopes			**Landform (broad):** re-contoured spoil dump			
Slope Shape:	convex								
Soils:	Rocky spoil, rough with pale grey to grey-brown, coarse rocky to gravely surface and occasional large boulders.								
Litter: 20-50	**Bare Soil**: 8		**Timber:** 3 -		**Rock**: 30		**Groundcover**: 10-40		
PHOTOS:	Photo No.	8471	8472	8473	8474	8477	8470	8475	8476
	Direction	N	E	S	W	0m - 65°	100m - 245°	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES: -very atypical adjustment of the monitoring plot that was undertaken in 2005 & 2008, wherein it has been moved from a Sally Wattle low woodland to tall open shrubland, which is representative of the primary vegetation cover on the broader rehabilitated mine spoil, to a narrow stand of Dawson River Gum and Spotted Gum

- plot run straight down slope rather than across the contour
- plot terminates in a small atypical stand of Belah
- old tubes (90 x 50 mm) scattered throughout the patch would indicate that these species have resulted from planted tubestock
- old pitfall line located in the patch of Belah at the toe of slope, as well as various labeled stakes scattered throughout
- vehicular access track close to the plot (approximately 30 m to the west)

REMNANT	~~Y~~	**N**	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**: start	**Latitude**: -24.659602	**Longitude**: 150.048001

(please circle)	median	height range (m)	intercept	dominance	Species
T1 [EDL]	15	12-20	V-S <5 -20%	d	*Eucalyptus cambageana*
				a/c	*Corymbia citriodora* subsp. *variegata*
				a/s	*Eucalyptus longirostrata*
T2	8	6-9	V 5-10%	d	*Acacia salicina*
				a/s	*Casuarina cristata,* juvenile T1
S1	4	1-6	V <5%	d	*Acacia salicina*
				a	-
S2					
G	0.4	0.01-0.7	V-M	d	**Cenchrus ciliaris*
				a/s	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
Eucalyptus cambageana		1	9		**Type**	**Severity (0 to 3)**
Corymbia citriodora			5		**Fire (& height in m)**	<1
Eucalyptus longirostrata			1		**Clearing**	n/a
"stag"	1	1			**Thinning/Ringbarking**	n/a
Acacia salicina	1	4	1		**Grazing**	0
					Exotic Flora	3 (g/c)
					Canopy Dieback	0
					Erosion	0
					Recruitment	<1
					Other	

SITE NUMBER: BC001	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Eucalyptus cambageana	4-5	T1
Corymbia citriodora subsp. *variegata*	4	T1
Acacia salicina	3-4	S1-T2
Eucalyptus tereticornis subsp. *tereticornis*	+	T1
**Cenchrus ciliaris*	6	G
Rhynchosia minima var. *australis*	+	G
Aristida ramosa	+	G
**Tridax procumbens*	2	G
Chamaesyce drummondii	+	G
Heteropogon contortus	+	G
Enneapogon gracilis	+	G
Enchylaena tomentosa var. *glabrescens*	+	G
Achyranthes aspera	2	G
Pterocaulon serrulatum	1	G
Einadia polygonoides	+	G
Mukia maderaspatana	+	G
**Cryptostegia grandiflora*	+	S1
Abutilon malvifolium	+	G

Species	Presence	Strata

BIO-CONDITION PARAMETERS			DATE: 12/12/2018			SITE: BC001					
GROUNDCOVER: (ten 1 x 1m plots)											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	0	0	0	0	0	0	0	0	0	0	**0**
Native herbs & forbs (non-grass)	0	0	0	0	0	0	0	0	0	0	**0**
Native shrubs (<1m in height)	0	0	0	0	0	0	0	0	0	0	**0**
Non-native grass	25	0	0	3	5	20	45	25	15	0	**13.8**
Non-native herbs & shrubs	0	0	0	0	0	0	0	0	0	0	**0**
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	**0**
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	**0**
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	**0**
Non-aquatic sedges	0	0	0	0	0	0	0	0	0	0	**0**
Ferns	0	0	0	0	0	0	0	0	0	0	**0**
Litter	17	39	95	69	67	25	45	50	75	95	**57.7**
Rock	8	25	5	25	21	55	10	20	10	3	**18.2**
Bare ground	50	36	0	3	7	0	0	0	0	0	**9.6**
(Other)	0	0	0	0	0	0	0	5	0	2	**0.7**
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion:	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
(Plot – 100x50m)	**Count Tally:**
<10cm wide: 0	**0.5, 1.0, 1.25, 2.0, 1.0, 0.5**
>10cm wide: 0	
TOTAL: 0	**TOTAL: 6.25 (62.5 m/ha)**



0 m



100 m



50 m (N)



groundcover

BIO-CONDITION ASSESSMENT									
Date: 13/12/2018		**Collector:**	Chris Hansen and Monica Campbell				**SITE: BC008**		
Time: 10:30		**Job No.**	18057						
Mapped RE:	nil								
Field RE:	nil ± **Vachellia farnesiana*					**Lot on Plan**: Lot 38 on SP157697 (ML5604)			
Structure:	*Acacia salicina* shrubland								
Slope : 0%	**Aspect:** 0		**Landform (local):** crest			**Landform (broad):** re-contoured and deeply ripped spoil dump			
Slope Shape:	convex (± undulated) crest								
Soils:	Firm sandy loam and very gravelly (with >60% rocks and gravel). No surface crust.								
Litter: 5	**Bare Soil**: 5		**Timber:** 0		**Rock**: 70-80		**Groundcover**: 10-20		
PHOTOS:	Photo No.	8459	8460	8461	8462	8465	8458	8463	8464
	Direction	N	E	S	W	0m - 140°	100m - 320°	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES: - no topsoil re-instated over re-contoured and ripped mine spoil
- boulders readily evident throughout with minimal soil development
- high weed infiltration (particularly **V. farnesiana*, **Clitoria ternatea* and **Tecoma stans*)
- tends to moderately intact and somewhat successful regeneration on easterly slopes of re-contoured dump (to east of plot), wherein eucalypt species and a mid-stratum of Sally Wattle prevalent (median height 15 m, cover intercept 20-30%)

REMNANT	~~Y~~	**N**	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**:	**Latitude**: -24.686077	**Longitude**: 150.05947

(please circle)	median	height range (m)	intercept	dominance	Species
T1					
T2					
S1 [EDL]	3.5	2-5	V-S 15-30%	d	*Acacia salicina*
				a	
S2	1.0	0.5-2	V 5-15%	d	**Vachellia farnesiana*
				a	*Acacia ligulata*, **Clitoria ternatea*
				a/s	*Senna notabilis*
G	0.4	0.01-0.5	V-S 10-20%	d	**Cenchrus ciliaris*
				a	*Heteropogon contortus*
				a/s	"See over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
A. salicina	1				**Type**	**Severity (0 to 3)**
					Fire (& height in m)	0
					Clearing	n/a
					Thinning/Ringbarking	n/a
					Grazing	0
					Exotic Flora	2 (g/c), 2 (S1)
					Canopy Dieback	n/a
					Erosion	0
					Recruitment	1
					Other	

SITE NUMBER: BC008	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Acacia salicina	5	S1-S2
Acacia ligulata	3-4	S2
**Vachellia farnesiana*	4-5	S2
Senna notabilis	1	S2
**Clitoria ternatea*	3	G-S2
**Macroptilium atropurpureum*	2	G-S2
**Macroptilium lathyroides*	1	G-S2
Acacia holosericea	+	S1
Senna artemisioides ssp. coriacea	+	S1
Erythrina vespertilio	+	S1
**Cenchrus ciliaris*	4-5	G
Heteropogon contortus	3-4	G
**Chloris gayana*	2	G
**Bothriochloa pertusa*	2	G
**Tecoma stans*	1	G-S2
**Melinis repens*	1	G
Salsola kali	1	G
**Urochloa mosambicensis*	1	G
Chamaesyce drummondii	1	G
**Tridax procumbens*	1	G
Vittadinia dissecta	+	G
**Setaria pumila*	+	G
**Cryptostegia grandis*	+	S2
Atalaya hemiglauca	+	S2
Solanum ellipticum	+	G
**Cymbopogon citrinus*	+	G
Alstonia constricta	+	S2
**Stachytarpheta jamaicensis*	+	G
Cassia brewsteri	+	G

Species	Presence	Strata

Lifeform	Native	Exotic
Tree	-	-
Shrub	9	3
Grass	1	7
Forb/Other	4	5

Crown Cover Intercept (100m)

Species	Height/ Strata	Intercept Range (m)		Cover (m)
A. salicina	3.0 – S1	9.70	12.90	3.20
*V. farnes	1.5 – S2	13.50	14.75	1.25
A. salic (x2)	3.0, 2.0 – S1	17.10	18.90	1.80
*V. farnes	1.7 – S2	19.10	21.10	2.00
A. salicina	3.2 – S1	20.70	22.60	1.90
*V. farnes	1.5 – S2	21.70	23.50	1.80
*V. far (x3)	1.7 – S2	24.60	27.90	3.30
A. salicina	2.4 – S1	24.20	25.10	0.90
A. salicina	2.5 – S1	29.00	27.60	1.40
*V. farnes	1.3 – S2	31.30	32.30	1.00
A. salicina	2.7 – S1	29.90	32.70	2.80
*V. farnes	1.6 - S2	31.30	32.30	1.00
*V. far (x2)	1.6 – S2	33.90	36.70	2.80
*V. farnes	1.8 – S2	37.80	38.60	1.80
A. salicina	2.9 – S1	38.00	40.40	2.40
*V. far (x3)	1.6 – S2	44.10	48.50	4.40
*V. far (x2)	1.7 – S2	49.55	51.40	1.85
A. salicina	3.2 – S1	50.45	48.70	1.75
A. salic (x2)	3.0 – S1	52.20	56.20	4.00
*V. farnes	1.8 – S2	52.90	54.20	1.30
*V. farnes	1.5 – S2	55.70	58.00	2.30
A. salicina	4.3 – S1	57.10	60.70	3.60
A. salicina	2.5 – S1	61.80	63.30	1.50
*V. far (x2)	1.2 – S2	62.50	64.35	1.85
A. salicina	3.2 – S1	64.20	66.60	3.50
A. lig/A.sali	2.0 – S2	75.10	73.65	1.45
A. salicina	3.8 – S1	75.60	79.50	2.90
~~A. salicina~~	~~2.0 – S1~~	~~76.45~~	~~78.20~~	~~1.75 Dead~~
*V. farnes	1.2 – S2	80.90	82.50	1.60
A. salicina	4.0 – S1	83.55	87.50	3.95
A. salicina	2.0 – S2	87.40	88.25	0.85
*V. farnes	1.0 – S2	96.50	97.50	1.20
A. salicina	2.4 – S1	96.50	99.20	2.70
A. salicina	2.3 – S1	99.40	100.00	0.60

	Cover	Height
T1	-	-
S1	38.90	3.0
S2	31.75	1.6

Presence: Braun-Blanquet Technique (scale: +, 1 through to 6) **© = collected**

Community Area (ha):	site only	<1	1-<5	5-<20	20-<50	>50	**Mapped:**	
Community Width (m):	<35	35-<75	75-<150	150-300	not linear	variable	Yes	**No**

BIO-CONDITION PARAMETERS	DATE: 13/12/2018	SITE: BC008

GROUNDCOVER: (ten 1 x 1m plots)

Ground Cover type	1	2	3	4	5	6	7	8	9	10	Mean
Native grass	0	0	0	0	0	0	0	0	0	10	**1.0**
Native herbs & forbs (non-grass)	0	0	0	0	0	0	0	0	0	0	**0**
Native shrubs (<1m in height)	0	0	0	0	0	1	5	0	0	0	**0.6**
Non-native grass	55	30	5	0	12	10	8	20	8	2	**15.0**
Non-native herbs & shrubs	0	5	35	45	8	0	0	20	12	3	**12.8**
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	**0**
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	**0**
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	**0**
Non-aquatic sedges	0	0	0	0	0	0	0	0	0	0	**0**
Ferns	0	0	0	0	0	0	0	0	0	0	**0**
Litter	30	40	5	10	2	9	20	5	25	2	**14.8**
Rock	10	23	50	30	75	55	64	55	40	3	**40.5**
Bare ground	5	2	5	15	3	25	0	0	15	80	**15.0**
(Other)	0	0	0	0	0	0	3	0	0	0	**0.3**
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION	**Plot size:**	100x50m	100x20m	**50x10m**

Species	Average Height (m)	Average DBH (mm)	Stems	Average Cover (%)	No. of quadrats (10 x 10 m)
Not perfomed					

Rill Erosion:
(Plot – 100x50m)
<10cm wide: 0

>10cm wide: 0

TOTAL: 0

Fallen Woody Material: (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
Count Tally:

0

TOTAL: 0



0 m



100 m



50 m (N)



groundcover

BIO-CONDITION ASSESSMENT				SITE: BC010
Date: 12/12/2018	**Collector:**	Chris Hansen and Monica Campbell		
Time: 11:45	**Job No.**	18057		

Mapped RE:	11.9.2/11.9.5/11.9.1 (60/30/10)		
Field RE:	11.9.9	**Lot on Plan**: Lot 41 on DW132 (ML 5656)	
Structure:	*Eucalyptus crebra* woodland		
Slope : 4-5 %	**Aspect:** NW	**Landform (local):** mid-slope	**Landform (broad):** undulated low rise
Slope Shape:	convex		
Soils:	Pale brown clayey gravelly sands (gravel <1-10 mm, average 5 mm). Negligible organics		
Litter: 40-50	**Bare Soil**: 4	**Timber:** 5-	**Rock**: 1	**Groundcover**: 40-50

PHOTOS:									
	Photo No.	8443	8444	8445	8446	8449		8447	8448
	Direction	N	E	S	W	0m - 193 °	100m - 13 °	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES:
- patchy distribution, particularly T1 with 'downed' trees prevalent throughout (cue unknown, but thought to be storm related)
- consistent S1 cover but groundcover heavily degraded by Buffel Grass
- 50 x 10 m plot started at the 0 m mark (as opposed to the 25 m mark of other sites) with the cover intercept plot extending a further 50 m past the 50m mark due to the presence of a detention basin 10 m immediately north of the 0 m mark of the established plot
- coal conveyor and haul road approximately 80 m to west of plot

REMNANT	**Y**	~~N~~	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**:	**Latitude**: -24.741807	**Longitude**: 150.068794

(please circle)	median	height range (m)	intercept	dominance	Species
T1 [EDL]	14	11-19	V-S 15-20%	d	*Eucalyptus crebra*
				a	-
T2	8	6-10	V 10-15%	d	*E. crebra*
				a	*Eremophila mitchellii, Acacia rhodoxylon*
S1	2	1-5	V 5-10%	d	*Pittosporum spinescens*
				a	*Erythroxylum australe, Psydrax* spp.
				a/s	*Acacia decora*
S2					
G	0.4	0.01-0.6	S-M	d	**Cenchrus ciliaris*
				a	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
E. crebra		4	11		**Type**	**Severity (0 to 3)**
"stag"		1	2		**Fire (& height in m)**	0
E. mitchellii		1			**Clearing**	0
					Thinning/Ringbarking	1
					Grazing	0
					Exotic Flora	3 (g/c)
					Canopy Dieback	1
					Erosion	0
					Recruitment	1
					Other	

SITE NUMBER: BC010	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Eucalyptus crebra	6	T2-T1
Acacia rhodoxylon	3	S1-T2
Pittosporum spinescens	4	S1
Triflorensia ixoroides	1	S1
Acacia decora	1	S1
Atalaya hemiglauca	3	S1
Hakea lorea	+	S1
Denhamia oleaster	2	S1
Ehretia membranifolia	1	S1
Capparis lasiantha	2	S1
Psydrax buxifolia	2	S1
Eremophila mitchellii	3	S1-T2
Alectryon diversifolius	+	S1
Psydrax odorata	+	S1
Marsdenia microlepis	+	S1
Jasminum didymum ssp. *racemosum*	+	S1
Capparis mitchellii	+	S1
Notelaea microcarpa	+	S1
Carissa ovata	2	S1
**Cenchrus ciliaris*	5	G
Scleria mackaviensis	+	G
Aristida calycina var. *calycina*	2	G
Evolvulus alsinoides ssp. *sericea*	1	G
Aristida ramosa	2	G
Bothriochloa decipiens var. *decipiens*	1	G
Hibiscus sturtii	1	G
Glycine tabacina	1	G
Brunoniella australis	1	G
Rostellularia adscendens	2	G
Lomandra multiflora	+	G
Glossocardia bidens	+	G
Enneapogon lindleyanus	3	G
Sporobolus sp.	1	G
**Cymbopogon citrinus*	2	G
**Melinis repens*	+	G
Cyperus gracilis	2	G
Chrysopogon fallax	1	G
Grewia latifolia	2	G
Melhania oblongifolia	2	G
Cymbopogon refractus	3	G
Paspalidium constrictum	+	G
Spermacoce multicaulis	+	G
Chloris ventricosa	1	G
Paspalidium caespitosum	1	G
Abutilon malvifolium	+	G
Lomandra filiformis	1	G
Digitaria brownii	+	G
Enteropogon ramosus	1	G
Pseuderanthemum tenellum	1	G
Entolasia stricta	+	G
Brachychiton australis	+	G
**Opuntia tomentosa*	+	G
Boerhavia dominii	+	G
Solanum parvifolium	1	G
Petalostigma pubescens	+	G
**Megathyrsus maximus* var. *pubiglumis*	1	G

Species	Presence	Strata
Alstonia constricta	+	S1
Abutilon oxycarpum	+	G-S1
Enteropogon unispiceus	1	G
Vittadinia dissecta	+	G
Jasminum simplicifolium	+	G
Breynia oblongifolia	+	S1
Senna sophera	+	G
Galactia tenuiflora	1	G

Lifeform	Native	Exotic
Tree	3	-
Shrub	20	-
Grass	14	4
Forb/Other	24	1

Crown Cover Intercept (100m)

Species	Height/ Strata	Intercept Range (m)		Cover (m)
E. crebra	16.5 – T1	0.00	2.20	2.20
E. mitch	7.5 – T2	7.70	10.75	3.05
A. rhod	3.0 – S1	8.60	11.60	2.00
E. mit/A. rh	9.0 – T2	11.21	15.40	4.20
E. crebra	19.2 – T1	11.70	17.80	6.10
A. rhod -2x	9.5 – T2	16.30	19.10	2.80
E. mit/A. rh	7.7 – T2	20.55	26.15	5.60
A. rhod -2x	6.0 – S1	27.60	30.85	3.25
A. hemi-2x	3.5 – S1	33.00	33.90	0.90
A. hemi	4.0 – S1	33.70	37.00	3.30
A. decora	2.5 – S1	37.10	(38.10)	(-)
A. hemi	4.2 – S1	37.70	39.80	2.70
E. creb	16.6– T1	42.30	46.10	3.80
E. creb	7.5 – T2	43.40	45.95	2.55
E. creb	10.2 – T2	52.70	56.00	3.70
A. decora	4.0 – S1	52.30	54.50	2.20
E. creb	17.5– T1	53.50	57.20	3.70
Ery. aust-2x	2.6 – S1	61.40	65.80	4.40
E. mitch	7.5 – T2	63.40	65.30	1.90
D. oleaster	2.0 – S1	69.00	69.20	0.70
D. viscosa	2.7 – S1	75.30	76.20	0.50
E. mitch	4.0 – S1	79.10	80.25	1.15
E. mitch	3.2– S1	85.80	87.30	1.50
D. ole/P spin	3.6 – S1	89.10	91.40	2.30
E. crebra	12.0 – T1	93.20	97.10	1.90
P. spine	2.0-S1	95.90	97.20	1.30
E. mitch	4.2-S1	7.40	7.95	0.55
A. div/P. sp	2.4-S1	66.60	(67.90)	-
E. mitch	4.6-S1	(66.70)	68.20	1.60

	Cover (m)	Height
T1	17.7	16.4
T2	23.8	8.4
S1	20.7	3.3

Presence: Braun-Blanquet Technique (scale: +, 1 through to 6) **© = collected**

Community Area (ha):	site only	<1	1-<5	5-<20	20-<50	>50	**Mapped:**	
Community Width (m):	<35	35-<75	75-<150	150-300	not linear	variable	**Yes**	No

BIO-CONDITION PARAMETERS	DATE: 12/12/2018	SITE: BC010

GROUNDCOVER: (ten 1 x 1m plots)

Ground Cover type	1	2	3	4	5	6	7	8	9	10	Mean
Native grass	6	10	25	35	0	35	3	10	35	1	16
Native herbs & forbs (non-grass)	0	1	2	5	2	3	2	2	2	0	1.9
Native shrubs (<1m in height)	0	2	0	0	0	0	2	0	0	34	3.8
Non-native grass	0	7	0	9	15	0	9	15	0	0	5.5
Non-native herbs & shrubs	0	0	0	0	0	0	0	1	0	0	0.1
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	0	0	3	3	2	0	0	0	0	0.8
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	60	50	70	57	75	15	90	22	40	65	54.4
Rock	0	0	3	0	1	5	0	0	0	0	0.9
Bare ground	14	25	0	0	0	20	3	50	23	0	13.5
(Other)	20	0	0	0	4	0	0	0	0	0	0.2
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION	Plot size:	100x50m	100x20m	50x10m

Species	Average Height (m)	Average DBH (mm)	Stems	Average Cover (%)	No. of quadrats (10 x 10 m)
Not Performed					

Rill Erosion:
(Plot – 100x50m)
<10cm wide: 0

>10cm wide: 0

TOTAL: 0

Fallen Woody Material: (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
Count Tally:
3.0, 3.75, 1.25, 3.0, 2.5, 4.25, 1.0, 2.0, 3.0, 1.0, 1.5, 2.0, 0.5, 0.5, 2.5, 3.0, 2.0, 3.0, 2.0, 2.5, 5.0, 3.5, 4.0

TOTAL: 56.75 (567.5 m/ha)


0 m


100 m


50 m (N)


groundcover

BIO-CONDITION ASSESSMENT									
Date: 12/12/2018			**Collector:**	Chris Hansen and Monica Campbell				**SITE: BC011**	
Time:			**Job No.**	18057					
Mapped RE:	nil								
Field RE:	nil (rehabilitation)					**Lot on Plan**: Lot 41 on DW132 (ML 5656)			
Structure:	*Acacia salicina* open shrubland								
Slope : 6 %	**Aspect:** NNW		**Landform (local):** upper slopes			**Landform (broad):** re-contoured spoil dump			
Slope Shape:	concave-convex								
Soils:	pale grey (± cream) gravelly sands with larger pebble ± rubble at surface throughout								
Litter: 10	**Bare Soil**: 10-40		**Timber:** 0		**Rock:** 10		**Groundcover**: 40-70		
PHOTOS:	Photo No.	8420	8421	8422	8423	8419	8418	8424	
	Direction	N	E	S	W	0m - 240°	100m - 60°	g/c	
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES: - not overly benched like other rehabilitation areas
- distribution patchy throughout but recruitment prevalent, however very low species richness
- topsoil primarily absent
- original 50 m transect started at old track (NB – Significantly widened prior to 2018 monitoring)
- solar telemetry installed adjacent to the peg adjacent to aforementioned plot peg
- NOTE: in 2014 and 2018 cover intercept only performed in original plot due to disturbances outside plot (e.g. tracks) (0-75 m)
- minor dieback in *Acacia salicina* but primarily in lower branches (natural) but most specimens in flush of new growth.

REMNANT	~~Y~~	**N**	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**:	**Latitude**: -24.74159	**Longitude**: 150.060274

(please circle)	median	height range (m)	intercept	dominance	Species
T1 {EDL}	6.5	5-9 (11)	V 5-10%	d	*Acacia salicina*
				a	-
T2					
S1	3	1-5	V 5-10%	d	*Acacia salicina*
				a	-
S2				d	*Acacia salicina*
				a	-
G	0.3	0.01-0.8	M 50-70%	d	**Cenchrus ciliaris*
				a	*Heteropogon contortus*
				a/s	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S2	S1	T1	E	Disturbance	
Acacia salicina	3	4			**Type**	**Severity (0 to 3)**
					Fire (& height in m)	0
					Clearing	n/a
					Thinning/Ringbarking	n/a
					Grazing	0
					Exotic Flora	3 (g/c)
					Canopy Dieback	<1
					Erosion	1-2
					Recruitment	1
					Other	

SITE NUMBER: BC011	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Acacia salicina	6	S2-S1
**Cenchrus ciliaris*	5	G
Heteropogon contortus	3	G
**Gomphocarpus physocarpus*	1	G
**Tridax procumbens*	2	G
Grewia latifolia	1	G
Pterocaulon serrulatum	2	G
Dichanthium fecundum	1	G
**Melinis repens*	2	G
**Macroptilium lathyroides*	1	G
Glossocardia bidens	1	G
**Stylosanthes scabra*	2	G
**Stylosanthes hamata*	+	G
Vittadinia dissecta	2	G
Brunoniella australis	+	G
Enneapogon avenaceus	+	G
Boerhavia dominii	+	G
**Bidens bipinnata*	2	G
Achyranthes aspera	1	G
**Bothriochloa pertusa*	2-3	G
Solanum ellipticum	+	G
Aristida latifolia	1	G
**Chamaesyce hirsuta*	+	G
Enneapogon lindleyanus	+	G
**Malvastrum americanum*	+	G
Enchylaena tomentosa	1	G
Sida rohlenae	+-2	G
**Cryptostegia grandiflora*	1	G
**Gomphrena celosioides*	1	G
Aristida leptopoda	+	G
**Clitoria ternatea*	+	G
**Erigeron* sp	+	G
Traverse		
**Tecoma stans*	2	S1

Species	Presence	Strata

BIO-CONDITION PARAMETERS			DATE: 12/12/2014			SITE: BC011					
GROUNDCOVER: (ten 1 x 1m plots)											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	0	0	15	0	0	25	30	0			8.8
Native herbs & forbs (non-grass)	0	0	0	0	0	0	0	0			0.0
Native shrubs (<1m in height)	0	0	0	0	0	0	0	0			0.0
Non-native grass	50	65	65	35	75	10	15	35			43.8
Non-native herbs & shrubs	5	15	5	5	10	0	0	0			5.6
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0			0.0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	Track		0.0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0			0.0
Non-aquatic sedges	0	0	0	0	0	0	0	0			0.0
Ferns	0	0	0	0	0	0	0	0			0.0
Litter	25	15	10	60	10	55	25	65			33.1
Rock	5	1	0	0	0	5	5	0			2.0
Bare ground	15	4	0	0	5	5	25	0			6.8
(Other)	0	0	5	0	0	0	0	0			0.6
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion: **(Plot – 100x50m)**	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
<10cm wide: 0	**Count Tally:**
>10cm wide: 0	**0**
TOTAL: 0	**TOTAL: 0**



0 m



100 m



50 m (N)



groundcover

BIO-CONDITION ASSESSMENT									
Date: 13/12/2018			**Collector:**	Chris Hansen and Monica Campbell			**SITE:** BC016_D		
Time: 09:05			**Job No.**	18057					
Mapped RE:	nil								
Field RE:	nil (rehabilitation)					**Lot on Plan**: Lot 68 on SP165458 (ML 5592)			
Structure:	Mixed eucalypt +/- *Acacia salicina* low woodland to shrubland								
Slope : 2-6 %	**Aspect:** NW		**Landform (local):** lower slopes and gully			**Landform (broad):** re-contoured mine spoil			
Slope Shape:	concavo-convex								
Soils:	negligible soil – primarily decomposed rock 7 gravel amongst pebble, rubble and boulders								
Litter: 18	**Bare Soil**: 8		**Timber:** 2		**Rock**:		**Groundcover**: 10-30		
PHOTOS:	Photo No.	8451	8452	8453	8454	nil	8450	8455	8456
	Direction	N	E	S	W	0m - 15 °	100m - 195 °	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES: - variable composition throughout with primarily Sally Wattle (+/- Yellow Bells) on upper slopes tending to a moderate cover of eucalypts in the gully

- relatively good health of eucalypts
- Buffel Grass and Butterfly Pea prevalent throughout and Yellow Bells in lower shrub layer on upper slopes but infiltration prevalent
- NOTE: no old monitoring plot only an opportunistic observation point 60 m upslope and to the east (this plot with flora, fauna and soil samples undertaken at three different locations – cue unknown
- NOTE: plot run at edge or transition between Sally Wattle (dominant vegetation on spoil dump) and eucalypt woodland in the gully → aim of this location is to monitor expansion or retraction of the eucalypt community
- Many *Acacia salicina* senescent or senescing, occasional *Eucalyptus crebra* failing.

REMNANT	~~Y~~	**N**	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**:	**Latitude**: -24.705955	**Longitude**: 150.062598

(please circle)	median	height range (m)	intercept	dominance	Species
T1 [EDL]	10	7-12 (14)	V-S 10-30%	d	*Corymbia citriodora* subsp. *variegata*
				a	*Eucalyptus crebra, Acacia salicina, Eucalyptus melanophloia, Corymbia leichhardtii*
				a/s	*Eucalyptus coolabah, Eucalyptus camaldulensis*
T2	6	5-7	V <5%	d	T1 spp
				a	-
S1	3	1-4	V 5-10%	d	**Tecoma stans*
				a	*Acacia salicina*
				a/s	*Corymbia leichhardtii*, *Corymbia citriodora*
				s	*Acacia podalyriifolia*, juvenile T1
S2					
G	0.4	0.01-0.7	V-S	d	**Cenchrus ciliaris*
				a	**Clitoria ternatea*
				a/s	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a -** associated; **s -** suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classes: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E
Eucalyptus coolabah			1	
Corymbia citriodora			5	
Eucalyptus melanophloia			2	
Acacia salicina			3	
Eucalyptus camaldulensis			3	
Eucalyptus crebra			2	
Corymbia leichhardtii			2	

Disturbance	
Type	**Severity (0 to 3)**
Fire (& height in m)	0
Clearing	n/a
Thinning/Ringbarking	n/a
Grazing	0
Exotic Flora	3 (g/c), 2 (S1)
Canopy Dieback	<1
Erosion	1
Recruitment	<1
Other	

SITE NUMBER: BC016_D	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Eucalyptus melanophloia	2	T1
Eucalyptus crebra	3	T1
Acacia salicina	3-4	S1-T1
**Tecoma stans*	4	S1
Corymbia citriodora subsp. *variegata*	4	T1
Eucalyptus coolabah	2	T1
Eucalyptus camaldulensis var. *obtusa*	3	T1
**Clitoria ternatea*	3	G-S1
Senna artemisioides subsp. *coriacea*	+	S1
Corymbia leichhardtii	3	S1-T1
**Cenchrus ciliaris*	6	G
**Mimosa* sp.	2	G
Vittadinia dissecta	+	G
Boerhavia dominii	+	G
Dichanthium fecundum	+	G
**Bothriochloa pertusa*	1	G
Solanum ellipticum	1	G
Pterocaulon redolens	+	G
**Melinis repens*	1	G
Salsola kali	2	G
Enchylaena tomentosa	+	G
**Parthenium hysterophorus*	+	G
traverse		
Acacia podalyriifolia	1	S1
Senecio lautus	1	G
**Malvastrum americanum*	1	G

BIO-CONDITION PARAMETERS			DATE: 13/12/2018			SITE: BC016_D					
GROUNDCOVER: (ten 1 x 1m plots)											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	0	0	0	0	0	0	0	0	0	0	0
Native herbs & forbs (non-grass)	0	0	0	0	0	0	0	0	0	0	0
Native shrubs (<1m in height)	0	0	0	0	0	0	0	0	0	0	0
Non-native grass	60	10	75	50	10	0	0	0	5	0	21.0
Non-native herbs & shrubs	5	5	2	3	6	2	2	3	3	3	3.4
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	0	0	0	0	0	0	0	0	0	0
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	28	68	20	40	75	87	78	90	65	82	63.3
Rock	4	5	2	5	5	8	12	7	15	15	7.8
Bare ground	3	2	1	2	4	3	8	0	12	0	3.4
(Other)	0	10	0	0	0	0	0	0	0	0	1.0
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion: **(Plot – 100x50m)** <10cm wide: 0 >10cm wide: 0	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m) **Count Tally:** **0**
TOTAL: 0	**TOTAL: 0**

{photo corrupted}

0 m



100 m



50 m (N)



groundcover

BIO-CONDITION ASSESSMENT				SITE: BC017
Date: 11/12/2018	**Collector:**	Chris Hansen and Monica Campbell		
Time: 09:10	**Job No.**	18057		

Mapped RE:	n-r		
Field RE:	n-r (rehabilitation)	**Lot on Plan**: Lots 4 & 5 on RP613366 [ML5657]	
Structure:	*Acacia salicina* and *Corymbia citriodora* open shrubland		
Slope : 0-15 %	**Aspect:** E	**Landform (local):** mid-slope bench	**Landform (broad):** re-contoured mine spoil
Slope Shape:	convex to level bench		
Soils:	mid-brown clayey loam to 30 cm in depth – underlying subgrade not breached		

Litter: 20-40	**Bare Soil**: 10		**Timber:** 5 -		**Rock**: -		**Groundcover**: 50-70	
PHOTOS:	Photo No.	8411	8412	8413	8415	8410	8409	8416
	Direction	N	E	S	W	0m - 345°	100m - 165 °	g/c
Type		Centre of Plot (50m)				Transect Ends		Extra

NOTES: - - plot located at the toe of a slope where it extends into a flat bench of approximately 20 m in width

- woody vegetation primarily limited to a narrow strip of regrowth with the balance of the bench and adjacent slope primarily devoid of woody vegetation
- scattered Sally Wattle and eucalypt species on edge of bench and slope to east
- large logs scattered throughout the narrow strip (placed in position)
- rehabilitation composition varies to the north of the plot (~ 100 m) wherein Sally Wattle is still present but Spotted Gum less common to absent and species such as *Acacia holosericea, Acacia ligulata, Eremophila maculata, Dodonaea viscosa, Senna* spp., *Erythrina vespertilio, Brachychiton populneus* and **Vachellia farnesiana*.
- In 2018, most *A. ligulata* in plot senescent or dead.

REMNANT	~~Y~~	**N**	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**: start (0m)	**Latitude**: -24.488813	**Longitude**: 150.062628

(please circle)	median	height range (m)	intercept	dominance	Species
T1					
T2					
S1 [EDL]	9	6-10.5	V-S <5-20	d	*Corymbia citriodora* subsp. *variegata*
				a/c	*Acacia salicina*
				s	*Eucalyptus tereticornis*
S2	2.5	1-4	V <5	d	*Acacia salicina*
				a/c	*Corymbia citriodora*
				a	**Vachellia farnesiana*
G	0.5	0.01-0.8	M 50-70	d	**Setaria pumila*
				a/s	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classes: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
Acacia salicina	2				**Type**	**Severity (0 to 3)**
Corymbia citriodora	3				**Fire (& height in m)**	0
					Clearing	n/a
					Thinning/Ringbarking	n/a
					Grazing	0
					Exotic Flora	3 (g/c), <1 (S2)
					Canopy Dieback	0
					Erosion	0
					Recruitment	<1
					Other	

SITE NUMBER: **BC017**	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Acacia salicina	4	S2-S1
Eucalyptus orgadophila	1	S2
**Vachellia farnesiana*	2	S2
Corymbia citriodora ssp. variegata	4	S2-S1
Eucalyptus tereticornis	+	S1
Acacia ligulata	2	S2
Acacia podalyriifolia	+	S2
**Leucaena leucocephala*	+	S2
**Setaria pumila*	4	G
Bothriochloa bladhii subsp. *bladhii*	3	G
Panicum decompositum var. *decompositum*	+	G
Dichanthium fecundum	2	G
**Bidens bipinnata*	1	G
Phyllanthus maderaspatensis	1	G
**Gomphocarpus physocarpus*	+	G
**Verbesina encelioides*	2	G
Myoporum acuminatum	+	G
traverse		
Acacia macradenia (dead)	+	S1
Haloragis aspera	1	G
Sesbania cannabina	+	G
Sonchus oleraceus	2	G
Macroptilium lathyroides	2	G
Tribulus micrococcus	+	G
**Cenchrus ciliaris*	+-2	G
Rhynchosia minima var. australis	+	G
**Clitoria ternatea*	+-(2)	G
**Lactuca serriola*	1	G

BIO-CONDITION PARAMETERS			DATE: 11/12/2018			SITE: BC017					
GROUNDCOVER: (ten 1 x 1m plots)											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	5	0	0	0	0	0	0	0	0	0	0.5
Native herbs & forbs (non-grass)	0	0	0	0	0	0	0	0	0	0	0
Native shrubs (<1m in height)	0	0	0	0	0	0	0	0	0	0	0
Non-native grass	5	25	55	60	5	60	55	30	10	60	36.5
Non-native herbs & shrubs	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	0	0	0	0	0	0	0	0	0	0
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	72	70	45	34	45	40	37	20	80	30	47.3
Rock	10	0	0	0	0	0	0	0	0	0	0.1
Bare ground	8	5	0	0	0	0	0	0	0	0	1.3
(Other)	0	0	0	6	50	0	8	50	10	0	12.4
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion: **(Plot – 100x50m)** <10cm wide: 0 >10cm wide: 0	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m) **Count Tally:** 3.0, 3.0, 4.0, 1.0, 5.0, 3.0, 0.5, 2.0, 8.0, 5.0, 4.0, 3.0, 2.0, 2.0, 5.0, 5.0, 4.0, 3.0, 4.5, 3.0, 2.0, 4.5, 3.0, 8.0, 2.5, 7.5, 2.5, 1.5, 2.0, 4.0, 1.5, 4.5, 2.5, 3.0, 4.5, 2.0, 1.0, 3.5, 3.5, 2.5
TOTAL: 0	**TOTAL: 136.0**



0 m



100 m



50 m (N)



groundcover

BIO-CONDITION ASSESSMENT									
Date: 12/12/20148			**Collector:**	Chris Hansen and Monica Campbell			**SITE: BC018**		
Time: 10.00			**Job No.**	18057					
Mapped RE:	11.9.2								
Field RE:	11.9.5 within a broader distribution 11.9.2 (patch too small to map, i.e. <2 ha)					**Lot on Plan**: Lot 13 on CP849905 [ML5656]			
Structure:	*Acacia harpophylla* woodland within a broader distribution of *Eucalyptus melanophloia* +/- *E. orgadophila* woodland								
Slope : 2-5 %	**Aspect:** S		**Landform (local):**			**Landform (broad):**			
Slope Shape:	convex								
Soils:	Brown, sandy clay								
Litter: 10	**Bare Soil**: 12		**Timber: 5**		**Rock**: 3		**Groundcover**: 70		
PHOTOS:	Photo No.	8435	8436	8437	8438	8439	8434	8440	8441
	Direction	N	E	S	W	0m - 275 °	100m - 95°	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES:
- small patch in broad fold at crest of low spur → community becomes progressively narrower downslope as fold narrows
- tends to remnant Silver-leaved Ironbark and Mountain Coolabah open woodland (11.9.2) on either side of the patch/broad gully tending to non-remnant to the north of the spur and remnant Poplar Box woodland (11.9.7) to the west and north-west
- choice of patch somewhat strange given that it is an atypical vegetation type within the broader landscape and not a mappable entity under the provisions listed in the *Vegetation Management Act 1999*
- NOTE: plot orientation reversed to orientation applied in 2011
- NOTE: cover intercept restricted to the western portion of the 50 x 10 m plot established in 2011, because beyond this the community is not representative of what is sampled in the main plot

- **2018** – first 1-7 m of transect are over a track

REMNANT ~~Y~~ **N** ~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition	**Waypoint**: start (0 m)	**Latitude**: -24.85103	**Longitude**: 150.047961

(please circle)	median	height range (m)	intercept	dominance	Species
T1 (outside patch)	12	8-14	V 10-20%	d	*Eucalyptus melanophloia*
				a/s	*Eucalyptus orgadophila*
T1 [EDL]	10	7-12	V-S 15-30%	d	*Acacia harpophylla*
				a/s	*Capparis lasiantha, Clematocissus opaca*
T2	5.5	3-7	V 5-10%	d	*Acacia harpophylla*
				a	*Geijera parviflora*
				s	*Brachychiton rupestris*
S1	1.5	0.5-3	V <5%	d	*Acacia harpophylla*
				a	*Atalaya hemiglauca, G. parviflora*
				a/s	*Pittosporum spinescens, Eremophila mitchellii*
G	0.2	0.01-0.4	M 70%	d	*Paspalidium caespitosum*
				c	**Cenchrus ciliaris*
				a	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
A. harpophylla		16	12		**Type**	**Severity (0 to 3)**
"stag"		6	7		**Fire (& height in m)**	0
E. melanophloia			2		**Clearing**	0
					Thinning/Ringbarking	? (historic)
					Grazing	2-3
					Exotic Flora	<1-3 (g/c)
					Canopy Dieback	1
					Erosion	<1
					Recruitment	1
					Other	

SITE NUMBER: BC018	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Santalum lanceolatum	1	S2
Acacia harpophylla	6	S2-T1
Atalaya hemiglauca	3	S2-S1
Geijera parviflora	3	S2-S1
Pittosporum spinescens	1	S2
Eremophila mitchellii	2	S2-S1
Capparis lasiantha	2	G-T1
Clematocissus opaca	1	G-T1
Owenia acidula	+	S1
Ehretia membranifolia	2	S2-S1
Denhamia cunninghamii	1	S2
Capparis mitchellii	+	S2
Paspalidium caespitosum	4-5	G
**Cenchrus ciliaris*	2-3	G
Enteropogon ramosus	2	G
Ancistrachne uncinulata	1-2	G
**Opuntia tomentosa*	+	G
Cheilanthes sieberi subsp. *sieberi*	2	G
Abutilon malvifolium	2	G
Pseuderanthemum tenellum	1	G
Panicum decompositum	+	G
Carissa ovata	2	G-S2
Brunoniella australis	1	G
Desmodium brachypodum	1	G
Nyssanthes erecta	2	G
Marsdenia viridiflora subsp. *viridiflora*	+	G
Cyperus gracilis	1	G
Dinebra decipiens	+	G
Capparis loranthifolia	+	S2
Oxalis sp.	1	G
Traverse		
Jasminum simplicifolium	1	S2
Brachychiton australis	+	S2
Alectryon oleifolius subsp. *elongatus*	+	S2
Solanum furfuraceum	+	S2
OUTSIDE community (in 11.9.2)		
Themeda triandra	1	G
Eucalyptus melanophloia	5	T1
Acacia decora	1	S2-S1
Aristida calycina var. *calycina*	1	G
Grewia latifolia	1	G
Grevillea striata	1	G
Calotis scabiosifolia	1	G
Rhynchosia minima var. *australis*	2	G
Spermacoce multicaulis	+	G
Solanum esuriale	+	G

Species	Presence	Strata
Hibiscus sturtii	1	G
Desmodium varians	2	G
Aristida jerichoensis	3-4	G
Evolvulus alsinoides subsp. *sericea*	1	G
Lysiana subfalcata	+	S1
Cymbopogon refractus	1	G
Aristida ramosa	3-4	G
NOTE: additional species not included in species richness count		

Lifeform	Native	Exotic
Tree	1	-
Shrub	16	-
Grass	5	1
Forb/Other	11	1

Crown Cover Intercept (100m)

Species	Height/ Strata	Intercept Range (m)		Cover (m)
A. harpo	6.1 – S1	98.05	94.60	3.45
G. parv, A.oleif	2.5/3.2 – S2	90.65	88.20	2.45
~~*A. harpo* (dead)~~	~~7.0 – S1~~	~~86.68~~	~~85.46~~	~~1.22~~
A. harpo	13.2 – T1	77.70	73.30	4.40
G. parv, A. hemi	3.8 (x2) – S2	65.85	62.50	3.35
~~*G. parv* x2~~	~~5.0 – S1~~	~~66.31~~	~~62.50~~	~~3.68~~
~~*A. harpo*~~	~~11.0 – T1~~	~~57.50~~	~~55.21~~	~~2.29~~
A. harpo	6.2 – S1	53.10	50.80	2.30
A. harpo	9.0 – T1	46.90	43.05	3.85
G. parvi	2.5 – S1	46.60	44.70	1.90
A. harpo	4.8 – S1	41.90	39.45	2.45
A. harpo	3.1 – S2	39.40	37.80	1.60
following cover intercepts not included in total as different RE (above divided by 70 m)				
E. melano	8.5 – T1	23.75	20.50	3.25
E. melano	11.0 – T1	19.70	12.30	5.40
P. spin	1.6 – S2	18.50	18.05	0.45
G. parvi	3.7 –S1	17.50	15.40	2.10
P. spin	1.1 – S2	16.05	15.10	0.95

SITE NUMBER: BC018	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m
Species (cont'd)	**Presence**	**Strata**	**Species**			**Presence**	**Strata**
OUTSIDE community (in 11.9.2) Cont							
Melhania oblongifolia	1	G					
Solanum ellipticum	1	G					
Rostellularia adscendens	1	G					
Trianthema triquetra	+	G					
Portulaca oleracea	1	G					
Brachychiton australis	+	S1					
Boerhavia dominii	+	G					
Aristida leptopoda	+	G					
**Cenchrus ciliaris*	2	G					
**Malvastrum americanum* var. *americanum*	+	G					
Panicum effusum	1	G					
Enneapogon avenaceus	+	G					
Bothriochloa decipiens var. *decipiens*	2	G					
Sida rohlenae	2	G					
Pittosporum spinescens	2-3	S1					
Santalum lanceolatum	3-4	S1					
Eremophila mitchellii	2	S1					
Geijera parviflora	1	S1					
Lysiphyllum carronii	+	S1					
Denhamia cunninghamii	1	S1					
Atalaya hemiglauca	2	S1					
Enneapogon lindleyanus	+	G					
**Bothriochloa pertusa*	1	G					

Presence: Braun-Blanquet Technique (scale: +, 1 through to 6)							© = collected	
Community Area (ha):	site only	**<1**	1-<5	5-<20	20-<50	>50	**Mapped:**	
Community Width (m):	<35	35-<75	75-<150	150-300	**not linear**	variable	Yes	**No**

BIO-CONDITION PARAMETERS			DATE: 10/10/2014			SITE: BC018					
GROUNDCOVER: (ten 1 x 1m plots) * Branch has fallen over plot 6 smothering everything											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	2	15	0	10	10	13	0	5	0	0	5.3
Native herbs & forbs (non-grass)	3	3	2	1	3	2	0	0	0	0	1.4
Native shrubs (<1m in height)	0	0	0	0	1	0	0	0	0	0	0.1
Non-native grass	25	0	55	5	2	5	0	25	10	45	17.2
Non-native herbs & shrubs	0	0	0	0	0	0	0	3	0	0	0.3
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	0	0	0	0	0	0	0	0	0	0
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	28	47	33	17	45	25	100	30	70	40	43.5
Rock	2	25	1	0	0	0	0	0	0	0	2.8
Bare ground	40	8	9	54	35	55	0	10	20	15	24.6
(Other)	0	2	0	3	4	0	0	27	0	0	3.6
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion: (Plot – 100x50m)	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
<10cm wide: 0	**Count Tally:**
>10cm wide: 0	1.5, 3.5, 2.5, 2.5, 2.5, 5.0, 3.5, 4.0, 4.0, 3.5, 1.0, 1.0
TOTAL:	**TOTAL: 34.5**


0 m


100 m


50 m (N)


groundcover

BIO-CONDITION ASSESSMENT				SITE: BC019
Date: 13/12/2018	**Collector:**	Chris Hansen and Monica Campbell		
Time: 12:45	**Job No.**	18057		

Mapped RE:	HVR (OC) [now regarded as non-remnant]		
Field RE:	n-r +/- HVR 11.3.25	**Lot on Plan**: Lot 78 on DW485 (ML 5650)	
Structure:	fragmented *Eucalyptus tereticornis* and *Acacia salicina* fringing low woodland		
Slope : 0 %	**Aspect:** 0	**Landform (local):** alluvial terrace	**Landform (broad):** Kianga Creek
Slope Shape:	nil		
Soils:	dark brown silty clays		
Litter: <5	**Bare Soil**: <1	**Timber:** -4	**Rock**: -	**Groundcover**: 90

PHOTOS:									
	Photo No.	8481	8482	8483	8484	8488	8480	8485	
	Direction	N	E	S	W	0m - 95°	50m - 275°	g/c	
Type		Centre of Plot (25m)				Transect Ends		Extra	

NOTES:
- site moved in 2011 approximately 90m to the west of original location (cue unknown) but no pegs located
- a 100 m cover intercept transect with a 50 x 10 m transect located centrally within (i.e. stakes at the 25 and 75 m mark) was not implemented as the new plot was positioned at the western limit of the vegetation type → further to the west woody vegetation is restricted to scattered Sally Wattle (median 5 m) within a broad, artificially created diversion channel
- woody vegetation primarily restricted to the immediate channel bank, while the flanking terrace adjacent to the non-augmented section of Kianga Creek lacks mature vegetation and is instead dominated by a sparse to mid-dense cover of juvenile Sally Wattle
- A levee bank to approximately 4 m in height is located 50 m to south of the plot
- Significant levels of dieback were also observed within the T1 layer (i.e. dead mature Queensland Blue Gum – cue uncertain)
- T2 *A. salicina* at western end of plot fallen (not yet dead but excluded from plot)
- Mistletoe in *A. salicina*

REMNANT	~~Y~~	**N**	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**: start (0m)	**Latitude**: -24.656193	**Longitude**: 150.052302

(please circle)	median	height range (m)	intercept	dominance	Species
T1 [+/- EDL]	20	17-23	V <5-10 %	d	*Eucalyptus tereticornis*
				a	-
T2 [+/- EDL]	10	7-12 (14)	V-S 10-20 %	d	*Acacia salicina*
				s	*Eucalyptus tereticornis, Melaleuca bracteata*
S1	3	1-6	V 5%	d	*Acacia salicina*
				a	**Vachellia farnesiana, Alectryon diversifolius*
				a/s	*Eucalyptus tereticornis*
S2					
G	0.4	0.01-1.0	D >90%	d	*Leptochloa digitata*
				a/c	*Sporobolus mitchellii, Einadia polygonoides*
				a	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
Eucalyptus tereticornis		1	4		**Type**	**Severity (0 to 3)**
"stag"	1	3	7		**Fire (& height in m)**	0
Melaleuca bracteata		1			**Clearing**	3
Acacia salicina	4	13			**Thinning/Ringbarking**	0
					Grazing	0
					Exotic Flora	<1 (g/c & S1)
					Canopy Dieback	2-3
					Erosion	0
					Recruitment	1
					Other	

SITE NUMBER: BC019	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Eucalyptus tereticornis	2	S1-T1
Acacia salicina	5-6	S1-T2
**Vachellia farnesiana*	2	S1
Lysiana subfalcata	2	T2
Alectryon diversifolius	2	S1
Melaleuca bracteata	1 (-3)	S1
Atalaya hemiglauca	+	S1
Leptochloa digitata	3-5	G
Sporobolus mitchellii	2-4	G
**Aster subulatus*	+	G
Atriplex muelleri	1	G
Cyperus sp. (n-r)	2	G
**Sonchus oleraceus*	1	G
Einadia polygonoides	2-4	G
Juncus continuus	+	G
Eriochloa procera	2	G
**Phyla nodiflora*	1	G
**Megathyrsus maximus* var. *pubiglumis*	1-2	G
**Senna barclayana*	+	G
Tetragonia tetragonoides	+	G
Lomandra longifolia	+	G
Cyanthillium cinereum	+	G
Chionachne cyathophora	+-3	G
**Bidens bipinnata*	1	G
Dodonaea viscosa	+	S1
Glycine tabacina	1	G
Enchylaena tomentosa var. *glabrescens*	+	G
Galactia tenuiflora	+	G
Myrsine variabilis	+	G
Alternanthera nodiflora	+	G
**Gomphocarpus physocarpus*	+	G
Cyperus gymnocaulos	+	G
**Modiola caroliniana*	1	G
Jasminum didymum var. *racemosum*	+	G
**Xanthium pungens*	+-2	G
Marsilea drummondii	+	G
Achyranthes aspera	+	G
Lythrum sp. ©	1	G
Mukia maderaspatana	1	G
**Vulpia bromoides*	1	G
**Lepidium bonariense*	**1**	G
Eremophila debile	+	G
Commelina cyanea	1	G

Species (cont'd)	Presence	Strata

BIO-CONDITION PARAMETERS	DATE: 13/12/2018	SITE: BC019

GROUNDCOVER: (ten 1 x 1m plots) **Note:** Fallen *A. salicina* in plot 3 affecting (other) score

Ground Cover type	1	2	3	4	5	6	7	8	9	10	Mean
Native grass	15	0	0	0	0	0	45	15	75	50	20.0
Native herbs & forbs (non-grass)	70	77	0	80	75	0	25	45	5	25	40.2
Native shrubs (<1m in height)	0	0	0	0	0	0	0	0	0	0	0
Non-native grass	0	0	0	0	0	0	0	0	0	0	0
Non-native herbs & shrubs	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	3	2	2	15	65	15	0	0	5	10.7
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	15	12	25	16	10	35	15	35	20	20	20.3
Rock	0	0	0	0	0	0	0	0	0	0	0
Bare ground	0	0	0	2	0	0	0	0	0	0	0.2
(Other)	0	8	73	0	0	0	0	5	0	0	8.6
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION	Plot size:	100x50m	100x20m	50x10m

Species	Average Height (m)	Average DBH (mm)	Stems	Average Cover (%)	No. of quadrats (10 x 10 m)
Not performed					

Rill Erosion:
(Plot – 100x50m)
<10cm wide: 0

>10cm wide: 0

TOTAL: 0

Fallen Woody Material: (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
Count Tally:

1.0, 1.0, 1.0, 1.5, 1.5, 1.5, 4.0, 3.5

TOTAL: 15.0 (150 m/ha)


0 m


100 m


25 m (N)


groundcover

BIO-CONDITION ASSESSMENT									
Date: 12/12/2018			**Collector:**	Chris Hansen and Monica Campbell			**SITE:** BC022		
Time: 08:25			**Job No.**	18057					
Mapped RE:	11.3.4/11.3.25 (85/15)								
Field RE:	11.3.25					**Lot on Plan**: Lot 13 on CP849905 [ML5656]			
Structure:	*Eucalyptus coolabah +/- E. tereticornis* fringing woodland								
Slope : 0 to 10-16 on banks %	**Aspect:** W		**Landform (local):** eastern bank and high flow terrace			**Landform (broad):** Dawson River			
Slope Shape:	convex and flat								
Soils:	mid-brown silty clay loam								
Litter: 23-48	**Bare Soil**: 20		**Timber:** 2		**Rock**: -		**Groundcover**: 30-50		
PHOTOS:	Photo No.	8427	8428	8429	8430	8433	8426	8431	8432
	Direction	N	E	S	W	0m - 181 °	100m - 1 °	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES: - plot supposed to be located in a nature reserve but the community is actively and somewhat pressured by extensive grazing, but fenced 100 m to north (adjacent lot, same owners ?) and cattle clearly excluded

- also evidence of timber harvesting
- primarily *E. coolabah* away from the edge of the Dawson River
- star pickets missing in 2014 → potentially washed away during floods

REMNANT	**Y**	~~N~~	~~Y/N?~~	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**: start (0m)	**Latitude**: -24.656193	**Longitude**: 150.052302

(please circle)	median	height range (m)	intercept	dominance	Species
T1 [EDL]	19	16-25 (30)	S-M 30-50%	d	*Eucalyptus coolabah*
				a	*Eucalyptus tereticornis, Corymbia tessellaris*
T2	12	9-14	V 5-10%	d	*Eucalyptus coolabah*
				a/c	*Melaleuca trichostachya* (toe of low flow bank)
				a/s	*Corymbia tessellaris*
				s	*Eucalyptus tereticornis*
S1	5	3-8	V 5%	d	*Eucalyptus coolabah*
				a/s	*Melaleuca trichostachya, Eucalyptus tereticornis*
				s	*Melaleuca bracteata, Atalaya hemiglauca*
S2					
G	0.15	0.01-0.5	S-M 30-50%	d	**Megathyrsus maximus* var. *pubiglumis*
				a	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classess: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S1	T2	T1	E	Disturbance	
Eucalyptus coolabah		6	9		**Type**	**Severity (0 to 3)**
Eucalyptus tereticornis		2	4		**Fire (& height in m)**	0
Corymbia tessellaris		1	1		**Clearing**	0
'stag'		1	1		**Thinning/Ringbarking**	? (historic)
					Grazing	2
					Exotic Flora	3 (g/c)
					Canopy Dieback	1
					Erosion	<1
					Recruitment	<1 (in S1)
					Other	

SITE NUMBER: BC022	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Eucalyptus coolabah	5	T2-T1
Eucalyptus tereticornis	2	T2-T1
Atalaya hemiglauca	+	S1
**Vachellia farnesiana*	2	S1
Acacia stenophylla	+	S1
Casuarina cunninghamiana	+	S1
Corymbia tessellaris	+	T2
**Megathyrsus maximus* var. *pubiglumis*	5	G
**Parthenium hysterophorus*	1	G
Tetragonia tetragonioides	2	G
Alternanthera denticulata	+	G
**Sonchus oleraceus*	+	G
Eustrephus latifolius	1	G
**Sida rhombifolia*	2	G
Marsilea drummondii	+	G
**Bidens bipinnata*	1	G
**Modiola caroliniana*	+	G
Dichanthium fecundum	1	G
**Cynodon dactylon*	+	G
**Urochloa mosambicensis*	1	G
Einadia hastata	+	G
Chamaesyce drummondii	1	G
Rorippa eustylis	+	G
Oxalis sp.	+	G
Cyperus gracilis	2-3	G
**Echinochloa colonum*	+	G
Commelina cyanea	+	G
**Xanthium pungens*	+	G
**Gomphrena celosioides*	+	G
**Glandularia aristigera*	+	G
Panicum larcomianum	1	G
Boerhavia dominii	+	G
Einadia polygonoides	1	G
Achyranthes aspera	+	G
Calotis scabiosifolia var. *scabiosifolia*	1-2	G
Digitaria sp.	1	G
Leptochloa digitata	+	G
Senna planiticola	+	G
Abutilon oxycarpum	+	G
Abutilon malvifolium	+	G
Ipomoea plebeia	+	G
Waltheria indica	+	G
Senecio lautus	+	G
traverse		
Melaleuca bracteata	+	S1
Melaleuca trichostachya	3-4 (ck)	S1-T2
Lysiphyllum hookeri	+	S1
Dianella revoluta	+	G
Cyanthillium cinereum	+	G

Species	Presence	Strata
Indigofera linnaei	1	G
Glycine tabacina	+	G
Dinebra decipiens	+	G
**Leucaena leucocephala*	+	S1
Nyssanthes erecta	2	G
Paspalidium distans	+	G
Pseuderanthemum tenellum	+	G
**Malvastrum americanum* var. *americanum*	2	G
Eremophila debile	+	G
Sporobolus caroli	+	G

Lifeform	Native	Exotic
Tree	4	
Shrub	6	2
Grass	6	4
Forb/Other	28	9

Crown Cover Intercept (100m)

Species	Height/ Strata	Intercept Range (m)		Cover (m)
E. coolabah	28.7 – T1	16.00	32.05	16.05
E. coolabah	15.8 – T1	43.35	(52.90)	–
E. coolabah	24.5 – T1	(51.65)	50.05	16.70
~~E. coolabah~~	~~20.0 – T1~~	~~55.60~~	~~59.74~~	DEAD ~~4.14~~
E. coolabah	20.0 – T1	60.30	63.55	3.25
E. coolabah	16.2 – T1	63.70	(70.80)	–
E. coolabah	11.0 – T2	69.50	71.15	1.65
E. coolabah	13.0 – T2	71.50	74.50	3.00
E. cool – 2x	22.6 – T1	(70.10)	(79.50)	–
E. cool	20.5 – T1	(79.40)	84.40	20.70
E. coolabah	19.0- T1	86.10	(91.40)	-
E. cool – 2x	20.5 – T1	(91.10)	100.00	13.90
E. coolabah	14.6 – T2	86.70	91.10	4.40

	Cover (%)	Height (m)
T1	70.60	20.87
T2	9.05	12.87

Presence: Braun-Blanquet Technique (scale: +, 1 through to 6) — **© = collected**

Community Area (ha):	site only	<1	1-<5	5-<20	20-<50	**>50**	**Mapped:**	
Community Width (m):	<35	35-<75	**75-<150**	150-300	not linear	variable	**Yes**	No

BIO-CONDITION PARAMETERS			DATE: 12/12/2018			SITE: BC022					
GROUNDCOVER: (ten 1 x 1m plots)											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	0	0	0	0	0	0	0	0	0	0	0
Native herbs & forbs (non-grass)	1	1	0	0	1	1	0	1	2	2	0.9
Native shrubs (<1m in height)	0	0	0	0	0	0	0	0	0	0	0
Non-native grass	55	35	5	30	35	45	50	24	0	0	27.9
Non-native herbs & shrubs	0	0	0	0	0	0	0	0	0	1	0.1
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	0	0	0	1	0	1	0	0	3	0.5
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	25	45	20	28	48	43	45	50	85	80	46.9
Rock	0	0	0	0	0	0	0	0	0	0	0
Bare ground	19	19	24	30	15	0	4	0	10	12	13.3
(Other)	4	0	1	12	0	10	0	25	3	2	5.7
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion: **(Plot – 100x50m)** <10cm wide: 0 >10cm wide: 0	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m) **Count Tally:** 3.0, 2.5, 4.0, 4.5, 1.0, 1.5, 0.75, 0.75, 3.75
TOTAL: 0	**TOTAL: 21.75**



0 m



100 m



50 m (N)



groundcover

BIO-CONDITION ASSESSMENT									
Date: 11/12/2018			**Collector:**	Chris Hansen and Xanthe Willis			**SITE:** BC023		
Time: 07:00			**Job No.**	18057					
Mapped RE:	11.4.9a/11.4.8/11.9.2 (60/30/10)								
Field RE:	11.4.9 (+/- RV)					**Lot on Plan**: Lot 19 on DW158 [ML 5611]			
Structure:	*Acacia harpophylla* regrowth shrubland								
Slope : 0 %	**Aspect:** flat		**Landform (local):** plain			**Landform (broad):** broad gently undulated plain			
Slope Shape:	flat with minor gilgai relief throughout								
Soils:	mid-brown clayey loam								
Litter: 45-50	**Bare Soil**: 40		**Timber:** 5		**Rock**:		**Groundcover**: 5-10		
PHOTOS:	Photo No.	8402	8403	8404	8405	8408	8401	8406	8407
	Direction	N	E	S	W	0m - 170°	100m - 350 °	g/c	Soils
Type		Centre of Plot (50m)				Transect Ends		Extra	

NOTES: - variable stages of recovery +/- remnant vegetation in polygon as a whole but site has been located in the youngest cohort and generally lacks larger *Acacia harpophylla* trees or eucalypts (e.g. *E. cambageana* or *E. thozetiana*)

- regrowth represents even-aged recovery, wherein the DBH, height and multi-leadered habit of the regrowth is consistent throughout the plot
- the cohort is separated from more mature patches by an access track/powerline easement in the east and an old track in the west
- two flora species that are listed as **ENDANGERED** under the *Nature Conservation Act 1992* were identified within this community, with one of the species recorded within the plot → *Solanum elachophyllum* and *Solanum johnsonianum*
- the latter is less prolific within the community
- Surveys in 2017/2018 recorded *Xerothamnella herbacea* and *S. dissectum* in broader patch.

REMNANT	~~Y~~	~~N~~	**Y/N?**	**Zone**: 55K	**Datum**: WGS84	
Vegetative Structure and Composition				**Waypoint**: start (0m)	**Latitude**: -24.622305	**Longitude**: 150.037208

(please circle)	median	height range (m)	intercept	dominance	Species
T1					
T2					
S1 [EDL]	4.5	3-6	S 35-50%	d	*Acacia harpophylla*
S2	1	0.5-2.5	V 5%	d	*Acacia harpophylla*
				a/c	*Eremophila deserti*
				a	*Apophyllum anomalum, Geijera parviflora*
				s	*Casuarina cristata*
G	0.10	0.01-0.3	V 5-10%	d	*Paspalidium caespitosum*
				a	"see over"

Herbarium RE definitions

dominance: **d:** dominant; **c** - co-dominant; **a** - associated; **s** - suppressed

cover intercept **I:** isolated *(0.2-2%)*; **V:** very sparse *(2-20%)*, **S:** sparse *(20-50%)*; **M:** mid-dense (50-81%); **D:** dense (81-100%)

Walter and Hopkins height classes: **1-3m** - dwarf, **3-6m** - low, **6-12m** - mid-high, **12-20m** - tall, **20-35m** - very tall, >35m - *extremely tall*

Walter and Hopkins crown cover classes: **<0.2%** - isolated trees or clumps; **0.2-20%** - open woodland, **20-50%** - woodland, **50-80%** - open forest, **80-100%** - closed forest

Basal Area [fixed point Bitterlich technique at factor of 1cm]

Species	S2	S1	T1	E	Disturbance	
Acacia harpophylla	4	29			**Type**	**Severity (0 to 3)**
"stag"	1	1			**Fire (& height in m)**	0
					Clearing	0 (historic)
					Thinning/Ringbarking	0 (historic)
					Grazing	0
					Exotic Flora	<1
					Canopy Dieback	<1
					Erosion	0
					Recruitment	1
					Other	

BC023	Random meander			(please tick)			
	Plot		Yes	~~1x1m~~	~~10x10m~~	~~20x20m~~	10x50m

Species (cont'd)	Presence	Strata
Acacia harpophylla	6	S1-S2
Casuarina cristata	+	S2
Eremophila deserti	2	S2
Apophyllum anomalum	1	S2
Clematocissus opaca	2	G-S2
Geijera parviflora	+	S2
Carissa ovata	+	S2
Paspalidium caespitosum	5-6	G
Enteropogon ramosus	3	G
Sclerolaena tetracuspis	2	G
Salsola kali	2	G
Parsonsia lanceolata	1	G
Eragrostis lacunaria	2	G
Sporobolus caroli	+	G
Brunoniella australis	1	G
Abutilon malvifolium	1	G
Aristida ramosa	+	G
Sclerolaena tricuspis	1	G
Marsdenia viridiflora var. viridiflora	+	G
Pseuderanthemum tenellum	1	G
**Portulaca oleracea*	1	G
***Solanum elachophyllum* (E)**	1	G
Nyssanthes erecta	1	G
Cyperus gracilis	1	G
Traverse		
Senna corallinoides	+	S2
***Solanum johnsonianum* (E)**	1	G
Enchylaena tomentosa	1	G
Amyema maidenii	1	T1
Teucrium dausus	1	G
Calandrinia pickeringii	1	G
Trianthema triquetra	1	G
Amyema quandang var. *bancroftii*	+	T1
Portulaca filifolia	1	G
Atalaya hemiglauca	1	S1
Alectryon diversifolius	1	S1

Species	Presence	Strata

BIO-CONDITION PARAMETERS			DATE: 11/12/2018			SITE: BC023					
GROUNDCOVER: (ten 1 x 1m plots)											
Ground Cover type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Native grass	2	3	4	8	0	5	6	6	10	5	4.9
Native herbs & forbs (non-grass)	2	1	1	2	1	2	2	1	0	1	1.3
Native shrubs (<1m in height)	0	1	0	0	1	0	0	0	1	0	0.3
Non-native grass	0	0	0	0	0	0	0	0	0	0	0
Non-native herbs & shrubs	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (floating)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (submerged)	0	0	0	0	0	0	0	0	0	0	0
Aquatic Vegetation (emergent)	0	0	0	0	0	0	0	0	0	0	0
Non-aquatic sedges	0	0	0	0	0	0	0	0	0	0	0
Ferns	0	0	0	0	0	0	0	0	0	0	0
Litter	13	60	55	75	13	13	70	39	75	70	48.3
Rock	0	0	0	0	0	0	0	0	0	0	0
Bare ground	83	35	32	13	85	80	22	54	14	24	44.2
(Other)	0	0	8	2	0	0	0	0	0	0	1.0
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

WOODY VEGETATION		**Plot size:**	100x50m	100x20m	**50x10m**
Species	**Average Height (m)**	**Average DBH (mm)**	**Stems**	**Average Cover (%)**	**No. of quadrats (10 x 10 m)**
Not performed					

Rill Erosion: **(Plot – 100x50m)**	**Fallen Woody Material:** (number of fallen woody logs >10cm diam and >0.5m - Plot: 50 x 10m)
<10cm wide: 0	**Count Tally:**
>10cm wide: 0	**1.0**
TOTAL:	**TOTAL: 1**



0 m



100 m



50 m (N)



groundcover

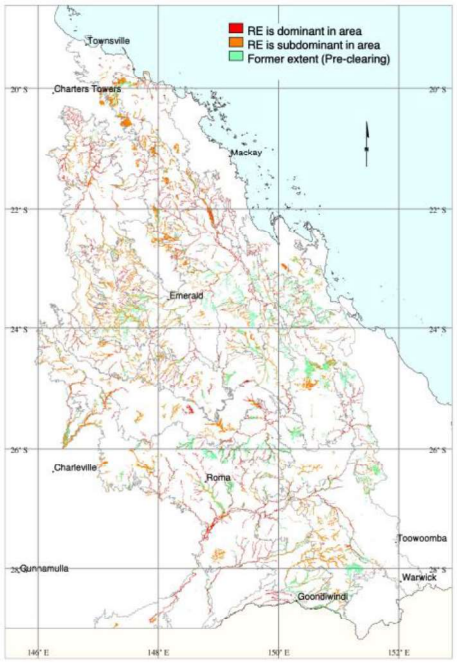
Appendix B

BioCondition benchmarks (REs 11.3.25, 11.4.9, 11.9.5, 11.9.9)

BioCondition benchmark for regional ecosystem condition assessment

Brigalow Belt — Regional ecosystem: 11.3.25

Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines





Annie Kelly

BioCondition attribute			Benchmark
Recruitment of dominant canopy species (%):			100
Native plant species richness:		Tree:	4
		Shrub:	2
		Grass:	8
		Forbs and other:	12
Trees:	Emergent canopy	Tree emergent canopy median height (m):	na
		Tree emergent canopy cover (%):	na
	Tree canopy	Tree canopy median height (m):	23
		Tree canopy cover (%):	22
	Tree sub-canopy	Tree sub-canopy median height (m):	na
		Tree sub-canopy cover (%):	na
	Large trees	Large eucalypt tree dbh threshold (cm):	49
		Number of large eucalypt trees per hectare:	14
		Large non-eucalypt tree dbh threshold (cm):	29
		Number of large non-eucalypt trees per hectare:	7
	Typical tree species: Eucalyptus tereticornis (blue gum), Casuarina cunninghamiana (fire oak), Angophora floribunda (rough-barked apple), Eucalyptus camaldulensis (river red gum)		
Shrubs:		Native shrub cover (%):	1
	Typical shrub species: Sida hackettiana, Rubus spp., Ficus opposita (sandpaper fig)		
Ground cover (%):		Native perennial grass cover (%):	12
		Organic litter cover (%):	15
	Typical ground cover species: Heteropogon contortus (black speargrass), Themeda triandra (kangaroo grass)		
Coarse woody debris: Total length (m) of debris ≥ 10cm diameter and ≥0.5m in length per hectare:			375
Non-native plant cover			0
	Typical non-native species: Lantana camara^, Megathyrsus maximus var. pubiglumis		

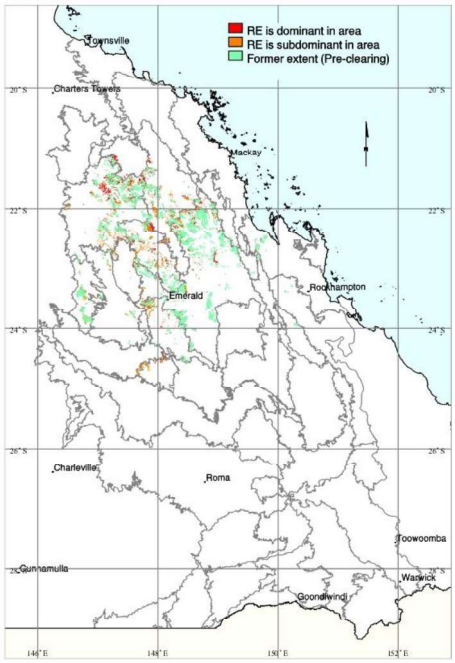
Benchmark based on: 6 reference sites, 37 Corveg sites and expert opinion **Benchmark reliability ranking:** high

Selected typical species are those that characterize the ecosystem, community or stratum at reference sites. Up to five frequently occurring species for each stratum are selected. Shrub and ground strata may contain recruiting canopy species. 'Eucalypt' refers to species belonging to the genera Eucalyptus, Corymbia, Angophora, Lophostemon and Syncarpia. Users should refer to regional ecosystem technical descriptions for more complete lists of characteristic species. Common names can differ between regions. Declared pest species in Queensland are designated (^).

BioCondition benchmark for regional ecosystem condition assessment

Brigalow Belt — Regional ecosystem: 11.4.9

Acacia harpophylla shrubby woodland with Terminalia oblongata on Cainozoic clay plains





Andrew Franks

BioCondition attribute			Benchmark
Recruitment of dominant canopy species (%):			100
Native plant species richness:		Tree:	5
		Shrub:	10
		Grass:	5
		Forbs and other:	10
Trees:	Emergent canopy	Tree emergent canopy median height (m):	na
		Tree emergent canopy cover (%):	na
	Tree canopy	Tree canopy median height (m):	13
		Tree canopy cover (%):	25
	Tree sub-canopy	Tree sub-canopy median height (m):	8
		Tree sub-canopy cover (%):	10
	Large trees	Large eucalypt tree dbh threshold (cm):	na
		Number of large eucalypt trees per hectare:	na
		Large non-eucalypt tree dbh threshold (cm):	28
		Number of large non-eucalypt trees per hectare:	45
	Typical tree species: Acacia harpophylla (brigalow), Acacia cambagei (gidgee), Lysiphyllum carronii (ebony tree), Terminalia oblongata, Casuarina cristata (belah)		
Shrubs:		Native shrub cover (%):	5
	Typical shrub species: Acacia harpophylla (brigalow), Carrisa ovata, Eremophila maculata, Eremophila mitchellii, Erythroxylum australe		
Ground cover (%):		Native perennial grass cover (%):	20
		Organic litter cover (%):	45
	Typical ground cover species: Paspalidium caespitosum (brigalow grass), Dactyloctenium radulans (button grass), Enteropogon acicularis (curly windmill grass), Sporobolus scabridus, Abutilon oxycarpum		
Coarse woody debris: Total length (m) of debris ≥ 10cm diameter and ≥0.5m in length per hectare:			1200
Non-native plant cover			0
	Typical non-native species: Malvastrum americanum, Cenchrus ciliaris (buffel grass), Parthenium hysterophorus^ (parthenium weed), Gomphrena celosioides		

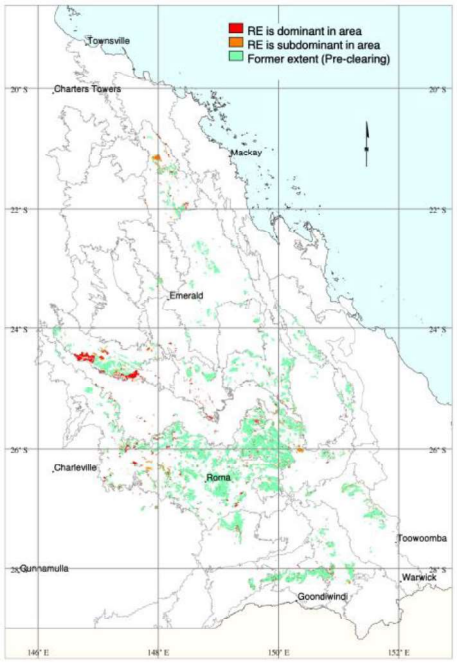
Benchmark based on: 2 reference sites, 4 Corveg sites and expert opinion **Benchmark reliability ranking:** moderate

Selected typical species are those that characterize the ecosystem, community or stratum at reference sites. Up to five frequently occurring species for each stratum are selected. Shrub and ground strata may contain recruiting canopy species. 'Eucalypt' refers to species belonging to the genera Eucalyptus, Corymbia, Angophora, Lophostemon and Syncarpia. Users should refer to regional ecosystem technical descriptions for more complete lists of characteristic species. Common names can differ between regions. Declared pest species in Queensland are designated (^).

BioCondition benchmark for regional ecosystem condition assessment

Brigalow Belt — Regional ecosystem: 11.9.5

Acacia harpophylla and/or Casuarina cristata open-forest on fine-grained sedimentary rocks





Don Butler

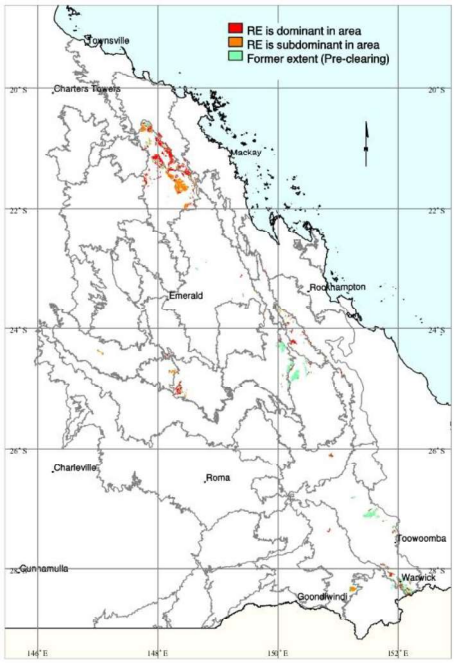
BioCondition attribute			Benchmark
Recruitment of dominant canopy species (%):			100
Native plant species richness:		Tree:	2 (east), 4 (west)
		Shrub:	10 (east), 5 (west)
		Grass:	4 (east), 5 (west)
		Forbs and other:	9 (east), 10 (west)
Trees:	Tree canopy	Tree canopy median height (m):	25 (east), 15 (west)
		Tree canopy cover (%):	59 (east), 32 (west)
	Tree sub-canopy	Tree sub-canopy median height (m):	8 (east), 8 (west)
		Tree sub-canopy cover (%):	48 (east), 30 (west)
	Large trees	Large eucalypt tree dbh threshold (cm):	na
		Number of large eucalypt trees per hectare:	na
		Large non-eucalypt tree dbh threshold (cm):	30 (east), 26 (west)
		Number of large non-eucalypt trees per hectare:	98 (east), 10 (west)
	Typical tree species: Acacia harpophylla (brigalow), Casuarina cristata (belah)		
Shrubs:		Native shrub cover (%):	11 (east), 19 (west)
	Typical shrub species: Geijera parviflora (wilga), Gossia bidwillii (smooth-barked ironwood), Eremophila mitchellii (false sandalwood), Eremophila deserti (Ellangowan poison bush)		
Ground cover (%):		Native perennial grass cover (%):	4 (east), 30 (west)
		Organic litter cover (%):	66 (east), 49 (west)
	Typical ground cover species: Paspalidium caespitosum (brigalow grass)		
Coarse woody debris: Total length (m) of debris ≥ 10cm diameter and ≥0.5m in length per hectare:			16 (east), 688 (west)
Non-native plant cover			0
	Typical non-native species: Opuntia tomentosa^ (velvety tree pear), Opuntia stricta^ (smooth pest pear)		

Selected typical species are those that characterize the ecosystem, community or stratum at reference sites. Up to five frequently occurring species for each stratum are selected. Users should refer to the regional ecosystem description database (REDD) and/or the technical description for more complete lists of characteristic species. Only the most frequently used common name is given. Other common names may be used in other regions. Declared pest species in Queensland are designated (^).

BioCondition benchmark for regional ecosystem condition assessment

Brigalow Belt — Regional ecosystem: 11.9.9

Eucalyptus crebra woodland on fine-grained sedimentary rocks





Annie Kelly

BioCondition attribute			Benchmark
Recruitment of dominant canopy species (%):			100
Native plant species richness:		Tree:	3
		Shrub:	7
		Grass:	7
		Forbs and other:	8
Trees:	Emergent canopy	Tree emergent canopy median height (m):	na
		Tree emergent canopy cover (%):	na
	Tree canopy	Tree canopy median height (m):	18
		Tree canopy cover (%):	20
	Tree sub-canopy	Tree sub-canopy median height (m):	6
		Tree sub-canopy cover (%):	4
	Large trees	Large eucalypt tree dbh threshold (cm):	51
		Number of large eucalypt trees per hectare:	12
		Large non-eucalypt tree dbh threshold (cm):	na
		Number of large non-eucalypt trees per hectare:	na
	Typical tree species: Eucalyptus crebra (narrow-leaved red ironbark), Eucalyptus moluccana (gum-topped box), Eucalyptus albens, Eucalyptus tereticornis, Corymbia erythrophloia		
Shrubs:		Native shrub cover (%):	5
	Typical shrub species: Carissa ovata (currantbush), Alphitonia excelsa, Grewia spp., Eremophila mitchellii, Petalostigma pubescens (quinine tree)		
Ground cover (%):		Native perennial grass cover (%):	22
		Organic litter cover (%):	39
	Typical ground cover species: Cheilanthes sieberi, Cymbopogon refractus (barbed-wire grass), Aristida caput-medusae, Ancistrachne uncinulata (hooky grass), Chloris ventricosa (tall chloris)		
Coarse woody debris: Total length (m) of debris ≥ 10cm diameter and ≥0.5m in length per hectare:			268
Non-native plant cover			0
	Typical non-native species: Cenchrus ciliaris (buffel grass), Opuntia spp.^		

Benchmark based on: 1 reference sites, 23 Corveg sites and expert opinion **Benchmark reliability ranking:** High

Selected typical species are those that characterize the ecosystem, community or stratum at reference sites. Up to five frequently occurring species for each stratum are selected. Shrub and ground strata may contain recruiting canopy species. 'Eucalypt' refers to species belonging to the genera Eucalyptus, Corymbia, Angophora, Lophostemon and Syncarpia. Users should refer to regional ecosystem technical descriptions for more complete lists of characteristic species. Common names can differ between regions. Declared pest species in Queensland are designated (^).

Appendix C

Fauna – Species inventory

Table C1: Fauna species list

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Amphibians													
Cane Toad	*Rhinella marina*	*	*		X (Sp)	X (Sp)			X (Sp,As)		X (Sp)	X (Sp)	
Desert Tree Frog	*Litoria rubella*	LC	NL								X (Sp)	X (As)	
Eastern Sedge Frog	*Litoria fallax*	LC	NL								X (Sp)		
Green-striped Burrowing Frog	*Cyclorana alboguttata*	LC	NL								X (Sp)	X (Sp)	
Green Tree Frog	*Litoria caerulea*	LC	NL							X (Sp)			
Ornate Burrowing Frog	*Platyplectrum ornatum*	LC	NL									X (Sp)	
Salmon-striped Frog	*Limnodynastes salmini*	LC	NL								X (Sp)		
Birds													
Australasian Darter	*Anhinga novaehollandiae*	LC	NL						X (Bs)				
Australian Hobby	*Falco longipennis*	LC	NL							X (Bs)			
Australian Magpie	*Cracticus tibicen*	LC	NL					X (Bs)		X (Bs)		X (Bs)	
Australian Reed Warbler	*Acrocephalus australis*	LC	NL								X (Sp)		
Australian Wood Duck	*Chenonetta jubata*	LC	NL									X (Bs)	
Bar-shouldered Dove	*Geopelia humeralis*	LC	NL						X (Bs)				
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	LC	NL		X (Bs)		X (Bs)		X (Bs)		X (Bs)	X (Bs)	X (Bs)
Blue-winged Kookaburra	*Dacelo leachii*	LC	NL									X (Bs)	
Brown Honeyeater	*Lichmera indistincta*	LC	NL		X (Bs)	X (Bs)	X (Bs)		X (Bs)				X (Bs)
Brush Cuckoo	*Cacomantis variolosus*	LC	NL		X (Bs)						X (Bs)	X (Bs)	

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Channel-billed Cuckoo	*Scythrops novaehollandiae*	LC	NL									X (Bs)	X (Bs)
Collared Sparrowhawk	*Accipiter cirrocephalus*	LC	NL								X (Bs)		
Crested Pigeon	*Ocyphaps lophotes*	LC	NL										X (Bs)
Dollarbird	*Eurystomus orientalis*	LC	NL									X (Bs)	
Double-barred Finch	*Taeniopygia bichenovii*	LC	NL	X (Bs)			X (Bs)	X (Bs)			X (Bs)		X (Bs)
Dusky Moorhen	*Gallinula tenebrosa*	LC	NL						X (Bs)				
Eastern Egret	*Ardea modesta*	LC	NL						X (Bs)				
Eastern Yellow Robin	*Eopsaltria australis*	LC	NL										X (Bs)
Forest Kingfisher	*Todiramphus macleayii*	LC	NL						X (Bs)			X (Bs)	
Galah	*Eolophus roseicapillus*	LC	NL									X (Bs)	
Grey Butcherbird	*Cracticus torquatus*	LC	NL							X (Bs)			
Grey Shrike Thrush	*Colluricincla harmonica*	LC	NL								X (Bs)		
Grey Teal	*Anas gracilis*	LC	NL						X (Bs)				
Horsfield's Bronze-Cuckoo	*Chalcites basalis*	LC	NL							X (Bs)	X (Bs)		X (Bs)
Leaden Flycatcher	*Myiagra rubecula*	LC	NL	X (Bs)			X (Bs)		X (Bs)		X (Bs)	X (Bs)	X (Bs)
Little Black Cormorant	*Phalacrocorax sulcirostris*	LC	NL						X (Bs)				
Little Friarbird	*Philemon citreogularis*	LC	NL										X (Bs)
Mistletoebird	*Dicaeum hirundinaceum*	LC	NL	X (Bs)	X (Bs)	X (Bs)	X (Bs)	X (Bs)	X (Bs)	X (Bs)	X (Bs)		X (Bs)

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Nankeen Kestrel	*Falco cenchroides*	LC	NL					X (Bs)					
Noisy Friarbird	*Philemon corniculatus*	LC	NL			X (Bs)							X (Bs)
Olive-backed Oriole	*Oriolus sagittatus*	LC	NL			X (Bs)		X (Bs)	X (Bs)				X (Bs)
Pacific Black Duck	*Anas superciliosa*	LC	NL								X (Bs)	X (Bs)	
Peaceful Dove	*Geopelia striata*	LC	NL					X (Bs)			X (Bs)	X (Bs)	X (Bs)
Peregrine Falcon	*Falco peregrinus*	LC	NL		X (Bs)								
Pheasant Coucal	*Centropus phasianinus*	LC	NL				X (Bs)		X (Bs)			X (Bs)	X (Bs)
Pied Butcherbird	*Cracticus nigrogularis*	LC	NL		X (Bs)	X (Bs)		X (Bs)					
Rainbow Bee-eater	*Merops ornatus*	LC	NL										X (Bs)
Rainbow lorikeet	*Trichoglossus haematodus*	LC	NL									X (Bs)	X (Bs)
Red-backed Fairy-wren	*Malurus melanocephalus*	LC	NL					X (Bs)			X (Bs)		
Rufous Songlark	*Cincloramphus mathewsi*	LC	NL			X (Bs)		X (Bs)					
Rufous Whistler	*Pachycephala rufiventris*	LC	NL	X (Bs)	X (Bs)	X (Bs)	X (Bs)	X (Bs)	X (Bs)		X (Bs)		X (Bs)
Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*	LC	NL				X (Bs)						X (Bs)
Speckled Warbler	*Chthonicola sagittata*	LC	NL										X (Bs)
Southern Boobook	*Ninox novaeseelandiae*	LC	NL									X (Sp)	
Striated Pardalote	*Pardalotus striatus*	LC	NL									X (Bs)	X (Bs)
Striped Honeyeater	*Plectorhyncha lanceolata*	LC	NL			X (Bs)		X (Bs)	X (Bs)	X (Bs)			X (Bs)
Sulphur-crested Cockatoo	*Cacatua galerita*	LC	NL							X (Bs)		X (Bs)	

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Superb Fairy-wren	*Malurus cyaneus*	LC	NL					X (Bs)					
Tawny Frogmouth	*Podargus strigoides*	LC	NL							X (Bs)			
Torresian Crow	*Corvus orru*	LC	NL	X (Bs, Ir)	X (Bs)	X (Bs, Ir)	X (Bs)	X (Bs)		X (Bs)	X (Bs, Ir)		X (Bs)
Tree Martin	*Petrochelidon nigricans*	LC	NL			X (Bs)	X (Bs)		X (Bs)				
Variegated Fairy-wren	*Malurus lamberti*	LC	NL				X (Bs)						X (Bs)
Wedge-tailed Eagle	*Aquila audax*	LC	NL					X (Bs)					X (Bs)
Weebill	*Smicrornis brevirostris*	LC	NL	X (Bs)			X (Bs)	X (Bs)			X (Bs)	X (Bs)	X (Bs)
Whistling Kite	*Haliastur sphenurus*	LC	NL			X (Ir)					X (Bs)		
White-bellied Sea Eagle	*Haliaeetus leucogaster*	LC	NL									X (Bs)	
White-breasted Woodswallow	*Artamus leucorynchus*	LC	NL						X (Bs)				
White-faced Heron	*Egretta novaehollandiae*	LC	NL								X (Bs)		
White-throated Honeyeater	*Melithreptus albogularis*	LC	NL								X (Bs)	X (Bs)	
White-winged Triller	*Lalage sueurii*	LC	NL					X (Bs)		X (Bs)			
Willie Wagtail	*Rhipidura leucophrys*	LC	NL					X (Bs)		X (Bs)	X (Bs)		
Mammals (excluding microbats)													
Black-striped Wallaby	*Macropus dorsalis*	LC	NL										X (Si)
Common Brush-tailed Possum	*Trichosurus vulpecula*	LC	NL						X (Ir)				

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Common Wallaroo	*Macropus robustus*	LC	NL		X (Ir)		X (Si,Sp)					X (Sp)	
Eastern Grey Kangaroo	*Macropus giganteus*	LC	NL					X (Bs)			X (Bs)		
Feral Cat	*Felis catus*	*	*								X (Ir)		
Northern Brown Bandicoot	*Isoodon macrourus*	LC	NL						X (Ir)				
Squirrel Glider	*Petaurus norfolcensis*	LC	NL									X (Sp)	
Swamp Wallaby	*Wallabia bicolor*	LC	NL		X (Sp)		X (Sp)		X (Si)				
Whiptail Wallaby	*Macropus parryi*	LC	NL				X (Sp)			X (Si,Sp)			
Microbats (recorded using Anabat)[3]													
Gould's Wattled Bat	*Chalinolobus gouldii*	LC	nl	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Chocolate Wattled Bat	*Chalinolobus morio*	LC	nl	□		□	□		□				
Little Pied Bat	*Chalinolobus picatus*	LC	nl	♦	♦		♦	♦	♦	♦	♦	□	♦
(a) Long-eared Bat	*Nyctophilus sp.*	LC	nl	♦		♦			♦	♦			♦
Inland Broad-nosed Bat	*Scotorepens balstoni*	LC	nl	♦		□	♦			♦		♦	♦
Little Broad-nosed Bat	*Scotorepens greyii*	LC	nl	□	♦		♦	♦	♦	♦		♦	♦
Eastern Cave Bat	*Vespadelus troughtoni*	LC	nl	□	♦	♦	♦	□	♦				
Eastern Bent-winged Bat	*Miniopterus orianae oceanensis*	LC	nl	♦	♦	♦	♦			♦		♦	♦

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Northern Free-tail Bat	*Chaerephon jobensis*	LC	nl	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Northern Free-tailed Bat	*Ozimops lumsdenae*	LC	nl	♦	♦		♦	♦	♦	♦	♦	♦	
Eastern Free-tailed Bat	*Ozimops ridei*	LC	nl	□	♦	♦	♦	□	♦	♦	♦	♦	♦
Yellow-bellied Sheath-tailed Bat	*Saccolaimus flaviventris*	LC	nl	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦ X (Sp)
Common Sheathtail Bat	*Taphozous troughtoni*	LC	nl		♦		□	□				□	
Reptiles													
Australian Coral Snake	*Brachyurophis australis*	LC	NL						X (Sp)				
Brown Tree Snake	*Boiga irregularis*	LC	NL									X (Sp)	
Burton's Legless Lizard	*Lialis burtonis*	LC	NL		X (Sp)								
Bynoe's Gecko	*Heteronotia binoei*	LC	NL	X (Sp)	X (Sp)					X (As,Sp)		X (As,Sp)	
Common Dwarf Skink	*Menetia greyii*	LC	NL							X (As)			
Dubious Dtella	*Gehyra dubia*	LC	NL		X (Sp)					X (Sp)		X (Sp)	
Eastern Bearded Dragon	*Pogona barbata*	LC	NL						X (As)				
Eastern Brown Snake	*Pseudonaja textilis*	LC	NL										X (As)
Grass Skink	*Lampropholis delicata*	LC	NL						X (As)				
Iridescent Litter-skink	*Lygisaurus foliorum*	LC	NL									X (As)	
Nobbi Dragon	*Diporiphora nobbi*	LC	NL										X (As)

Common name	Scientific name	Status[1]		Monitoring site number and type [2,3]									
		NC Act	EPBC Act	S1	S8	S11	S16	S17	S10	S18	S19	S22	S23
				BMU3	BMU3	BMU3	BMU3	BMU3	BMU2	BMU4	BMU5	BMU5	BMU2
				Rehab	Rehab	Rehab	Rehab	Rehab	Rem	Rem	Rem	Rem	Rem
Oscillated Velvet Gecko	*Oedura monilis*	LC	NL										X (Sp)
Open-litter Rainbow-skink	*Carlia pectoralis*	LC	NL									X (As)	
Prickly Knob-tailed Gecko	*Nephrurus asper*	LC	NL						X (Sp)	X (As)			
Robust Velvet Gecko	*Nebulifera robusta*	LC	NL									X (Sp)	
Total number of species per assessment site:				**15**	**24**	**19**	**25**	**24**	**34**	**27**	**32**	**40**	**38**
Total number of species – remnant versus rehab:				**45**					**97**				
TOTAL SPECIES				**104**									

[1] Status under Queensland *Nature Conservation Act 1992* (NC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act): **LC**-Least Concern; **NL**-Not Listed; *****-Introduced Species.

[2] X, present and record captured through:

As - Active Search; **Bs** - Bird Survey; **Ir** - Infrared Camera; **Si –** Sighted; **Sp -** Spotlight

[3] Microbat species recorded with Anabat:

♦ = definitely present - at least one call from the site was attributed unequivocally to the species

□ = possibly present - calls similar to those of the species were recorded, but could not be reliably identified (these species have not been included in the 'number of species' counts.

Appendix 4.11 Geotechnical Stability Assessment

ENVIRONMENTAL RESOURCES MANAGEMENT AUSTRALIA PTY LTD

Assessment of Geotechnical Stability of Residual Voids at Dawson North, Dawson Central and Dawson South Mines

March 2024

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1. INTRODUCTION

Dr Sue Henderson (RPEQ 4952) of Henderson Geotech Pty Ltd was requested to provide assessment of pit wall geotechnical stability for inclusion in void closure plans for Dawson North, Dawson Central and Dawson South Coal Mines. The work was undertaken in the second half of 2023 and the first half of 2024.

The assessment described in this report was made in accordance with the principles of the DRAFT Guidelines for Assessment of Geotechnically Safe and Stable Post-Mining Landforms (Simmons et al, 2024).

1.1 Limitation

This report has been prepared by Henderson Geotech Pty Ltd for Environmental Resources Management Australia Pty Ltd (ERM) on behalf of Anglo American Steelmaking Coal Pty Ltd (Client) for the purpose of supporting preparation of Progressive Rehabilitation and Closure Plans for Dawson North, Dawson Central and Dawson South Coal Mines. No parties other than the Client and the Department of Environment, Science and Innovation are authorised to rely on this report without the prior written consent of Henderson Geotech Pty Ltd.

This report is, in part, based on information provided by the Client or by other parties on behalf of the Client (Client-supplied information) in addition to data collected by Henderson Geotech Pty Ltd from the public domain. Henderson Geotech Pty Ltd has not always verified the accuracy of such information and makes no representations regarding its accuracy. Henderson Geotech Pty Ltd is not responsible for the consequences of any error or omission in Client-supplied information.

Henderson Geotech Pty Ltd has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same specialist field for projects of a similar nature and at the time and in the jurisdiction where the services were rendered. Henderson Geotech Pty Ltd makes no warranty, express or implied.

The geotechnical stability analyses and assessment described in this report are applicable only to the scenarios and inputs also described herein. A new assessment will be required if there are:

- Non-trivial changes to the location or geometry of the planned residual voids;
- Changes to proposed post-mining land uses of the voids or adjoining lands;
- Substantial changes to the understanding of stratigraphy or geotechnical properties; or
- Substantial changes to the understanding of end-of-mining and long-term groundwater levels or long-term pit lake levels.

2. STATEMENT OF LANDFORM DESIGN INTENT

These assessments of geotechnical stability for residual voids at Dawson North, Dawson Central and Dawson South Mines were undertaken to support the 2024 Progressive Rehabilitation and Closure Plans, to demonstrate that the voids can be rehabilitated as NUMAs that will not adversely impact adjacent grazing, cropping, native ecosystem, and third-party infrastructure PMLUs for at least 50 years.

3. GEOTECHNICAL MODEL

Topographic models of the proposed final landform surfaces provided in December 2023 were examined to identify locations with proposed deepest voids, highest spoil, and void walls close to the diverted Kianga Creek, and also to cover the extent of mining from south to north. The cross-sections subsequently selected for geotechnical stability analysis are listed in Table 3-1.

Table 3-1: Cross-section locations

Section	Void	Northing	Easting start	Easting finish
Dawson South DS1	Pit 28	7240250	200000	202000
Dawson South DS2	Pit 25	7251200	199250	202000
Dawson South DS3	Pit 24	7253950	199250	202000
Pit 1324-1	Pit 19	7260450	199500	204000
Pit 1324-2	Pit 13	7269100	199750	202500
Pit 0312-1	Pit 3-12 south	7271150	198500	202500
Pit 0312-2	Pit 3-12 north	7274000	198500	202500
Pit 02	Pit 2	7283500	199400	202500
Dawson North DN1	Backfilled north	7291300	199750	202750
Dawson North DN2	Northern	7293050	198750	202750

3.1 Strata and Properties

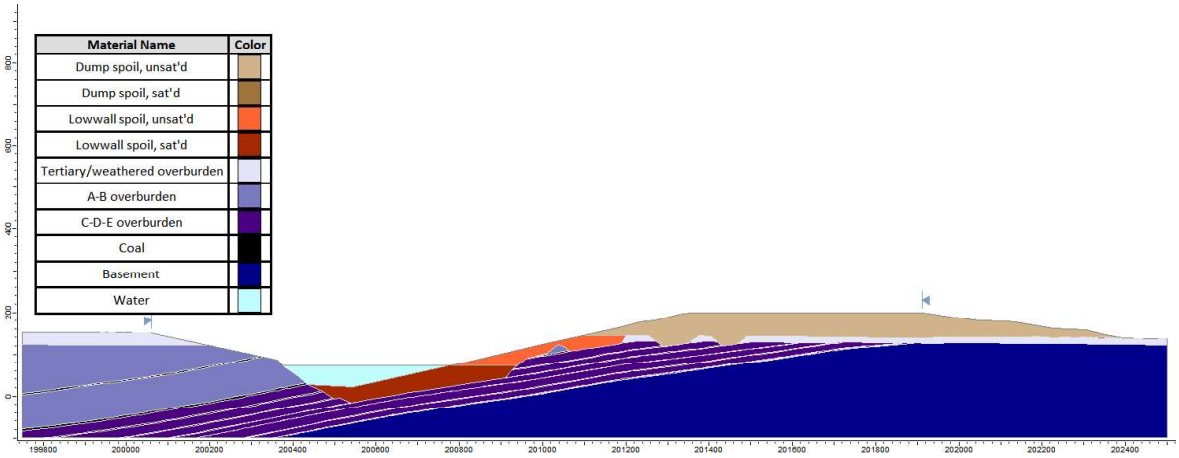
For each cross-section, the Client's geotechnical and geological departments provided base of weathering, and coal seam roofs and floors – all extracted from the site geological model – plus the current mined floor and surface topography. The surface topography and associated end-of-mining pit shells for the final landform, dated December 2023, were provided through ERM.

Strength properties were sourced from Anglo American (2022), Table 2. Some of the selected geological cross-sections showed faulting; where this occurred, an enclosing region was defined and assigned the properties of fault/shear plane material. The properties applied in the geotechnical model are summarised in Table 3-2 and an example of a cross-section set up for stability analysis is included as Figure 3-1.

Table 3-2: Material strength properties

Model Name	Unit weight (kN/m^3)	Cohesion (kPa)	Phi (°)	Anglo American Table 2 Material
Dump spoil, unsaturated	18	20	25	BMA Spoil Cat 1U
Dump spoil, saturated	20	0	18	BMA Spoil Cat 1S
Lowwall spoil, unsaturated	18	45	30	BMA Spoil Cat 2.3U
Lowwall spoil, saturated	20	18	25	BMA Spoil Cat2.3S
Tertiary/weathered overburden	18	30	28	Weathered Tertiary
A-B seams overburden	24	419	35.1	Between Weathered (SW) & Fresh Overburden
C-D-E seams overburden	24	568	36.1	Fresh Overburden
Coal	15	35	30	Coal
Fault zone	24	0	20	Fault/Shear Plane
Basement	24	568	36.1	Fresh Overburden

Figure 3-1: Sample cross-section for analysis



3.2 Groundwater Pressure Model

Piezometric heads for the shallowest aquifer were interpolated from groundwater contour plots in Klohn Krippen Berger (2024a and 2024b) and applied as total head to the western and eastern boundaries of each cross-section. Both reports included plots for end-of mining that were used directly. Contour plots for 100 years after end-of-mining were provided for Dawson Central and North voids and these were used to estimate long-term groundwater conditions. For Dawson South, only contours for end-of-mining and 1000 years later were provided so groundwater heads that were the average of these were used to approximate long-term conditions.

Long-term pit lake water levels, determined by mass void water balance modelling, were provided by ERM on schematics entitled “{number} – Final Landform Water Levels – {pit name}”.

Three groundwater scenarios were applied in highwall and lowwall stability analyses for each cross-section, namely:

- dry void at end-of mining with zero pore water pressure at the lowest part of the mined floor;
- void lake at predicted long-term water level; and
- void lake at an interim water level about mid-way between dry (end-of-mining) and the long-term average.

Hydraulic properties were generally adopted from Klohn Krippen Berger (2024a), except as noted in Table 3-3. In particular, the higher permeabilities assumed here for spoil are consistent with its looser, more open, structure but may also reflect the scale difference between regional groundwater modelling and seepage modelling for stability cross-sections.

Table 3-3: Hydraulic properties

Model Name	k_h (m/s)	k_h/k_v	Comment
Dump spoil, unsaturated	3.50e-6	0.25	Vertical permeability lower than for pushed lowwall spoil
Dump spoil, saturated	3.50e-6	0.25	
Lowwall spoil, unsaturated	3.50e-6	0.50	More permeable than Tertiary / weathered overburden
Lowwall spoil, saturated	3.50e-6	0.50	
Tertiary/weathered overburden	2.31e-6	0.10	
A-B seams overburden	1.91e-8	0.10	
C-D-E seams overburden	1.91e-8	0.10	
Coal	2.75e-8	0.10	
Fault zone	1.00e-7	0.50	More permeable than coal
Basement	1.23e-9	0.10	

3.3 Potential Geotechnical Instability Mechanisms

As noted in Section 3.1, faulting was modelled using specific, lower, strength properties. The impact of other minor structures – for example bedding and general jointing – is accommodated in the rock-mass strength parameters. The geological model at the selected cross-sections did not show other major structures. It is possible that such structures might occur at cross-sections not analysed or might not yet have been discovered and incorporated in the geological model; however, any such structures would be encountered during mining operations and managed through pit wall design at that time. Consequently, it is not necessary to address them specifically in the long-term planning phase.

In this context, 2D circular and non-circular slip surfaces were considered appropriate potential failure mechanisms - circular slips are typical of relatively homogeneous spoil and sedimentary rock masses, while non-circular slips might be dictated by changes in material such as coal seams and fault zones in the highwall and endwall, and the pit floor and the saturated spoil interface in the lowwall.

Rainfall runoff over the highwalls and endwalls will be limited by exclusion works and/or flood protection landforms as necessary. The level of geotechnical profile detail available for this assessment did not suggest weak overburden strata overlain by more competent strata that could be susceptible to undercutting. On the lowwall side, rainfall runoff will mainly flow straight down the batters, with vegetation in native ecosystem and agriculture PMLUs limiting the quantity of such runoff. On these bases, it was concluded that erosion is not likely to materially affect long-term geotechnical stability.

The lack of identified major structure also suggests that, within the time frame nominated for this assessment, weathering on highwalls and endwalls is unlikely to penetrate deeply enough to cause geotechnically significant surface fretting. The open porous character of dumped spoil may allow physical weathering, such as slaking, to some depth, however, the associated strength reduction is already accommodated in the provided strength parameters.

The residual voids are either outside the modelled 1:1000 AEP floodplain and/or landforms to prevent inundation to that standard are included in the mine's final landform design. The void water balance modelling covered periods of greater than 150 years. Therefore, the effects of severe hydrological events are managed outside the scope of this geotechnical stability assessment.

3.4 Statement of Model Uncertainty

The stability assessment methodology described in Simmons et al (2024) includes a matrix to consider and score the geotechnical model, based of the quality of input data for various aspects of the model. This subsidiary assessment is included as Appendix A. In summary. the combined geotechnical and groundwater pressure model has a reliability score of 46/100 for pit walls that were completed at least five years ago and 31/100 for all other void walls. Both scores are <50/100 and the model is therefore ranked as High Uncertainty.

4. CONSEQUENCE ASSESSMENT

A consequence assessment, undertaken in accordance with Simmons et al (2024), is included as Appendix B and the outcomes are summarised as follows:

Scenario	**Consequence of Geotechnical Instability**
Highwall instability that extends to third party infrastructure behind crest	Medium-High
Highwall instability that extends into grazing PMLU behind crest	Medium
Highwall instability that extends creek channels or flood protection structures behind crest	Medium
Highwall instability that extends into native ecosystem PMLU behind crest	Low
Highwall instability that does not extend outside NUMA	Negligible
Lowwall instability that extends into grazing PMLU	Low
Lowwall instability that extends into native ecosystem PMLU	Low
Lowwall instability that does not extend to within 50m PMLU	Negligible

5. DESIGN ACCEPTANCE CRITERIA

Instability along potential slip surfaces is most commonly assessed using limit equilibrium analyses, with results expressed as Factor of Safety. The typical range in factor of safety adopted for slope design is 1.2 to 1.5, with the target value reduced for lower model uncertainty and/or less severe consequences. Based on assessment of the geotechnical model as High Uncertainty and the consequence levels listed in Section 4, the selected minimum factors of safety are set out in Table 5-1.

Table 5-1: Adopted design acceptance criteria

Scenarios	Minimum Factor of Safety
Instability extending into infrastructure or grazing PMLUs	1.50
Instability extending to watercourses or flood protection structures	1.50
Instability extending into native ecosystem PMLU	1.35
Instability contained within NUMA	1.25

6. STABILITY ANALYSES

Two cross-sections have been analysed using Slide2 Modeler, 2D Limit Equilibrium Analysis for Slopes. For the first cross-section – Pit 3-12 south – the lowwall was analysed using three analytical methods, namely:

- Spencer, Vertical Slices, Circular Surfaces with Auto Refine Search – suitable for homogenous materials and profiles without frequent interfaces;
- Sarma, Vertical Slices, Non-Circular Surfaces with Auto Refine Search – suitable for layered profiles where materials have strongly contrasted strength properties; and
- Sarma, Vertical Slices, Non-Circular Surfaces with Block Search – used to force the minimum factor of safety search routine to follow a narrow band of weaker material

The results of all analyses undertaken are included in Appendix C. For Pit 3-12 south lowwall, the analytical methods with auto refine search produced the same results and very similar slip surfaces, while the block search method produced the same or higher minimum factors of safety. On these bases, it was concluded that the Spencer circular method is sufficient for lowwall stability analysis going forward.

Only Sarma methods were used for the highwalls, to accommodate the interbedding of overburden, interburden and coal seams. In the two highwall sections analysed, the minimum factor of safety occurred in spoil backfill at the base of the final landform highwall, rather than through intact rock. The block search was used to force slip surfaces through coal seams, but this resulted in higher minimum factors of safety because the coal seams dip into the wall and therefore do not generally contribute to geotechnical instability. If a particular profile included faults dipping toward the void, the block search method might be advisable but otherwise, the auto-refine search for non-circular slip surfaces is considered sufficient for stability assessment.

The results of stability analyses undertaken are summarised in Table 6-1. All minimum factors of safety were greater than 1.5, which is the most stringent design acceptance criterion in Table 5-1. Consequently, it was not necessary consider whether each critical slip surface was contained within the void NUMA or extended into an adjoining PMLU. That is, all cases analysed met the required design acceptance criteria.

Table 6-1: Results of stability analyses

Location & Scenario	Minimum Factor of Safety
Pit 3-12 south lowwall	
Dry void	2.48
Intermediate pit lake	2.12
Long-term pit lake	2.10
Pit 3-12 south highwall	
Dry void	2.37
Intermediate pit lake	1.57
Long-term pit lake	1.86
Pit 25 lowwall	
Dry void	3.62
Intermediate pit lake	2.99
Long-term pit lake	2.93
Pit 25 highwall	
Dry void	3.12
Intermediate pit lake	2.12
Long-term pit lake	2.42

7. CONCLUSIONS

Cross-sections for the southern end of Pit 3-12 (Dawson Central) and Pit 25 (Dawson South), with the final landform and prime mined surfaces provided in December 2023, showed acceptable long-term geotechnical stability for the proposed post-mining land uses.

Other locations may have different geometry, faulting behind the highwall and/or different predicted long-term pit lake levels. These factors could affect geotechnical stability and therefore cross-sections at other locations should also be analysed.

8. REFERENCES

Anglo American, April 2022, Geotechnical Guidelines for Mine Planning Dawson Mine Version 2, internal document.

Klohn Krippen Berger, March 2024a, Dawson Central and North Progressive Rehabilitation and Closure Plan Groundwater Modelling Report Draft.

Klohn Krippen Berger, March 2024b, Dawson South EA Amendment Groundwater Impact Assessment Report Final.

Simmons J, Henderson S and Kennedy G, January 2024, Guidelines for Assessment of Geotechnically Safe and Stable Post-Mining Landforms, draft C34028 project report submitted to ACARP.

APPENDIX A MODEL RELIABILITY STATEMENT

Model Element	**Max.**		**Uncertainty Level**	**and Weighting**		**Score**
	Score	Introductory	High	Medium	Low	
		0.0	0.2	0.5	1.0	
Strata & landform profile information	10	Basic surfaces with unreliable or absent data	Assessment based on 'typical' regional conditions.	Geological surfaces extracted from site geological model.	Use of information such as drill logs and field mapping to define sub geotechnical units within broader geological units.	5
Structural Model	8	No information	Structure assumed typical of the region	Structure broadly understood from observation and experience at the site	Either no dominant structure OR structure well understood from mapping and drilling	4
Strata Complexity	8	No information	Strata or structure are highly variable with distance OR properties are greatly affected by moisture content.	Strata and structure do not vary rapidly with distance, AND properties not greatly affected by moisture content changes.	Strata quite uniform in thickness and properties AND structure clearly defines slip surfaces	1.6
Strength Properties	10	No information	Derived from published data for the material classifications, without specific regional data.	Derived from tests on key strata sampled from sites within the region.	Derived from site specific tests on key strata	5
Deformation Properties	4	No information, or not considered in stability assessment	Derived from published data for the material classifications, without specific regional data.	Derived from tests on key strata sampled from sites within the region.	Derived from site specific tests on key strata	0

Groundwater Pressure Model	20	No site measurements; conceptual hydrogeological assessment only	Pre-mining groundwater study OR sensitivity analyses included in stability analyses	>2 years measurement for site groundwater network, with interpretation	>2 years measurement of at least 2 piezometers at the slope in question, with associated groundwater analysis	10
Method of Analysis	10	No quantitative analyses	Able to accurately represent the failure mechanism BUT there is limited industry experience interpreting the results	Able to approximately represent the failure mechanism AND there is wide industry experience in interpreting the results	Able to accurately represent the failure mechanism AND there is wide industry experience in interpreting the results	5
Reported field performance observations	30	<2 years visual observation ***for pits not yet mined***	2-5 years visual observation	>5 years visual observation or > 2 years movement measurement ***for existing voids***	> 5 years movement measurement	0 or 15

TOTAL = 31 or 46

Rating	**Ranking**	**Safety and Stability Implications**
80 - 100	Low Uncertainty	Risk management to an ALARP standard is possible with due allowances for model elements ranked as medium or high uncertainty level
50 - 79	Medium Uncertainty	Risk management to an ALARP standard may not be possible without some combination of improvements to the model, significant increases in design acceptance criteria, or uncertainty allowances in observational stability acceptance criteria
< 50	High Uncertainty	Risk management to an ALARP standard is not likely to be possible. Assessment must be qualified accordingly, or significant improvements made to the model, significant increases in design acceptance criteria, or uncertainty allowances in observational acceptance criteria prior to finalising assessment.

APPENDIX B CONSEQUENCE CATEGORY ASSESSMENT

Consequence Category Levels and Thresholds

	N/A or Negligible	Low	Medium	High
Harm to Humans				
	People are not routinely present in the impacted area or only injuries requiring first aid are likely	Loss of life is not expected and only short-term disabling injuries are expected.	Single loss of life or long-term disabling injuries are expected	Multiple loss of life expected
Environmental Harm				
	Minor, temporary impact to the environment	Measurable impact to an area ≤ 1km^2; where remediation of damage is likely to take ≤ 1 year	Impact to an area ≤ 5km^2; where remediation of damage is likely to take ≤ 5 years	Impact to an area > 5km^2; where remediation of damage is likely to take > 5 years
Property Loss & Damage				
	Minor, temporary community impact that recovers with little intervention; Damage to property or compensation or repair costs < $0.5M	Measurable but limited community impact lasting less than six months; Damage to property or compensation or repair costs $0.5M - $10M	Serious impact on community lasting up to 12 months; Damage to property or compensation or repair costs $10M - $50M	Severe impact on community lasting more than 12 months; Damage to property or compensation or repair costs > $50M

Assessment for Dawson Mines Highwall / Endwall

Extent of Instability *(length or area affected)*	**Exposure** *(people, ecosystems & property within extent)*	**Harm to Humans**		**Environmental Harm**		**Property Loss & Damage**	
		Impacts	***Cat.***	***Impacts***	***Cat.***	***Impacts***	***Cat.***
Crest Zone							
Native ecosystem PMLU	People will not routinely access the area	People not routinely present	Negl.	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of vegetation would take <1year	**Low**	No repair or compensation costs	Negl.
Grazing PMLU	A small number of people likely to access the area due to cattle grazing operations Property such as fencing and water troughs may be present	Single loss of life or long-term disabling injuries are possible	**Medium**	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of grassland would take <1year	Low	Costs to replace damage property expected to be <$0.5M	Negl.
Third party infrastructure	Several people likely to access the area. Property such as buildings and equipment are present.	Multiple loss of life not expected but possible.	**Medium -High**	Minimal environmental values around infrastructure	Negl.	Damage to property or compensation or repair costs < $10M	Low
Kianga Creek	People will not routinely access the area	People not routinely present	Negl.	Measurable impact to area <1km^2 Repair work including to re-establish vegetation would take >1year	**Medium**	Damage to property or compensation or repair costs $0.5M - $10M	Low
Body of Slope							
Within NUMA	People will not routinely access the slope No property on slope	People not routinely present	Negl.	Minor impact to the environment	Negl.	No repair or compensation costs	Negl.

Extent of Instability *(length or area affected)*	**Exposure** *(people, ecosystems & property within extent)*	**Harm to Humans**		**Environmental Harm**		**Property Loss & Damage**	
		Impacts	***Cat.***	***Impacts***	***Cat.***	***Impacts***	***Cat.***
Toe Zone							
Within NUMA	People will not routinely access NUMA Low value habitat in pit lake No property in NUMA	People not routinely present	Negl.	Minor impact to the environment	Negl.	No repair or compensation costs	Negl.

Negligible consequence for geotechnical instability contained within NUMA

Low consequence for geotechnical instability that extends into Native Ecosystem

Medium consequence for geotechnical instability that extends into Agricultural land or to Kianga Creek

Medium-High consequence for geotechnical instability that extends into land containing third party infrastructure

Assessment for Dawson Mines Lowwall

Extent of Instability *(length or area affected)*	**Exposure** *(people, ecosystems & property within extent)*	**Harm to Humans**		**Environmental Harm**		**Property Loss & Damage**	
		Impacts	***Cat.***	***Impacts***	***Cat.***	***Impacts***	***Cat.***
Crest Zone							
Native ecosystem PMLU	People will not routinely access the area	People not routinely present	Negl.	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of vegetation would take <1year	**Low**	No repair or compensation costs	Negl.
Grazing PMLU	A small number of people likely to access the area due to cattle grazing operations Grassland habitat with some shade trees, suitable for managed grazing Property such as fencing and water troughs may be present	Only short-term disabling injuries expected	**Low**	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of grassland would take <1year	Low	Costs to replace damage property expected to be <$0.5M	Negl.
Body of Slope							
Native ecosystem PMLU	People will not routinely access the area	People not routinely present	Negl.	Measurable impact to area <1km^2 Stabilisation work to encourage re-establishment of vegetation would take <1year	**Low**	No repair or compensation costs	Negl.
Within NUMA	People will not routinely access NUMA Low value habitat on slope No property in NUMA	People not routinely present	Negl.	Minor impact to the environment	Negl	No repair or compensation costs	Negl.

Extent of Instability *(length or area affected)*	**Exposure** *(people, ecosystems & property within extent)*	**Harm to Humans**		**Environmental Harm**		**Property Loss & Damage**	
		Impacts	***Cat.***	***Impacts***	***Cat.***	***Impacts***	***Cat.***
Toe Zone							
Within NUMA	People will not routinely access NUMA Low value habitat in pit lake No property in NUMA	People not routinely present	Negl.	Minor impact to the environment	Negl.	No repair or compensation costs	Negl.

Negligible consequence for geotechnical instability in NUMA

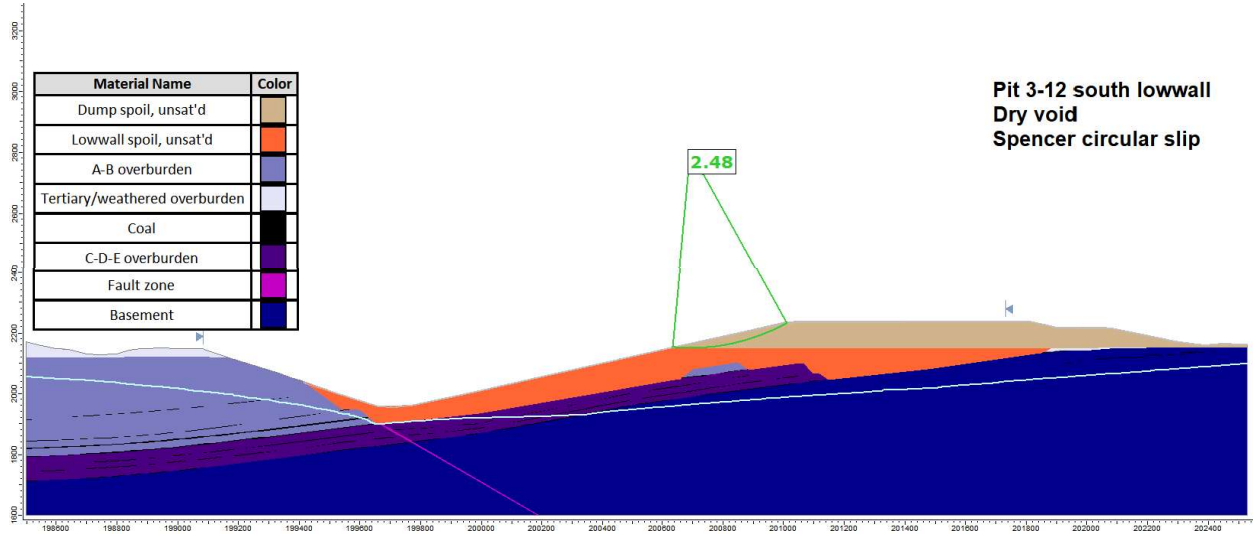
Low consequence for geotechnical instability that extends into Native Ecosystem or Agricultural Land

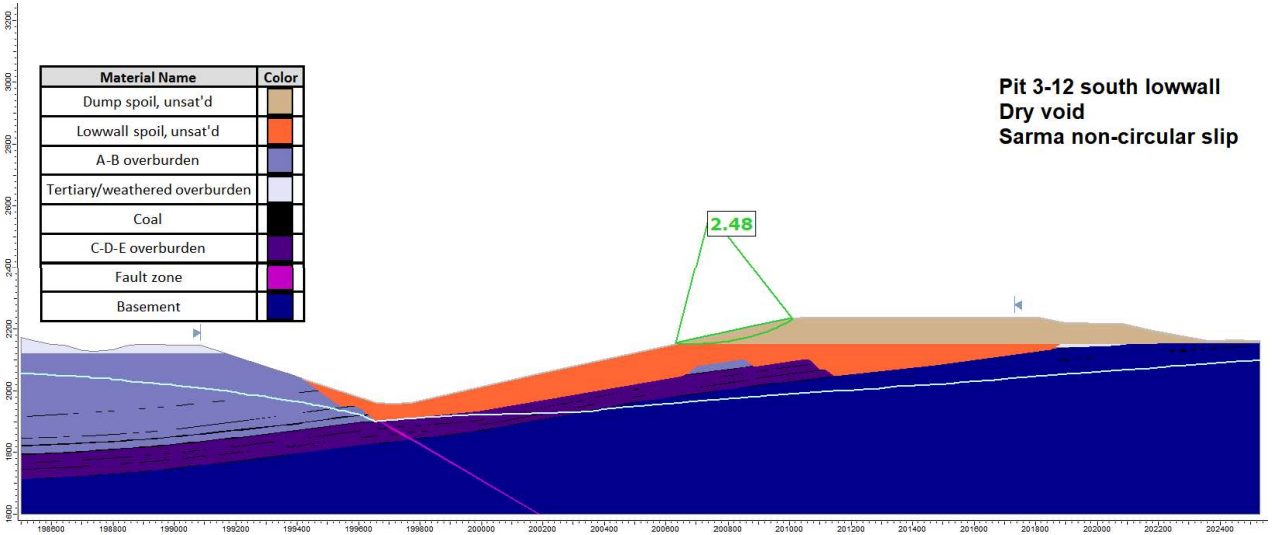
APPENDIX C STABILITY ANALYSES

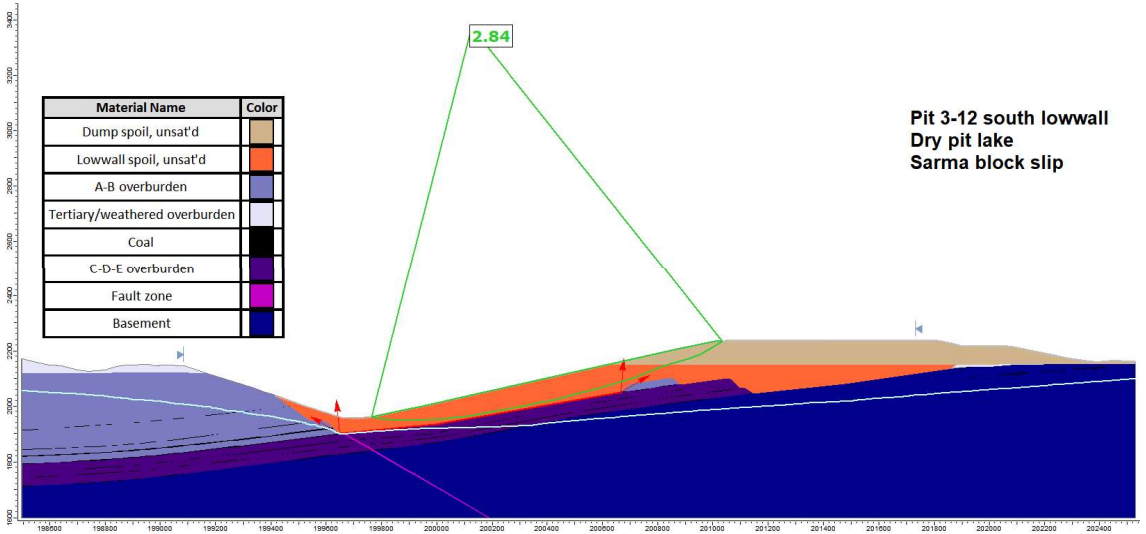
Factors of Safety from Analyses

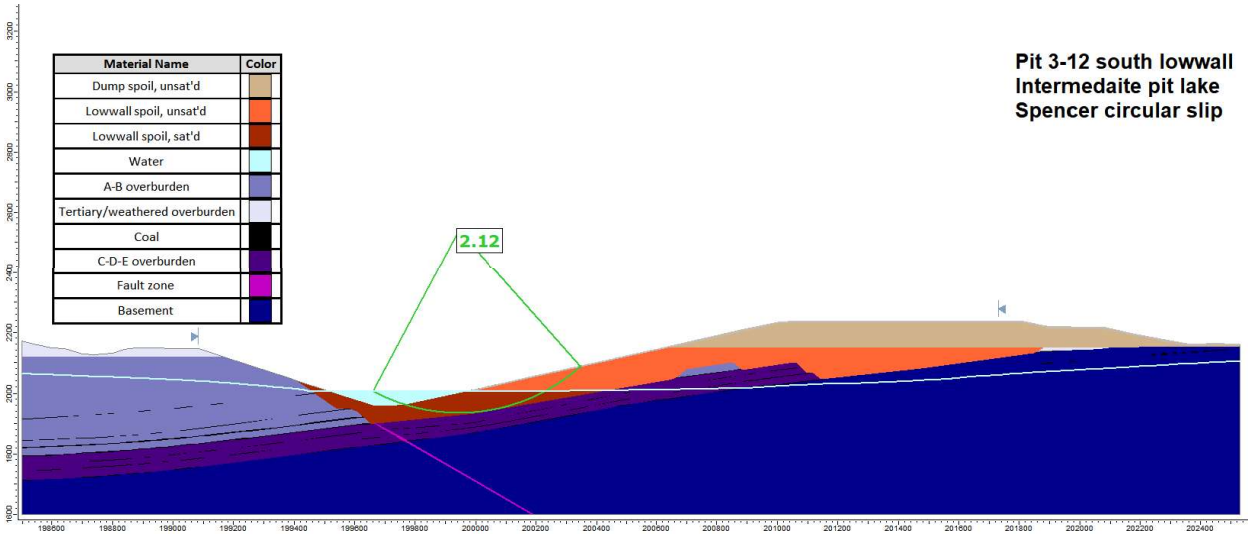
Void	Location	Scenario	Spencer circular	Sarma non-circular	Sarma block
Pit 3-12 south	lowwall	dry void	2.48	2.48	2.84
		intermediate pit lake	2.12	2.12	2.12
		long-term pit lake	2.10	2.10	2.10
Pit 3-12 south	highwall	dry void		2.37	3.07
		intermediate pit lake		1.57	2.38
		long-term pit lake		1.86	2.59
Pit 25	lowwall	dry void	3.62		
		intermediate pit lake	2.99		
		long-term pit lake	2.93		
Pit 25	highwall	dry void		3.12	3.83
		intermediate pit lake		2.12	2.93
		long-term pit lake		2.42	2.99

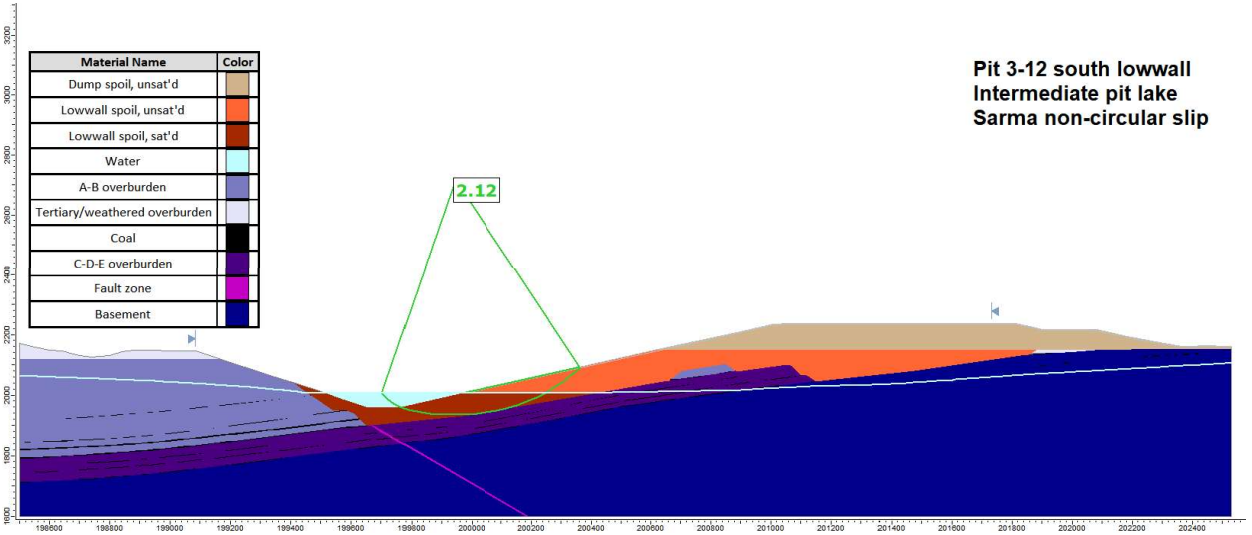
Pit 3-12 south lowwall



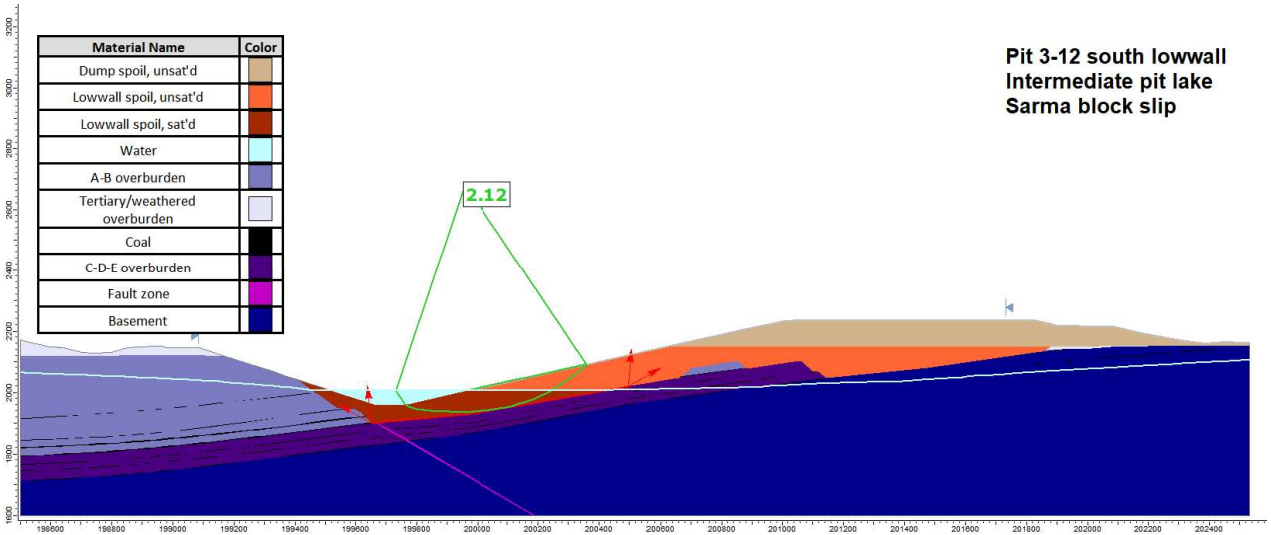



2.84
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement
Pit 3-12 south lowwall
Dry pit lake
Sarma block slip

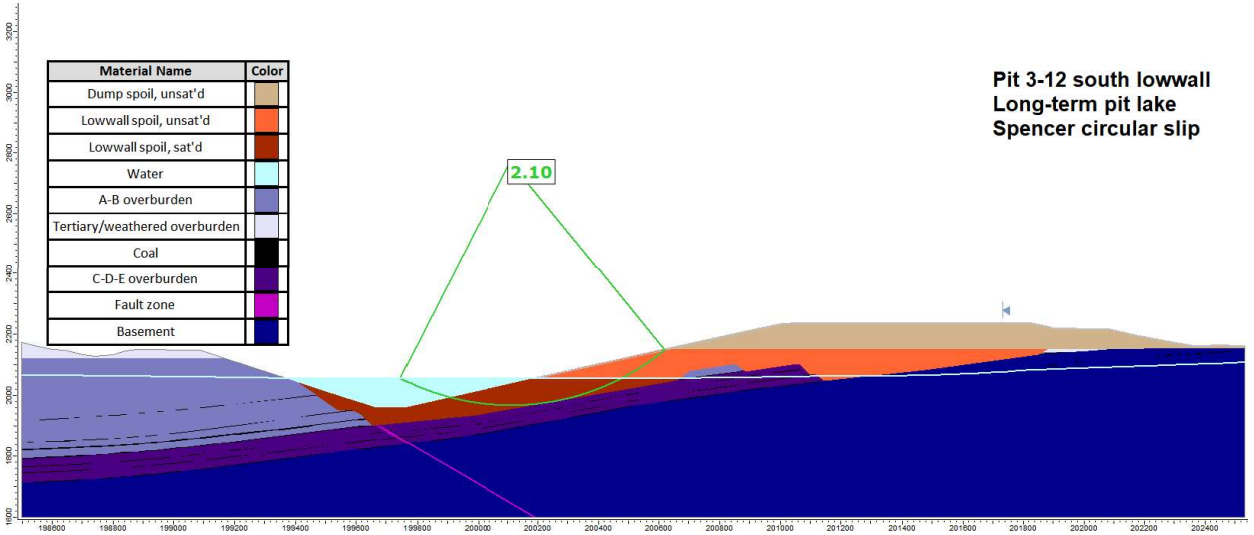

2.12
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
Water
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement
Pit 3-12 south lowwall
Intermedaite pit lake
Spencer circular slip

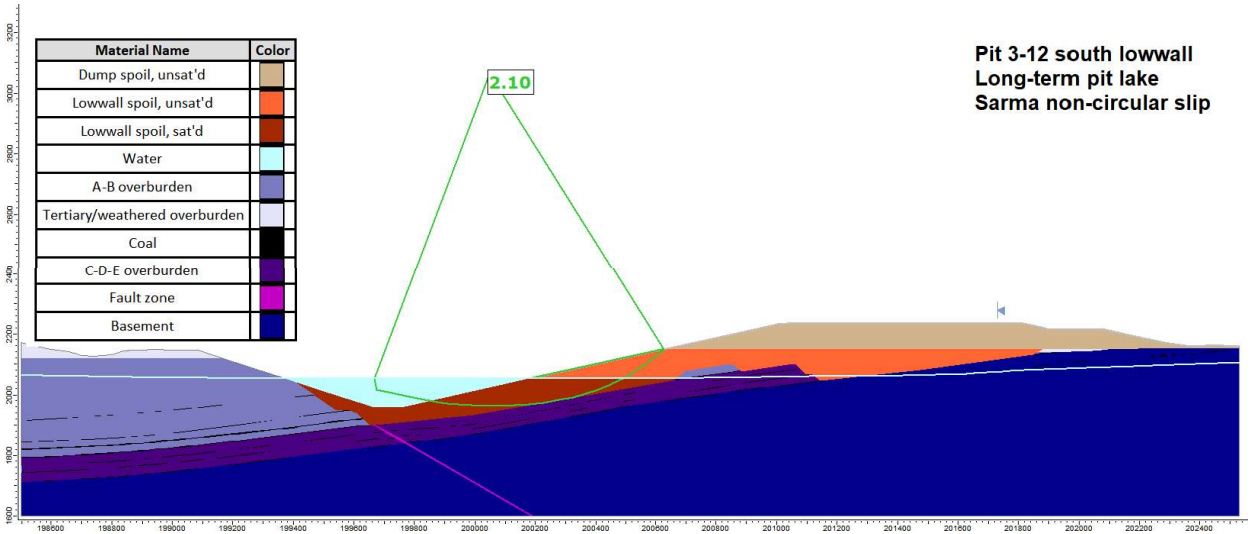


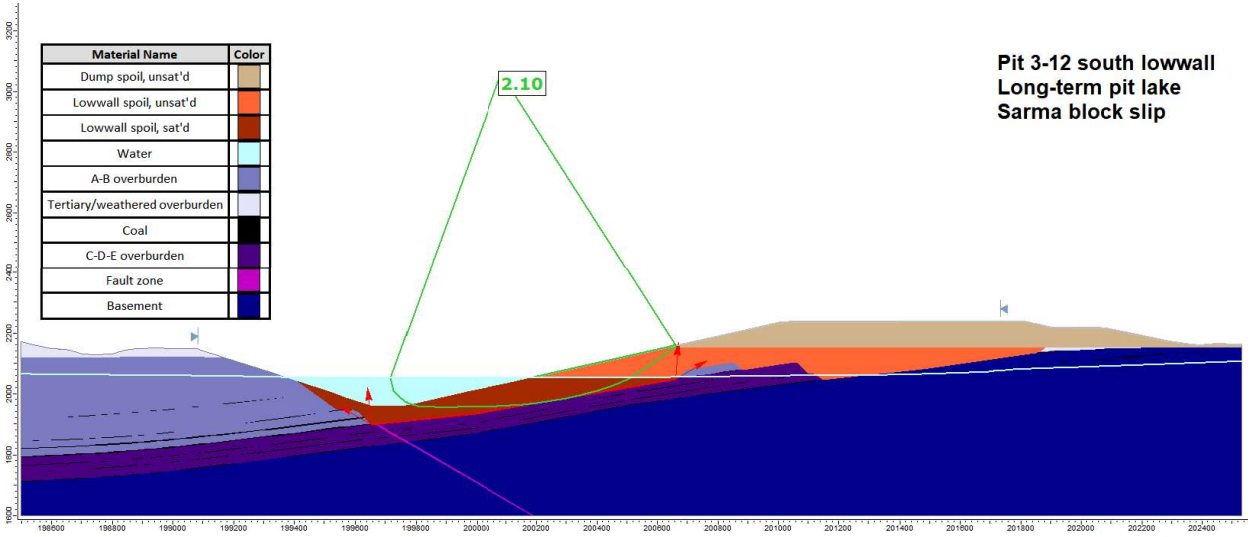
Pit 3-12 south lowwall
Intermediate pit lake
Sarma non-circular slip



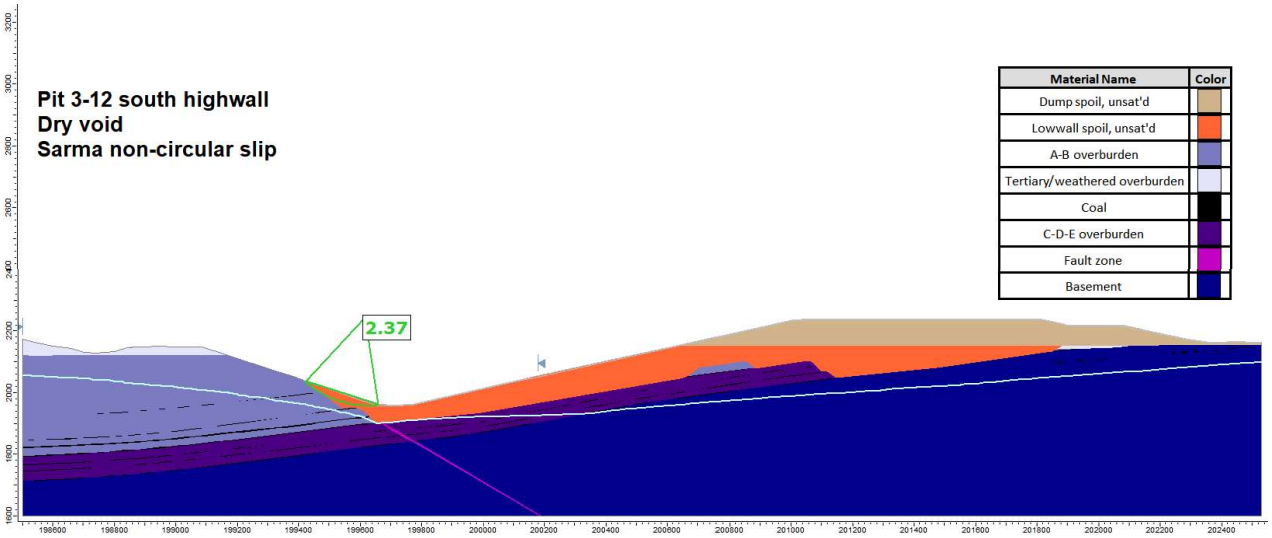
Pit 3-12 south lowwall
Intermediate pit lake
Sarma block slip

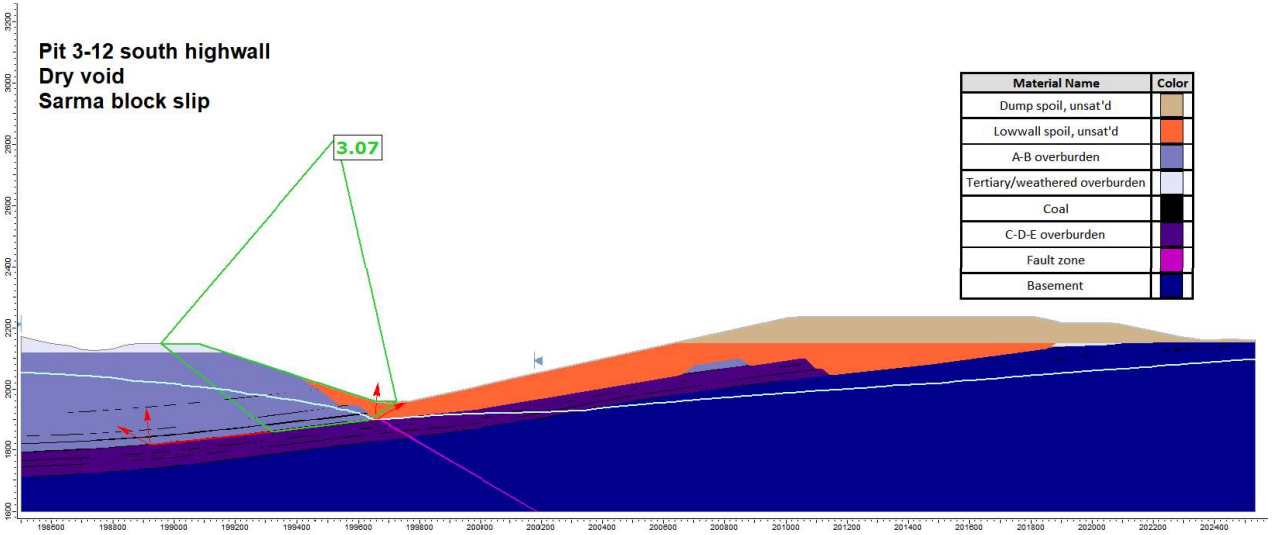

Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
Water
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement
Pit 3-12 south lowwall
Long-term pit lake
Spencer circular slip
2.10

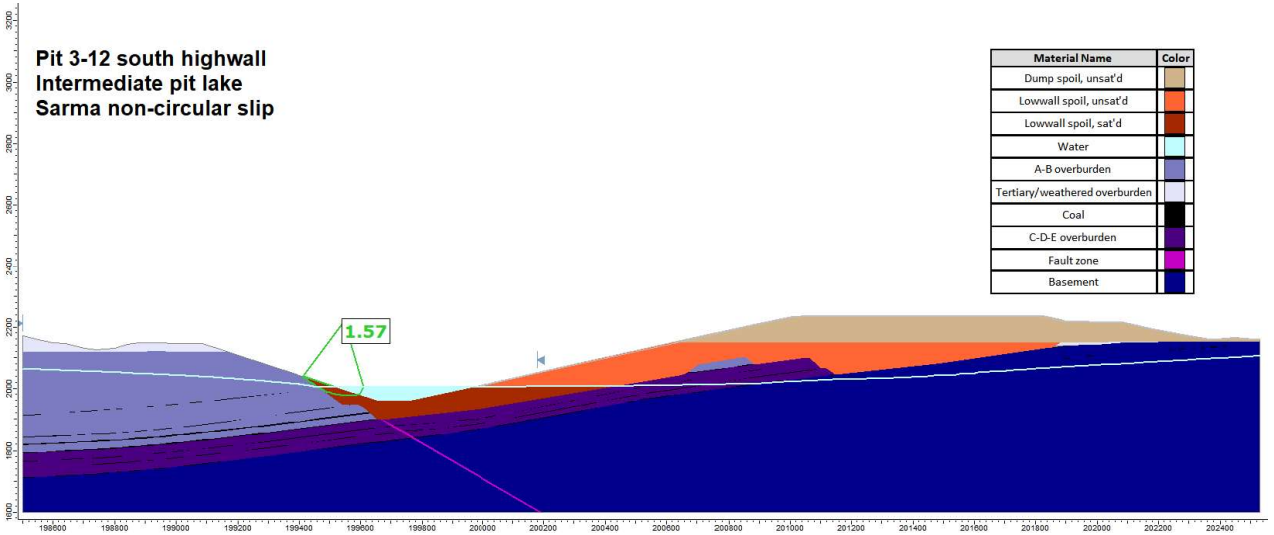

Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
Water
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement
Pit 3-12 south lowwall
Long-term pit lake
Sarma non-circular slip
2.10

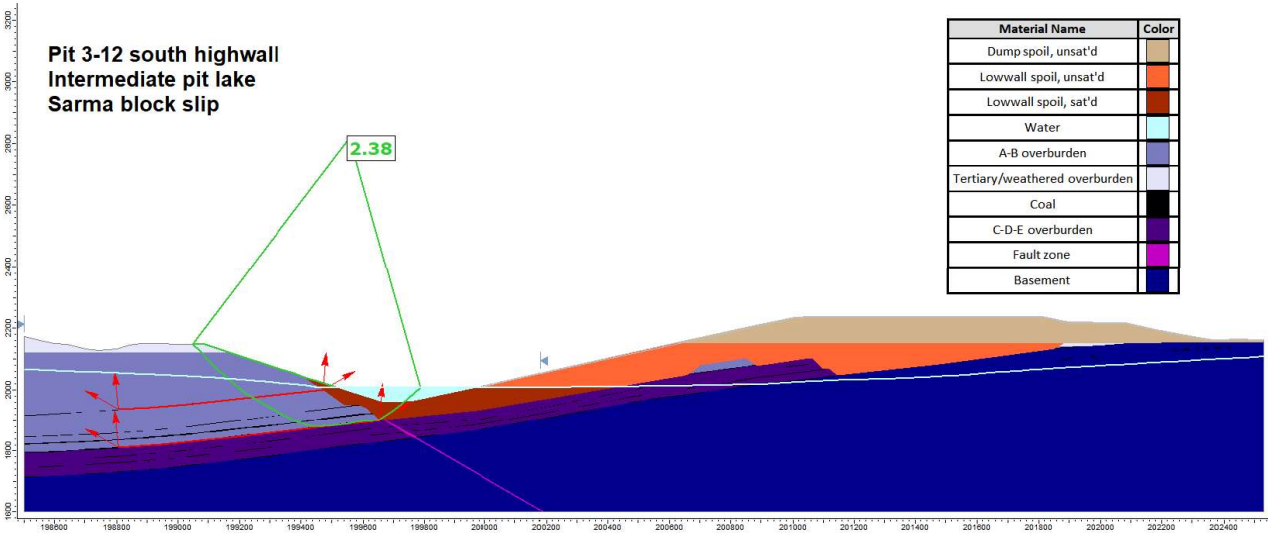


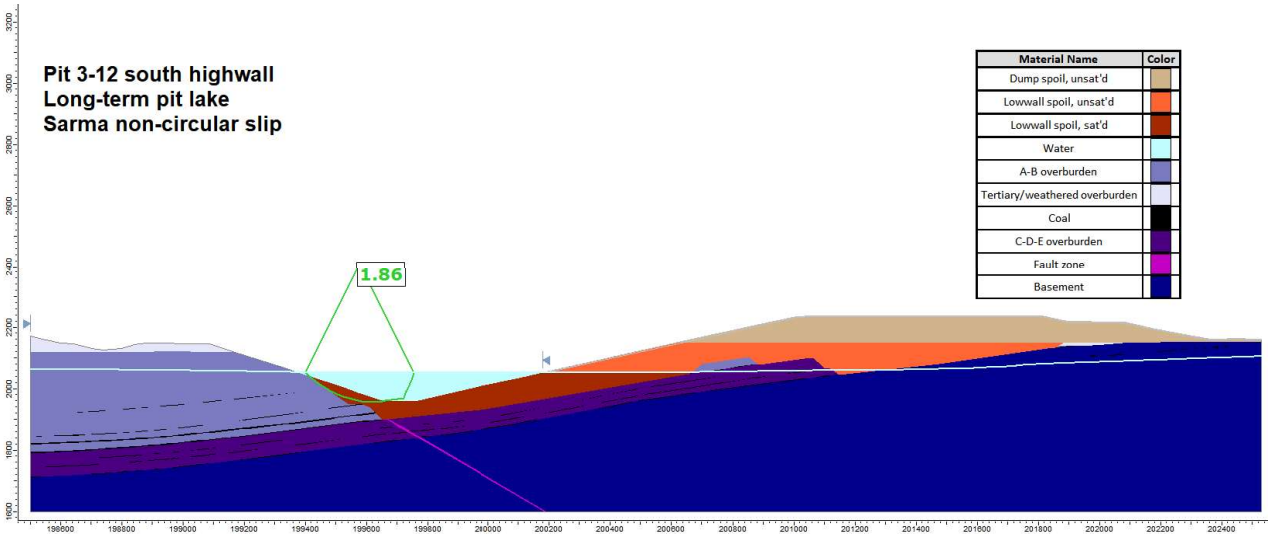
Pit 3-12 south highwall

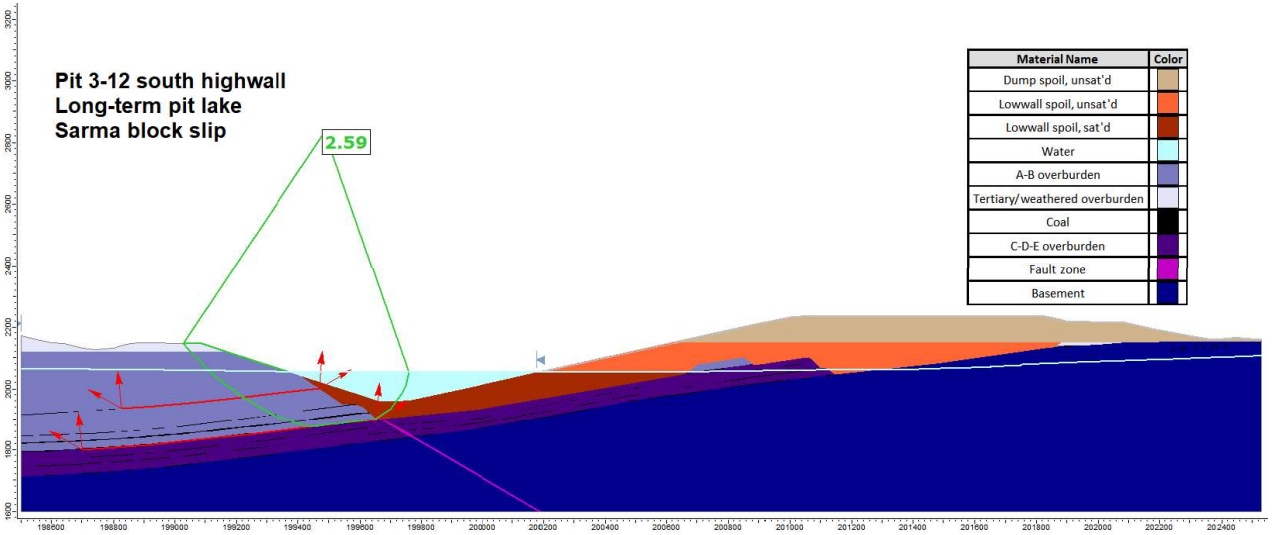



Pit 3-12 south highwall
Dry void
Sarma block slip
3.07
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement

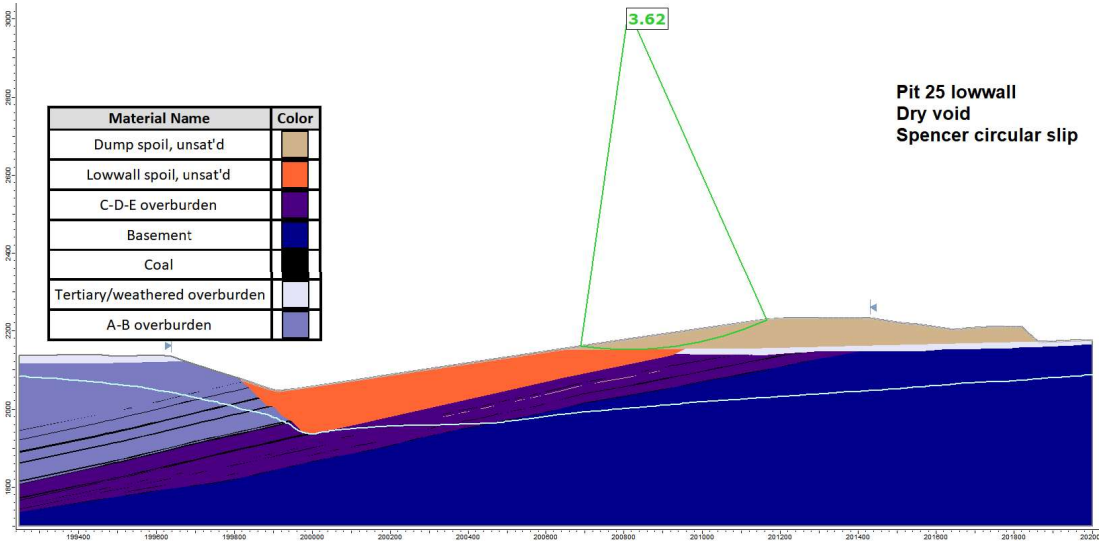

Pit 3-12 south highwall
Intermediate pit lake
Sarma non-circular slip
1.57
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
Water
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement

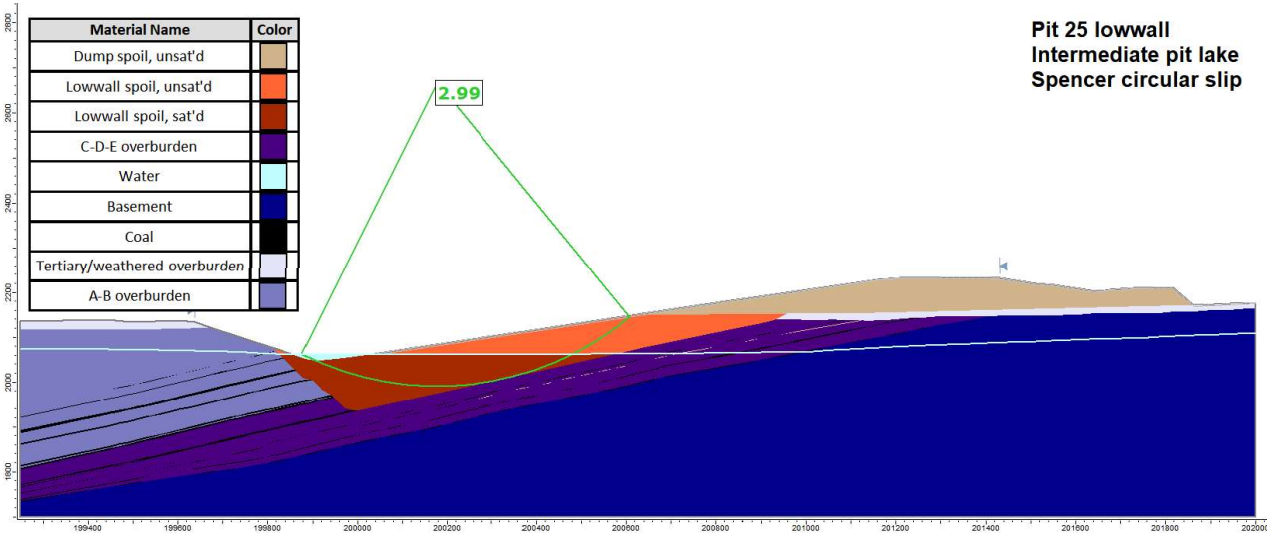

Pit 3-12 south highwall
Intermediate pit lake
Sarma block slip
2.38
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
Water
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement

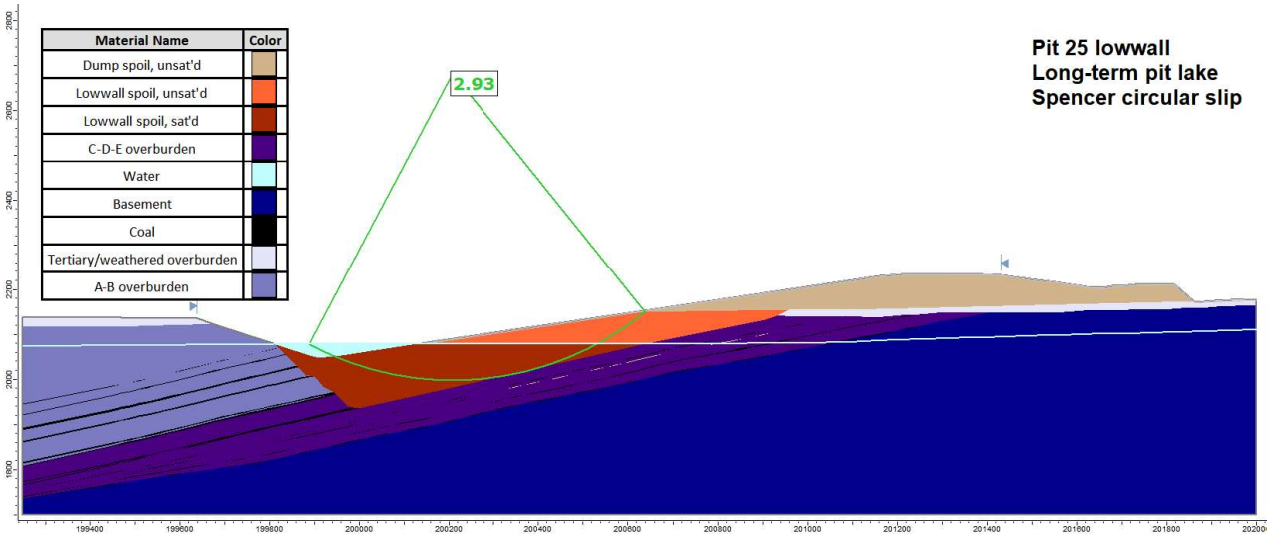

Pit 3-12 south highwall
Long-term pit lake
Sarma non-circular slip
1.86
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
Water
A-B overburden
Tertiary/weathered overburden
Coal
C-D-E overburden
Fault zone
Basement



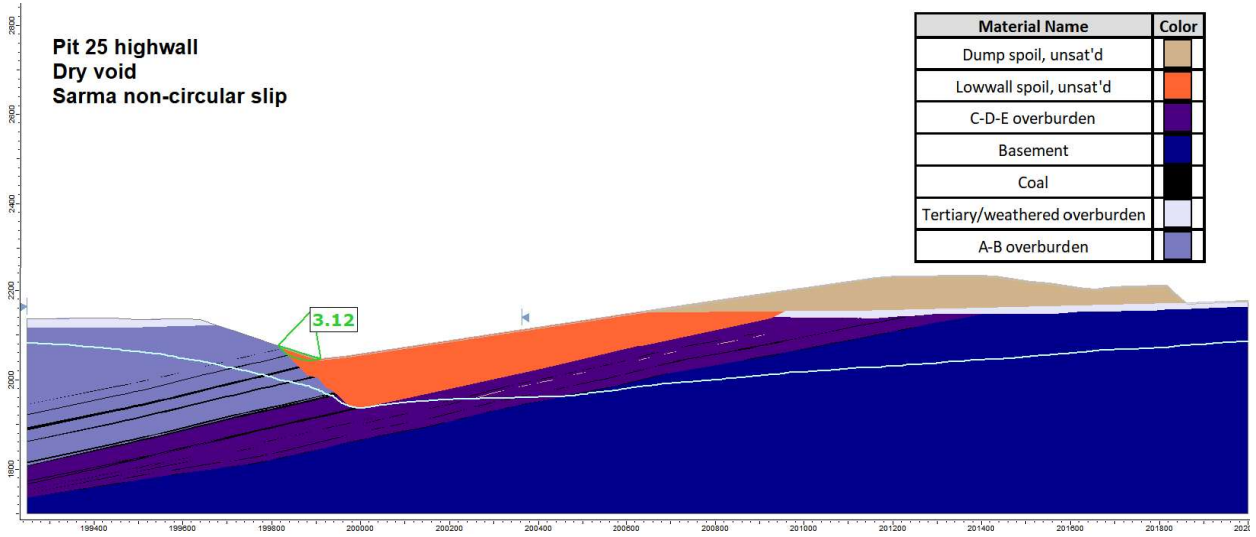
Pit 25 lowwall

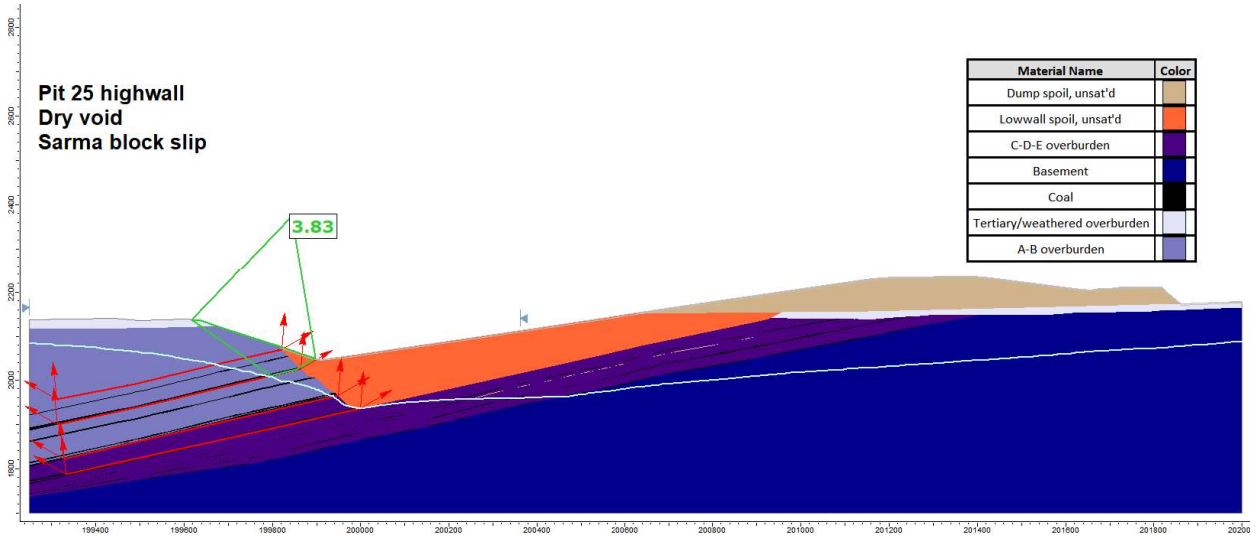


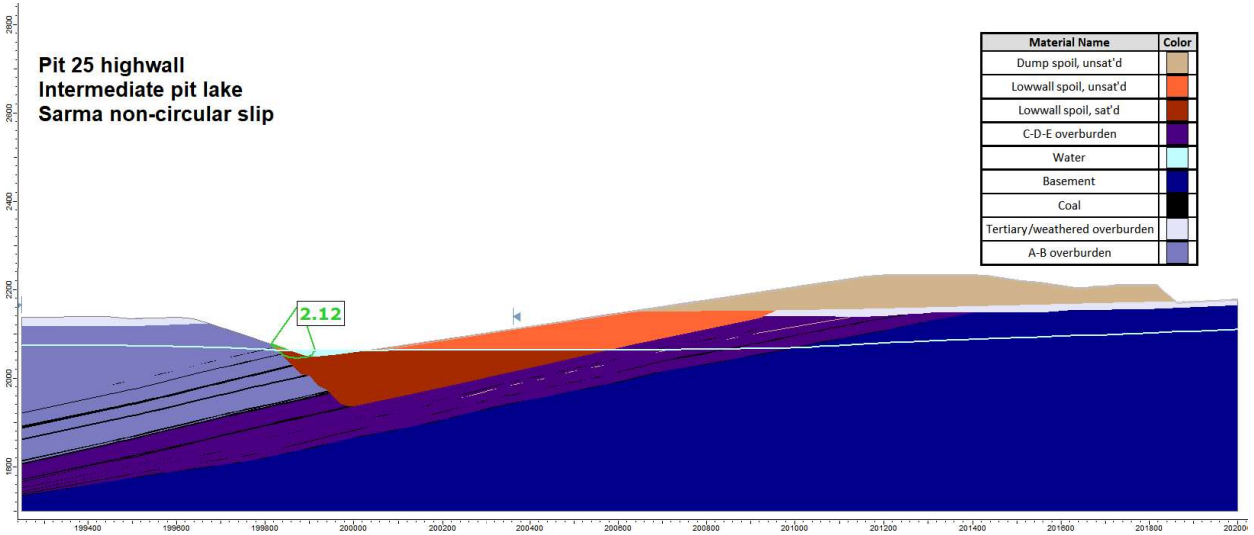

Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
C-D-E overburden
Water
Basement
Coal
Tertiary/weathered overburden
A-B overburden
2.99
Pit 25 lowwall
Intermediate pit lake
Spencer circular slip

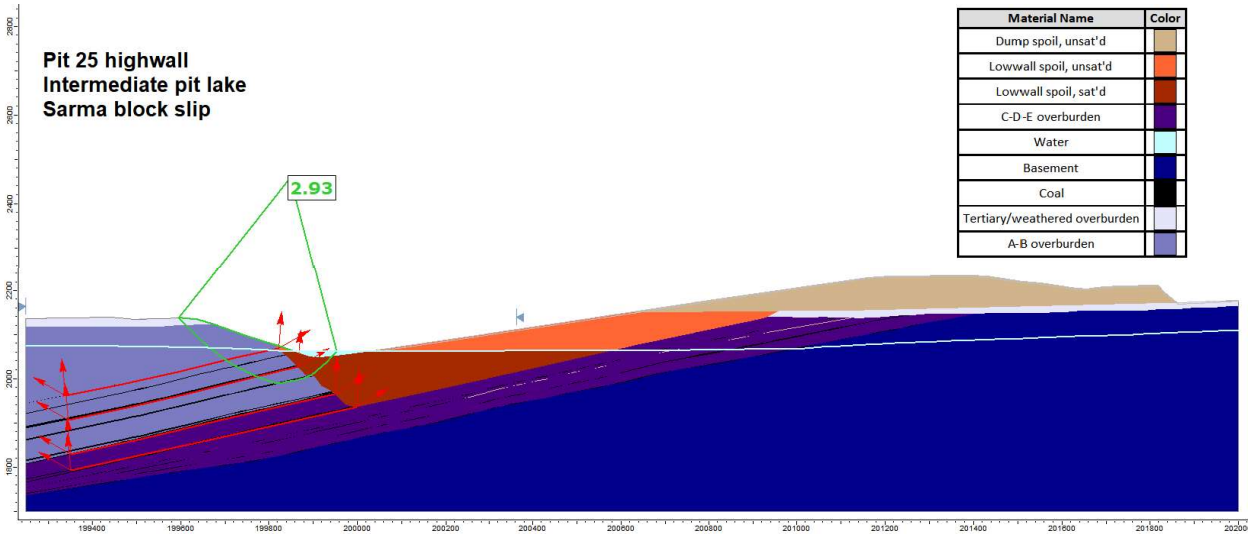

Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
C-D-E overburden
Water
Basement
Coal
Tertiary/weathered overburden
A-B overburden
2.93
Pit 25 lowwall
Long-term pit lake
Spencer circular slip

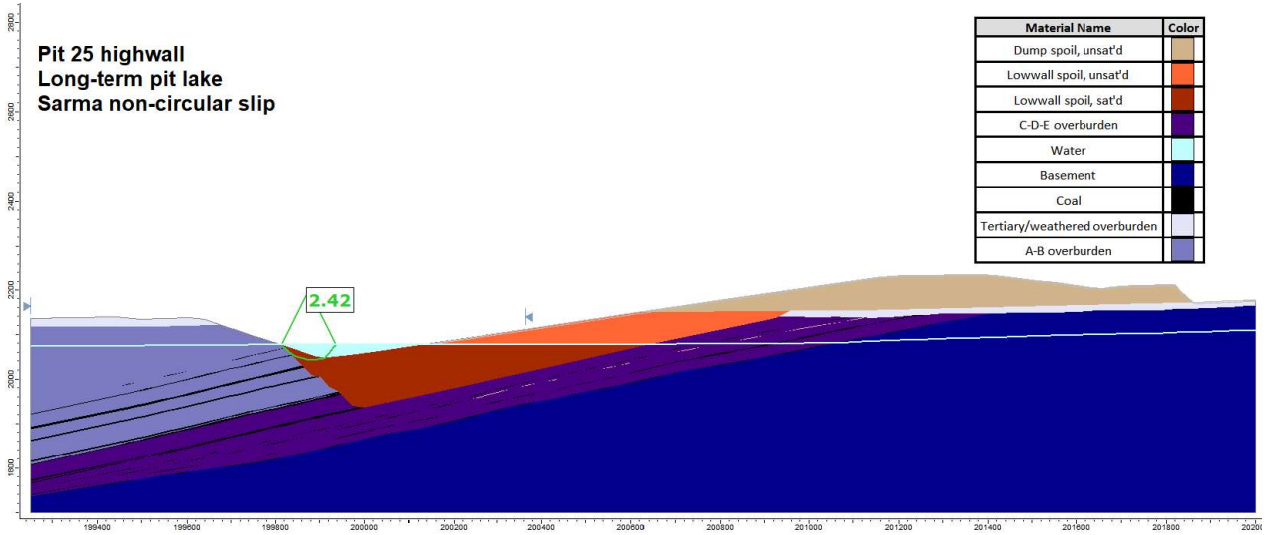
Pit 3-12 south highwall

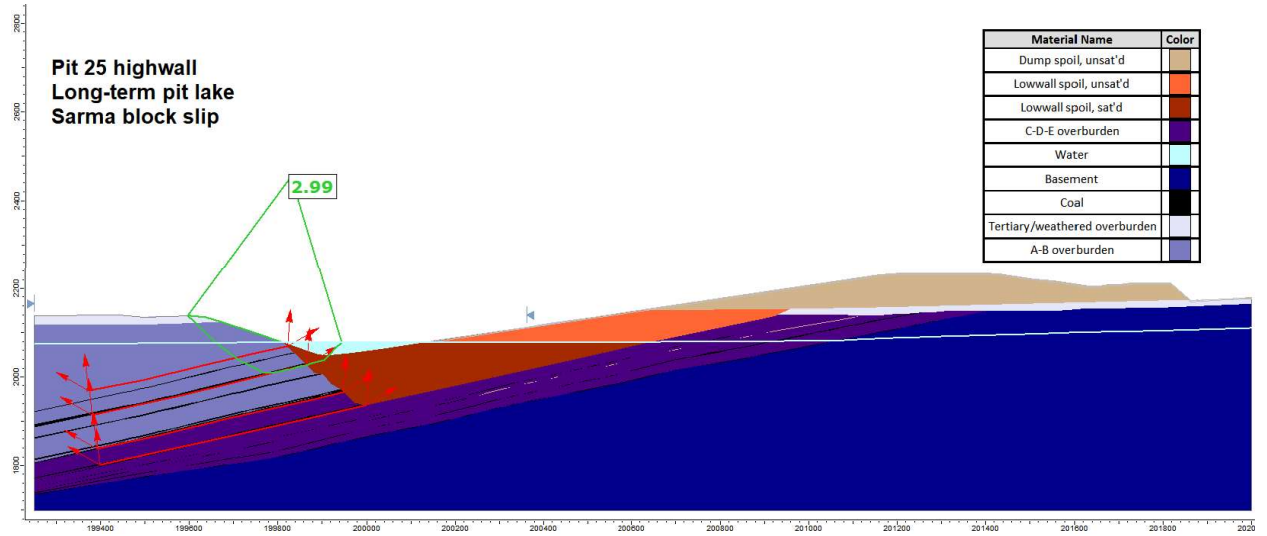





Pit 25 highwall
Intermediate pit lake
Sarma non-circular slip
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
C-D-E overburden
Water
Basement
Coal
Tertiary/weathered overburden
A-B overburden
2.12


Pit 25 highwall
Intermediate pit lake
Sarma block slip
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
C-D-E overburden
Water
Basement
Coal
Tertiary/weathered overburden
A-B overburden
2.93


Pit 25 highwall
Long-term pit lake
Sarma non-circular slip
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
C-D-E overburden
Water
Basement
Coal
Tertiary/weathered overburden
A-B overburden
2.42


Pit 25 highwall
Long-term pit lake
Sarma block slip
Material Name
Color
Dump spoil, unsat'd
Lowwall spoil, unsat'd
Lowwall spoil, sat'd
C-D-E overburden
Water
Basement
Coal
Tertiary/weathered overburden
A-B overburden
2.99

Appendix 4.12 Pit 28 Levee Design

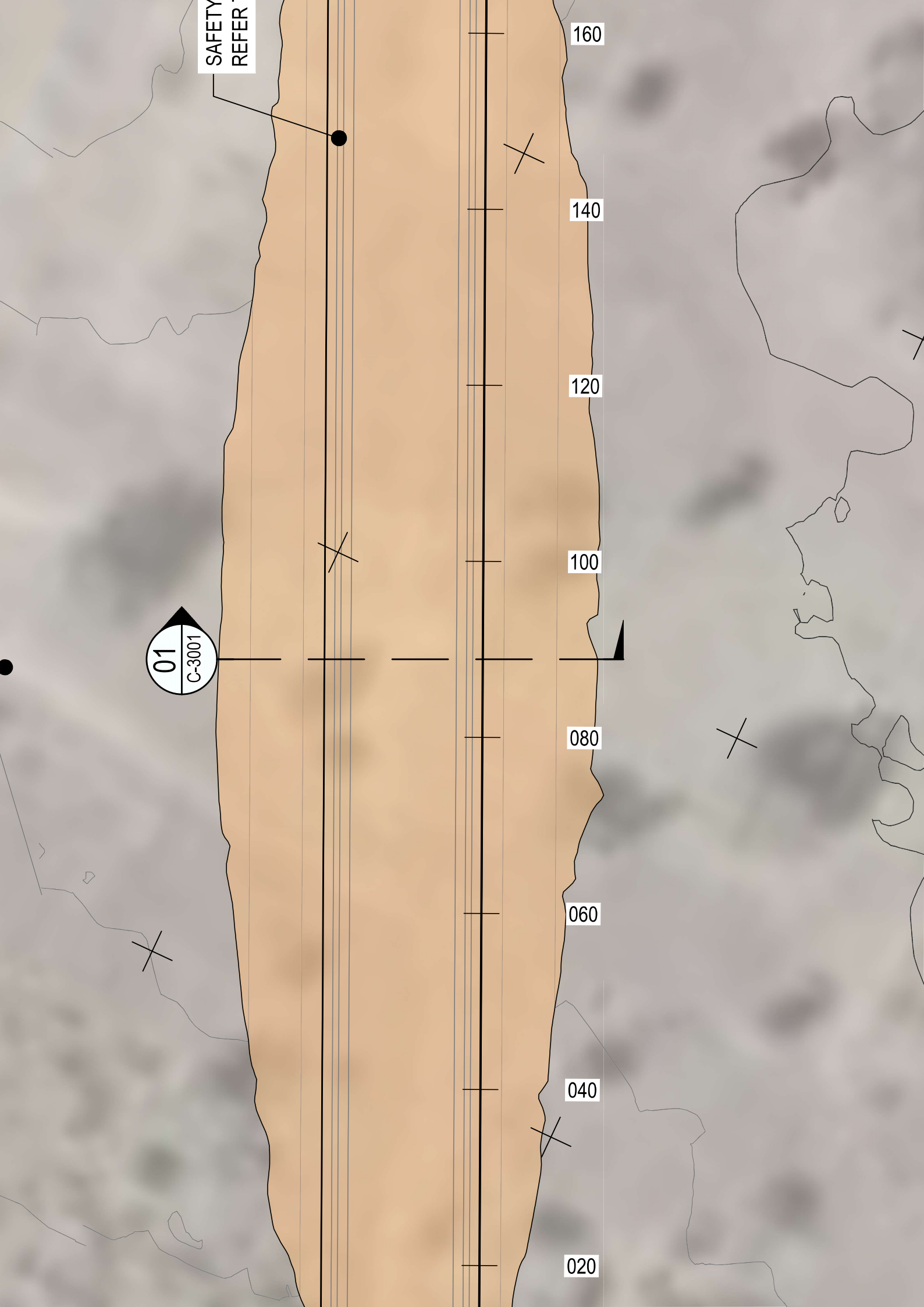

02
GN 03
PIT 28 DESIGN BY OTHERS

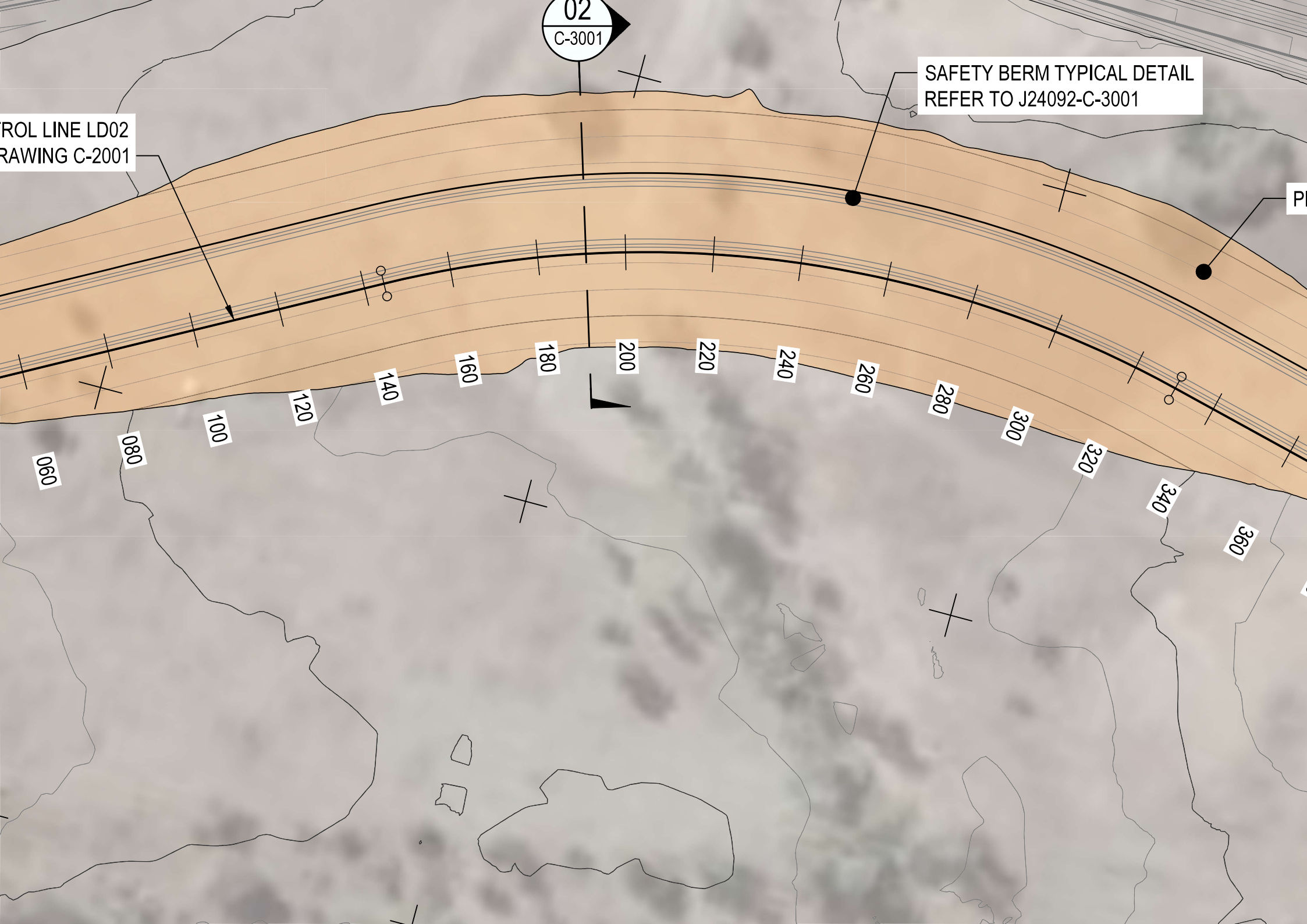

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72450
72400

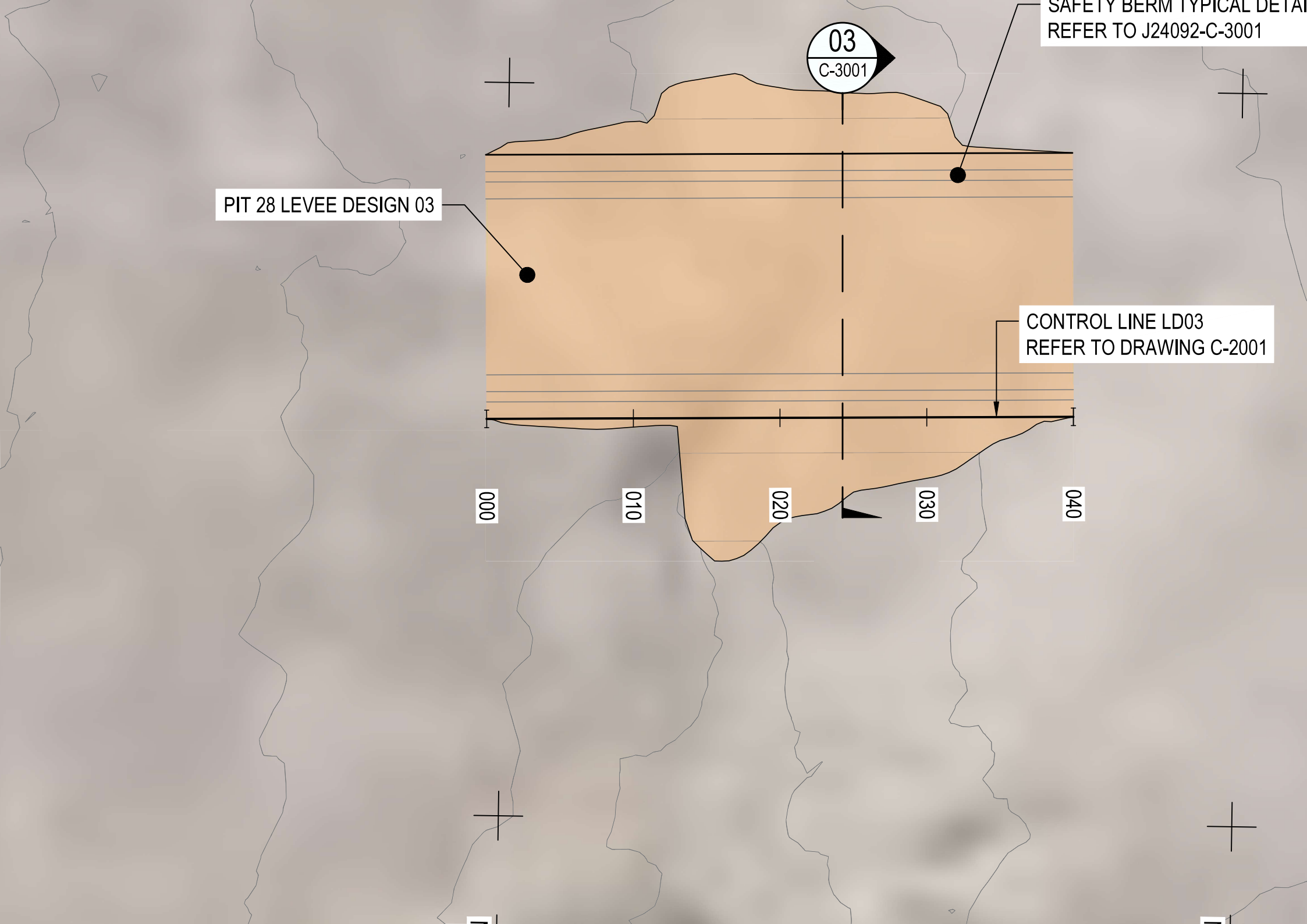
TOUT TO BE REGULARLY CHECKED TO CONFIRM THE
BE COMPILED THROUGHOUT THE PROJECT TO CONFIRM THE

ECHNICAL SPECIFICATIONS.
CTION OF THE REQUIRED DIVERSION BUNDS.
NIMUM OF 95% OF STANDARD MAXIMUM DRY DENSITY (SMDD).
N DRAIN SPECIFICATIONS.

O CHANGE


SAFETY
REFER
160
140
120
100
01
C-3001
080
060
040
020


02
C-3001
SAFETY BERM TYPICAL DETAIL
REFER TO J24092-C-3001
TROL LINE LD02
RAWING C-2001
060
080
100
120
140
160
180
200
220
240
260
280
300
320
340
360

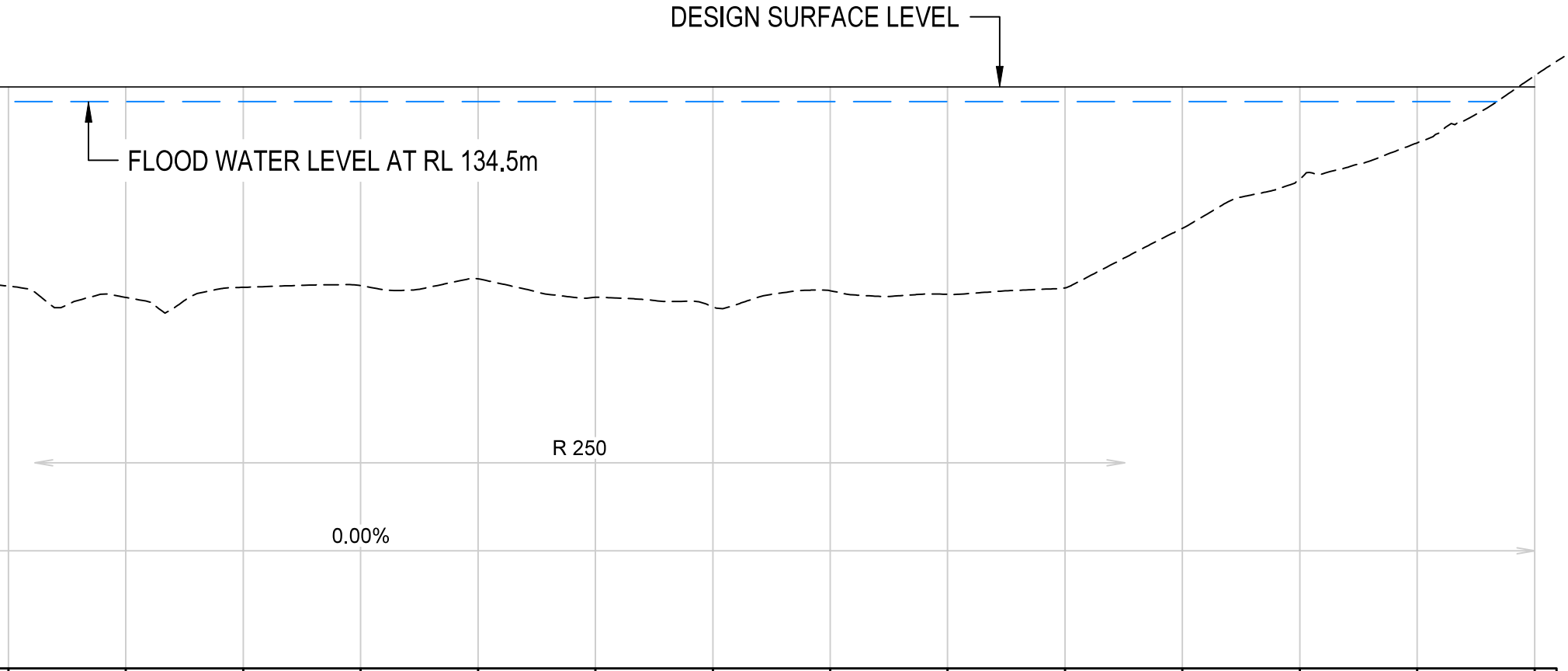

03
C-3001
SAFETY BERM TYPICAL DETAI
REFER TO J24092-C-3001
PIT 28 LEVEE DESIGN 03
CONTROL LINE LD03
REFER TO DRAWING C-2001
000
010
020
030
040

20 40 60 80 100 120 140 160

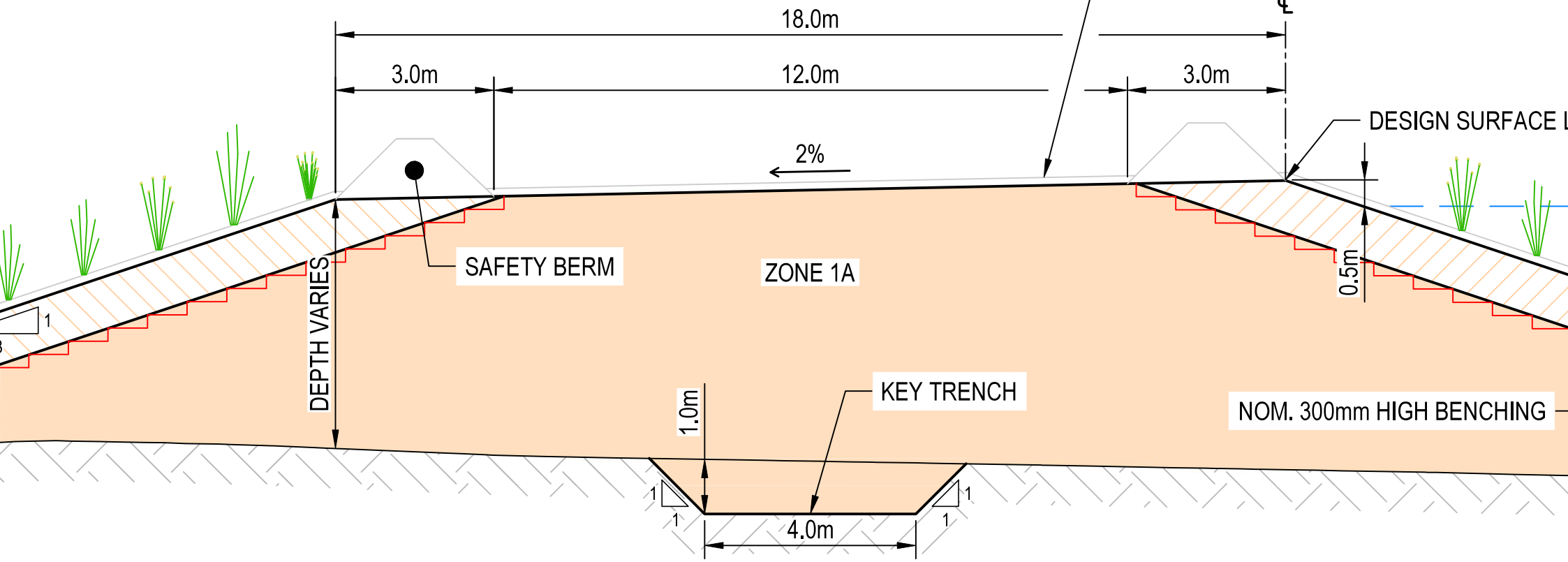
PIT 28 LEVEE DESIGN 01 - LONGITUDINAL SECTION

LD01
C-1001

HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



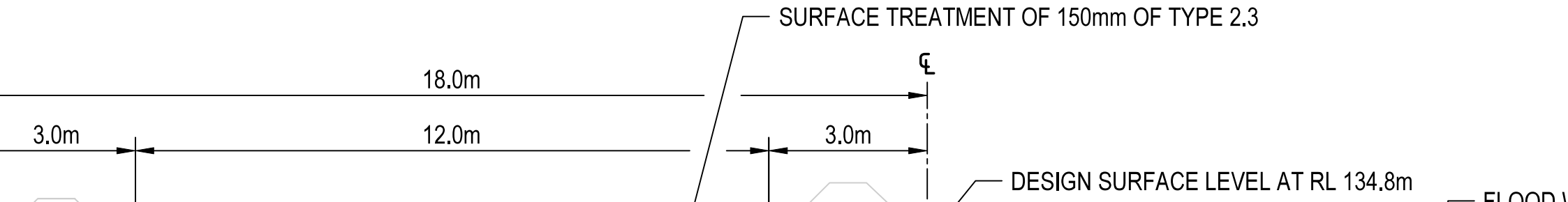
	127.629	127.973	128.031	128.263	127.632	127.310	127.859	127.737	127.954	129.981	131.656	132.892	135.179
	7.171	6.827	6.769	6.537	7.168	7.490	6.941	7.063	6.846	4.819	3.144	1.908	0.379



PIT 28 LEVEE DESIGN 02 - CROSS SECTION 02

1:100 SCALE

C-1002



Appendix 4.13 Landform Evolution Modelling: Dawson Pit Highwalls

Landloch

LANDFORM EVOLUTION MODELLING: DAWSON PIT HIGHWALLS

Anglo American

December 2017







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1 INTRODUCTION

Landloch Pty Ltd were engaged by Anglo American to undertake erosion modelling of the pit highwalls at the Dawson Coal Mine in the Bowen Basin, Queensland. Anglo American are investigating the erosion implications of several potential rehabilitation options for two pit highwalls (Pit 2 and Pit 20) at their Dawson operations. Given the erodible nature of the materials, Anglo American wish to understand the short and long-term erosion potential of the highwalls to inform their closure designs. Landloch has undertaken an assessment of erosion potential of several rehabilitation options using the landscape evolution model SIBERIA.

Landscape evolution models can be used to determine erosion rates and landscape development over timescales from tens to thousands of years. Post-closure landform designs often include strategies to minimise erosion through use of surface treatments, but must also consider an overall landform shapes as a means of reducing erosion risk.

SIBERIA is a sophisticated 3-D landform evolution model that simulates runoff and erosion, and predicts the long-term evolution of channels and hillslopes in a catchment. SIBERIA runs with a gridded digital elevation model (DEM). The DEM evolves through time in response to runoff and erosion. Rather than modelling individual events, SIBERIA predicts how a catchment will look on average at a given time. This makes the SIBERIA model an important tool for understanding the interactions between geomorphology, erosion, and hydrologic processes, as the sensitivity of a system to changes in physical properties of the landform can be investigated without the difficulties associated with field studies.

This report outlines the results of the erosion modelling for Pit 2 and Pit 20 at the Dawson mine site, including:

- Development of the rehabilitation DEMs for input into the SIBERIA model:
    - Pit 2 with highwalls not reprofiled, reprofiled to 1:2 (V:H) slopes, and reprofiled to 1:3 slopes;
    - Pit 20 with highwalls not reprofiled, reprofiled to 1:2 (V:H) slopes, and reprofiled to 1:3 slopes;
- Derivation of input parameters for SIBERIA;
- Outcomes of the long-term landform evolution of the rehabilitation DEMs; and
- Overall conclusions from the study.

2 FINAL LANDFORMS

The final landforms were developed using existing DEM data of the mine site provided by Anglo American. Two DEMs were provided that covered large portions of the mine site, including the two pits in question, waste dumps, mine infrastructure and the surrounding land. The Pit 2 and Pit 20 highwalls were excised from the overall DEMs to allow SIBERIA to model the specific sections of the site at a higher resolution. The existing highwalls were reshaped to develop slopes at 1:2 and 1:3 gradients for Pit 2 and Pit 20. To do this, the existing contour data was deleted across the highwall, with new elevation data inserted to produce to desired slope gradient. Given the length and shape of the highwalls, there was minor variability in slope angle across the highwall. The resultant shapes used for SIBERIA modelling are presented in Figure 1-6 below.

2.1 Pit 2 digital elevation model

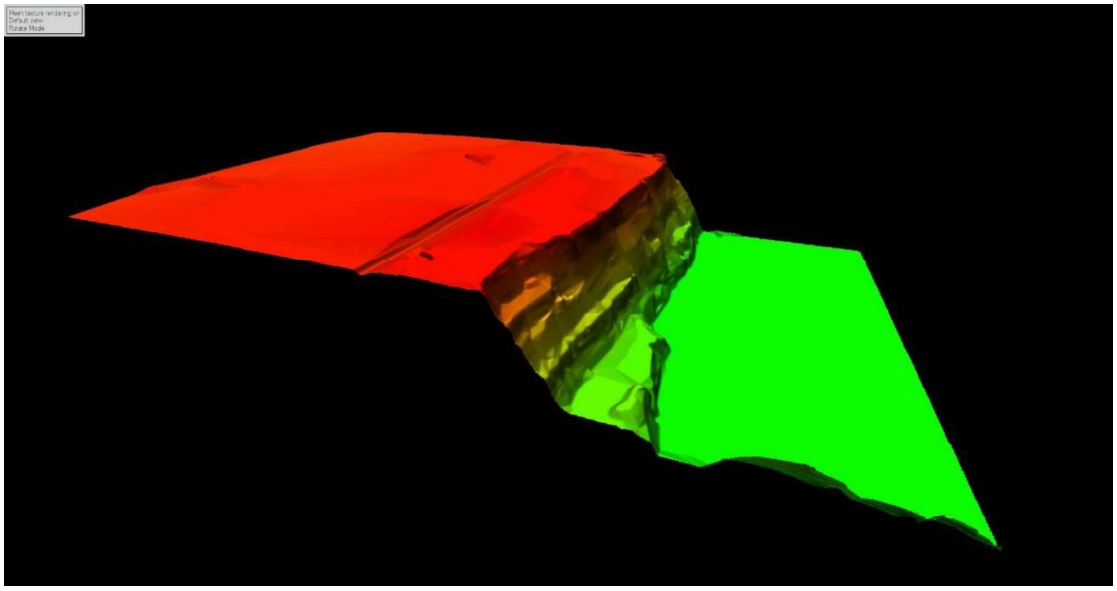


Figure 1: Pit 2 no treatment landform.

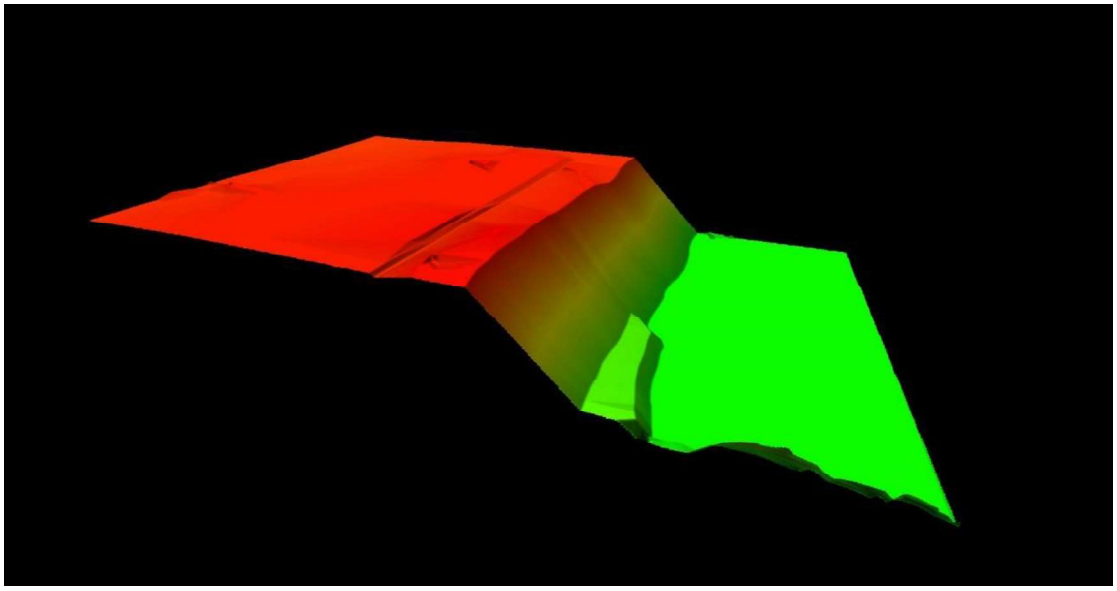


Figure 2: Pit 2 reshaped to a 1:2 slope.

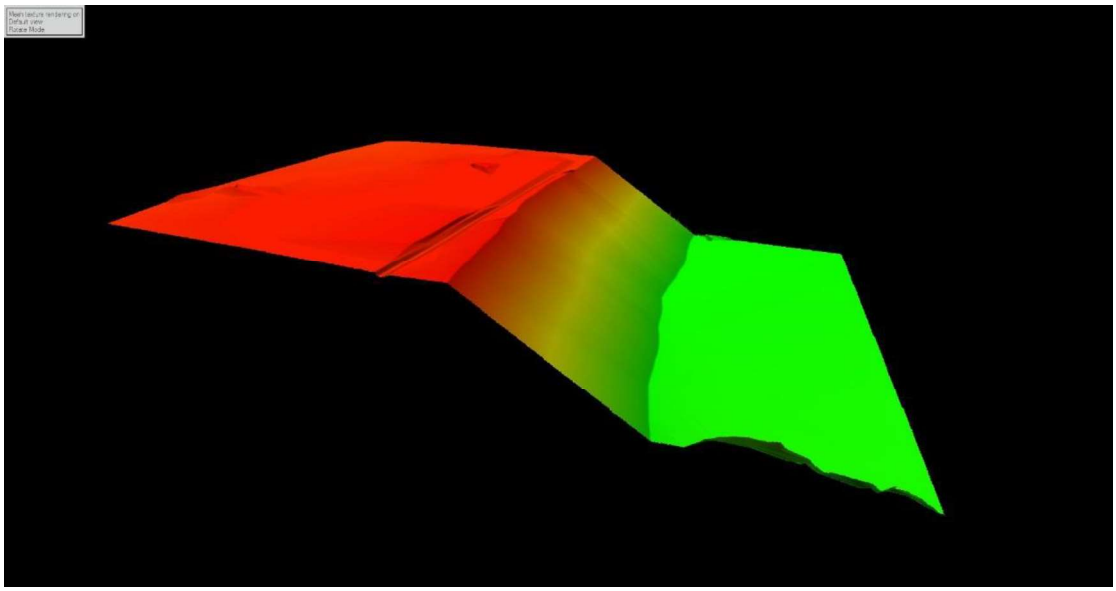


Figure 3: Pit 2 reshaped to a 1:3 slope.

2.2 Pit 20 digital elevation model

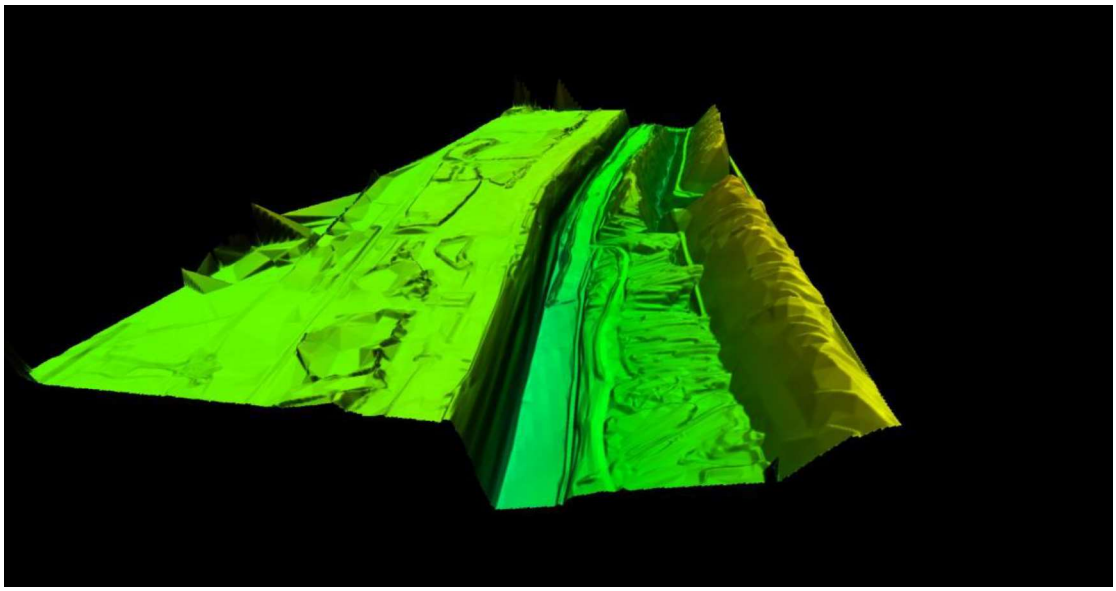


Figure 4: Pit 20 no treatment landform.

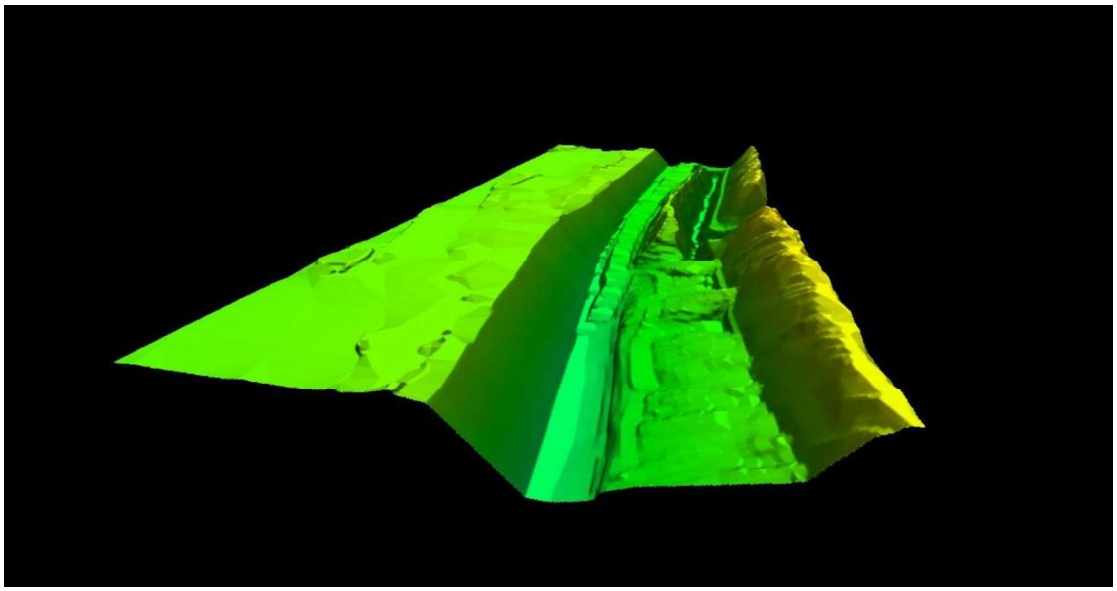


Figure 5: Pit 20 reshaped to a 1:2 slope.

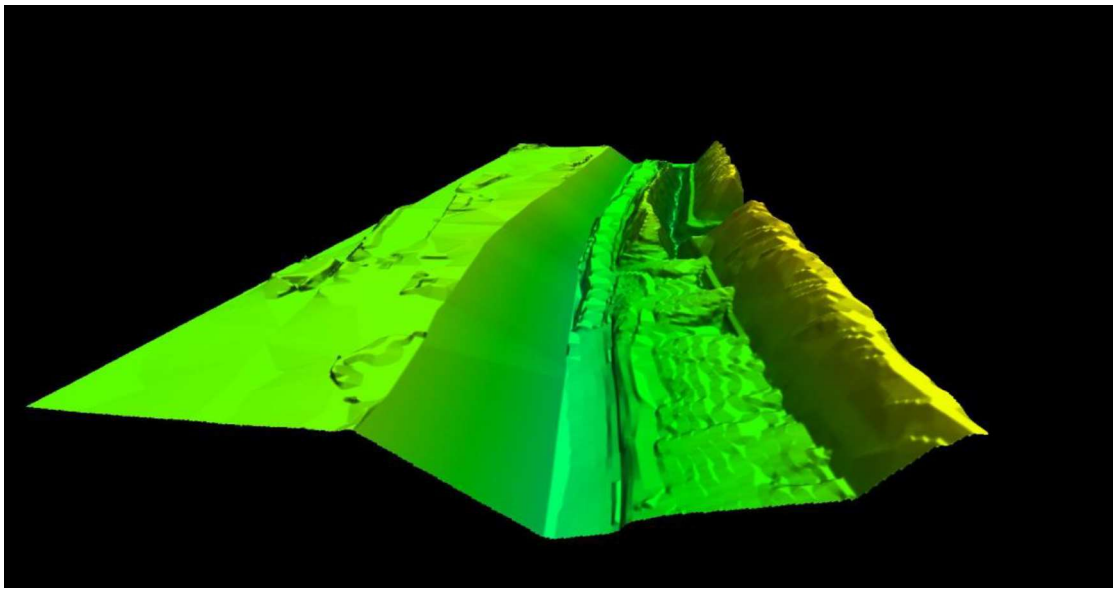


Figure 6: Pit 20 reshaped to a 1:3 slope.

3 LANDFORM EVOLUTION MODELLING

To undertake erosion modelling on the designs, material specific parameters must be derived. Parameters were derived on the basis of existing data as supplied to Landloch by Anglo American.

3.1 Existing data

The underlying lithology of the Dawson mine is characterised by five interseam coal units, A – E. The overlying sediments of the A and B seams consist of thinly interbedded siltstones, shales and claystones. The lower B to D interseam units consist of massive

strongly jointed thickly bedded sandstones. The E interseam unit is comprised of Yarabee Tuff. These interseam units are the primary constituents of the pit highwalls, and form the basis of the spoil materials produced on site. Stratigraphic diagrams for Pit 2 and Pit 20 are available in Appendix A. As such, characterisation data on the spoil materials were considered to develop SIBERIA parameters.

The site uses four spoil management units (SMUs) to reflect *in situ* spoil quality (PW Baker & Assoc. 2010):

- Type 1 – Dawson coarse sandstone spoils (mostly C, D and E seams);
- Type 2 – Gibihi intergrade spoil (mostly a mixture of B/C seams);
- Type 3 – Fine Kianga spoil with few significant chemical/physical limitations (mostly B seam); and
- Type 4 – Fine Kianga spoil with increased chemical/physical limitations (mostly A seam).

The following generalised overburden/spoil types are outlined in Table 1 below.

Table 1: Summary of Dawson Mine Spoil Types (Adapted from PW Baker & Assoc. 2010)

Dawson Overburden	Resultant General Spoil Type	Description
A seam Overburden	Type 4 Spoil	Weathered material, primarily sandy clay and shale
B seam Overburden	Type 2 and 3 Spoil	Sandstone (some siltstone interbedded)
C seam Overburden	Type 1 Spoil	Sandstone
D seam Overburden	Type 1 Spoil	Sandstone
E seam Overburden	Type 1 Spoil	Sandstone

The available particle size distribution data was used to derive the model input parameters, in conjunction with available data for the spoils from erodibility studies conducted during the ACARP-funded Post Mining Landscapes Parameters project, which provided erosion data for:

- Black cracking clay topsoil
- Type 1 Rocky D Seam spoil
- Type 4 yellow A seam spoil

In addition to this, particle size distribution data was collected during an Enviroscience (1991) assessment of three coarse spoil samples, two A seam samples and one B seam sample. The results from both investigations are outlined in Table 2.

Table 2: Particle size distribution data available for the spoils

Report	Material	Clay % (<0.002mm)	Silt % (0.002-0.02 mm)	Sand % (0.02-2mm)	Gravel % (2-20mm)
PW Baker & Assoc. (2010)	Black earth topsoil	45	23	32	12
	A Seam spoil	33	20	47	5
	D Seam Spoil	28	11	63	43
Enviroscences (1991)	Coarse Spoil	11	6	29	53
	A Seam	25	13	49	15
	B Seam	20	20	35	25

Images of the Pit 2 and Pit 20 materials were captured during a site visit by Anglo American in November 2017 (Figure 7) and assessed in order to determine which materials dominate the pit highwalls. Samples of the materials were sent to the Landloch laboratory in Toowoomba for hand texture analysis. Results of the analysis are outlined in Table 3.

Given the abundance of clay within the samples and the general lack of coarse fraction, the closest matching spoil material for which particle size data is available is the Type 4 – A seam spoil. As such, the particle size data for the A seam spoil was used for the development of the modelling parameters for both Pit 2 and Pit 20.



Figure 7: Pit 2 highwall material (left) and Pit 20 highwall material (right)

Table 3: Hand texture analysis on samples of Pit 2 and Pit 20 material

Sample ID	Texture	Approximate clay percentage (fine fraction)	Fine fraction (<2mm) percentage	Coarse fraction (>2mm) percentage
Pit 2C sample 1	Light Clay	35 – 40%	88%	12%
Pit 2C sample 2	Light Clay	35 – 40%	90%	10%
Pit 20 sample 1	Medium/Heavy clay	>50%	70%	30%
Pit 20 sample 2	Medium/Heavy clay	>50%	77%	23%

3.2 SIBERIA parameterisation

SIBERIA is a model that predicts the development of erosion of catchments and their channel networks. It predicts changes in 3D landform shape and hence is useful for Dawson to consider the depth of rilling and change in landform shape for the Pit 2 and Pit 20 highwalls.

The long-term average elevation change of a point is determined by predicting the volume of sediment lost from and added to a node on a digital elevation model using the fluvial sediment transport equation (based on the Einstein-Brown equation):

$$q_{sf} = \beta_1 q^{m1} S^{n1}$$

where q is the discharge per unit width (m^3/y), S (m/m) the slope in the steepest downslope direction; and β_1, m_1 and n_1 are calibrated parameters. SIBERIA uses a subgrid effective parameterisation to relate discharge to area draining through a point as:

$$q = \beta_3 A^{m3}$$

where β_3 is the runoff rate constant, and m_3 is the exponent of area, both of which are calibrated.

To run SIBERIA, the parameters β_1, β_3, m_1, m_3 and n_1 are usually needed. The β_1 parameter controls the 'rate' of erosion across the landform and controls the rate of sediment movement. The m_1 parameter controls the slope length response and the dominant erosive processes. However, there is interaction between all of the parameters with the result that an almost infinite number of parameter sets will all show the same rate of erosion, though some aspects of the pattern of erosion predicted will vary. For this reason, fixed values of n_1 and m_3 are adopted.

If the batter area to be modelled is identical to the batter for which erosion data is available for calibration, m_3 and β_3 can be taken as 1.0 and a value of $n_1 = 1.5$ can be adopted. Therefore, the two key parameters that require derivation are β_1 and m_1. Landloch's methodology for derivation of these parameters seeks to fit them to time-series data of runoff and erosion from the WEPP runoff and erosion.

3.2.1 WEPP

The WEPP model was used in this project for the generation of the necessary time-series runoff and erosion data. It was developed by the United States Department of Agriculture (USDA) to predict runoff, erosion, and deposition for hillslopes and catchments.

WEPP is a simulation model with a daily input time step, although sub-daily parameters are used to describe storm events used to calculate runoff and erosion (enabling more accurate estimation of runoff and erosion potential than achievable with daily time step models).

In the WEPP model erodibility is described via a number of specific parameters:

- Interrill erodibility (K_i);
- Rill erodibility (K_R);
- Critical shear for rill initiation (τ_c); and
- Effective hydraulic conductivity (K_e).

For this project, WEPP erodibility parameters were set by comparing the available particle size distribution data for the Dawson materials with those of materials in Landloch's materials library, and assigning parameter values for materials with similar particle size distributions that had been assessed within Landloch's erosion assessment facilities. These parameters were then used in computer simulations of runoff and erosion, with the output of this being analysed to derive the necessary SIBERIA input parameters.

WEPP requires a long-term climate file in order to predict long-term erosion rates. All WEPP simulations use a 100-year climate file developed by Landloch. Observed data was sourced from the climate station at Moura.

3.2.2 Analysis of existing erosion

LiDAR data and site photography were provided to Landloch to facilitate assessment of the extent of existing erosion on the Pit 2 and Pit 20 highwalls. The LiDAR data included three separate years of imagery, however the images were provided in .jpg format which were unable to be manipulated to observe the pit highwalls. The data within the provided dxf files were generally sparse across the highwalls. This data is typically generated through LiDAR point data which is stripped down to remove excess points. The removal of points reduces the resolution of data, which prohibited analysis of existing erosion on the pit highwalls. As a result, the accuracy of the data for back calculation was low.

As such, the site photography was used as a guide for development of SIBERIA parameters, particularly in considering the density of rills. However, the photography was unable to be used to estimate rill depth or length.

The SIBERIA parameters were applied to the existing pit highwalls, and the β_1 and m_1 parameters adjusted until the modelled rill formation visibly matched the observed rill formation in the provided imagery (Figure 8 and Figure 9).

3.2.3 Derived Parameters

Based on the existing data, the WEPP analysis and the analysis of existing erosion, the following parameters were derived for use in the simulations:

- β_1 – 0.0268[1]
- m_1 – 1.37
- n_1 – 1.5

Using these parameters, the simulations for Pit 2 and Pit 20 were undertaken, with results presented in the following section.

[1] Note that due to the extreme erosion rate, these parameters represent 1/10th of the erosion rate, with the model runtime increased by a factor of 10 to allow SIBERIA to manage the material movement.



Figure 8: Pit 2 highwall with rill formation evident



Figure 9: Pit 20 highwall in the distance.

4 MODELLING OUTCOMES

Modelling was undertaken for Pit 2 and Pit 20 designs with the following outputs:

- 50, 100 and 200 year simulation outputs;
- Average gully depth for each output year;
- Average erosion in tonnes/hectare/year and mm/year for each output year; and
- Cross section of the slope indicating the change in landform shape at each output year.

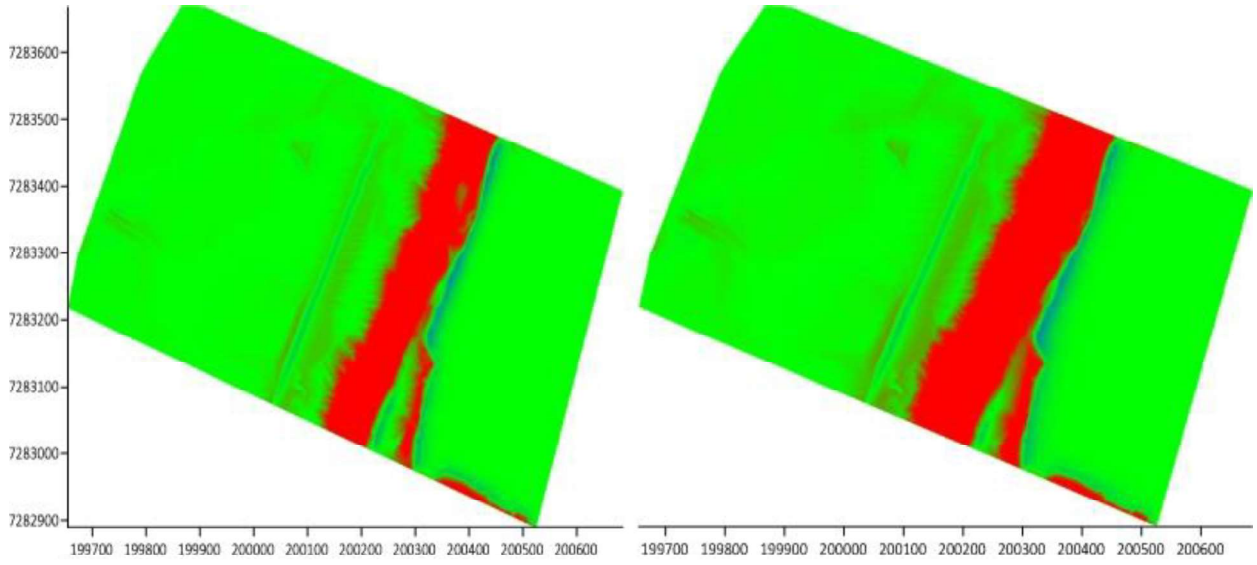
4.1 Pit 2

Results from the SIBERIA simulations are outlined in Table 4, with images for simulations provided in Figure 10 to Figure 15. Included in each section is a cross section erosional profile indicating the change in landform shape across each of the three treatments.

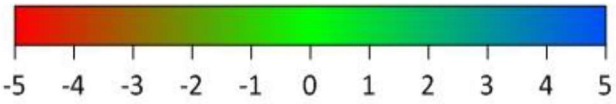
Table 4: Summary of average gully depth (m) and average erosion (t/ha/y) across all simulations of Pit 2

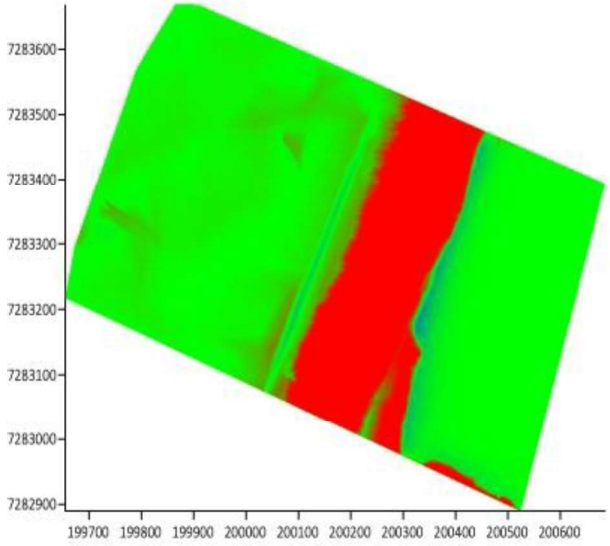
Simulation year	Average gully depth (m)	Average gully length (m)	Average erosion (t/ha/y)	Average erosion (mm/y)
Pit 2 – no treatment				
50	1.84 m	52 m	2769 t/ha/y	27.7 mm/y
100	2.31 m	58 m	2284 t/ha/y	22.8 mm/y
200	2.04 m	75 m	1627 t/ha/y	16.2 mm/y
Pit 2 – 1:2 slope				
50	0.72 m	70 m	1182 t/ha/y	11.8 mm/y
100	1.09 m	74 m	1072 t/ha/y	10.7 mm/y
200	0.70 m	89 m	833 t/ha/y	8.3 mm/y
Pit 2 – 1:3 slope				
50	0.37 m	102 m	456 t/ha/y	4.6 mm/y
100	0.55 m	112 m	504 t/ha/y	5.0 mm/y
200	0.36 m	112 m	454 t/ha/y	4.5 mm/y

4.1.1 No treatment



(a) Pit 2 no treatment after 50 years (b) Pit 2 no treatment after 100 years





(c) Pit 2 no treatment after 200 years

Figure 10: Pit 2 no treatment after 200 years of simulation with erosion (red) and deposition (blue) indicated in metres. Co-ordinates on the axis are in Eastings and Northings.

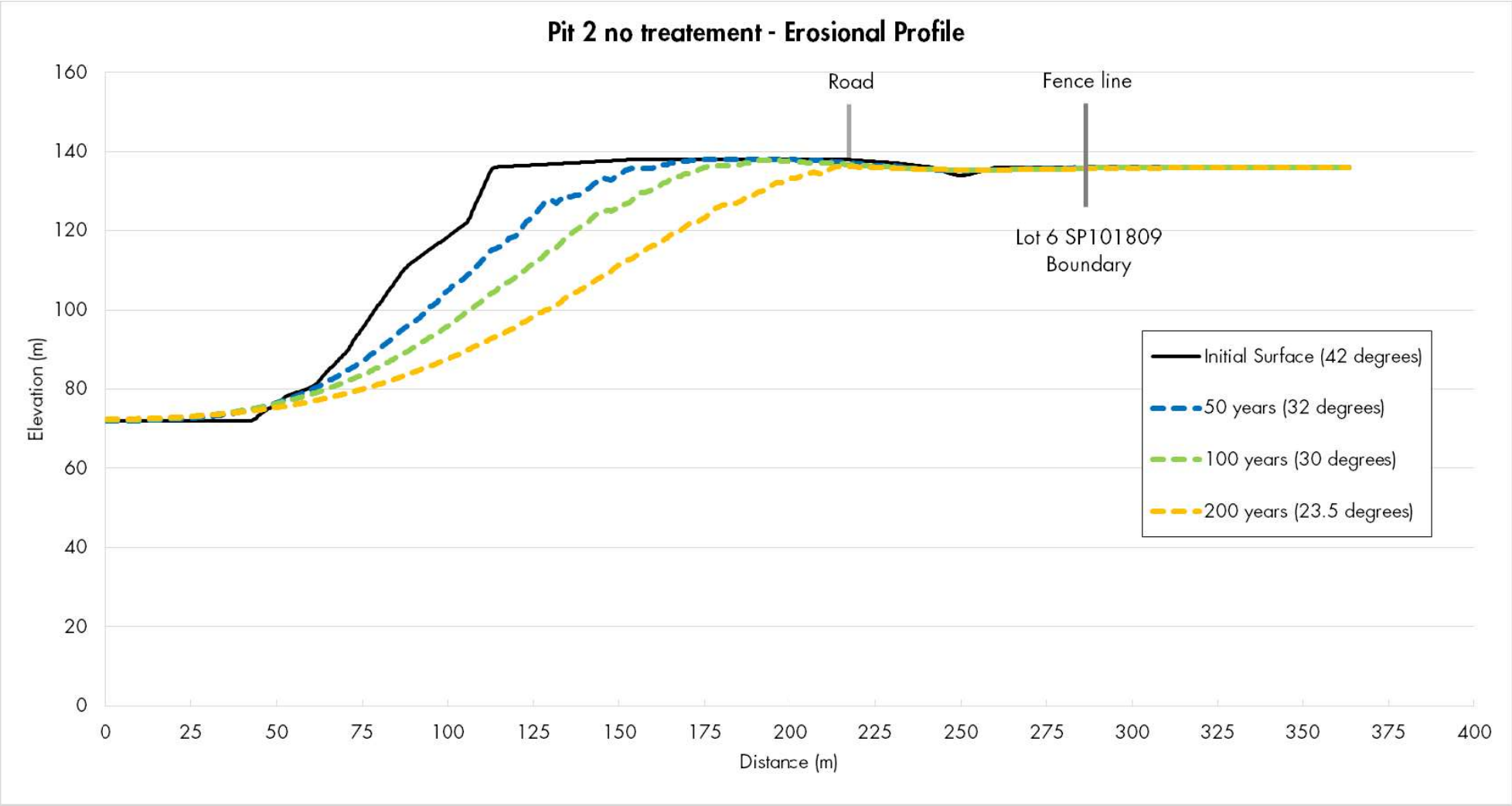


Figure 11: Pit 2 no treatment – change in slope profile after 50, 100 and 200 years of simulation

4.1.2 Reshaped to 1:2 gradient

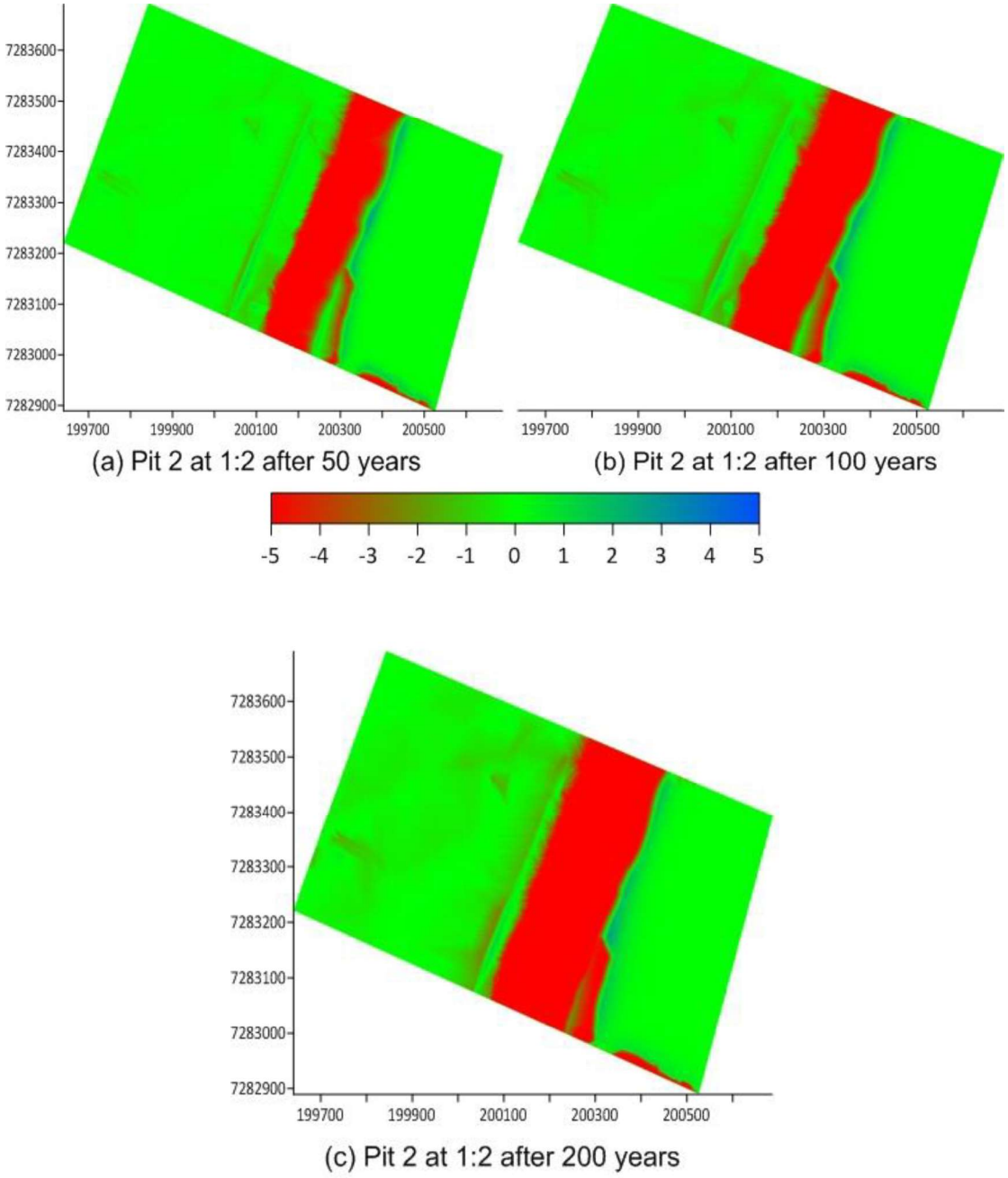


Figure 12: Pit 2 at 1:2 slope after 200 years of simulation with erosion (red) and deposition (blue) indicated in metres. Co-ordinates on the axis are in Eastings and Northings.

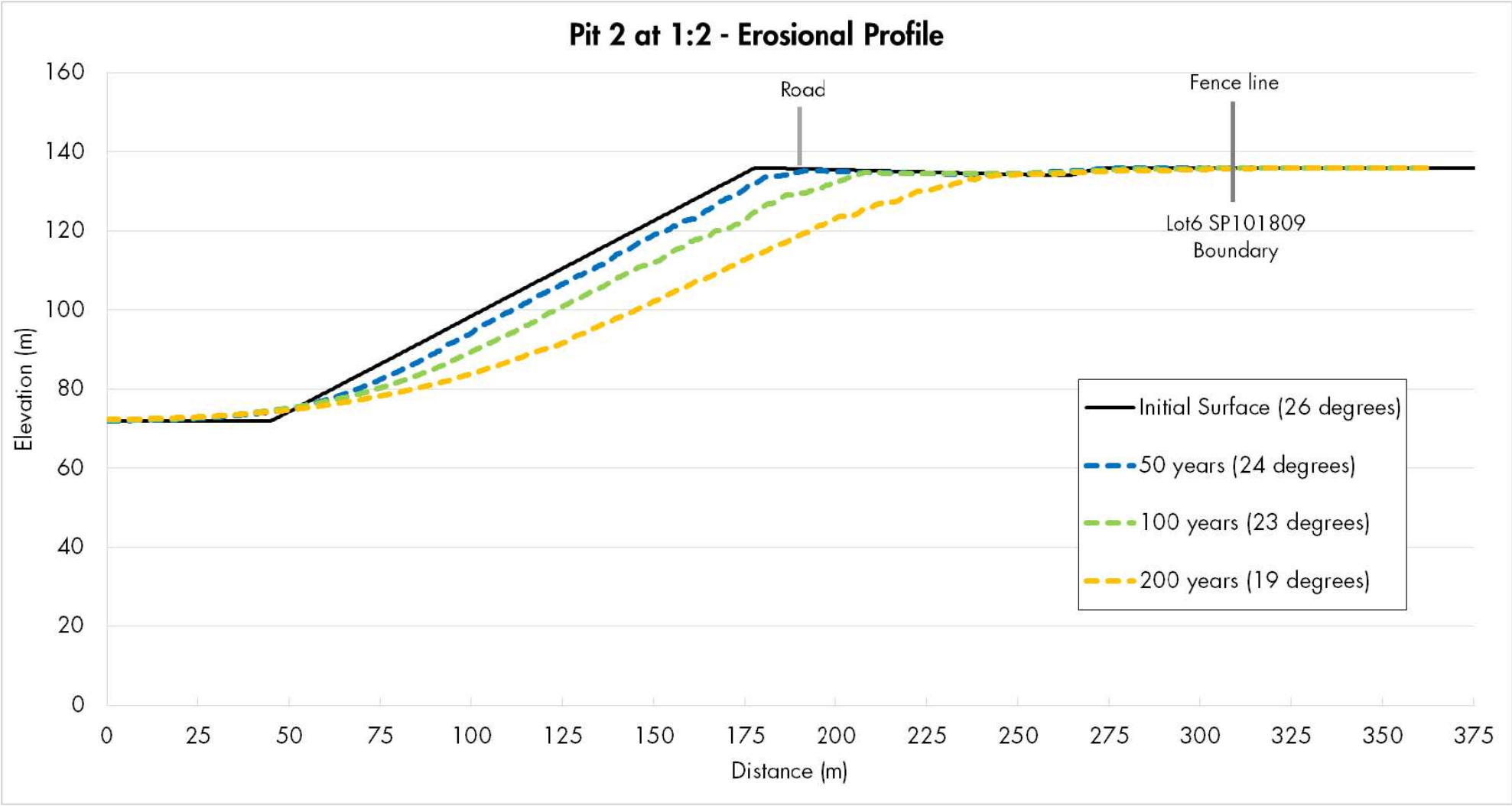


Figure 13: Pit 2 at 1:2 – change in slope profile after 50, 100 and 200 years of simulation

4.1.3 Reshaped to 1:3 gradient

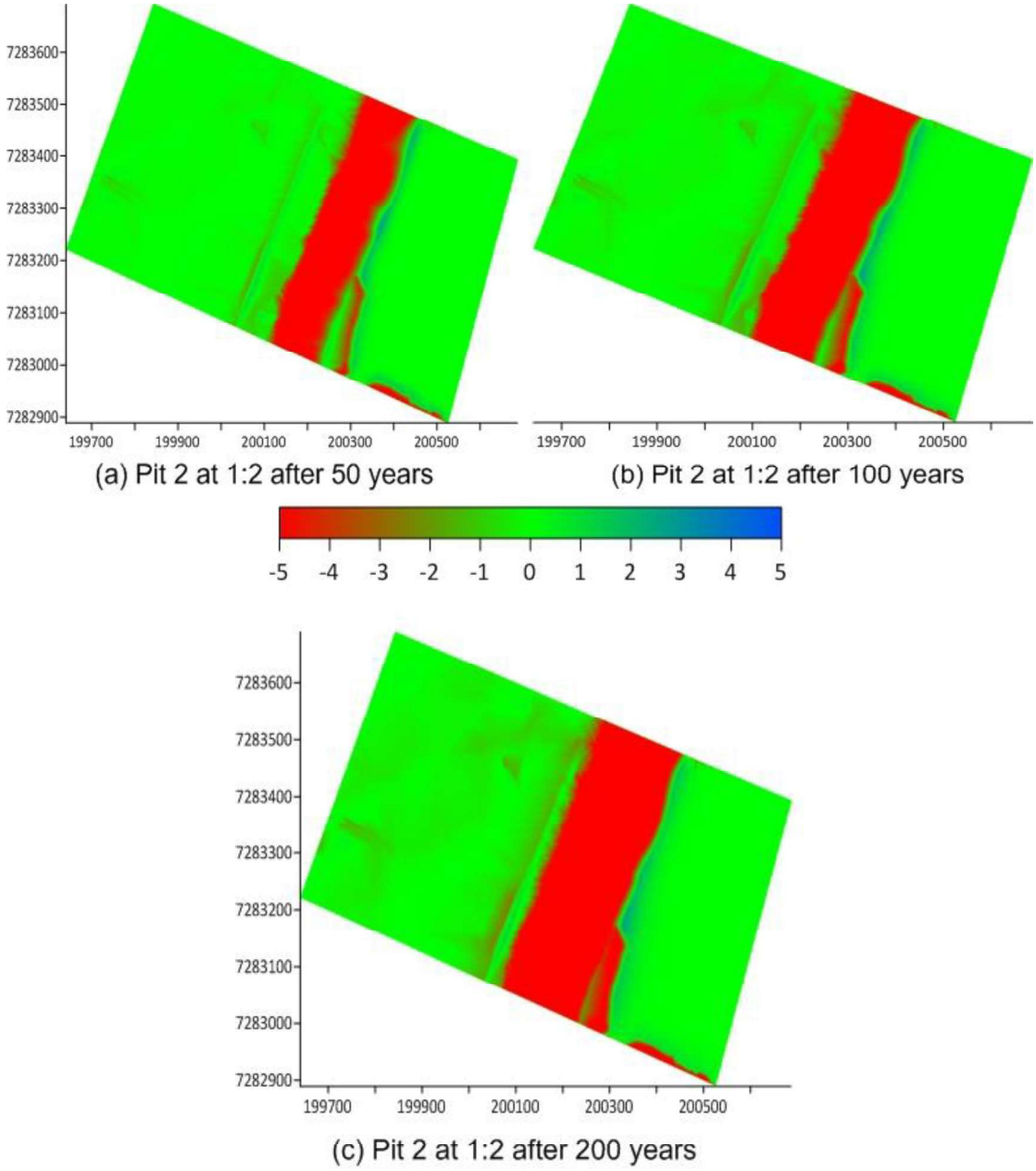


Figure 14: Pit 2 at 1:3 slope after 200 years of simulation with erosion (red) and deposition (blue) indicated in metres. Co-ordinates on the axis are in Eastings and Northings.

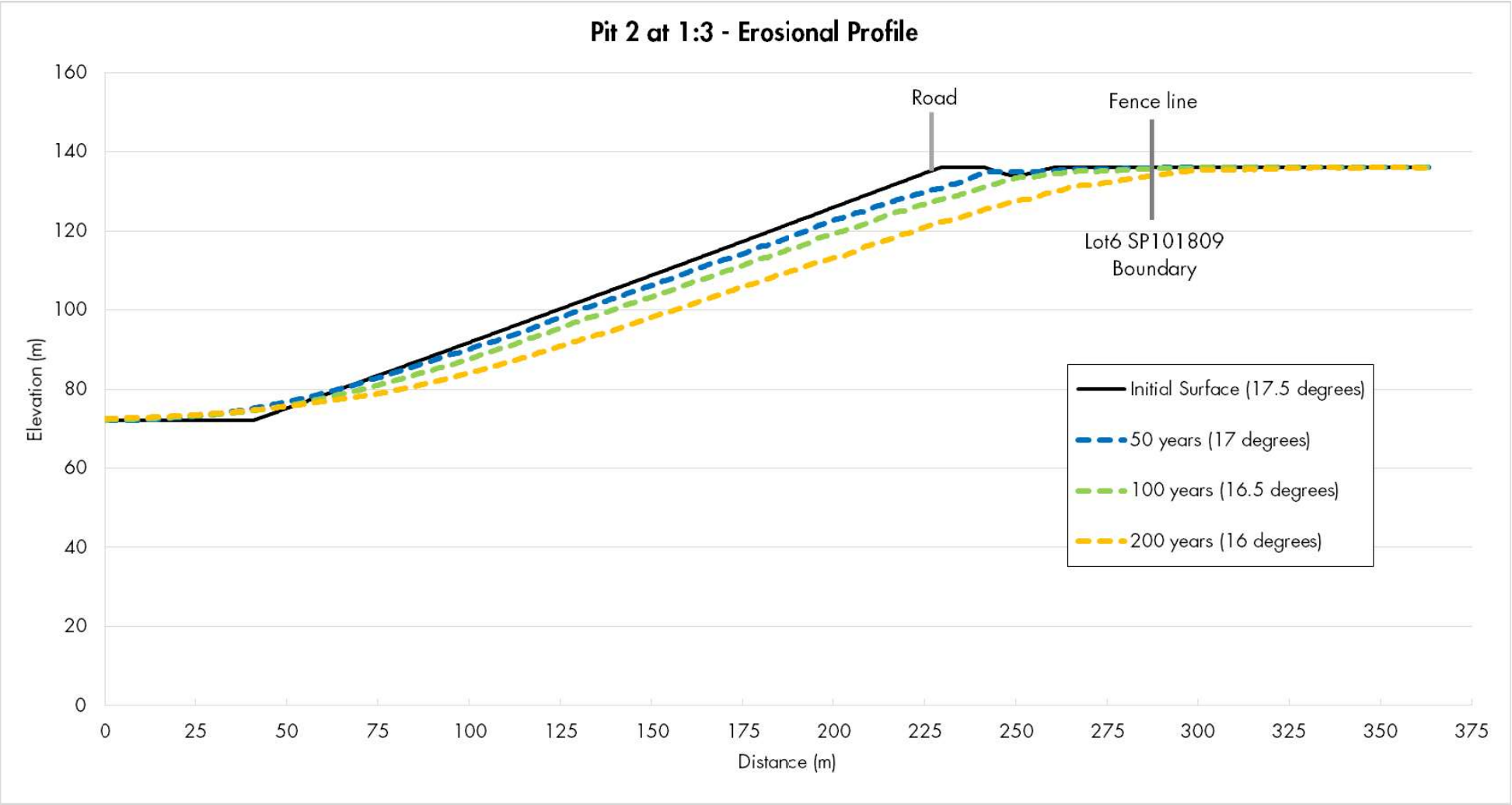


Figure 15: Pit 2 at 1:3 – change in slope profile after 50, 100 and 200 years of simulation. Co-ordinates on the axis are in Eastings and Northings.

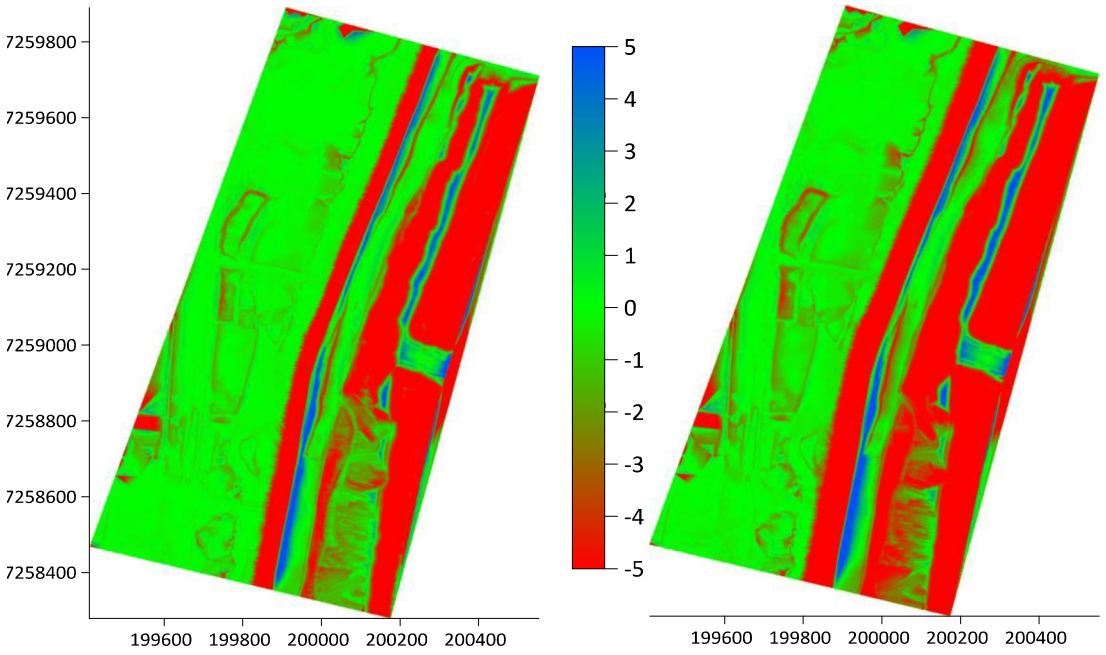
4.2 Pit 20

Results from the SIBERIA simulations are outlined in Table 5 below, with images for simulations provided in Figure 16-18. Included in each section is a cross section erosional profile indicating the change in landform shape across each of the three treatments.

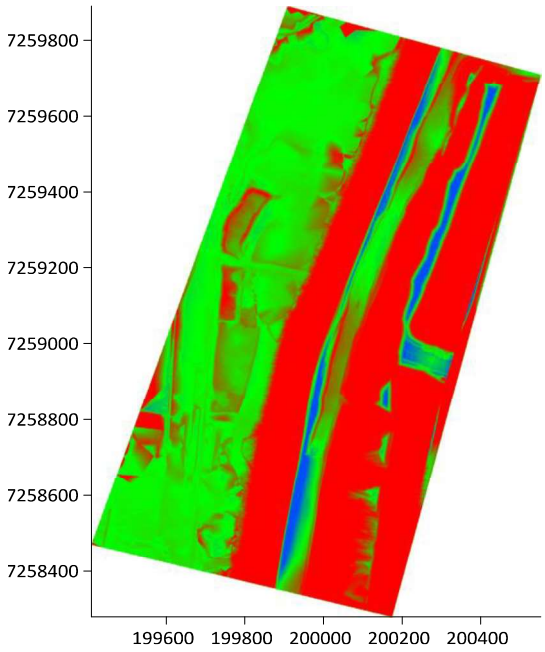
Table 5: Summary of average gully depth (m) and average erosion (t/ha/y) across all simulations of Pit 20

Simulation year	Average gully depth (m)	Average gully length (m)	Average erosion (t/ha/y)	Average erosion (mm/y)
Pit 20 – no treatment				
50	1.24 m	26 m	3168 t/ha/y	31.7 mm/y
100	1.72 m	31 m	2390 t/ha/y	23.9 mm/y
200	0.98 m	41 m	1517 t/ha/y	15.1 mm/y
Pit 20 – 1:2 slope				
50	1.06 m	31 m	1102 t/ha/y	11.0 mm/y
100	1.24 m	42 m	1025 t/ha/y	10.3 mm/y
200	0.86 m	50 m	816 t/ha/y	8.2 mm/y
Pit 20 – 1:3 slope				
50	0.45 m	30 m	558 t/ha/y	5.6 mm/y
100	0.63 m	59 m	561 t/ha/y	5.6 mm/y
200	0.62 m	68 m	474 t/ha/y	4.7 mm/y

4.2.1 No treatment



(a) Pit 20 no treatment after 50 years (b) Pit 20 no treatment after 100 years



(a) Pit 20 no treatment after 200 years

Figure 16: Pit 20 current landform after 200 years of simulation with erosion (red) and deposition (blue) indicated in metres. Co-ordinates on the axis are in Eastings and Northings.

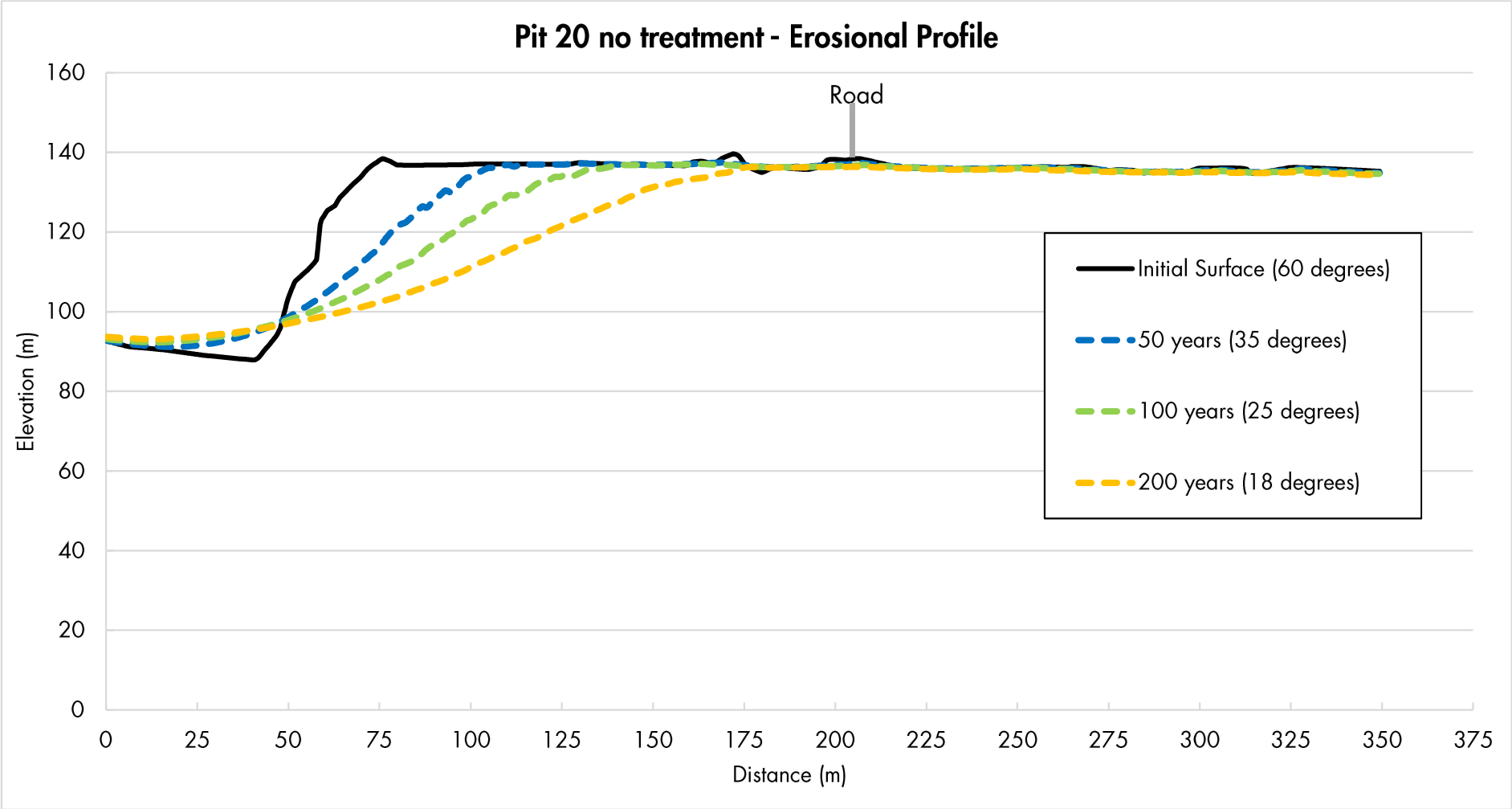
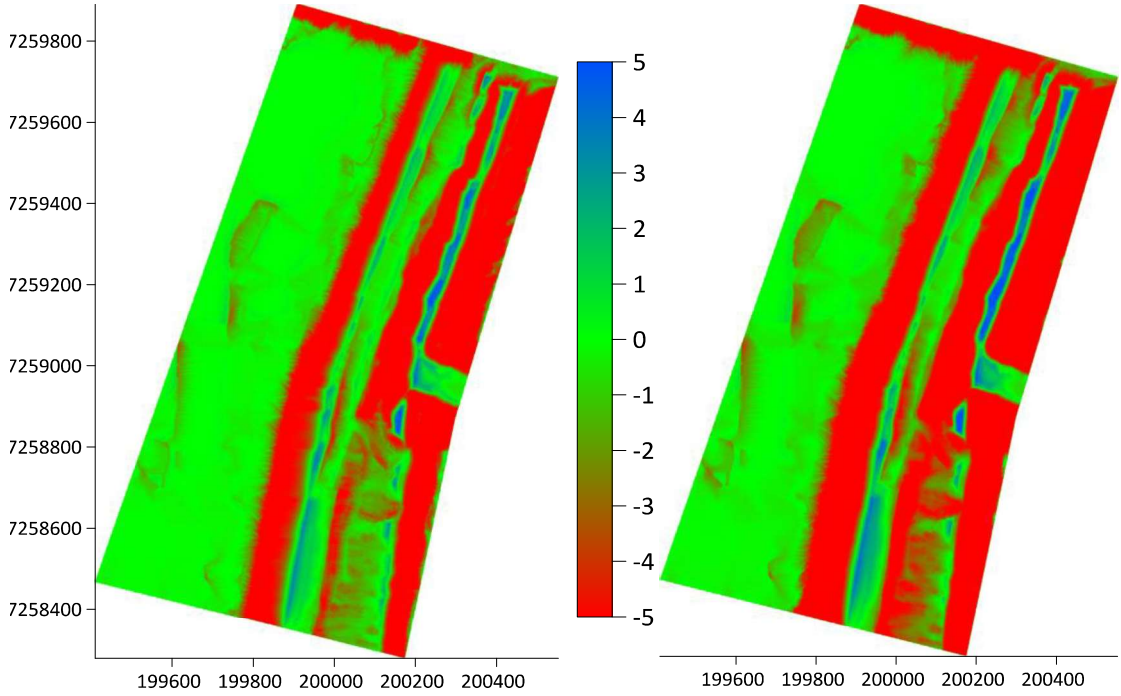


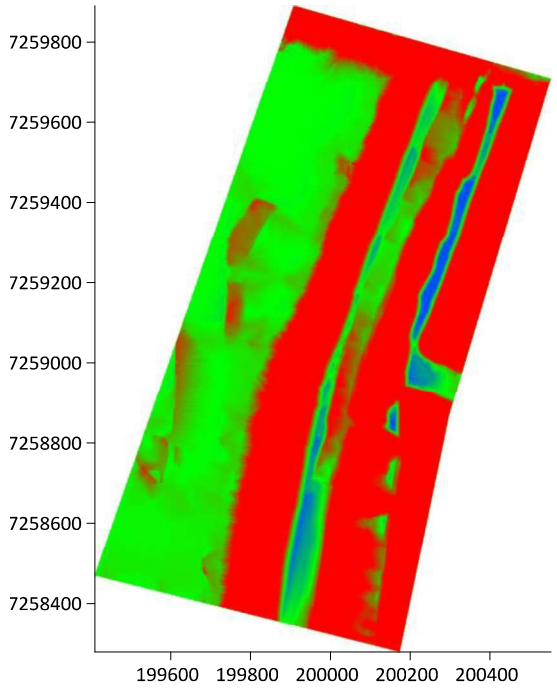
Figure 17: Pit 20 current landform – change in slope profile after 50, 100 and 200 years of simulation

4.2.2 Reshaped to 1:2 gradient



(a) Pit 20 at 1:2 after 50 years

(b) Pit 20 at 1:2 after 100 years



(c) Pit 20 at 1:2 after 200 years

Figure 18: Pit 20 at 1:2 after 200 years of simulation with erosion (red) and deposition (blue) indicated in metres. Co-ordinates on the axis are in Eastings and Northings.

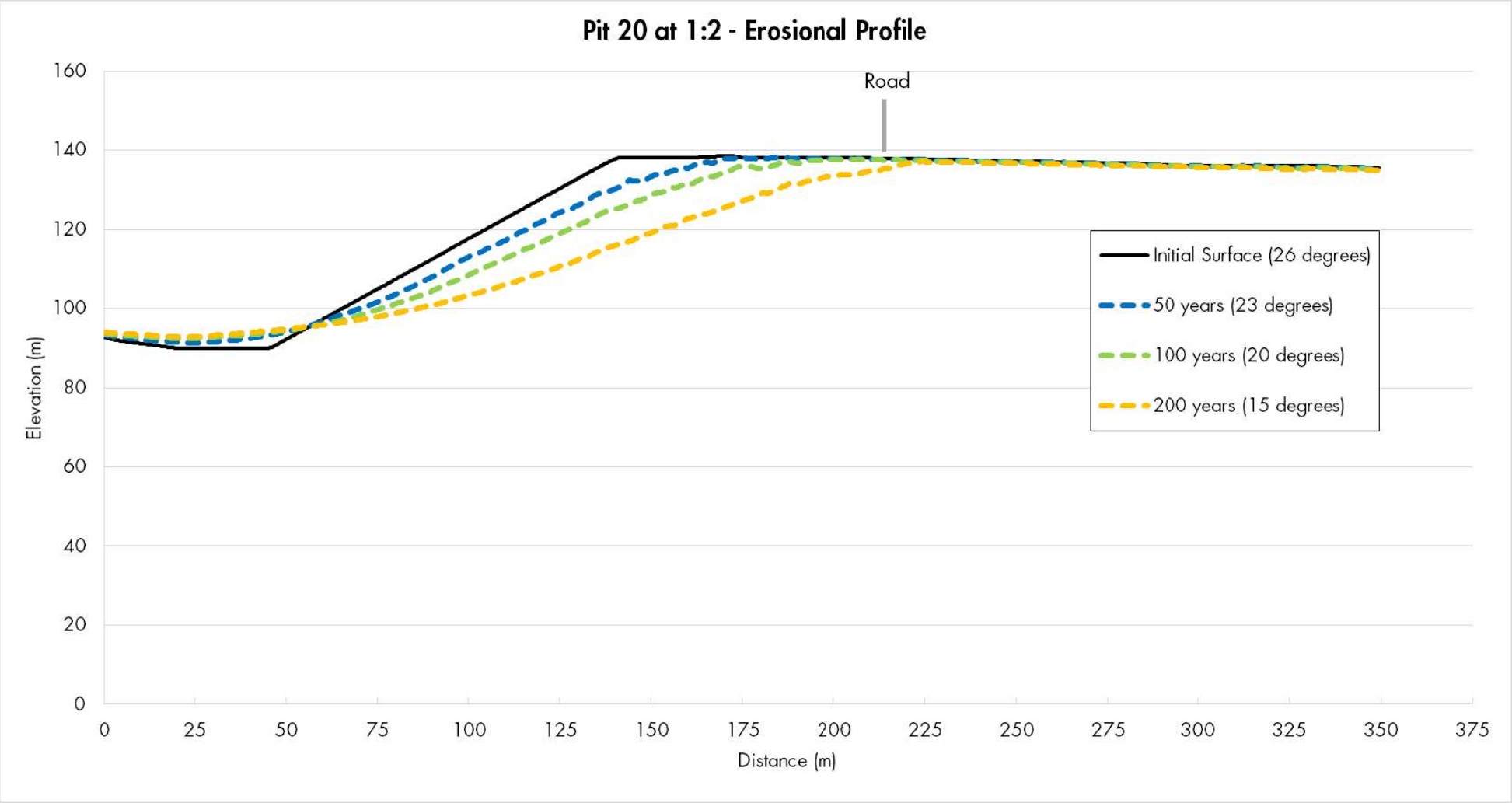


Figure 19: Pit 20 at 1:2 – change in slope profile after 50, 100 and 200 years of simulation

4.2.3 Reshaped to 1:3 gradient

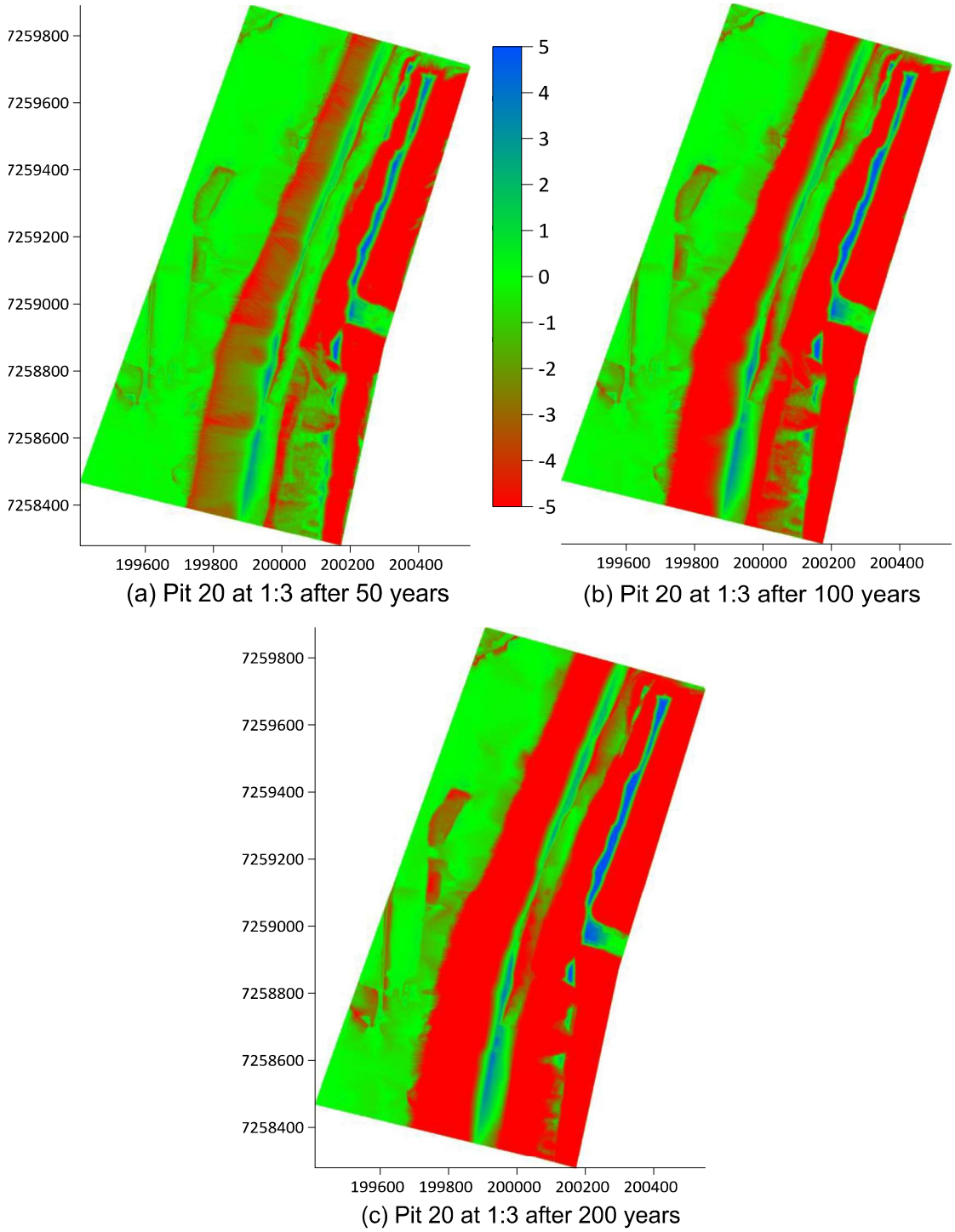


Figure 20: Pit 20 at 1:3 after 200 years of simulation with erosion (red) and deposition (blue) indicated in metres. Co-ordinates on the axis are in Eastings and Northings.

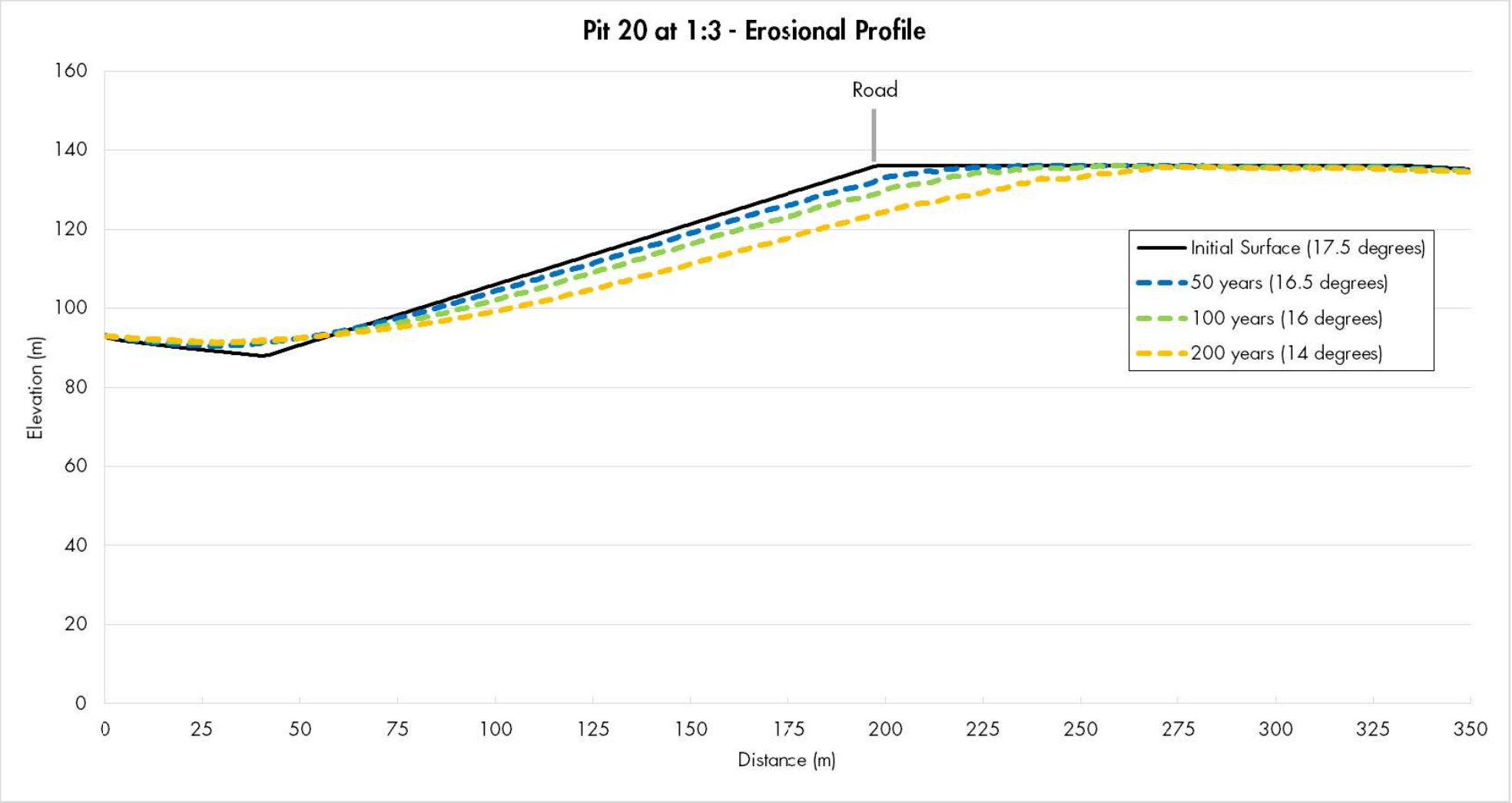


Figure 21: Pit 20 at 1:3 – change in slope profile after 50, 100 and 200 years of simulation

5 DISCUSSION

5.1 No treatment

The unaltered landforms of Pit 2 and Pit 20 represent the highest rates of erosion and degree of landform reshaping. At year 50, Pit 2 erodes at a rate of 2,769t/ha/y with Pit 20 at 3,168t/ha/y. These rates steadily decline as the simulation progresses, reducing to 1,627t/ha/y for Pit 2 and 1,517t/ha/y for Pit 20 at year 200. This is a result of the change in landform shape, as illustrated in Figure 11 and Figure 17. By year 200, the crest of the landform at Pit 2 has retreated 100m, and the toe has advanced 46m. On Pit 20, the crest has retreated 135m and the toe advanced 50m. The resultant shape for both landforms after 200 years is a concave slope profile.

There is an abundance of rills and gullies over the entire pit highwall. Gully depths for Pit 2 and Pit 20 are greater than 1m by year 50, but reduce in depth at year 200. This is a result of the complete reshape of the landform, with material from above filling the gullies below.

Landforms that are not prone to extensive rilling tend to have long-term erosion rates in the order of 10t/ha/y. As such, the rates for the unaltered landforms are not erosionally stable. To place that in perspective, an annual erosion rate of 1,000t/ha/y is losing ~100mm of material from the surface every year. Such rates would lead to extensive rilling and gullying and the prevention of vegetation establishment. This is likely to be unacceptable with respect to the guidelines for Rehabilitation Requirements for Mining Resource Activities (DEHP 2014) because the:

- Battered slopes are likely to be devoid of vegetation and the reinstatement of a functional ecosystem is unlikely; and
- Erosion poses a threat to nearby infrastructure (tenure boundary, fence lines, roads).

5.2 Reshaped to 1:2 gradient

The highwall reshaped to 1:2 gradient does decrease the erosion rate for Pit 2 and Pit 20 when compared with the current landform, but there is still a significant degree of reshaping. At year 50, Pit 2 erodes at a rate of 1,182t/ha/y, more than half of the rate seen on the unaltered landform. Pit 20 erodes at a rate of 1,102t/ha/y after 50 years. These rates decrease across both landforms by year 200, with Pit 2 eroding at 883t/ha/y and Pit 20 at 816t/ha/y. By year 200, the landform has been reshaped, with the Pit 2 crest retreating 135m, and the toe advancing by 45m. The Pit 20 crest has retreated by 129m, with the toe advancing by 45m. The resulting shape is a far longer but lower-gradient concave slope.

Similar to the unaltered design, there is an abundance of rill and gullies over the pit highwall. Gully depths are shallower, peaking at 1m by year 100 for Pit 2, and 1.3m for Pit 20 at year 100. These gully depths decrease by year 200 to ~1.1m for both pits.

5.3 Reshaped to 1:3 gradient

The highwall reshaped to 1:3 gradient is the least erosion-prone of the three designs. At year 50, Pit 2 erodes at a rate of 456t/ha/y, and Pit 20 at a rate of 558t/ha/y. These rates decrease by year 200 to a rate of 454t/ha/y for Pit 2 and 474t/ha/y for Pit 20. By year 200 the slope has been reshaped similar to the 1:2 and unaltered designs, however not to the same extent. The Pit 2 crest has retreated 100m, and the toe advanced by 35m. Similarly, the Pit 20 crest has retreated 95m, and the toe advanced by 40m.

Gully depths were generally lower than the other treatments, but still abundant across the landforms. By year 100, the Pit 2 gully depths were 0.5m and Pit 20 depths at 0.6m. By year 200, the Pit 2 depths had decreased to 0.36m and Pit 20 depths remaining the same at 0.6m.

5.4 Comparison with existing 1:4 gradient slopes

The highwalls of Pit 17b and Pit 18b have been battered down to 1:4 gradient. Although the age of the rehabilitation is unclear, in their current state, they appear to have minimal erosion and are supporting some vegetation. This suggests that adoption of lower slope gradients will produce improved outcomes in terms of minimising erosion and enabling vegetation growth. It is noted that the levels of vegetation cover present is low (estimated to be ~10%), and further amendment of the materials may produce improved vegetation outcomes.



Figure 22: Pit 17b highwall reshaped to 1:4 gradient



Figure 23: Pit 18b highwall reshaped to 1:4 gradient

5.5 Summary

The highest rates of erosion are associated with the pits in their current shape (>1000t/ha/y), decreasing at 1:2 slopes (>500t/ha/y) and again with 1:3 slopes. Even when reshaped to 1:3 gradient, the predicted erosion is still estimated to be extremely high (>300t/ha/y). By comparison, landforms that are not prone to rilling tend to have long-term erosion rates in the order of <10t/ha/y.

Erosion rates decrease as the simulations progress to 200 years; a result of the complete reshaping of the landforms through erosion processes to a more erosionally stable concave shape. This is most evident with the current landform designs, but can also be clearly seen with all rehabilitation designs. The resultant landform slopes at year 200 were generally between 14-16 degrees, which indicates this is likely to be a more stable slope angle in the long term. This stable gradient is strongly dependent on the SIBERIA parameters used in the modelling, and these were based on limited particle size distribution data. Landloch cautions against broad adoption of this gradient at Dawson without completion of more rigorous erodibility testwork.

Although gully depths appeared relatively shallow (generally <1m), it is far more likely that they will increase rather than decrease in depth as the landforms age. The reduction in gully depth is a result of SIBERIA reshaping the landform through both rilling and sheet erosion. In reality, it is more likely that there will be large, deep gullies penetrating the landform, as evident through the existing observed erosion.

The erosion of the crest of the highwalls is predicted to impact on nearby infrastructure. On Pit 2, the road above the highwall will be eroded when gradients of 1:2 and 1:3 are used. Further, at 1:3 gradient the boundary of Lot 6 SP101809 will be affected by year 100. For Pit 20, the road above the highwall will be affected by erosion after 100 years at 1:2 and 1:3 gradient, and a section of the road will be affected after 200 years with no alteration of the surface profile.

Although sediment loads in runoff are likely to be high, it will be contained within the pit and have no impact on the surrounding land, other than limiting any possible growth of vegetation on the pit floor.

The predicted erosion rates are likely to lead to extensive rilling and gullying and the prevention of vegetation establishment. This is likely to be unacceptably with respect to the guidelines for Rehabilitation Requirements for Mining Resource Activities (DEHP 2014) because the battered slopes are likely to be devoid of vegetation (other than possibly some hardy weed species) and the reinstatement of a functional ecosystem is unlikely.

The modelling was conducted using Type 4 – A seam material over the entire batter face. Different lithologies will have different erosion potentials, and if they are present at the surface as could likely happen in the condition where no reshaping is performed, (i.e. the 'no treatment' scenario) the resultant erosion of the slope will be different.

6 CONCLUSIONS

Based on the modelling results, it is predicted that both Pit 2 and Pit 20, under all rehabilitation scenarios, will erode at rates likely to provide erosionally unstable batters highly prone to rill and gully erosion. All rehabilitated landforms are predicted to undergo comprehensive reshaping through erosive processes, with severe degradation of the designs. The following can be concluded:

- The clay rich materials are highly erodible and are predicted to be highly erodible when placed on the landform without alteration;
- The slope gradients and lengths are predicted to be unstable for the given material, with the final landform shapes shifting to a concave slope between 14-16 degrees after 200 years;
- Run-on from the above slope is predicted to contribute to the overall erosion of the highwalls; and
- A vast network of rills and gullies are predicted to form across all designs by year 50.

Given the extreme rates of erosion predicted by the modelling for all scenarios considered, the following recommendations may result in a decrease in erosion and more stable landforms:

- Installation of a crest bund will reduce run-on from the catchment above the highwalls.
- A reduction in slope gradient will facilitate greater stability in the long-term. An indicative gradient of 14-16 degrees was predicted by the SIBERIA modelling. However, this should be underpin by more rigorous erodibility testwork of the surface materials before broad adoption on site. Figure 24 indicates how this design may potentially look.
- Addition of rocky, durable, competent material to the existing clay rich materials will assist in reducing the overall erosion rate. However, this may be an expensive option and potentially unpractical at steep slope gradients.
- Rapid establishment of vegetation will potentially reduce erosion rates by several orders of magnitude when coupled with the addition of competent rock

Additional SIBERIA modelling under some or all of the above scenarios may provide an indication of their effectiveness in reducing erosion and further guide closure strategies.

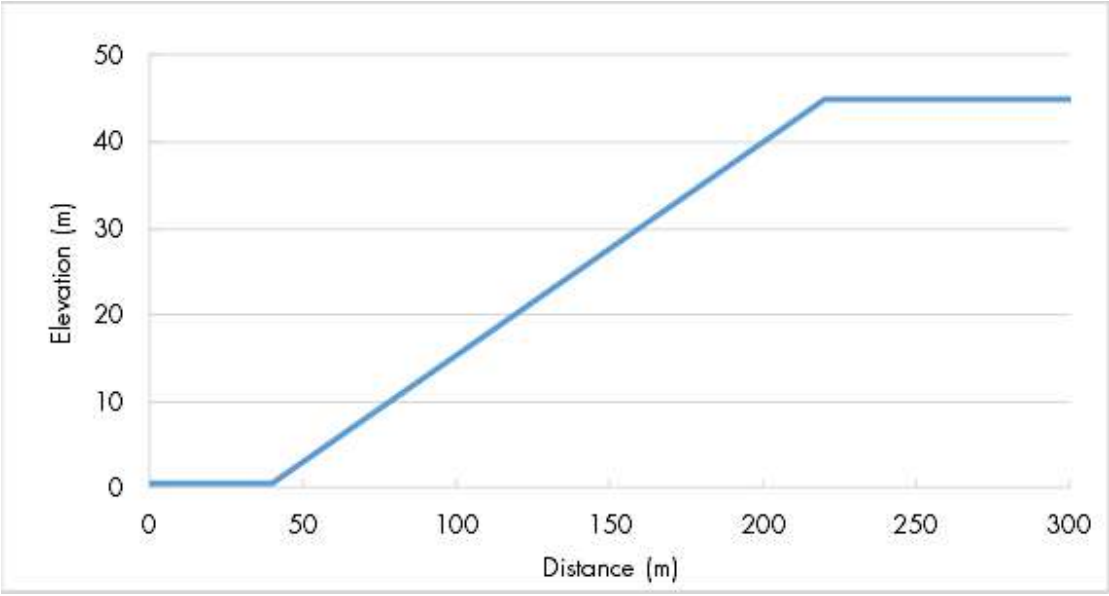


Figure 24: Potential final design based on outcomes of SIBERIA modelling. Based on a concave shaped landform with 14-16 degree slopes.

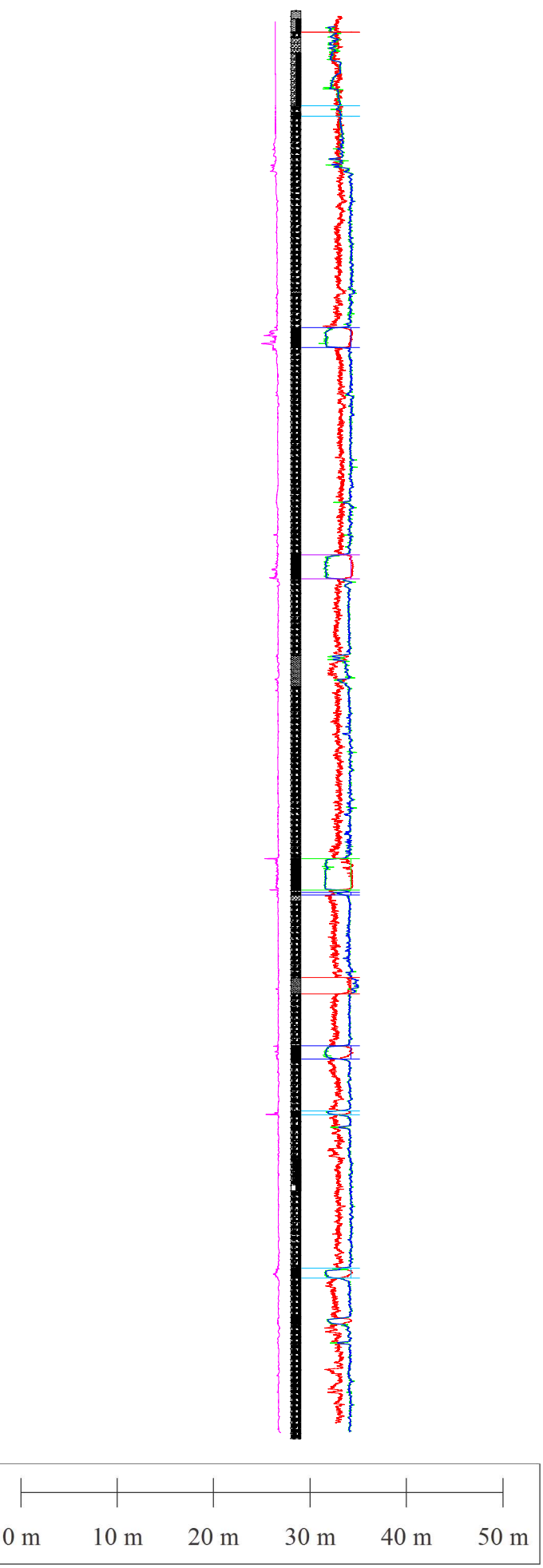
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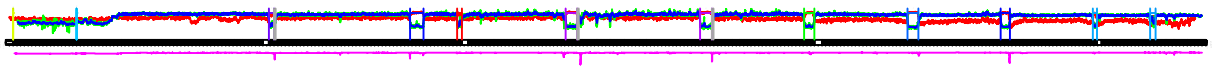
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Appendix A. Pit 2 Stratigraphic Diagram


0 m
10 m
20 m
30 m
40 m
50 m

Appendix B. Pit 20 Stratigraphic Diagram



Appendix 4.14 Dawson Pit 2 and Pit 20: Highwall Erosion Modelling

Landloch



DAWSON PIT 2 AND PIT 20: HIGHWALL EROSION MODELLING



Anglo American

November 2018

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Disclaimer: All care and diligence has been exercised in testing, interpreting data and the development of recommendations presented in this report. The monitoring and testing have been undertaken in a skilled, professional manner, according to accepted practices. Specific circumstances and research findings after the date of publication may influence the accuracy of the data and recommendations within this report.

The landscape is not uniform. Because of this non-uniformity, no monitoring, testing or sampling technique can produce completely precise results for any site. Any conclusions based on the monitoring and/or testing presented in this report can therefore only serve as a 'best' indication of the environmental condition of the site at the time of preparing this document. It should be noted that site conditions can change with time.

The information that comprises this report should only be used within the limitations stipulated in this report. Landloch does not accept any risks and responsibilities for losses, damages, costs and other consequences resulting from using any information, material and recommendations in this report.

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1 INTRODUCTION

This document summarises the WEPP[1] erosion modelling undertaken by Landloch Pty Ltd (Landloch) for Anglo American for waste located within the highwall of Pit 2 and Pit 20 at the Dawson Coal Mine in the Bowen Basin, Queensland. Anglo American are investigating the erosion implications of several potential highwall rehabilitation options at their Dawson operations.

The overall objective of the study is to assess the long-term erosional stability of a range of rehabilitation landform shapes for the Pit 2 and Pit 20 highwalls. The effect of vegetation is also to be assessed. To achieve this aim, Landloch has completed the following:

- Characterisation of Pit 2 highwall material selected by Anglo American and provided to Landloch that will constitute the majority of the material present at the surface of the reshaped highwall.
- Water erosion studies including application of both simulated rain and overland flows, and assessment of the properties of the sediment present.
- WEPP runoff/erosion simulations to assess the erosion performance of batters with the selected materials applied to the surface. Additionally, simulations of the effect of differing vegetation cover on these surfaces is considered.

2 EROSION STUDY OVERVIEW

2.1 Material selection

This study is focused on the measurement of erosion rates for the waste that will be present at the surface of the reshaped highwalls at Pit 2 and Pit 20 (Figures 1-3). Stratigraphic diagrams for Pit 2 and Pit 20 are available in Appendix A.

The underlying lithology of the Dawson mine is characterised by five interseam coal units, A – E. The overlying sediments of the A and B seams consist of thinly interbedded siltstones, shales and claystones. The lower B to D interseam units consist of massive (lacking structure), strongly jointed, thickly bedded sandstones. The E interseam unit is comprised of Yarabee Tuff. These interseam units are the primary constituents of the pit highwalls and form the basis of the spoil materials produced on site. For this report, it is assumed that once the highwall is reshaped and prepared for rehabilitation (e.g. ripped and seeded), they will have a friable surface in which vegetation can grow. As such, the erosional properties of the surface materials once prepared for rehabilitation will resemble the properties of the disturbed spoils.

[1] Water Erosion Prediction Project

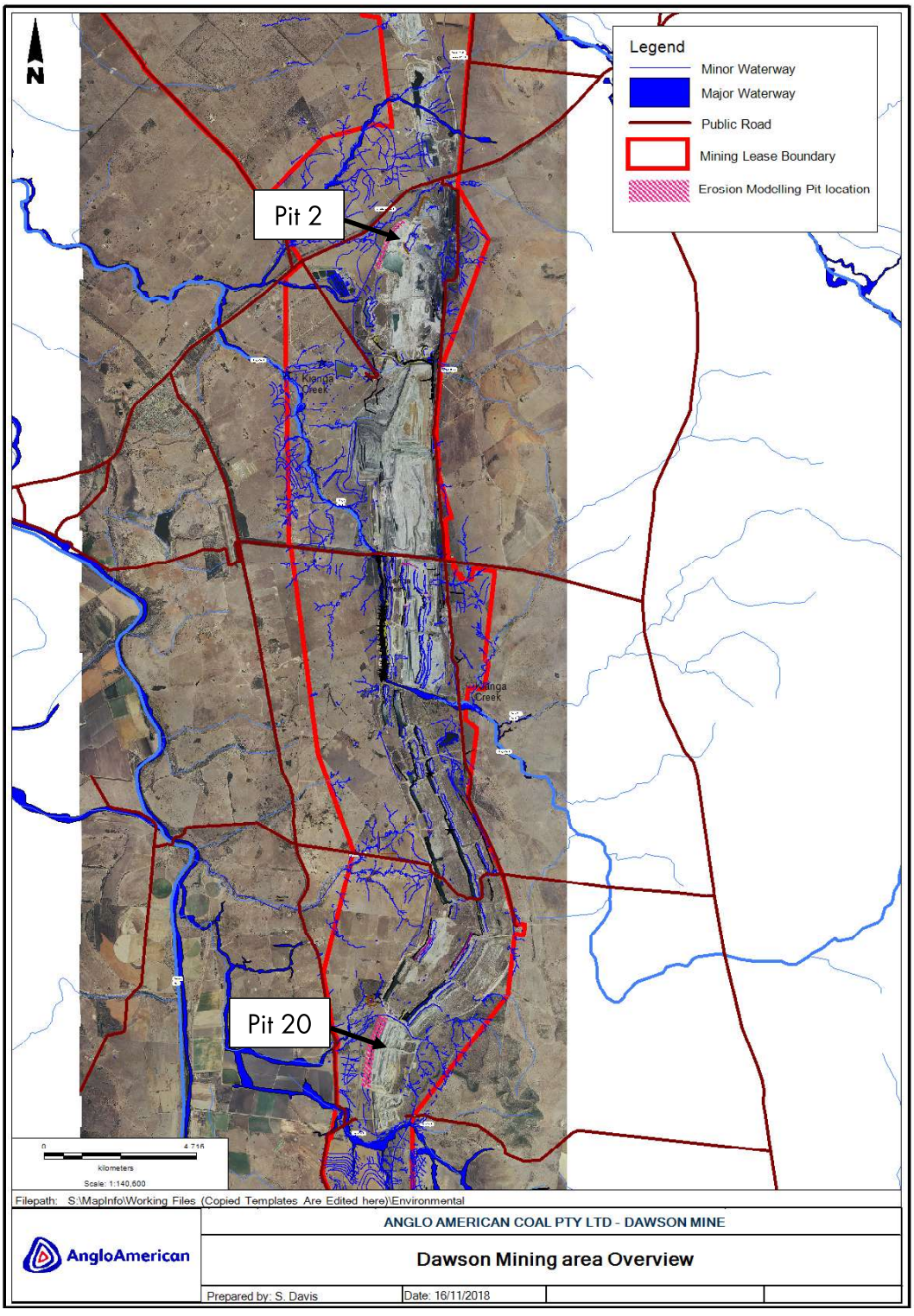


Figure 1: Dawson mining area overview (Source: Anglo American)

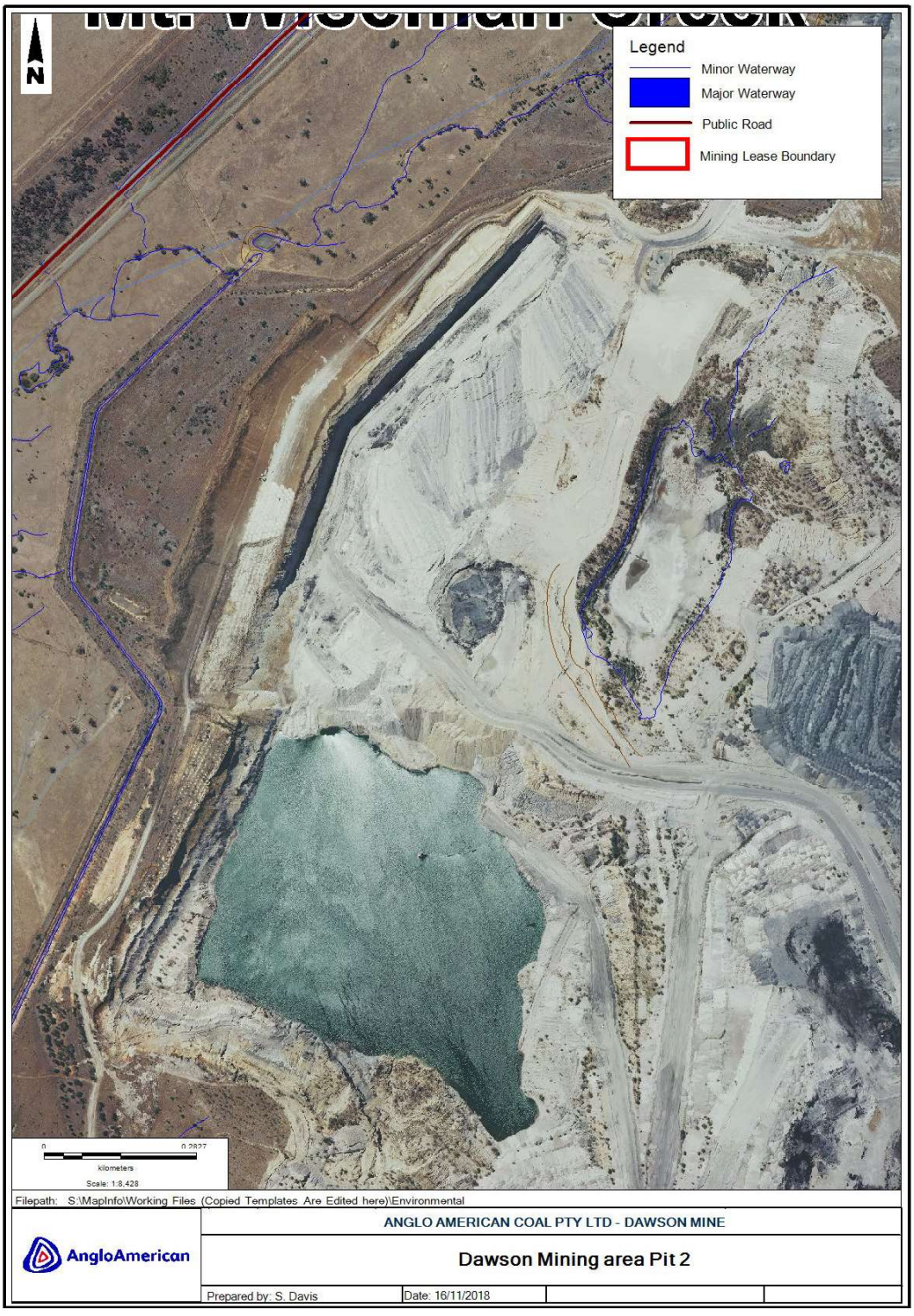


Figure 2: Dawson Pit 2 (Source: Anglo American)



Figure 3: Dawson Pit 20 (Source: Anglo American)

Dawson uses four spoil management units (SMUs) to reflect *in situ* spoil quality (PW Baker & Assoc. 2010):

- Type 1 – Dawson coarse sandstone spoils (mostly C, D and E seams);
- Type 2 – Gibihi intergrade spoil (mostly a mixture of B/C seams);
- Type 3 – Fine Kianga spoil with few significant chemical/physical limitations (mostly B seam); and
- Type 4 – Fine Kianga spoil with increased chemical/physical limitations (mostly A seam).

A generalised description of the overburden and resultant SMUs is given in Table 1. Available particle size distributions are given in Table 2. Images of the Pit 2 and Pit 20 materials were captured during a site visit by Anglo American in November 2017 (Figure 4).

Table 1: Summary of Dawson's spoil types (adapted from PW Baker & Assoc. 2010)

Dawson Overburden	Resultant Typical SMU	Description
A seam	Type 4	Weathered material, primarily sandy, clay and shale
B seam	Type 2 and 3	Sandstone (some interbedded siltstone)
C seam	Type 1	Sandstone
D seam	Type 1	Sandstone
E seam	Type 1	Sandstone

Table 1: Particle size distribution data available for the spoils and topsoil

Source	Material	Clay % (<0.002mm)	Silt % (0.002-0.02 mm)	Sand % (0.02-2mm)	Gravel % (2-20mm)
PW Baker & Assoc. (2010)	Black earth topsoil	45	23	32	12
	A Seam spoil	33	20	47	5
	D Seam Spoil	28	11	63	43
Envirosciences (1991)	Coarse Spoil	11	6	29	53
	A Seam	25	13	49	15
	B Seam	20	20	35	25
Landloch 2018 (this study)	Highwall spoil	24	14	37	24

Samples of material from Pit 2 and Pit 20 highwall were sent by Anglo American to the Landloch laboratory in Toowoomba for hand texture analysis and sieving. In addition, a bulk sample of Pit 2 material (image provided in Appendix B) was also provided as part of this study, and was assessed for particle size distribution (together with other properties) (see Table 2 for the PSD of the fine fraction for this sample). Results of the analyses are outlined in Table 3. The particle size distribution of the bulk sample fall within the range of clay contents and coarse fraction contents measured for the other Pit 2 and Pit 20 samples and are consistent with A Seam and B Seam overburdens. Given

the dominance of weathered materials and relatively low proportion of blocky rock (the maximum rock size within the bulk sample was 25mm, and 90% of the sample had particle sizes less than 5mm), it was concluded that the Type 4 – A Seam spoil dominates the highwall surface of both Pit 2 and Pit 20. As such, the A Seam spoil was used for the development of the WEPP modelling parameters for both Pit 2 and Pit 20.

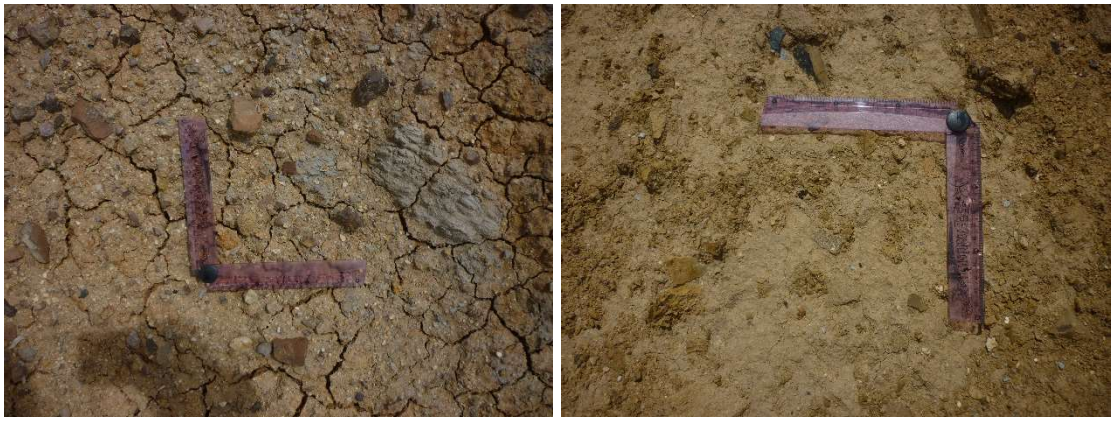


Figure 4: Pit 2 highwall material (left) and Pit 20 highwall material (right)

Table 2: Texture analysis on samples of Pit 2 and Pit 20 material

Sample ID	Hand Texture	Approximate Clay Content+ (%)	Fine Fraction (<2mm) (%)	Coarse Fraction (>2mm) (%)
2017 Sampling – Grab Samples				
Pit 2C sample 1	Light Clay	35 – 40	88	12
Pit 2C sample 2	Light Clay	35 – 40	90	10
Pit 20 sample 1	Medium/Heavy clay	>50	70	30
Pit 20 sample 2	Medium/Heavy clay	>50	77	23
2018 Sampling – Bulk Sample				
Highwall spoil (this study)	-	25-40*	70	30

+ Clay percentages are reported as the percentage of the fine fraction only (<2mm), i.e. excluding the coarse fraction
* The sum of silt and clay is reported here at the approximate clay content as it is difficult to differentiate these fractions by hand texturing. The approximate clay content of the 2017 samples are likely to be a combination of clays and silts.

2.1.1 Baseline material properties

A bulk sample (~1m^3) of the Type 4 SMU material was supplied to Landloch by Anglo American and used within the laboratory-based erodibility study. A subsample (diameters <2mm) was analysed for the following:

- Soil $pH_{1:5}$ (H_2O);
- Electrical Conductivity ($EC_{1:5}$);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, K^+ and Al^{3+});
- Effective Cation Exchange Capacity;
- Exchangeable Sodium Percentage;
- Particle size distribution (rock, pebble, gravel, sand, silt, clay); and
- Emerson class number.

2.2 Computer simulation of runoff and erosion from landform batters

2.2.1 The WEPP model

The Water Erosion Prediction Project (WEPP) model was used for simulations of runoff and erosion. It was developed by the United States Department of Agriculture (USDA) to predict runoff, erosion, and deposition for hillslopes and catchments.

WEPP has a daily input time step, although internal calculations use shorter time steps. Plant and soil characteristics important to erosion processes are updated every day. When rainfall occurs, those plant and soil characteristics are considered in determining the occurrence of runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope profile.

The erosion component uses a steady-state sediment continuity equation as the basis for erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than the soil's critical shear stress, and when the sediment load of the flow is below transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

2.2.2 Climate sequence

A climate input file is needed to simulate runoff and erosion with the WEPP model. For each day of simulation, WEPP requires ten daily weather variables:

- Precipitation;
- Precipitation duration;
- Peak storm intensity;
- Time to storm peak;
- Average minimum temperature;
- Average maximum temperature;
- Dew point temperature;
- Solar radiation;
- Wind speed, and
- Wind direction.

Of these, the four precipitation-related variables (underlined in list above) are of particular importance because previous studies have shown that predicted runoff and erosion are most sensitive to these variables (Nearing *et al.* 1990).

For most sites around the world, complete historical data for these variables are not available. Therefore, to use WEPP for runoff and erosion prediction, synthetic weather sequences that statistically preserve the mean and variations in the historical observations are required.

CLIGEN is a stochastic weather generator that can be used to provide WEPP climate input files. CLIGEN has been extensively assessed for a wide range of climates in Australia, and it was found that CLIGEN was suitable to provide the required climate input for WEPP to predict runoff and erosion in Australia (Yu 2003).

Daily and sub-daily climate data for Moura were sourced from the Australian Bureau of Meteorology (BoM). Using these data sets, the following parameter values were computed and used to develop the synthetic climate sequence for Dawson:

- Mean daily rainfall on wet days for each month,
- Standard deviation and skewness coefficient of daily rainfall for each month,
- Probability of a wet day following a dry day for each month,
- Probability of a wet day following a wet day for each month,
- Mean daily max. temperature for each month,
- Standard deviation of daily max. temperature for each month,
- Mean daily min. temperature for each month,
- Standard deviation of daily min. temperature for each month,
- Mean maximum 30-min rainfall intensity for each month, and
- Probability distribution of the dimensionless time to peak storm intensity.

These parameter values were assembled to create a CLIGEN parameter file for the site. Wind data (used to calculate soil evaporation) were not synthesised by CLIGEN because Priestley-Taylor's method for estimating the potential evaporation will automatically be used by WEPP. A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002).

2.2.3 Determination of calibrated WEPP erodibility parameters

Within WEPP, erodibility is described via a number of specific parameters:

- Effective hydraulic conductivity (K_e);
- Interrill erodibility (K_i);
- Rill erodibility (K_R); and
- Critical shear for rill initiation (τ_c).

Interrill erodibility (K_i) describes the detachment and movement of particles by the combined action of raindrops and shallow overland flows. Rill erodibility (K_R) describes the detachment of particles by shear stresses caused by concentrated flows. Critical shear for rill initiation (τ_c) is the shear stress applied by concentrated flows to the surface above which particle detachment and transport by flow rapidly increases and rills form. Within WEPP, effective hydraulic conductivity (K_e) defines the rate of water movement through a defined soil profile in response to wetting by rainfall, and is derived through analysis of a material's steady infiltration and runoff rates. Effective hydraulic conductivity that required within the van Genuchten water retention model, and is different to saturated hydraulic conductivity. The calibrated WEPP erodibility parameters were derived from data collected using laboratory-based experimental methods involving the application of:

- Simulated rain and measurement of runoff rate and sediment loads in runoff to obtain estimates of K_i and K_e;
- Concentrated surface water flows and measurement of flow characteristics and sediment loads to obtain estimates of K_R and τ_c; and

Interrill erosion was measured by applying simulated rain with known rainfall intensity to simulation plots 0.75m wide and 0.75m long (Figure 5). Rill erosion was measured by applying overland flow to simulation flumes 0.4m wide and 2.0m long (Figure 6).

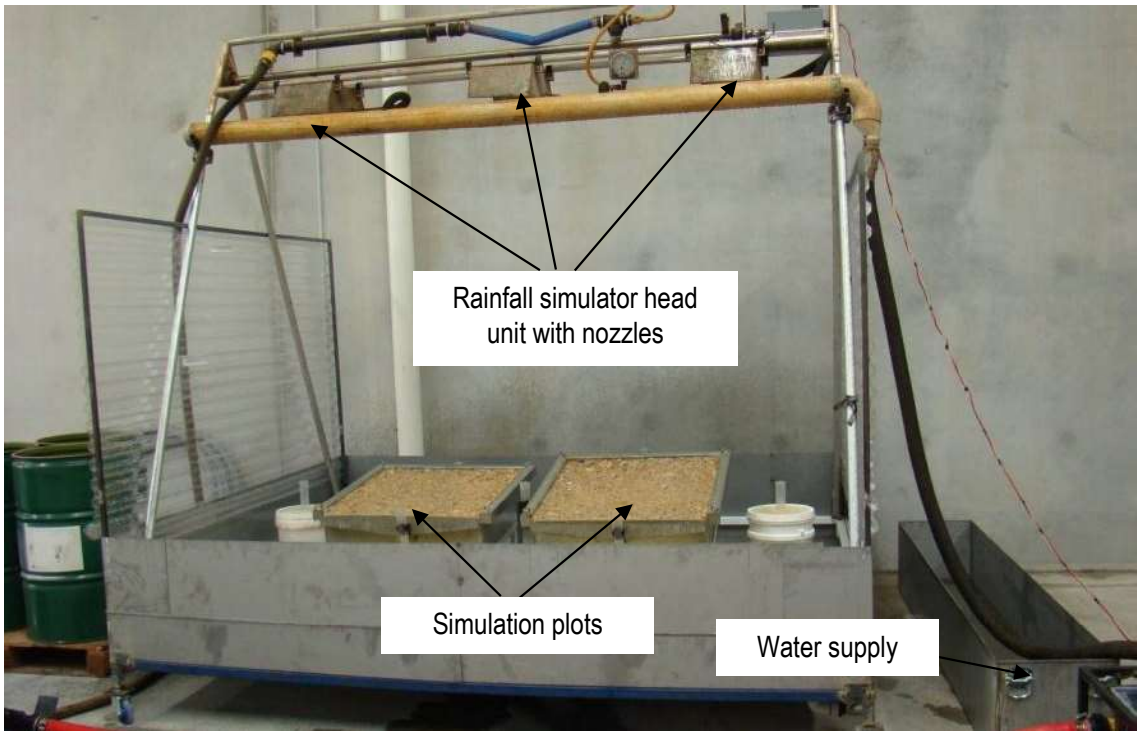


Figure 5: Laboratory-based rainfall simulator installation.

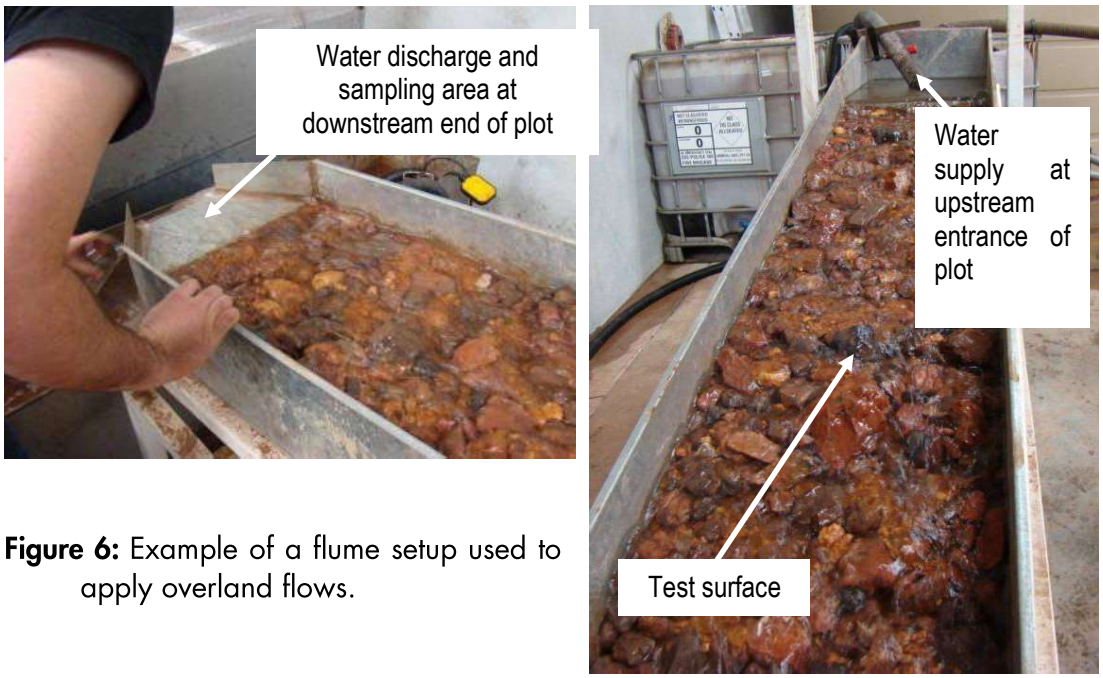


Figure 6: Example of a flume setup used to apply overland flows.

Estimates of erosion rates are sensitive to the particle size and density distributions of the eroded sediment. The version of the WEPP model available for general use has been coded to estimate sediment properties solely on the basis of input soil particle size distribution data. However, Landloch has access to a modified version of WEPP that specifically allows input of material-specific sediment particle size and density distributions. This modified version of the WEPP has been applied in this study because it can more accurately predict erosion and transport. Settling columns (Figure 7) were used to develop the necessary sediment properties.



Figure 7: Landloch's automated settling columns deployed on site in support of field-based rainfall simulation.

2.2.4 Definition of acceptable erosion

The concept of 'acceptable' erosion is widely mentioned, but common definitions appear to have little relevance to minesite rehabilitation. For example, Wischmeier and Smith (1978) defined tolerable soil loss for cropland as "*the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.*"

A value of 11.2t/ha/y is often cited as a tolerable soil loss rate, but that value was derived by US soil conservation agencies for deep fertile cultivated soils, and has little relevance to most rehabilitated minesites. Using similar criteria to those applied for crop land, a lower soil loss tolerance value of 4.5 t/ha/y was developed by US agencies for erosion of rangeland soils and shallow cultivated soils (Wight and Siddoway 1979).

Landloch's approach to landform design aims to create slopes on which rilling will be minimised, thereby reducing or eliminating the potential for rills to gradually develop into gullies. If rilling and gullying are avoided, the slope should be sustainable. Surfaces eroded by interrill erosion typically become armoured in any case.

Landloch has considerable experience in modelling erosion, and assessing erosion processes and rates in the field. Landloch has observed that landforms designed with a predicted mean average annual erosion rate (averaged over the whole slope for a 100-year period) less than 5t/ha/y, together with a predicted peak average annual erosion rate at any point on the slope less than 10t/ha/y exhibit a low tendency to rill. These values are also broadly consistent with erosion values reported in the available literature.

These erosion threshold values were adopted as acceptable for this report. To date, observations made by Landloch on several sites indicate that this erosion threshold definition has produced batters with low rilling potential that have been consistent with rehabilitation success (DRET 2009).

2.2.5 Impacts of vegetation

To simulate the various levels of cover the WEPP hydraulic conductivity parameter (K_e) was modified to account for impacts of cover on steady infiltration rate as shown by rangeland research (Kato *et al.* 2009) (Figure 8). Effectively, steady infiltration rate generally increases by 7-10 mm/h for each 10% increase in surface cover. The effect of this change on K_e is determined by fitting the WEPP model to the increased steady infiltration values. For this project, it is assumed that a 10% increase in surface cover increases steady infiltration by 7mm/hr.

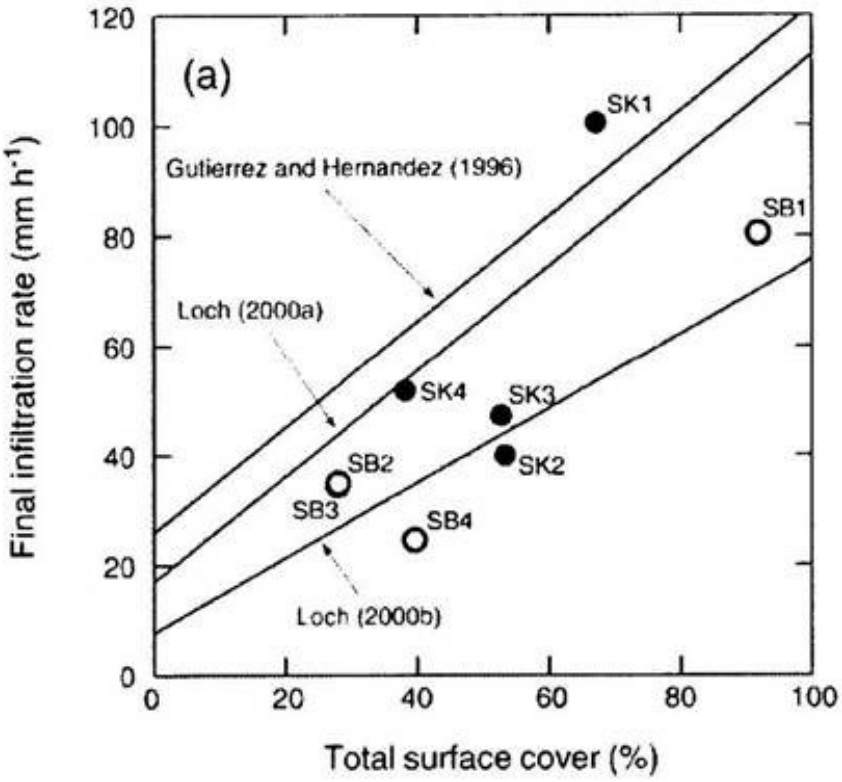


Figure 8: Impacts of cover on steady infiltration rate. Figure is based on a number of research studies and taken from Kato *et al* (2009).

WEPP allows for variations in the degree of cross-slope flow concentration that occurs on a slope. Particularly in the mining context, that is a very useful option, as some practices such as the installation of large cross-slope rip lines can cause significant concentration of flow, triggering almost instant gullies. As well, the level of surface hydraulic roughness present (as opposed to the "form roughness" provided by rip lines) can significantly affect flow concentration.

Generally, for a cross-slope ripped soil or fine- textured oxidised waste, Landloch uses a cross-slope rill spacing of 5m. For heavily vegetated or rock armoured slopes, that spacing is reduced to 1m, meaning that flow in each rill is greatly reduced in volume and erosion power. In this case, for 40-60% cover, a rill spacing of 2 m was adopted, and for 60-80% a rill spacing of 1m was adopted.

To account for direct effects of cover on erosion (i.e. detachment of particles from the surface), cover factors (C factors) were derived using the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.* 1997), for 40%, 60%, and 80%. It was assumed that the surface roughness was 8mm, that the bare surface was fully consolidated, and that erosion is dominated by rill erosion if the surface is bare.

2.2.6 WEPP model assumptions

The Type 4 SMU material was used within WEPP in several simulations of runoff and erosion (Table 4). All batters considered did not contain berms.

Table 4: Summary of WEPP simulations

Pit	Simulation No.	Description
2	1	1V:3H linear slope at 40 % surface cover
	2	1V:3H linear slope at 60 % surface cover
	3	1V:3H linear slope at 80 % surface cover
	4	1V:4H linear slope at 60 % surface cover
	5	1V:4H linear slope at 80 % surface cover
	6	1V:5H linear slope at 60 % surface cover
	7	1V:5H linear slope at 80 % surface cover
	8	Concave (1V:3H and 1V:5H) at 60% surface cover
	9	Concave (1V:3H and 1V:5H) at 80% surface cover
20	10	1V:3H linear slope at 40 % surface cover
	11	1V:3H linear slope at 60 % surface cover
	12	1V:3H linear slope at 80 % surface cover
	13	1V:4H linear slope at 60 % surface cover
	14	1V:4H linear slope at 80 % surface cover
	15	1V:5H linear slope at 60 % surface cover
	16	1V:5H linear slope at 80 % surface cover
	17	Concave (1V:3H and 1V:5H) at 60% surface cover
	18	Concave (1V:3H and 1V:5H) at 80% surface cover

It is noted that the modelling is predicting erosion rates if the surface cover levels indicated are achieved. In practice, the stability of the rehabilitated batter will be influenced by the actual level of surface cover achieved. Therefore, if slopes that assume a certain level of cover are adopted as final rehabilitation profiles, it is critical that both the batter profile shape and the level of surface contact cover be achieved. If a batter is reprofiled to the incorrect shape (steeper gradient or more convex in profile) or does not support the required surface cover, the batter is likely to be erode more than predicted.

It is also important that the measure of surface cover be clearly understood. Surface cover in erosion modelling is that part of the vegetative cover that is in direct contact with the surface. It excludes the canopy cover provided by shrubs and trees but often included in measures of cover, particularly those estimated using remote techniques. To achieve 40-80% surface cover, rehabilitation will have to be dominated by grass species, and preferentially species that are stoloniferous in form (i.e. not buffel grass). Rhizomes, in contrast, are root-like stems that may either grow horizontally at the soil surface or in other orientations underground.

WEPP simulations were conducted using the following model settings:

a) Rill spacing was set at 5m when the surface cover was 0%, 2m when surface cover was 40 and 60%, and 1m when surface cover was 80%.
b) Surface roughness was set at 3cm, consistent with the value used when calibrating the model runoff predictions. It is also consistent with a lightly cross-slope ripped rehabilitated batter surface.
c) No allowance was made for water from the top of the landform to discharge onto the batter slopes. Retention of water on top of the landform will considerably reduce potential erosion rates. This is assumed to be achieved through the installation of crest bunding.
d) The vertical height of Pit 2 and Pit 20 was assumed to be 70m and 60m respectively. This is based on data presented in Landloch (2018).

2.3 Erosion prediction validation using LiDAR data

LiDAR data was used as a means of validating the WEPP model. High resolution LiDAR data of Pit 2 and Pit 20 at September 2017 were provided by Anglo American in xyz format. These data were and processed to produce a surface elevation file gridded at a fine resolution (0.5 x 0.5m). Anglo American also provided data indicating the age of rehabilitated surface located near Pit 2 and Pit 20. Through interrogation of the surface elevation files, a representative rehabilitated surface near Pit 2 that was constructed in 2010 was selected (Figure 9). It consists of a linear, 15° slope that is 65m long and 20m high.

The volume of material eroded from this batter slope was determined by creating a high-resolution contour file (1m contours) and then smoothing it to 'fill' in all erosion features present. This smooth surface was compared with the eroded surface to produce a volume difference that represents that volume of materials eroded. The total volume of material removed over the life of the landform was estimated to be 1216m^3 over 1.73ha. Assuming a bulk density of 1.3 g/cm^3 and a 7-year lifespan, an average rate of erosion of 130t/ha/y was calculated. The WEPP model was run using the parameters derived from the erosion test work detailed in this report. The same slope configuration was input and WEPP was run to produce a long-term annual erosion prediction. The predicted erosion was then factored to account for the fact that the period 2010-2017 was 21% wetter than the long-term average. The WEPP predicted erosion was 134t/ha/y, a difference of 3%. This indicates that the modelling results are very similar to those estimated using LiDAR data. Given the similarities in erosion rates, the WEPP parameters are considered suitable for use.

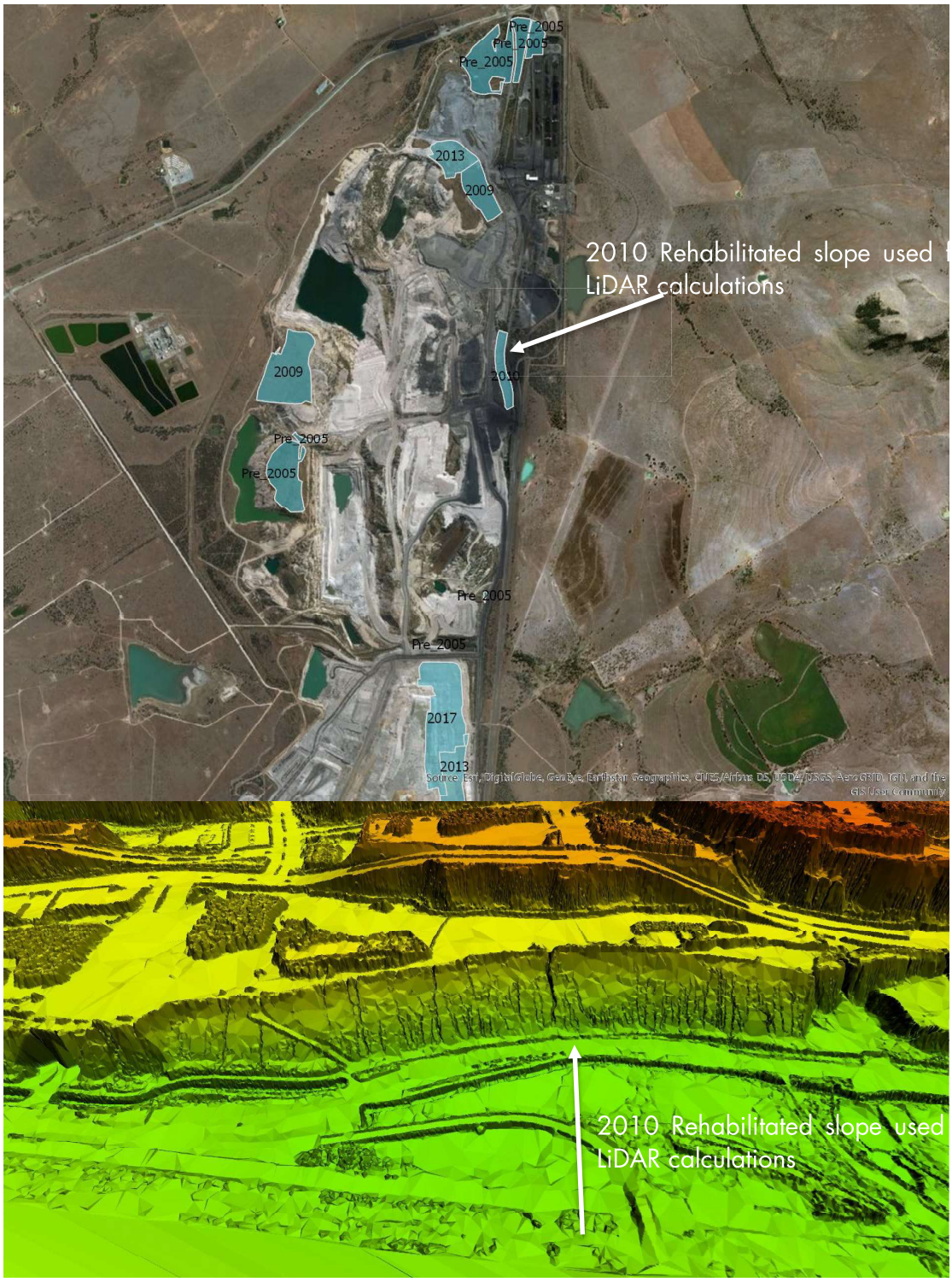


Figure 9: Areas rehabilitated at Pit 2 (top image), with LiDAR data of the area used for calculation of existing erosion over the 7 year period (bottom image).

3 RESULTS

3.1 Material properties

Baseline material characterisation results for the Type 4 SMU are provided in Table 5. An interpretation of the results follows. Assessments of values for pH, EC, exchangeable cations, and Emerson dispersion class were based on industry standards (Hazelton and Murphy 2007).

3.1.1 Soil pH

The pH of the Type 4 SMU sample was very strongly alkaline. Soil pH affects the availability of various nutrients and other elements to plant roots. In some cases, high pH can lead to a deficiency in nutrients such as nitrogen and phosphorus and some micronutrients (copper, zinc, manganese). This may adversely impact on plant growth potential.

3.1.2 Salinity ($EC_{1:5}$)

Salinity of the Type 4 SMU material is high and will likely affect the germination and growth of salt sensitive and mildly salt tolerant plant species. Hazelton and Murphy 2011) suggest that $EC_{1:5}$ values greater than ~0.8dS/m can be used to define high salinity for soils with clay contents of ~40%.

3.1.3 Particle size distribution

The Type 4 SMU material is predominantly comprised of fine fraction (70%). Only 10% of the material has particle sizes greater than 5mm. Coarse and fine sands make up 62% of the fine fraction, with 14% being silt, and 24% clay. The material has a clay loam texture (Figure 10).

3.1.4 Exchangeable cations and dispersion

The Exchangeable Sodium Percentage (ESP) is extremely high. Values greater than 10-14% are typically used to define materials that are strongly sodic and highly prone to clay dispersion. The material also has a clay loam texture with an appreciable clay fraction and sufficient ECEC (>3meq/100g) and exchangeable Na (>0.3meq/100g) to indicate that the dispersed clay will cause degradation of the structure of the material (McKenzie et al 2004). This will likely manifest itself by:

- Increased soil bulk density and hardset surfaces, leading to adverse effects on plant germination and root growth;
- Reduced infiltration and increased runoff potential leading to increased erosion risk; and
- Increased risk of tunnel erosion.

Table 5: Baseline material characterisation data

Analysis		Unit	Type 4 SMU
$pH_{1:5}$ - Water		pH units	9.83
Electrical Conductivity, $EC_{1:5}$		dS/m	0.80
Exchangeable Cations*	Test method	-	15C1
	Ca^{2+}	meq/100g	4.82
	Mg^{2+}	meq/100g	4.98
	K^{+}	meq/100g	0.28
	Na^{+}	meq/100g	3.90
	Al^{3+}	meq/100g	0.01
	ECEC	meq/100g	14.0
	ESP	%	27.8
Particle Size Distribution of Fine Fraction+	Coarse Sand	%	25
	Fine Sand	%	37
	Silt	%	14
	Clay	%	24
Particle Size Distribution All Sizes+	Rock	%	0
	Pebble	%	0
	Coarse Gravel	%	10
	Gravel	%	20
	Fines	%	70

Note: *ECEC: Effective Cation Exchange Capacity; ESP: Exchangeable Sodium Percent. +Rock: >45mm; Pebble: 45-25mm; Coarse gravel: 25-5mm; Gravel: 5-2mm; Fines <2mm; Coarse sand: 2-0.2mm; Fine sand: 0.2-0.02mm; Silt: 0.02—0.002mm; Clay: <0.0002mm.

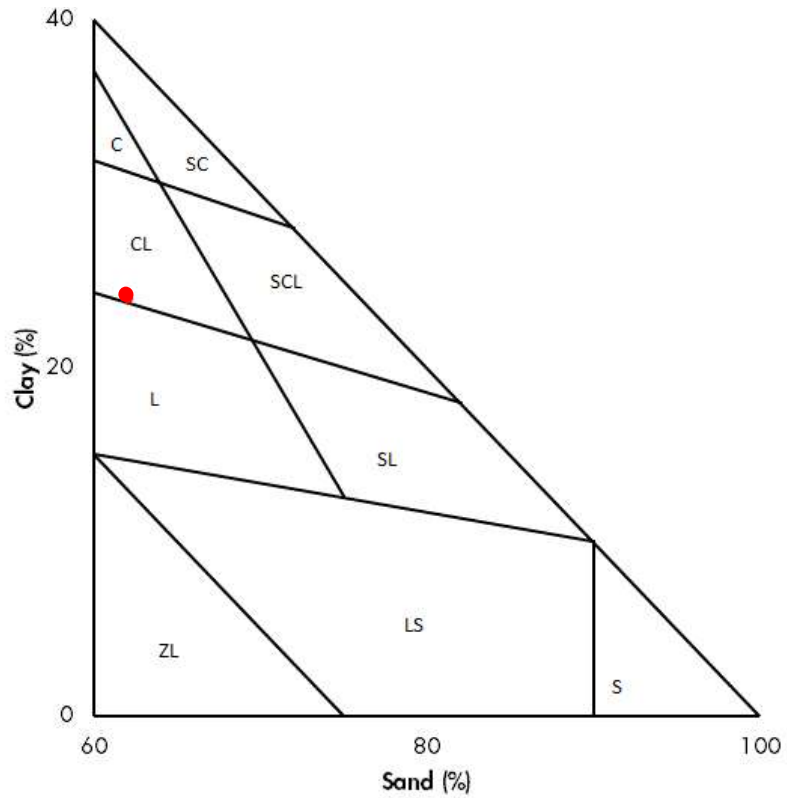


Figure 10: Texture of the Type 4 SMU material (red dot on above figure).

The ratio of a material's cation exchange capacity to clay (also known as CCR) provides a surrogate measure of clay mineralogy. The Type 4 SMU material has a CCR of 0.58, indicating that the material has a mixed clay mineralogy with a high proportion of montmorillonite. Montmorillonite clays are highly prone to swelling and shrinking as they wet and dry. The process of swelling and shrinking means that they tend to crack on drying and maintain a relatively friable surface as a result when dry and a hardened surface when wet. This was observed during the erosion testing (Figure 11). The material's propensity to crack and become friable on drying will compete against its tendency to disperse and hardset, making its performance in terms of erosion difficult to predict. However, as a guide, it is likely that it will initially be permeable as rainfall enters the profile through macropores (i.e. cracks). But as it wets and swells these macropores will close and the material will likely become less permeable and more likely to runoff, particularly given the clay fraction is dispersive (Figure 11). The clay dispersion will act to harden the surface to some degree and lower the potential for sediment to detach.



Figure 11: Surface cracking of the dried Type 4 SMU material when packed into a flume (left). The cracks close and the surface hardens once wet (right).

3.2 WEPP parameters

WEPP erodibility parameters were derived using data collected from the rainfall and overland flow simulations. The derived WEPP erodibility parameters are provided in Table 6.

Table 6: WEPP parameters for the Type 4 SMU material derived from laboratory testing

Material	Effective hydraulic conductivity, K_e	Interrill erodibility, K_i	Rill erodibility, K_R	Critical shear, τ_c
	mm/h	kg.s/m^4	s/m	Pa
Type 4 SMU	2	1,328,870	0.0005	4

The Type 4 SMU material has very low effective hydraulic conductivity. The interrill erodibility value is high, indicating that the surface does erode under rain splash. The critical shear is low, meaning that rills are likely to form. However, the rate of rill detachment is lower than typically measured for fine-grained materials. This is likely due to hardening of the surface as clay disperses.

3.3 Sediment properties

Equivalent sand particle size distribution curves for each material is provided in Figure 12. A total of 4 samples were assessed (grey lines) and the average line used within WEPP is shown in red.

The data show quite consistent sediment particle size distributions for the four samples assessed. They also show that ~50% of the sediment that is generated from the Type 4 SMU material will not readily settle and will likely remain in suspension in runoff. Particles less than approximately 0.1mm tend to be difficult to settle. Based on this, it is likely that runoff waters will remain turbid.

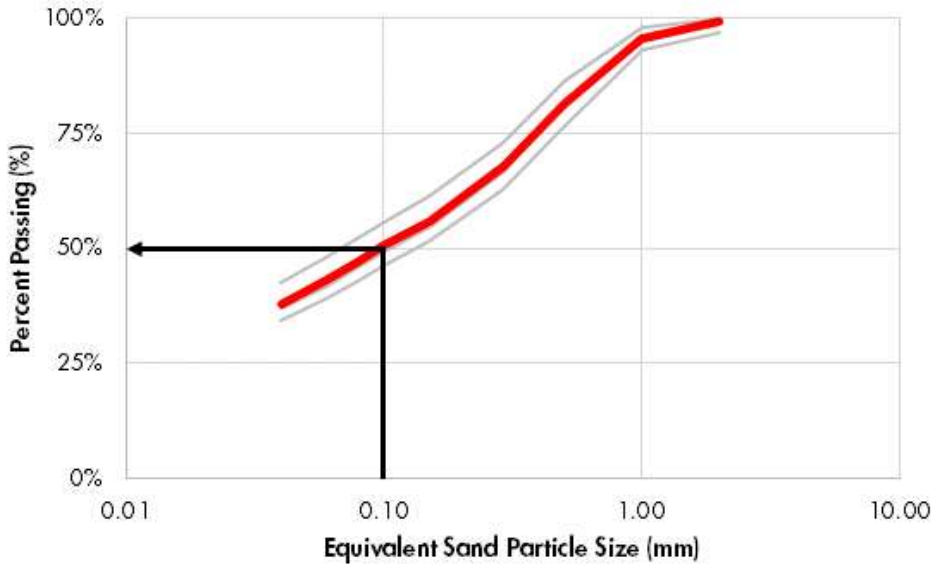


Figure 12: Equivalent sand sediment particle size distributions

3.4 Surface cover levels

The modified effective hydraulic conductivity values and C factors used to account for increased vegetation surface cover are listed in Table 7.

Table 7: Modified effective hydraulic conductivity and C-factors used to account for different surface cover levels.

Surface Cover (%)	Effective Hydraulic Conductivity, K_e (mm/hr)	C-Factor
0	2	1.000
40	20	0.059
60	31	0.030
80	42	0.015

4 WEPP MODELLING RESULTS

4.1 Pattern of erosion

In order to describe the pattern of erosion along a typical batter slope length, WEPP was used to predict erosion for a 60m high linear lift with a gradient of 18 degrees and no surface cover (Figure 13). Erosion is initiated at very short slope lengths (~5m). From there, erosion rates are predicted to increase relatively linearly for the remainder of the slope. This pattern is consistent with a material for which both interrill and rill erosion are occurring, and for which rilling is initiated at relatively short slope lengths. The erosion of these materials tends to be sensitive to both slope gradient and slope profile shape.

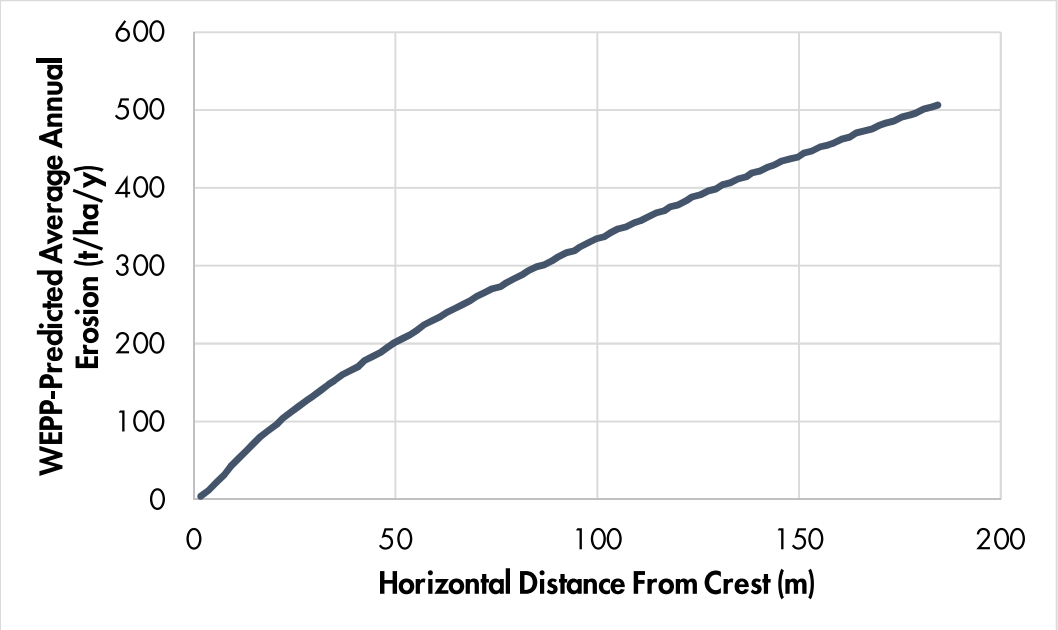


Figure 13: WEPP predicted average annual erosion for the Type 4 SMU material for an unvegetated batter, 18 degrees, 60m high.

4.2 Long-term erosion rates

The WEPP model results for the scenarios presented in Table 4 are given in Table 8 for Pit 2 and Table 9 for Pit 20. Erosion predictions for a bare (unvegetated) batter is also provided. Cells shaded green indicate combinations of dump height and gradient that achieve acceptably low erosion potential. Cells shaded orange have combinations of dump height, gradient and cover that do not achieve acceptably low erosion potential. The values shown are WEPP-predicted mean and peak average annual erosion rates.

Table 8: WEPP-predicted erosion rates for a simulations of the Pit 2 highwall

Sim. Number	Surface Cover (%)	Batter Height (m)	Batter Gradient (°)	Batter Gradient (%)	Slope Length (m)	WEPP-Predicted Average Annual Erosion (t/ha/y)	
						Mean	Peak
-	0 (bare)	70	18	33	210	335	563
10	40	70	18	33	210	4.2	7.2
11	60	70	18	33	210	1.3	2.1
12	80	70	18	33	210	0.5	0.9
-	0 (bare)	70	14	25	280	328	552
13	60	70	14	25	280	1.2	2.0
14	80	70	14	25	280	0.5	0.8
-	0 (bare)	70	11	20	360	314	526
15	60	70	11	20	360	1.0	1.7
16	80	70	11	20	360	0.4	0.7
-	0 (bare)	70	18, 11	33, 20	280	299	463
17*	40	70	18, 11	33, 20	280	3.5	5.5
18*	60	70	18, 11	33, 20	280	0.4	0.7

* The gradient is changed at 35m vertical interval.

Table 9: WEPP-predicted erosion rates for a simulations of the Pit 20 highwall

Sim. Number	Surface Cover (%)	Batter Height (m)	Batter Gradient (°)	Batter Gradient (%)	Slope Length (m)	WEPP-Predicted Average Annual Erosion (t/ha/y)	
						Mean	Peak
-	0 (bare)	60	18	33	180	300	507
10	40	60	18	33	180	3.9	6.6
11	60	60	18	33	180	1.2	2.0
12	80	60	18	33	180	0.5	0.8
-	0 (bare)	60	14	25	240	296	499
13	60	60	14	25	240	1.1	1.8
14	80	60	14	25	240	0.4	0.8
-	0 (bare)	60	11	20	300	285	480
15	60	60	11	20	300	0.9	1.6
16	80	60	11	20	300	0.4	0.7
-	0 (bare)	60	18, 11	33, 20	240	299	463
17*	40	60	18, 11	33, 20	240	3.5	5.5
18*	60	60	18, 11	33, 20	240	1.1	1.6

* The gradient is changed at 30m vertical interval.

For the unvegetated simulations, erosion rates are very high and will cause excessive rill and gully erosion. For all vegetated simulations, erosion rates are predicted to reduce to acceptable rates. Therefore, for the heights of the Pit 2 and Pit 20 highwalls (70m and 60m respectively), creation of a vegetated surface with at least 40% surface cover is predicted to result in an erosionally stable landform.

5 DISCUSSION

5.1 Suitable batter configurations

Establishment of a vegetated surface is critical for successful rehabilitation. The following batter configurations were simulated:

Pit 2

- 70m high linear lift, 18 degree batter angle and 210m slope length
- 70m high linear lift, 14 degree batter angle and 280m slope length
- 70m high linear lift, 11 degree batter angle and 360m slope length
- 70m high concave lift, 18/11 degree batter angle and 280m slope length

Pit 20

- 60m high linear lift, 18 degree batter angle and 180m slope length
- 60m high linear lift, 14 degree batter angle and 240m slope length
- 60m high linear lift, 11 degree batter angle and 300m slope length
- 60m high concave lift, 18/11 degree batter angle and 240m slope length

Erosion rates of all batter simulations for the unvegetated condition are predicted to be very high. Given the estimated erosion rates for the above simulations, the resultant batter would likely be heavily rilled and gullied under the bare scenario.

Establishment of at least 40% surface cover is predicted to result in rehabilitated highwalls for both Pit 2 and Pit 20 that erode at acceptable rates in the long-term. It is estimated that a batter angle as high as 18 degrees with long slopes (210m for Pit 2 and 180m for Pit 20) would erode at acceptable rates if early establishment of 40% or greater surface cover is achieved using early colonising stoloniferous grass species.

However, Anglo American consider that batter angles may need to be restricted to 14 degrees as conventional rehabilitation techniques may not be achievable on 18 degree batter slopes.

5.2 Vegetation

Establishment of high levels of surface cover (a minimum of 40%) is critical for erosional stability, which means that vegetation should be largely grass-dominant (in contact with the soil surface), with only a low density of shrubs/small trees. Grass vegetation should be dominated by stoloniferous species that typically produce higher levels of cover in direct contact with the soil surface. (Species producing high densities of small tussocks

also tend to be more effective in controlling erosion than grasses such as Buffel that forms relatively widely spaced tussocks[2]. Potential grass species include:

- Keppel couch (*Bothriochloa pertusa*) (stoloniferous, salt tolerant)
- Sabi grass (*Urochloa mosambicensis*) (stoloniferous, salt tolerant)
- Rhodes grass (*Chloris gayana*) cv. Tolgar (highly stoloniferous, salt tolerant)
- Forest bluegrass (*Bothriochloa bladhii* ssp. *glabra*) (small tussocks)
- Red natal grass (*Melinis repens*) (small tussocks at high densities)

Salt-tolerant shrubs that could be considered include:

- Ruby Saltbush (*Enchylaena tomentosa*),
- Old Man Saltbush (*Atriplex nummularia*), and
- Soapbush (*Acacia holosericea*).

The material properties of the Type 4 SMU pose significant limitations on the achievement of high levels of surface cover if the material is not amended. These limitations and their amendments are discussed below.

5.2.1 Impacts of dispersion

The potential for the materials to disperse will likely limit water entry and reduce the volume of water available to plants as they establish and grow. Clay dispersion could also make plant germination more difficult as the surface seals and sets hard. Clay dispersion could be mitigated through application of gypsum. Based on the properties of the bulk sample supplied, gypsum application rates of 10t/ha are recommended. This assumes a 70% effectiveness of gypsum, a residual ESP of 4%, and a bulk density of 1.4g/cm^3. Gypsum should be thoroughly incorporated into the surface 0.2m of material through ripping practices. A further 1t/ha should then be applied to the surface once the 10t/ha amount has been ripped into the profile. This can occur in conjunction with application of fertiliser, but prior to seeding.

Organic matter can also be added to the soil to improve and consolidate soil structure. This in turn makes it easier for sodium to leach out, as organic matter binds soil aggregates together and helps resist physical breakdown of the soil. However, organic matter is best applied in conjunction with gypsum, and should not be considered an alternative source of Calcium.

5.2.2 Impacts of salinity

The Type 4 SMU material had elevated salinity, which would be increased further through application of gypsum. Therefore preference should be given to vegetation that is salt tolerant. Potential salt tolerant grass and shrub species were noted in section 5.2 (above).

[2] Buffel grass is widely recognised as being susceptible to rill erosion by overland flows moving between the tussocks.

5.3 Tunnel erosion risk

The high ESP value indicates that the Type 4 SMU material is at risk of tunnel erosion. For tunnel erosion to manifest in these materials, the following conditions are required:

- Free water or a positive pore water pressure at the depth of tunnel initiation; and
- An exit point for the tunnel.

Common locations where these conditions are meet are in very large rip lines, on mid-slope berms, and directly behind top crest bunds. In all these landform positions water is able to pond (satisfying the requirement for free water or positive pore water pressures) and an exit point for the tunnel is nearby. Given that berms do not form part of the proposed designs, the possible drivers of tunnel erosion that require management are the rip lines and crest bunding.

5.3.1 Crest bunding

The risk of tunnel erosion can be mitigated by the use of appropriately sized and shaped crest bunds (Figure 14). Crest bunds should be:

- High enough to contain extreme rainfall events while allowing some freeboard (i.e. 1:100 rainfall event);
- Thoroughly compacted and constructed of stable (non-dispersive) material;
- Have their outer face continuous with the reshaped highwall profile and have the same surface treatments applied to it;
- Have a width across the top of the bund of at least 2m; and
- Have their inner face sloping gradually inwards at a gradient of 1V:10H.

The gentle inward gradient ensures that any water that ponds will be ponded well away from the outer batter slope, thereby minimising the potential for any tunnel that may form to reach the outer batter slope and create an "instant gully".

This crest bund will also be critical for eliminating the risk of uncontrolled discharge of runoff from upslope areas onto the rehabilitated batters.

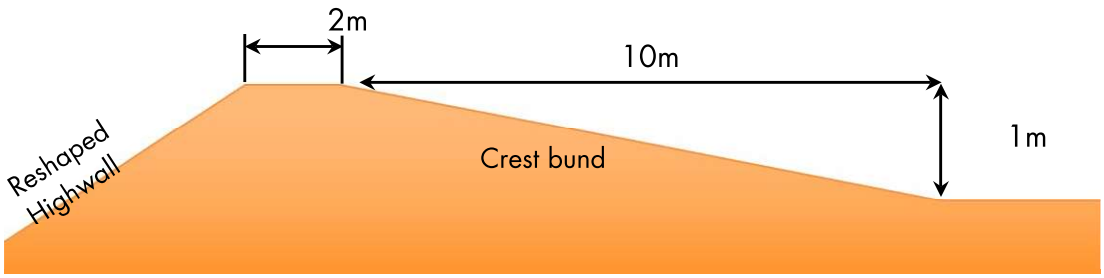


Figure 14: Typical crest bund configuration

5.3.2 Ripping

To achieve long-term stability of batter slopes on this landform, it is critical that flow ponding and lateral concentration be minimised. These can be managed by minimising the size of cross-slope rip lines. Rip lines should be no deeper than 300mm from peak to trough of the rip line once settlement has occurred. To achieve this, it is likely that an unconsolidated rip line ~500mm in depth will be required.

Ripping will be desirable to incorporate gypsum to mitigate the dispersion risk, and to potentially add fertiliser to encourage vegetation growth. Given the critical importance of minimising ponding and flow concentration, it will be essential that construction does not create rip lines that are off-contour.

Ripping should use a triple tyne ripper mounted on a dozer. The tynes should be set no more than 1.0m apart. Given that inversion of the materials is not required, use of a winged tyne is not recommended. Alternatively, a scarifier towed behind a grader could also be considered. Again, the tynes should be set no further than 1.0m apart. The resultant ripping should produce a ripped surface similar to that shown in Figure 15.

Equipment used for rehabilitation works should have precision guidance systems installed. Operators should be highly skilled and experienced. It is noted that rehabilitation earthworks are significantly different to earthworks typically conducted by mining staff, and requires great precision and adherence to the specified designs if successful rehabilitation is to be achieved.



Figure 15: Examples of a ripped batter surface.

5.4 Final land use

The target end land use for Pit 2 and Pit 20 highwalls is the creation of native bushland that remains safe, stable, self-sustaining and non-polluting. The objective is to create a native ecosystem within 3-5 years at completion of rehabilitation. Indicators for success and completion criteria include:

- Native plant species richness (total no. in RE): 15
- Non-eucalypt trees (stems per ha): 200
- Tree canopy cover: 30%
- Native shrub cover: 20%
- Organic litter cover: 60%

In terms of achieving sufficient vegetation cover to stabilise the final landforms, the proposed land use can potentially meet the required cover level. Although not a completion criterion, Landloch recommends that grass species are included in any seed mix to assist in stabilising the slopes, as shrub and tree canopy cover alone may not be sufficient.

Lastly, we note that native bushland will be preferable to returning the land to pasture, as regular grazing of the land may reduce vegetation cover and leave the highwalls susceptible to erosion. Given that vegetation surface cover is the key defence against excessive erosion, it is vital that the cover level is maintained where possible.

6 CONCLUSIONS

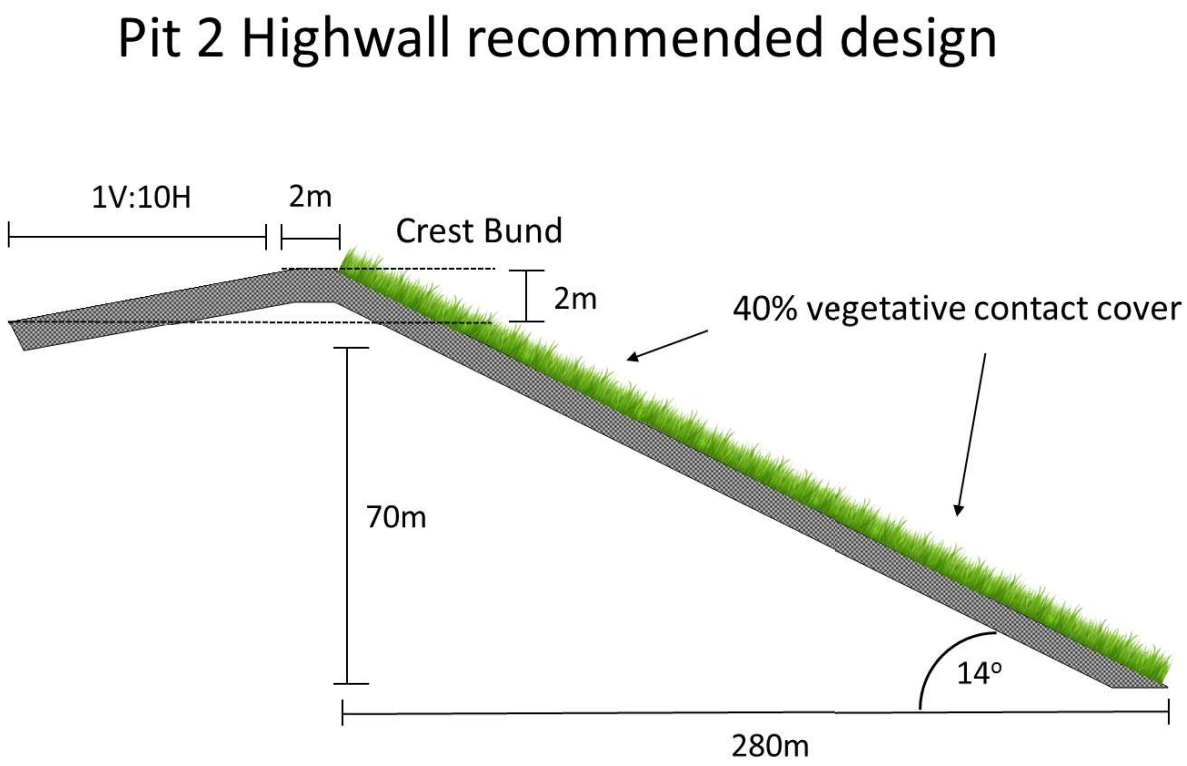
Based on the modelling results and the range of slope configurations considered (gradients, slope lengths, and profile shapes), it is predicted that both Pit 2 and Pit 20 under unvegetated rehabilitation scenarios will erode at rates likely to provide erosionally unstable batters prone to rill and gully erosion.

However, the establishment of vegetation that provides 40% contact cover will allow flexibility in final landform design, with all landforms predicted to remain erosionally stable. The following can be concluded:

- The establishment of high levels of surface cover is critical for erosional stability. In particular, vegetation should be dominated by stoloniferous grass species that are in direct contact with the soil surface.
- The material properties of the Type 4 SMU pose significant limitations on the achievement of high levels of surface cover.
- Given the dispersive nature of the material, gypsum should be applied and ripped into the material.
- Preference should be given to salt tolerant species that can germinate in the saline conditions.
- Crest bunds should be installed on the top of the highwalls to mitigate the risk of tunnel erosion.
- Flow ponding and lateral concentration should be minimised through cross-slope rip lines on the contour at a depth of 300mm with a triple tyne ripper.
- Profile gradients should be restricted to 14 degrees as Anglo American consider that conventional rehabilitation techniques are not achievable on steeper gradient slopes.

Based on this, the recommended landform for Pit 2 is a 70m high linear lift, 14 degree batter angle and 280m slope length, and for Pit 20 a 60m high linear lift, 14 degree batter angle and 240m slope length (Figure 16). A lower gradient profile (11 degree linear) would also be stable but would use more footprint and likely require more earthworks to achieve.

Recommendations for further work include additional SIBERIA modelling of the recommended designs with 40% vegetation cover incorporated into the model parameterisation. This will assist in identifying any areas of flow concentration leading to rill and gully initiation.



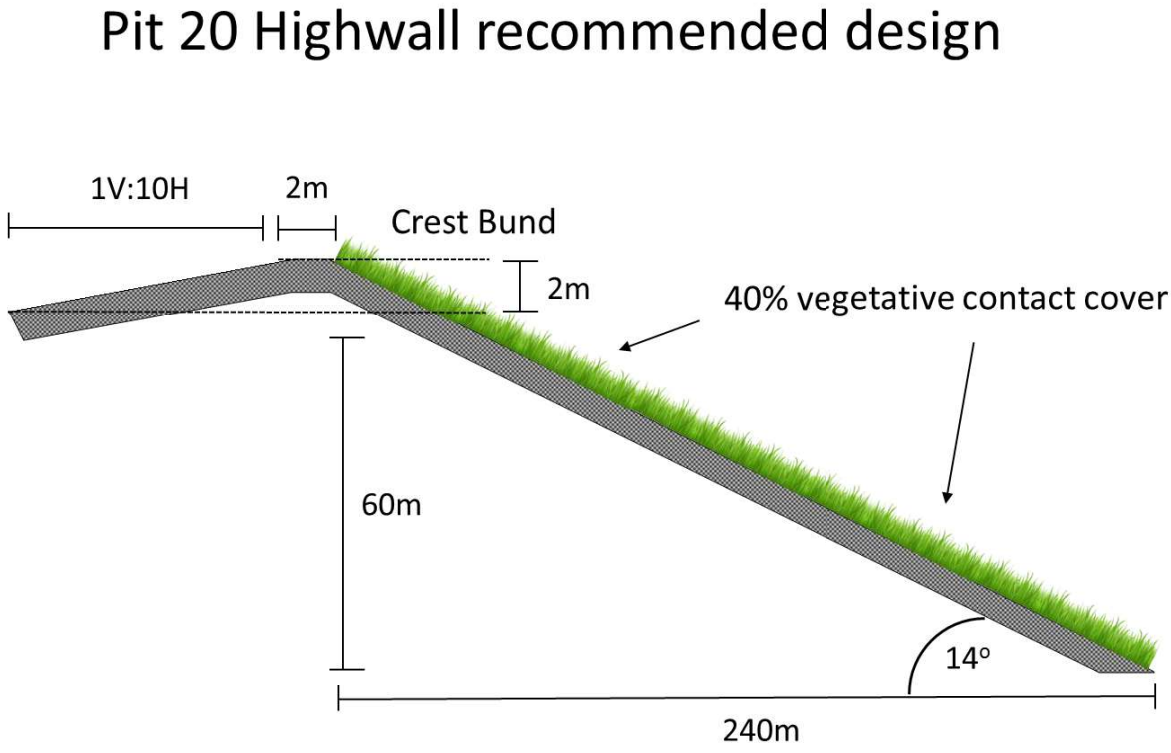


Figure 16: Recommended design for Pit 2 (top image) and Pit 2 (bottom image) highwalls

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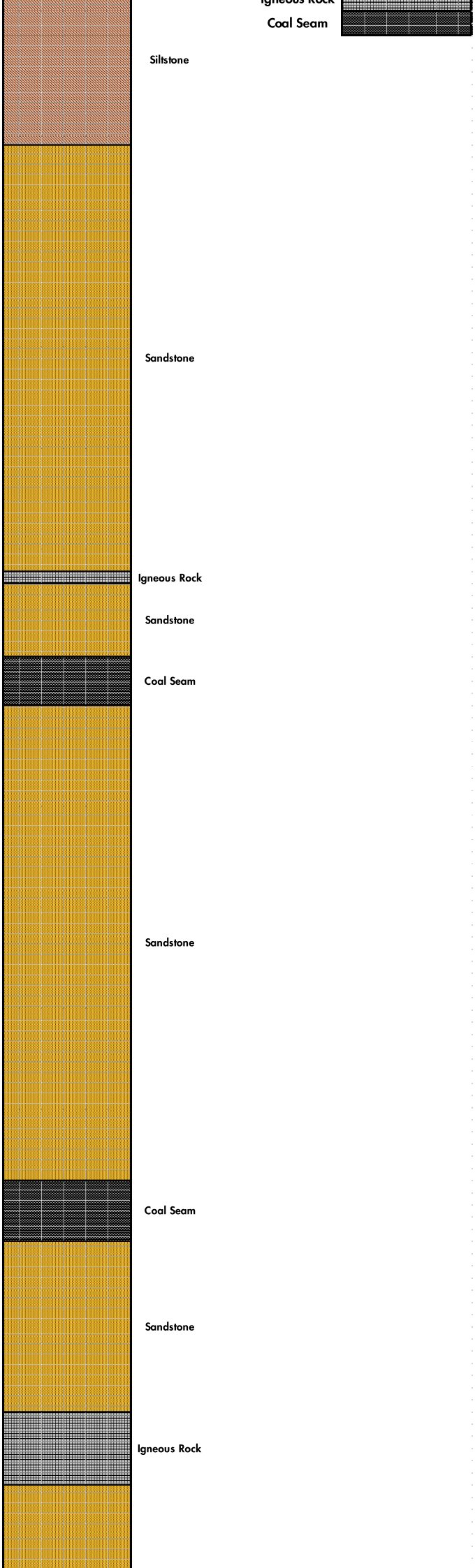
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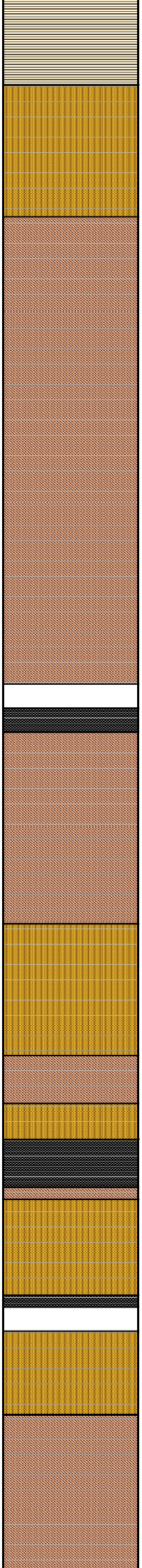
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APPENDIX B: LABORATORY IMAGES

Sample As Supplied


Prior to simulation	Post simulation
	
Flumes, 10%	Flumes, 10%

Prior to simulation	Post simulation
	No Photo
Flumes, 20%	Flumes, 20%
	
Flumes, 30%	Flumes, 30%

	
Rainfall Simulation – Pre-rain, Plot 1	Rainfall Simulation – Post-rain, Plot 1
	
Rainfall Simulation – Pre-rain, Plot 2	Rainfall Simulation – Post-rain, Plot 2
	
Rainfall Simulation – Pre-rain, Plot 3	Rainfall Simulation – Post-rain, Plot 3

Appendix 4.15 Dawson Pit 21 – Hybrid Design Report

TECHNICAL MEMORANDUM

DATE 1 October 2020 **Reference No.** 19129349-006-M-Rev0

TO Jason Fittler, Anglo American

CC

FROM Chris Waygood and Sven Dressler **EMAIL** CWaygood@golder.com.au;

DAWSON PIT 21 – HYBRID DESIGN REPORT

1.0 INTRODUCTION

At the request of Anglo American, a collaborative study was undertaken by Golder Associates Pty Ltd (Golder) and 3D Data Guidance (3D Data) to design a hybrid landform design for the rehabilitation of Dawson Pit 21. Previously the two companies had provided separate designs, being a geomorphic design by Golder and a linear design by 3D Data.

The rationale behind adopting a hybrid landform was that:

- The geomorphic design for the entire area was considered to be environmentally and visually desirable. It also presented certain advantages in terms of sustainability, particularly in areas of flow concentration such as internal corners, or where slopes are too long for construction without the use of contour banks.

  However, retrofitting the geomorphic design to spoil dumps already tipped to suit a linear design was found to be more costly than applying the linear design due to the need to move material sideways to form ridges and drainage lines.

- The linear design (with slopes at 1V:4H) was more cost effective, particularly where the slopes are short enough to not need contour banks.

  The linear design was considered less desirable in areas where flow concentration could occur, either through the geometrical layout of the landform, or due the slopes being longer in length.

Consequently, applying both design approaches to different parts of Pit 21 was considered to provide a robust outcome limiting the erosion risk while maximising the environmental benefits. The intention of the hybrid design was to ensure costs remained as low as possible.

This report sets out the design assumptions used in developing the hybrid landform.

1.1 Design Assumptions

Assumptions relevant to the designs detailed here include:

- No further material will be imported into Pit 21
- The potential benefits of cast blasting the highwall will not be considered
- No further mining will be carried out in this area,
- A crest berm will be constructed along the final highwall cut to prevent overspill from the west

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- Slopes will average 1H:4H, but not exceed 1V:3H, this being the maximum slope considered desirable to allow contour ripping of the slope with a dozer prior to seeding
- All earthmoving operations will be undertaken using dozing operations only
- The final rehabilitated surface will be largely water shedding, but runoff from some areas will drain to the final void and not to the downstream catchment, particularly areas that are lower lying.

2.0 DESIGN ITERATIONS

The design of the final landform at Pit 21 was undertaken in three stages:

- Firstly, 3D Data carried out a linear design using the existing tipped surface reshaped to 1V:4H slopes with a balanced cut to fill (Figure 1). They have used their software to optimise the material movement.

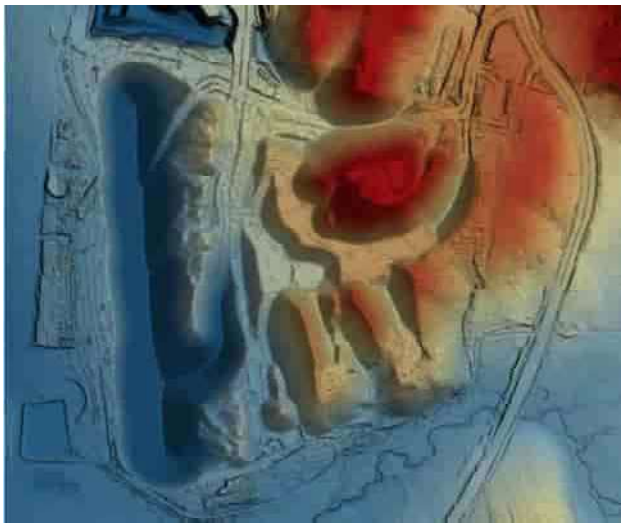


Figure 1: Linear Design

- Secondly, Golder developed a geomorphic design incorporating drainage density to limit the length of overland flow (Figure 2). This approach is typical of natural systems where flow occurs across the slope to dendritic drainage lines. These areas are then provided with rock armouring where the combination of catchment and slope results in tractive stresses greater than those the vegetated landform can accommodate.



Figure 2: Geomorphic Design

- Thirdly, the hybrid landform was developed incorporating the best of both designs (Figure 3).

  The hybrid design has:

  - Linear slopes in any areas where the erosional risk was considered low, including the highwall am much of the dumped material. The erosional risk is discussed in Section 2.3.
  - Geomorphic designs were retained for areas on the low wall and adjacent areas demonstrating a risk of concentrated flow erosion.

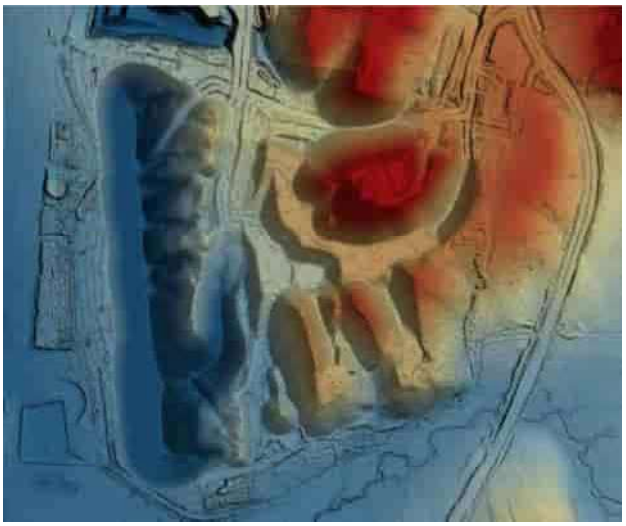


Figure 3: Hybrid Design

2.1 Construction Volumes and Costs

The construction volumes and costs for each of the options were determined by 3D data and are presented in Table 1. The volumes moved per distance interval are shown in Figure 4.

Table 1: Construction Volumes and Costs (from 3D-Data investigation)

Design DTM Start Topo: March 2020 LIDAR (High wall swell 1.2 assumed)	Total Cut (LCM)	Total Cost (estimate)	Variation (%)
Linear 1V:4H: Optimised Des01	1,997,000	$ 840,000	-
Golder Geomorphic Landform	2,239,000	$ 1,110,000	32%
Golder Hybrid Landform	2,053,000	$ 895,000	6.5%

It is important to note that geomorphic design for Pit 21 is effectively retrofitting with spoils currently placed assuming a linear final surface. It was found that the geomorphic landform increased the dozing volumes by around 10%, but the cost was higher at 32% due to dozing across the slope to form the ridge lines and drainage lines, rather than straight down the slope.

The hybrid option results in a 6% increase in costs.

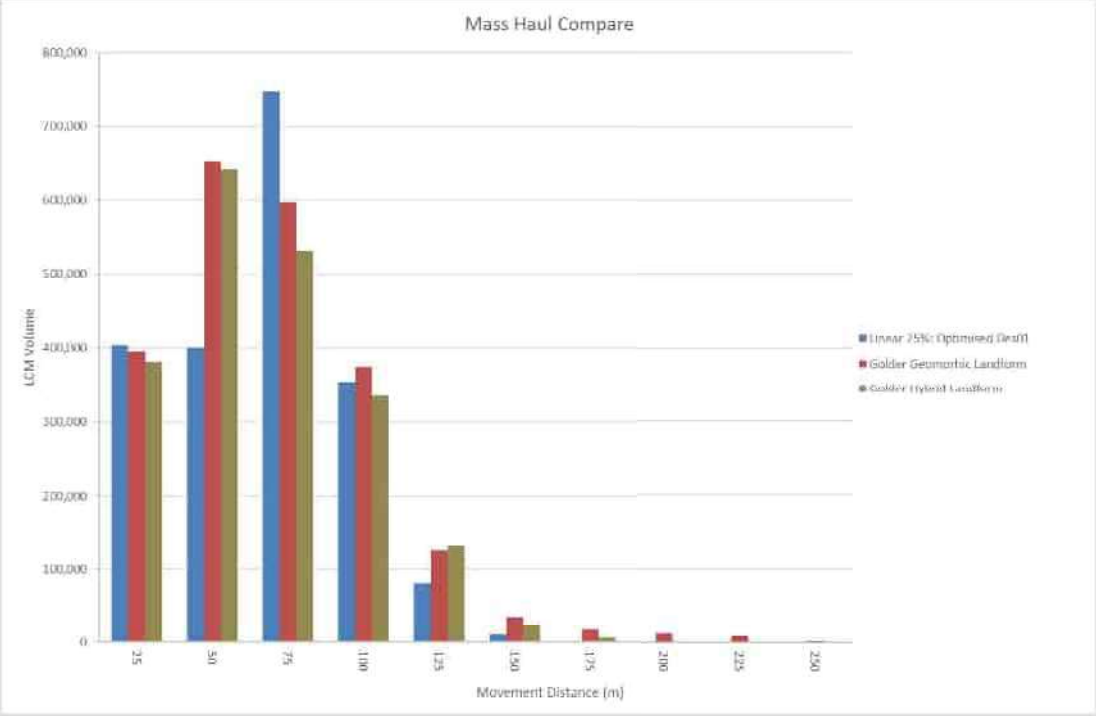


Figure 4: Dozing Distances as from 3D Data Analysis

2.2 Slope

The average design slopes for the area were taken to be 1V:4H or 25%. This grade has been applied elsewhere with observed stability of similar height of slopes at Pit 17b and 18b[1]. It should however be noted that the age and height of these slopes may be different and they may prove to be unstable in future.

For the geomorphic design, the overall average slope (from toe to crest) is maintained at 1V:4H but with both steeper and flatter areas to obtain the cross fall. The slopes for the three design options are shown in Figure 5.

[1] Landform Evolution Modelling: Dawson Pit Highwalls, Landloch, February 2018.

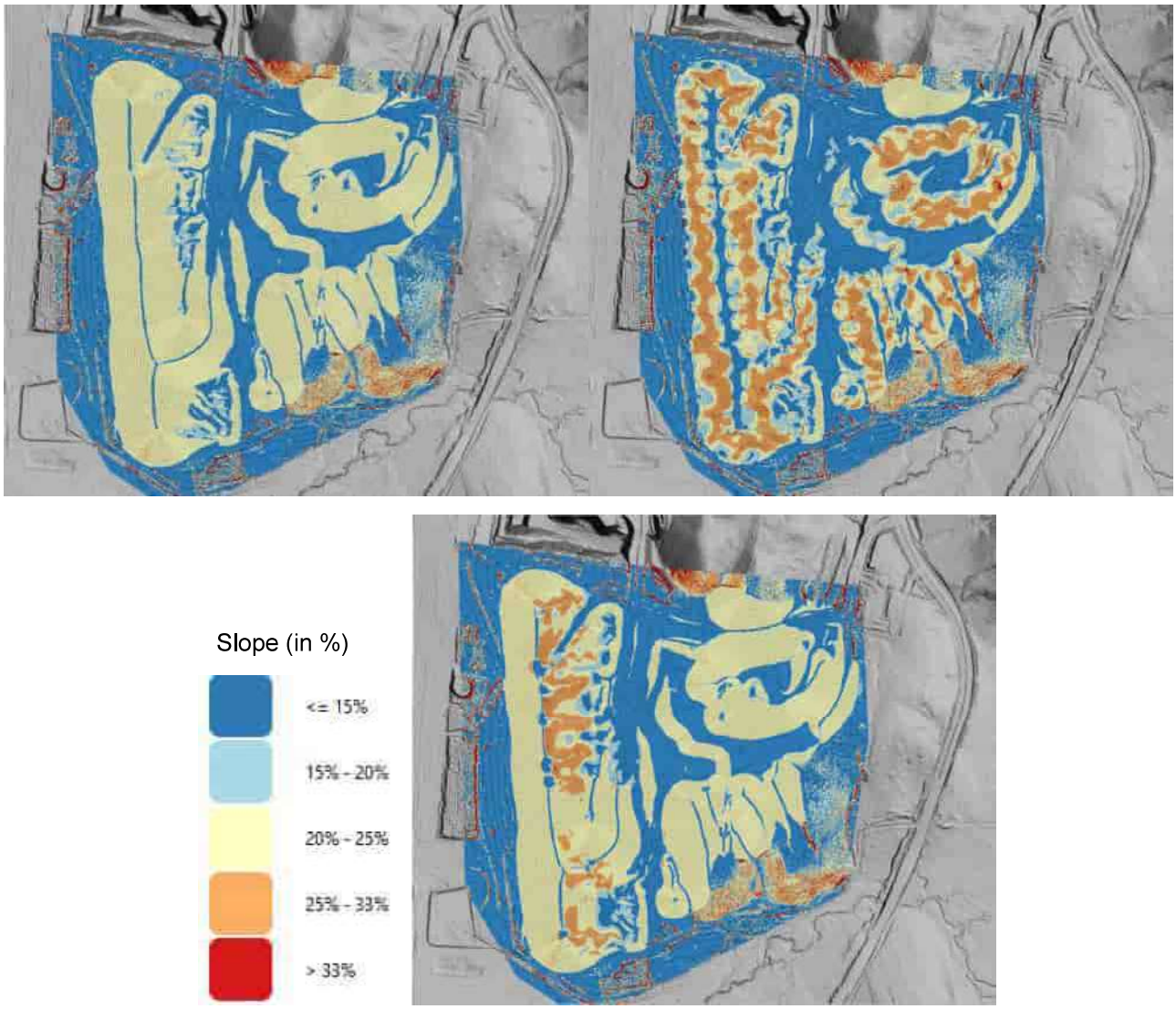


Figure 5: Dawson Pit 21 Design Slopes, (Clockwise from top left: 25% linear design, Geomorphic design, Hybrid design)

2.3 Erosion

An erosion assessment for the highwalls at Dawson was undertaken by Landloch[2]. As part of the study the erosivity of the capping material was determined. The report contains a derivation of a function describing erosion of the capping material:

$$q_s = \beta * A^{m_1} * S^{n_1}$$

Where q_s is the erosion rate, A is the catchment area, S is the slope and β, m_1 and n_1 are constants (derived to be 0.268, 1.37 and 1.5 respectively). Using these derived parameters, the relative erosion of the designed surfaces was determined and is presented in Figure 6. It should be noted that the equation derived by Landloch forms part of a more complex landform evolution model (LEM), which accounts for detachment and sedimentation over time. The presented figures therefore only represent the relative performance between the surfaces and a LEM would be required to determine their absolute performance.

[2] Landform Evolution Modelling: Dawson Pit Highwalls, Landloch, February 2018.

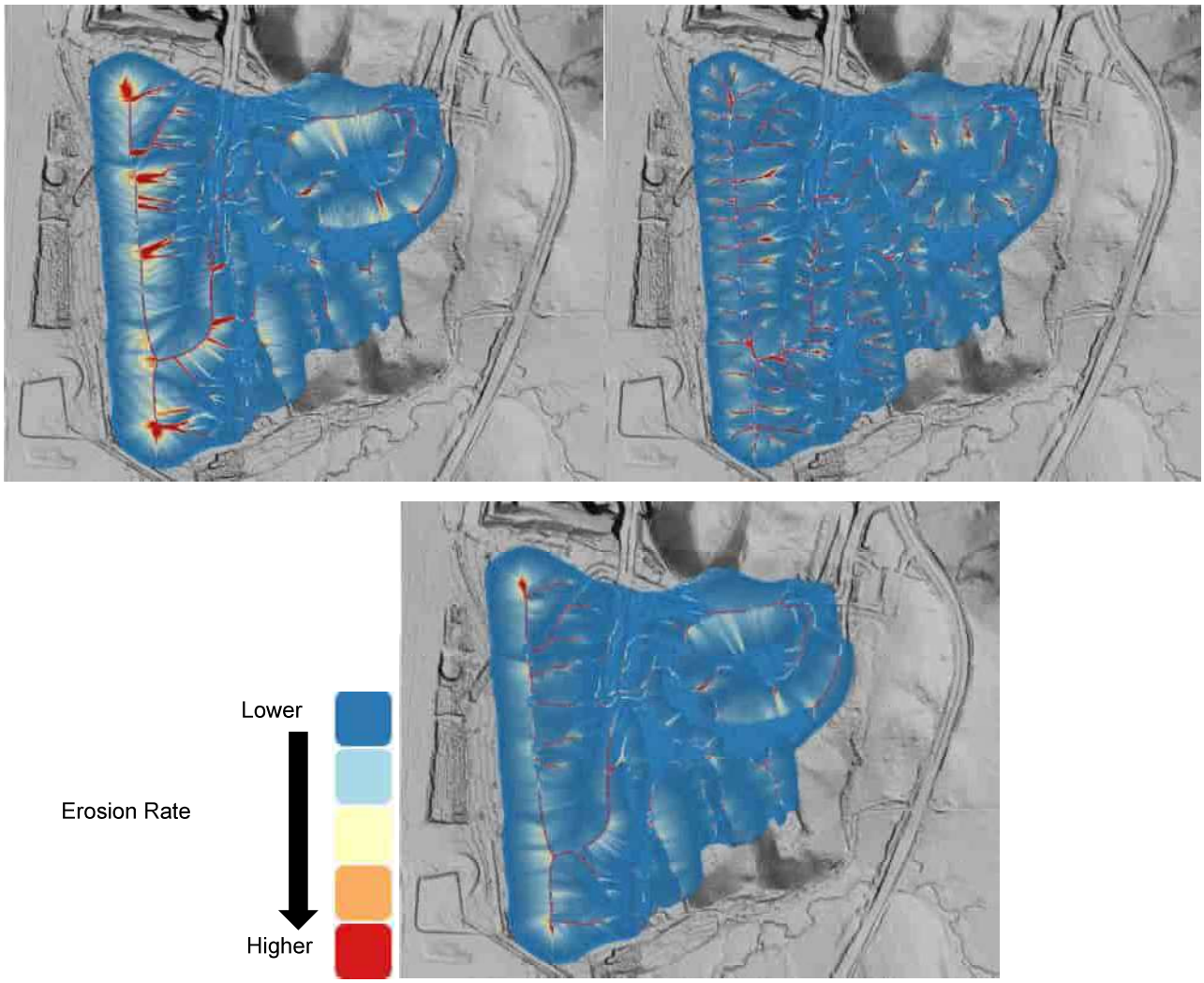


Figure 6: Dawson Pit 21 Modelled Erosion (Clockwise from top left: linear design, Geomorphic design, Hybrid design)

It is evident by comparing the extent of higher erosion risk areas in Figure 6 that the hybrid option provides a more stable solution than the linear solution for areas on the low wall experiencing concentrated flow.

It should be noted that adequate vegetation establishment will be critical for the stability of this site. It is also apparent from the areas of higher erosion risk that rock armouring is necessary for all the designs to limit the erosion risk in areas of concentrated flow. In our experience, it is also possible to generate a design where the drainage lines are not as well defined as the hybrid developed, that is, a surface characterised by wider valleys. While modelling of a surface with wider and flatter drains can theoretically indicate a lower erosion risk, in practice, when flow does start to concentrate through the variations that can be expected in construction, the extent of rock lining then becomes significant. Our preference is for a more clearly defined drainage line.

Using an indicative storm event and the methods provided in the Catchments and Creeks Background to Rock Sizing Equations (2011), the rock sizes and extents were determined. It was found that a D_{50} (or median) rock size of 200 mm would be sufficient for the drainage lines in Pit 21. The extent of the rock protection is shown in Figure 7.



Figure 7: Dawson Pit 21 Hybrid Design Location and Extent of Required Rock Lining

3.0 CONCLUSION

Three different possible designs were investigated for the closure of Dawson Mine Pit 21.

The preferred option is a hybrid design incorporating both geomorphic and linear designs. This combination or hybrid design combined the strengths of both design approaches.

While this hybrid design is estimated to be 6% more expensive than the linear design, an erosion risk assessment has indicated that there are likely to be more areas requiring rock armouring for the linear design than the hybrid design.

It should be noted that the Landloch study has indicated the capping material to be highly erodible prior to vegetation, and rock armouring (expected to be rock of around 200 mm) is likely to be required in the drainage lines.

GOLDER ASSOCIATES PTY LTD

Chris Waygood
Principal Mine Closure Specialist

André Kemp
Principal Engineer and Closure Consultant

CW/AK/hn

https://golderassociates.sharepoint.com/sites/115785/project files/6 deliverables/006 pit 21 hybrid design 2020/19129349-006-m-rev0.docx

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