Hope Downs 2 Mine Closure Plan

October 2023

IMS #	RTIO-1025466
Environmental Group Name	Hope Downs 1
Environmental Group Code	S0019112
Mineral Field Numbers	47 – West Pilbara
Proponent	Hamersley HMS PTY LTD ABN 51 115 004 129 Level 18, Central Park, 152-158 St Georges Terrace, Perth WA 6000 T: +61 (08) 9327 2000

Tenement	Tenement Holder	Environmental Group Site
ML282SA Sections 001 and 002 (or part thereof);	Hope Downs JV	Hope Downs 1

Disclaimer and Limitation

This Mine Closure Plan (MCP) has been prepared by Rio Tinto's Iron Ore group (Rio Tinto) on behalf of Hamersley HMS Pty Ltd (the Proponent) to support a Part IV (*Environmental Protection Act 1986*) application for the Hope Downs 2 Proposal (the Proposal).

Closure Plan Submission History		
Date	**Purpose**	**Status**
July 2022	Support the submission of the Environment Review Document for the Proposal.	Draft
April 2023	Support the submission of the Environment Review Document for the Proposal.	Draft
August 2023	Support the submission of the Environment Review Document for the Proposal.	Final Draft
October 2023	Final version for Public Review	Final

Acknowledgement of Country

Rio Tinto would like to acknowledge the Nyiyaparli, Banjima and Ngarlawangga people as the Traditional Custodians of the country upon which the Proposal is located.

We would like to pay our respects to their Elders, past and present.

Rio Tinto is committed to working in collaboration with the Nyiyaparli, Banjima and Ngarlawangga people and their representatives towards a responsibly designed proposal that minimises impacts to the environment, social, cultural and heritage values.

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EXECUTIVE SUMMARY

The Hope Downs 2 (HD2) Proposal (the Proposal) is in the Pilbara region of Western Australia, approximately 80 km north-west of the township of Newman in the Shire of East Pilbara and is located predominantly on the traditional lands of the Nyiyaparli people, with smaller portions located on land held by the Banjima and Ngarlawangga people. The Proposal is made on behalf of the Hope Downs Joint Venture (HDJV), which is an unincorporated joint venture (50:50) between Hope Downs Iron Ore Pty Ltd (a member of Hancock Prospecting Group) and Hamersley WA Pty Ltd (a member of the Rio Tinto Group). The HDJV is managed by Hamersley HMS Pty Ltd (HHMS), a Rio Tinto Group company.

The Proposal is being assessed under Part IV of the *Environmental Protection Act 1986* (EP Act) and Part 6 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Subject to approval, the Proposal will comprise open cut mining utilising conventional drill-and-blast and ore haulage. Iron ore mined from the deposits will be transported by truck or conveyor to the adjacent Hope Downs 1 (HD1) operations and then transported by train to Rio Tinto's coastal export facilities. The Proposal comprises Above Water Table (AWT) mining of the HD2 and Bedded Hilltop (BHT) deposits with an operational life of 15 years and completion of mining currently scheduled for 2040. The current mine plan includes a production rate of 26.0 Mt/ annum in 2027 and then 31.4 Mt/ annum from 2028 onwards.

The closure boundary for the HD2 proposal includes infrastructure from HD1, including HD1S ROM and associated infrastructure. The closure boundary shows overlap of Baby Hope waste dumps at HD1 due to the HD2 Proposal use of the BH haul roads to transport ore to HD1 infrastructure as mentioned above. Once HD2 is approved, this HD1 infrastructure will be reassigned as HD2 infrastructure. The MCP text will be reviewed and amended to clarify this.

Mineral waste generated by the Proposal will be placed in permanent external waste rock landforms and used for the construction of temporary and permanent landbridges. The site is expected to encounter some highly erodible material which will be placed in external waste rock landforms with appropriate final parameters. The site has been assessed as having a low geochemical risk, with no Potentially Acid Forming (PAF) or fibrous mineral wastes expected to be encountered in the pits. No pit lakes are expected to form post-closure due to mining activities being AWT only.

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Scope

This HD2 Mine Closure Plan (MCP) is applicable to mine developments and all associated infrastructure at HD2 and BHT deposits and is required to be submitted with the environmental review document (ERD) to support the environmental impact assessment of the Proposal. The MCP is anticipated to be reviewed and updated every three years (unless otherwise agreed) following issue of a Ministerial Statement.

This MCP excludes:

- unapproved future mine developments, mainline railway infrastructure and rail corridor disturbance areas beyond those within the defined MCP scope;
- infrastructure beyond the closure boundary that is covered under the HD1 2020 MCP; and
- infrastructure beyond the closure boundary that is connected to an integrated network (e.g., power, communications).

Closure outcomes

The following closure outcomes are proposed for the Proposal:

1. Cultural heritage values have been preserved where possible, in consultation with stakeholders.
2. Public health and safety hazards have been appropriately managed.
3. Infrastructure has been appropriately managed.
4. The final landform is stable, and its design considers hydrological and ecological factors.

5. Contamination risks have been appropriately managed and do not preclude the agreed post-mining land use(s).
6. Vegetation on rehabilitated land is self-sustaining native species and compatible with the post-mining land use.
7. Conservation significant flora and fauna habitat is not significantly impacted by closure activities.

Risk assessment

The first full closure risk assessment for the Proposal was conducted in 2020 and has been updated in support of drafting this MCP. The current Proposal closure risk profile includes twelve active risks. Of these, one is a Class IV (critical) risk, nine are Class III (high) risks, and two are Class II risks.

The causes, impacts, existing controls, evaluation rationale and actions of all risks associated with closure of the Proposal are appended to this MCP as the Closure Risk Register and the Closure Action Register.

Post-mining land use

The HD2 closure boundary is on land the subject of three different Native Title Determinations:

- The Nyiyaparli section covers the majority of the proposed closure boundary, including the entirety of HD2 and BHT deposits and associated mineral waste management infrastructure. Nyiyaparli lands generally extend to the south and east from the proposed closure boundary.
- Banjima land lies to the north and intersects proposed infrastructure areas north of Pebble Mouse Creek, adjacent to the existing rail loop and access corridor connecting the Proposal with HD1 operations.
- A narrow part of the southwestern end of the proposed closure boundary, including the Great Northern Highway (GNH) alignment and realignment option, coincides with Ngarlawangga land, which extends west and south from the proposed closure boundary.

These determinations recognise each Traditional Owner groups' non-exclusive right to continue to access, use and enjoy their country.

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Other significant land use within the closure boundary includes public and private infrastructure (including roads and railways) and Unallocated Crown Land (UCL). Within the broader Proposal region, mining related activities are the primary commercial land use, as well as pastoral activities.

As above, Nyiyaparli, Banjima and Ngarlawangga Traditional Owners have ongoing native title rights to access, use and enjoy the land within their respective Native Title Determinations. Consultation has been undertaken, and is ongoing, with all groups to understand the key social, cultural and environmental values associated with the Proposal, to inform project design and options to avoid, minimise and manage impacts to these values.

Post-mining land use options in the Pilbara are generally limited due to the remote location. Subject to the Native Title Determinations noted above and ongoing use of the land by Traditional Owners, the main underlying land use within the closure boundary of the Proposal is Unallocated Crown Land (UCL). The proposed post-mining land use assumes that the site will be rehabilitated to create a safe, stable, and non-polluting landscape revegetated with native species, to maintain environmental and cultural heritage values and ensure the site does not adversely impact current surrounding land use. The post-mining land use will be determined in consultation with key stakeholders, including Traditional Owners.

Due to the nature of the mining activity undertaken, some closure landforms will be visually and structurally different to the pre-mining landscape, including waste rock landforms and large voids. Some voids will remain at closure and these will be unlikely to support land use by Traditional Owners or other post mining land uses due to safety considerations. The post-closure land use will need to consider the native title rights of Traditional Owners as well as their previous, ongoing, and desired future use of the area. Post-closure land use will also need to consider that surrounding areas are likely to remain subject to pastoral activity. While pastoralism is not proposed for the site, closure outcomes need to consider that livestock from surrounding areas are likely to access the site inadvertently.

Post-mining land use will also be informed by the Australian Land Use Management Classification system (ALUM). Areas will be classified by either ALUM 1.3.4 (Rehabilitation), ALUM 1.3.3 (Residual Native Cover) or ALUM 5.8.4 (Extractive Industry – not in use). ALUM 1.3.4 (Rehabilitation) and ALUM 1.3.3 (Residual Native Cover) will remain consistent with the surrounding area's land use of UCL, including access and use for traditional indigenous uses as well as re-establishment of traditional owner values and uses. Areas such as pit voids, which are unlikely to support safe access and use for traditional indigenous uses, will be designated 'Extractive Industry – not in use' (Extractive Industry – not in use).

Closure strategy

To manage risks associated with closure of the Proposal, the following closure strategies will be implemented:

- Alignment with the HD2 Social Cultural Heritage Management Plans (SCHMP) and the HD2 Aboriginal Cultural Heritage Management Plan (ACHMP) to ensure agreed social and cultural heritage values and sites are protected, and adequate post-mining land access is facilitated.
- Placement of abandonment bunding to manage risks associated with inadvertent public access post-closure.
- Ongoing engagement with internal and external stakeholders to ensure that closure outcomes and completion criteria are considered and incorporated, where appropriate, into life of mine and closure planning and decision-making processes.
- Removal of relevant infrastructure at closure unless otherwise agreed with relevant stakeholders, as required under the *Iron Ore (Hope Downs) Agreement Act 1992*.
- Rehabilitation of ex-pit waste landforms, with design informed by waste characterisation, ecological and hydrological factors to ensure long term stability and minimise the risk of erosion.
- Revegetation of disturbed areas, including the spreading of topsoil, where available, the ripping and seeding with local native (local provenance) species.
- Implementation of progressive rehabilitation (landform reshaping to final closure design and revegetation) to make disturbed areas compatible with the post-mining land use as soon as possible, including during operations where feasible. Monitoring of progressive rehabilitation to inform closure planning, closure outcomes and refinement of completion criteria.
- Explore opportunities to partner with Traditional Owners to implement, maintain and monitor rehabilitation, where possible. Surface water and groundwater modelling to inform operations, closure planning and design to ensure no unacceptable impacts to sensitive receptors.
- Maintenance of exclusion zones and management plans implemented for environmentally and culturally significant values.

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Corporate endorsement:

I hereby certify that to the best of my knowledge, the information within this Hope Downs 2 (HD2) Mine Closure Plan is true and correct and addresses the relevant requirements of the *Statutory Guidelines for Mine Closure Plans* approved by the Director General of Mines, Industry Regulation and Safety.

Sarah Carroll

General Manager – Studies, Rehabilitation and Closure

Date: 20 October 2023

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Abbreviations

ABA	Acid Base Accounting
ACHMP	Aboriginal Cultural Heritage Management Plan
AEP	Annual Exceedance Probability
AGM	Alternative Growth Media
ALUM	Australian Land Use Management
AMD	Acid and Metalliferous Drainage
ANC	Acid Neutralising Capacity
ANFO	Ammonium Nitrate Fuel Oil
ANZMEC	Australian and New Zealand Minerals and Energy Council
AWT	Above Water Table
BIF	Banded Iron Formation
BHT	Bedded Hill Top
BOM	Bureau of Meteorology
BWT	Below Water Table
CKB	Closure Knowledge Base
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Department of Agriculture, Water and the Environment
DISER	Department of Industry, Science, Energy and Resources
DMIRS	Department of Mines, Industry Regulation and Safety (Formerly DoIR and DMP)
DMP	Department of Mines and Petroleum (now DMIRS)
DoIR	Department of Industry and Resources (now DMIRS)
DWER	Department of Water and Environmental Regulation (including EPA Services, Water and Environmental Regulation)
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESP	Exchangeable Sodium Percentage
FMMP	Fibrous Minerals Management Plan
GNH	Great Northern Highway
GDE	Groundwater Dependent Ecosystem
GHG	Greenhouse Gas
GRM	Global Climate Model
HD1	Hope Downs 1
HD2	Hope Downs 2
HD4	Hope Downs 4
ha	Hectares
HHMS	Hamersley HMS Pty Ltd
IBRA	Interim Biogeographic Regionalisation for Australia
ICMM	International Committee for Mining and Minerals
ILUA	Indigenous Land Use Agreements
IOD	Indian Ocean Dipole
IODMS	Iron Ore Document Management System
LG	Low Grade
LEM	Landform Evolution Modelling

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LoM	Life of Mine
JTSI	Department of Jobs, Tourism, Science and Innovation
m	Meters
MCA	Minerals Council of Australia
MCP	Mine Closure Plan
MEZ	Mining Exclusion Zone
mRL	Metres above Relative Level (Sea Level)
NTA	Native Title Agreement(s)
NVCP	Native Vegetation Clearing Permit
NAF	Non-acid Forming
P1	Priority 1 species
P2	Priority 2 species
PA	Participation Agreement
PAF	Potentially Acid Forming
PCO	Present Closure Obligation
PE	Potential Evaporation
PEC	Priority Ecological Community
PMC	Pebble Mouse Creek
PRG	Pilbara Rehabilitation Group
PSD	Particle Size Distribution
PUPEZ	Potentially Unstable Pit Edges Zone
RCP	Representative Concentration Pathways
Rio Tinto	Rio Tinto Iron Ore
RORB	Run Off Routing on Burroughs model
RUSLE	Revised Universal Soil Loss Equation
RQA	Rehabilitation Quality Assessments
SCARD	Spontaneous Combustion and Acid Rock Drainage
SCHMP	Social and Cultural Heritage Management Plan
SME	Subject Matter Expert
TPC	Total Projected Closure
TUFLOW	Two-dimensional Unsteady FLOW model
UCL	Unallocated Crown Land
UWA	University of Western Australia
WABSI	Western Australian Biodiversity and Science Institute
WD	Waste rock landform/ Waste Rock Dump
WEPP	Water Erosion Prediction Program
WWC	Weeli Wolli Creek
WWTP	Wastewater Treatment Plant
WWS	Weeli Wolli Spring
UCL	Unallocated Crown Land

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1 Purpose and Scope

1.1 Mine Closure Plan Purpose

Planning for closure of a site is a critical business process that demonstrates the proponent's commitment to sustainable development. This Mine Closure Plan (MCP) follows the format and content requirements for MCPs as required in the Department of Mines, Industry Regulation and Safety (DMIRS) *Mine Closure Plan Guidance - How to prepare in accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans* (2020) and *Statutory Guidelines for Mine Closure Plans* (2020a)

This MCP has been prepared to achieve the following goals:

- Reflect the current knowledge and requirements for closure of the Hope Down 2 (HD2) Proposal (the Proposal) (including stakeholder feedback to date) and identify the future requirements to continue to progress towards a planned and managed closure, including future opportunities for consultation.
- Support environmental assessment of the Proposal comprising of the HD2 and BHT deposits.
- Inform key stakeholders on how Rio Tinto plans to meet its mine rehabilitation and closure requirements for the Proposal.
- Meet the requirements in the DMIRS Statutory Guidelines to meet the internal requirements of the Rio Tinto Closure Standard (2021) mandated for all Rio Tinto Assets.
- To inform the development of closure provisions.

1.2 Mine Closure Plan Scope

This MCP covers the development of the Proposal within a defined closure boundary (Figure 1). Tenure within the closure boundary is listed below and presented in Figure 2. This MCP is applicable to areas, infrastructure and mine development features including:

- State Agreement Mining Lease 282 Sections 1 and 2 (or part thereof); and
- the most eastern extent of Miscellaneous Licence 47/52 (L47/52), granted under the *Mining Act 1978 (WA (the Mining Act)* (Road/Pipe/AC 1)[1].

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This MCP excludes the following:

- Potential future deposits within the area, subject to relevant approvals these may be subsequently incorporated into future updates of this MCP.
- Other Rio Tinto mines in the Hope Downs area (e.g., Hope Downs 1 [HD1] and Hope Downs 4 [HD4]) which are subject to separate MCPs.
- The Rio Tinto rail network across the Pilbara (covered in a separate closure planning process).
- Rio Tinto exploration areas and exploration infrastructure.
- Ri Tinto infrastructure currently in use at HD1 mining operations including primary crushing and processing facilities, roads and utilities. This infrastructure liability will transfer across to this MCP once the Proposal is approved,
- Rio Tinto infrastructure that is connected to an integrated network (e.g., power, communications).

[1] L47/52 is considered part of the scope of the Rio Tinto West Angelas Closure Plan. The re-alignment of the Great Northern Highway will not be constructed under the L47/52 tenure, rather a Miscellaneous Licence or similar will be sought. Once the realignment route is finalised, this tenure may be removed from the scope in future updates to this MCP as new tenure will be acquired to address this.

1.3 Mine Closure Plan review and update

This is the first MCP completed for the Proposal. This MCP was prepared to support the Part IV environmental assessment of the Proposal. MCPs are generally updated every three years in line with the DMIRS *Statutory Guidelines for Mine Closure Plans* (2020), or a Ministerial Statement condition.

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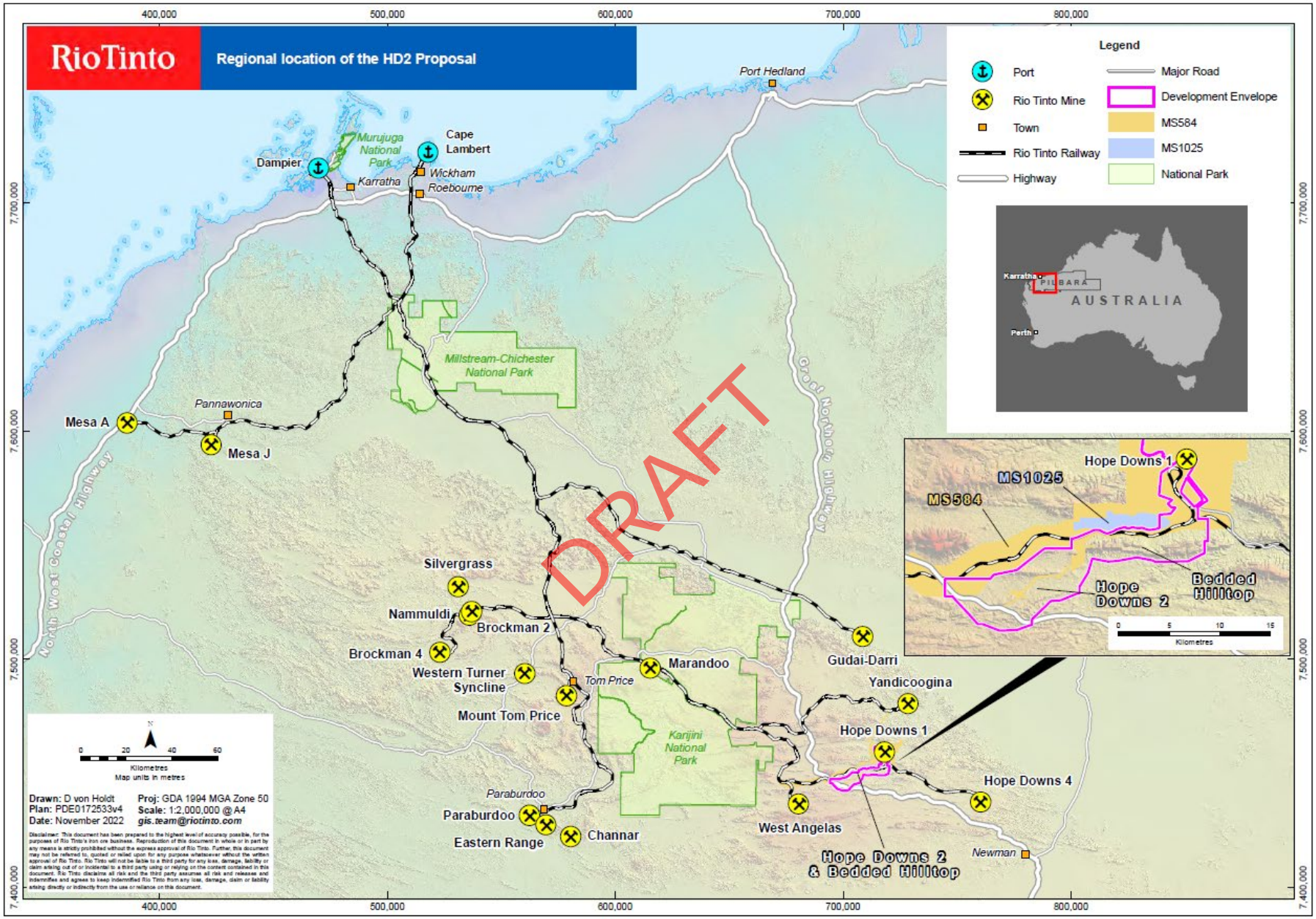

Figure 1: Regional location of Hope Downs 2

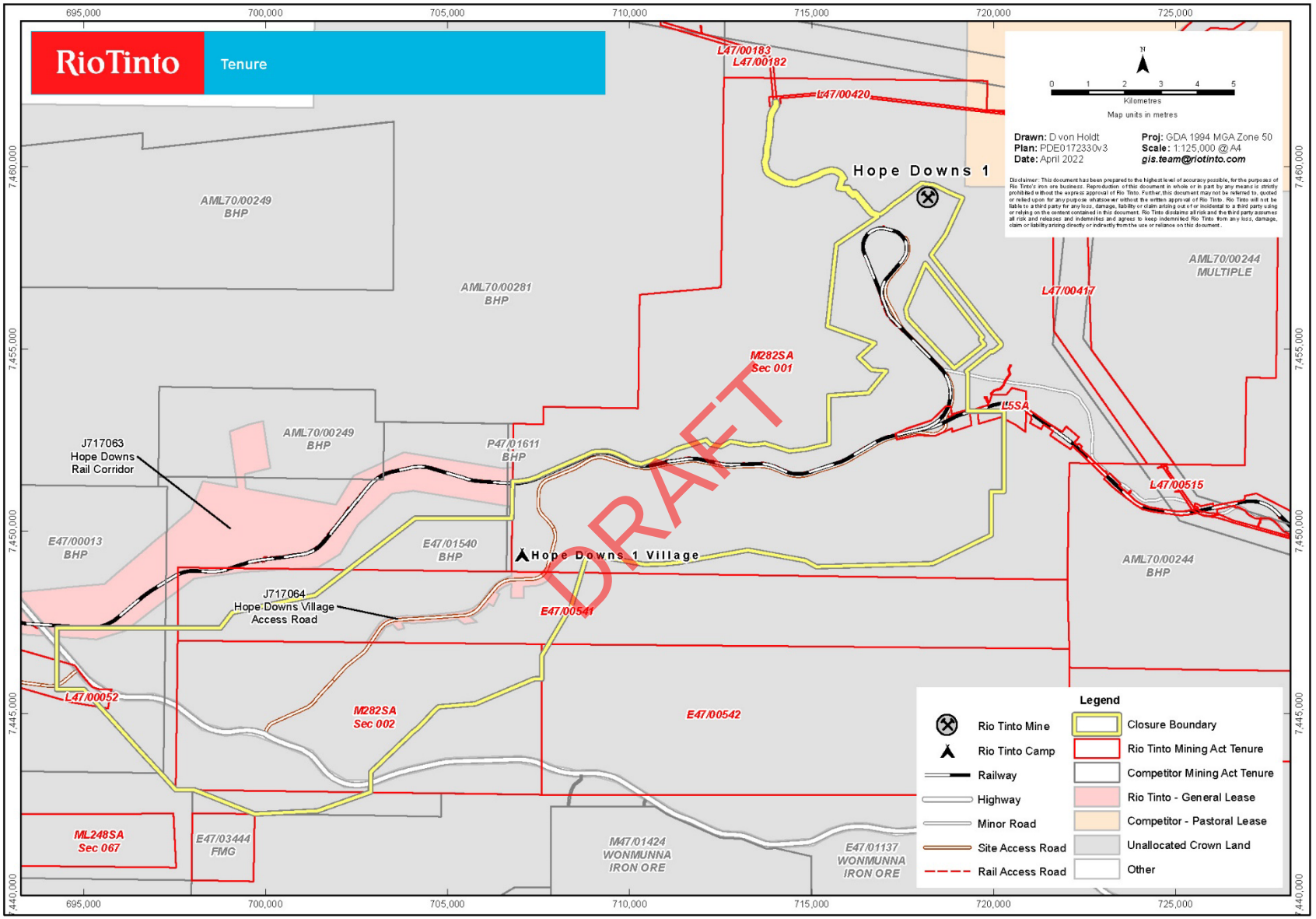

Figure 2: Tenure

2 Project Summary

2.1 Proponent information

The Proposal is made on behalf of the Hope Downs Joint Venture (HDJV), which is an unincorporated joint venture (50:50) between Hope Downs Iron Ore Pty Ltd (a member of Hancock Prospecting Group) and Hamersley WA Pty Ltd (a member of the Rio Tinto Group). The HDJV is managed by Hamersley HMS Pty Ltd (HHMS), a Rio Tinto Group company. For the purposes of this MCP the proponent will be referred to as Rio Tinto.

2.2 Location

The Proposal closure boundary covers 12,410 ha of land in the Pilbara region of Western Australia and is approximately 80 km northwest of the township of Newman.

The closure boundary is in the Shire of East Pilbara (Figure 1), a sparsely populated region with approximately 11,000 residents living in an area of around 372 km^2 (ABS 2020, Shire of East Pilbara 2020). Newman is the administrative centre and largest town in the Shire, with a population of approximately 7,000 (ABS 2020). Site access to the Proposal is via the Great Northern Highway (GNH) (Figure 1).

The Proposal closure boundary is located predominantly on land the subject of the Nyiyaparli People Native Title determination (WCD2018/008), with two small portions intersecting land the subject of the Banjima People Native Title determination (WCD2014/001) to the north and land the subject of the Ngarlawangga People Native Title determination (WCD2016/007) to the south west (refer Figure 3 and Section 5.1.1). Other Aboriginal communities near to the Proposal are:

- Parnpajinya, part of the Newman townsite;
- Youngaleena, approximately 90 km northwest;
- Innawonga, approximately 100 km west;
- Irrugadji (Five Mile) near Nullagine, approximately 140 km northeast; and
- Jigalong and associated satellite communities, approximately 160 km east. Jigalong is the largest of these Aboriginal communities, with a population of approximately 300 (ABS, 2020).

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The GNH intersects the southern end of the Proposal, providing public access between the towns of Newman and Port Hedland and tourist access to Karijini National Park, approximately 30 km to the west of the Proposal at its nearest point. The GNH forms part of the National Highway Network and provides a strategic freight link between Perth and the state's north as well as Darwin and the Northern Territory. The GNH is the region's major road, and most other public roads outside town areas, of which there are few, are unsealed, reflecting the 'remote' and sparsely populated character of the region.

2.3 Land Use

Land use within the region is constrained by the remote location, with historical and current land uses differing significantly.

There is a long history of Aboriginal People interacting with the land within the closure boundary. In addition to the respective Native Title Determinations recognising each Traditional Owner group's non-exclusive right to continue to access, use and enjoy country (refer Section 5.1.1), this area is also one of the main ways to access Weeli Wolli Creek (WWC) and Weeli Wolli Spring (WWS), which are of environmental, social and cultural significance in the region.

Recent land use associated with the Proposal continues to include traditional and customary uses but now also includes industrial, agricultural and tourism land uses.

Land tenure associated with the Proposal has been issued on UCL and includes State Agreement, miscellaneous and exploration tenure (refer Figure 2). There is no pastoral activity in the immediate vicinity of the mine, with Marillana Station (N050368) the nearest pastoral station lease, approximately 2 km east of the northern boundary section. Marillana Station lease is owned and operated by Broken Hill Proprietary Limited (BHP Limited).

More recently, the vicinity has been targeted for its mineral resources. Current mining projects in the region, in addition to the Proposal, include:

- Rio Tinto – HD1 Iron Ore Mine (including Baby Hope), immediately north;
- Rio Tinto – West Angelas Iron Ore Mine, approximately 10 km southwest;
- Rio Tinto – Yandicoogina Iron Ore Mine, approximately 25 km northeast;
- BHP Limited – Area C Southern Flank Iron Ore Mine, approximately 12 km north-northwest;
- Rio Tinto – Hope Downs 4 Iron Ore Mine, approximately 42 km southeast;
- BHP Limited – Yandi Iron Ore Mine, approximately 25 km north-northwest; and
- Wonmunna Mining Area and Wonmunna Copper Mine, approximately 15 km to the south.

Tourism is also an important part of the regional economy, accounting for 14.3% of jobs in the Shire of East Pilbara (DPIRD 2020). A lookout and rest area are located at Mt Robinson, 5.5 km northwest of the closure boundary along the GNH. With a variety of facilities, it is described as 'busy' by caravanning and camping websites. WWS, 16 km to the north-east of the closure boundary, is a local tourist destination and Weeli Wolli Pool, to the northeast of the closure boundary, is listed on the Shire of the East Pilbara municipal inventory of significant places (Heritage Council of Australia, 2020).

2.4 Environmental, social, and cultural values

The Proposal is close to the following sensitive environmental receptors, or social and cultural heritage values:

- The Priority 1 WWS Priority Ecological Community (PEC) buffer is located approximately 6 km northeast of the BHT deposit and approximately 20 km northeast of the HD2 deposit. The cultural and environmental significance of this PEC is discussed further in Sections 5.1 and 5.12.2, respectively.
- Groundwater Dependent Ecosystems (GDEs) and permanent pools have significant environmental and/or cultural value:
    - Ben's Oasis (a permanent pool) is located approximately 2 km south of the BHT deposit and 15 km east of the HD2 deposit. Preliminary hydrogeology investigations suggest that the surface water present is likely groundwater fed but sourced from a southern catchment and therefore not in hydraulic connection with the catchment in which the proposed HD2 mine is located.
    - New locations of conservation significant Priority 1 (P1) and Priority 2 (P2) flora have been recorded at BHT and are discussed further in 5.13.1.
- To date, two sites of particularly high cultural significance have been identified by Nyiyaparli Traditional Owners within the Proposal closure boundary and the mine design has been amended to avoid direct impacts to these sites, being:
    - a heritage complex (HOPE4-07) which is located immediately east of the HD2 deposit, but outside of the Proposal conceptual footprint; and
    - a rock shelter containing rock art (BDH16-03) which is located 300 m from the edge of a proposed a BHT pit.

  These sites are discussed in more detail in Section 5.1.2 and heritage surveys and consultation are ongoing and may identify additional heritage sites and places or identify known sites and places that are of high cultural significance.
- Vertebrate fauna of conservation significance (Northern Quoll, Ghost Bat, and Western Pebble-mound Mouse) that have been recorded within the closure boundary. Several caves identified as potential diurnal roosts for the Pilbara Leaf-nosed Bat and Ghost Bat have been recorded at the BHT and HD2 deposits. Conservation significant fauna and habitat are discussed further in 5.14.3.

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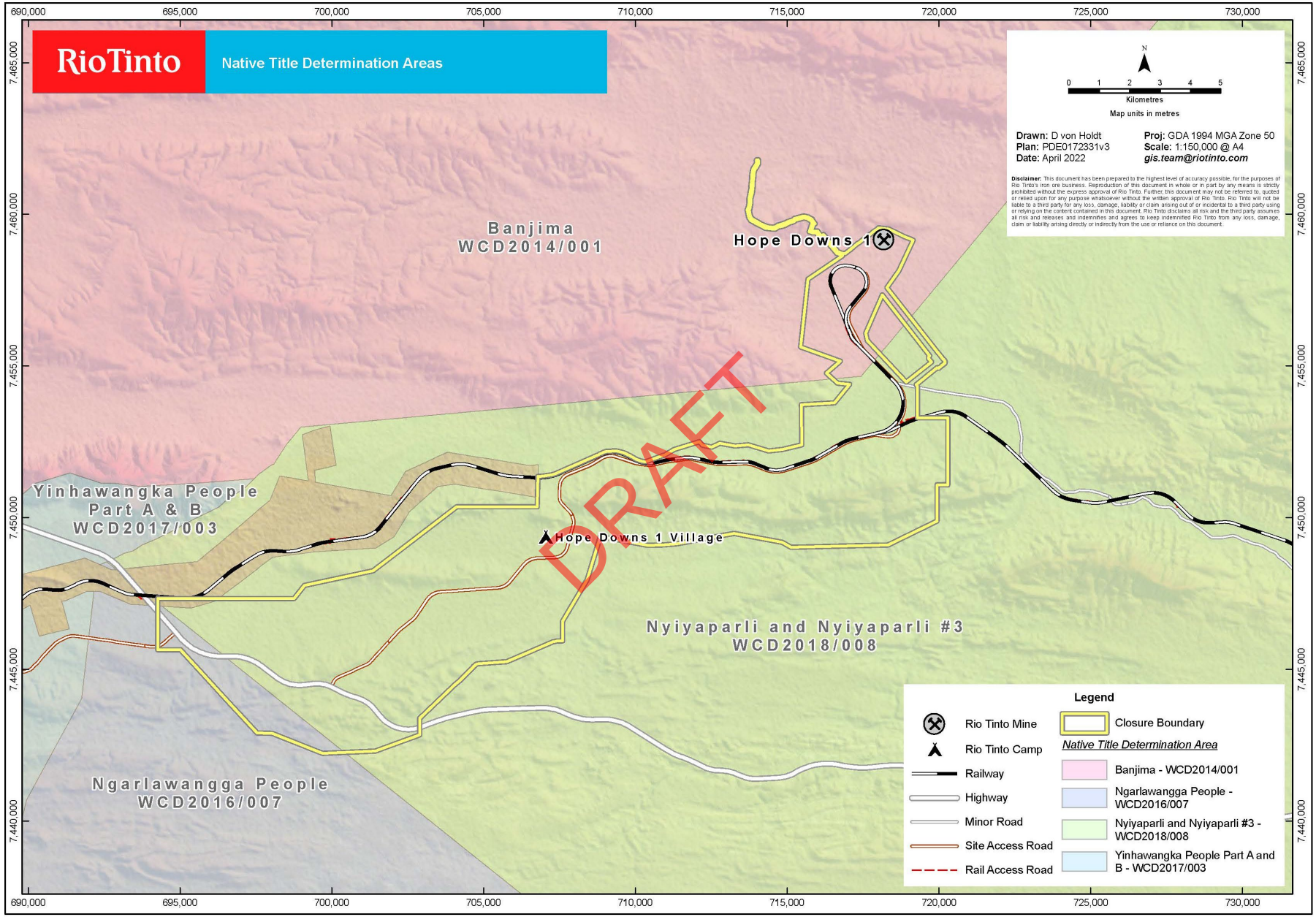

Figure 3: Native Title Determination Areas

2.5 Mine operations

Subject to approvals, construction of the Proposal is planned to commence in 2025, with mining expected to occur between 2027 and 2040. Traditional open pit, drill-and-blast and load-and-haul methods will be used to mine the BHT and HD2 deposits.

Mine planning schedules are continuously revised to maximise efficiencies and incorporate proposed new deposits. Several scenarios are still under evaluation, each of which would result in changes to the projected commencement and cessation dates of various deposits and pits. The mine schedules and plans are subject to regular review to ensure optimised performance of the operations and are therefore subject to change.

Iron ore mined from the deposits will be transported by truck or conveyor to the adjacent HD1 operations and then transported by train to Rio Tinto's coastal export facilities. The current mine plan includes a production rate of 26.0 Mt/ annum in 2027 and then 31.4 Mt/ annum from 2028 onwards during an operational life of nine years, with completion of mining currently scheduled for 2040 (Table 2-1).

Table 2-1: Indicative mining schedule

Pit	Commencement	Completion	Description
HD2 West	2026	2040	AWT
HD2 Centre	2026	2040	AWT
HD2 East	2026	2040	AWT
BHT West	2027	2040	AWT
BHT Centre	2027	2040	AWT
BHT East	2027	2040	AWT

Note: * The mining period end date is indicative and is subject to change based on the mine plan.

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The orebody consists of six AWT pits, across two deposits (HD2 and BHT), spanning an area of approximately 25 km. Mineral waste generated by the Proposal will be placed in permanent external waste rock landforms and used for the construction of temporary and permanent landbridges. Opportunities for progressive backfill of pits will be investigated as mine planning becomes further advanced. The conceptual mine layout is presented in Figure 4.

Waste rock landforms and associated infrastructure cover an area of up to 4,900 ha within a 12,409.5 ha closure boundary. This area constitutes the Proposal conceptual footprint, and the sum of disturbance associated with the Proposal. The Proposal utilises existing ore handling and processing infrastructure at HD1, supported by the construction and utilisation of the following:

- Dry crushing and screen processing facilities at HD2 and/or BHT deposits
- Run of mine (ROM) pads
- Ore stockpile.

No wet processing of ore is proposed, as deposits are AWT. The support facilities include some existing facilities from HD1 but will largely consist of new facilities constructed at HD2 and BHT deposits that may include but not be limited to:

- Heavy and light vehicle workshops and fixed plant workshops
- Hydrocarbon storage areas,
- ANFO facilities,
- Laydown areas,
- Turkey's nests,
- Transfer pads,
- Roads and haul roads,
- Offices.

The accommodation for the operational workforce will result in the upgrade or expansion of the existing HD1 accommodation and/or the installation of an additional camp within the Proposal conceptual footprint. These camps may also be developed to support the construction crew. The key landforms associated with the Proposal are listed in Table 2-2.

Once HD2 is approved, infrastructure currently associated with HD1 in list above will be reassigned as HD2 infrastructure recognising that the operational life of HD2 will extend beyond that at HD1.

Table 2-2: Mining landform inventory

Landform	Type	Footprint (ha)	Status	Indicative completion
HD2 West	Pit	965.89	Proposed	2040
HD2 Centre	Pit			
HD2 East	Pit			
BHT West	Pit			
BHT Centre	Pit			
BHT East	Pit			
HD2 DP_NW (Goanna)	Waste rock landform (WRL)	939.24	Proposed	
HD2 DP_NC (LG) (Tortoise)	WRL			
BHT DP_NEWD	WRL			
BHT DP_NELG	WRL			
BHT LB_Central 3	Landbridge	62.88	Proposed	
BHT LB_Central	Landbridge			
BHT LB_East 6	Landbridge			
BHT LB_East	Landbridge			
BHT LB_West	Landbridge			
Infrastructure	Heavy and light vehicle workshops and fixed plant workshops Hydrocarbon storage areas, ANFO facilities, Laydown areas, Turkey's nests, Transfer pads, Roads and haul roads, Offices.	2932.14	Proposed	

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It should be noted that there is the potential for further ongoing development of additional deposits subject to future approvals. Should these exploration areas eventually be developed, mining at the Proposal could continue significantly longer than indicated in Table 2-1. The addition of new deposits would also significantly affect the mining sequence and schedules for currently approved or proposed deposits.

The HD2 deposit intersects the GNH, north of the HD1 mine access road and south of the West Angelas mine access road (Figure 4). The Proposal includes realignment of approximately 6 km of the Highway off

tenure to access the ore body below. Preliminary consultation with Main Roads Western Australia, BHP, the Shire of East Pilbara and the Ngarlawangga Traditional Owners have commenced and will continue through Life of Mine (LoM) (Section 4) to agree an appropriate reinstatement approach with stakeholders. All future design updates will be included in subsequent updates to this MCP.

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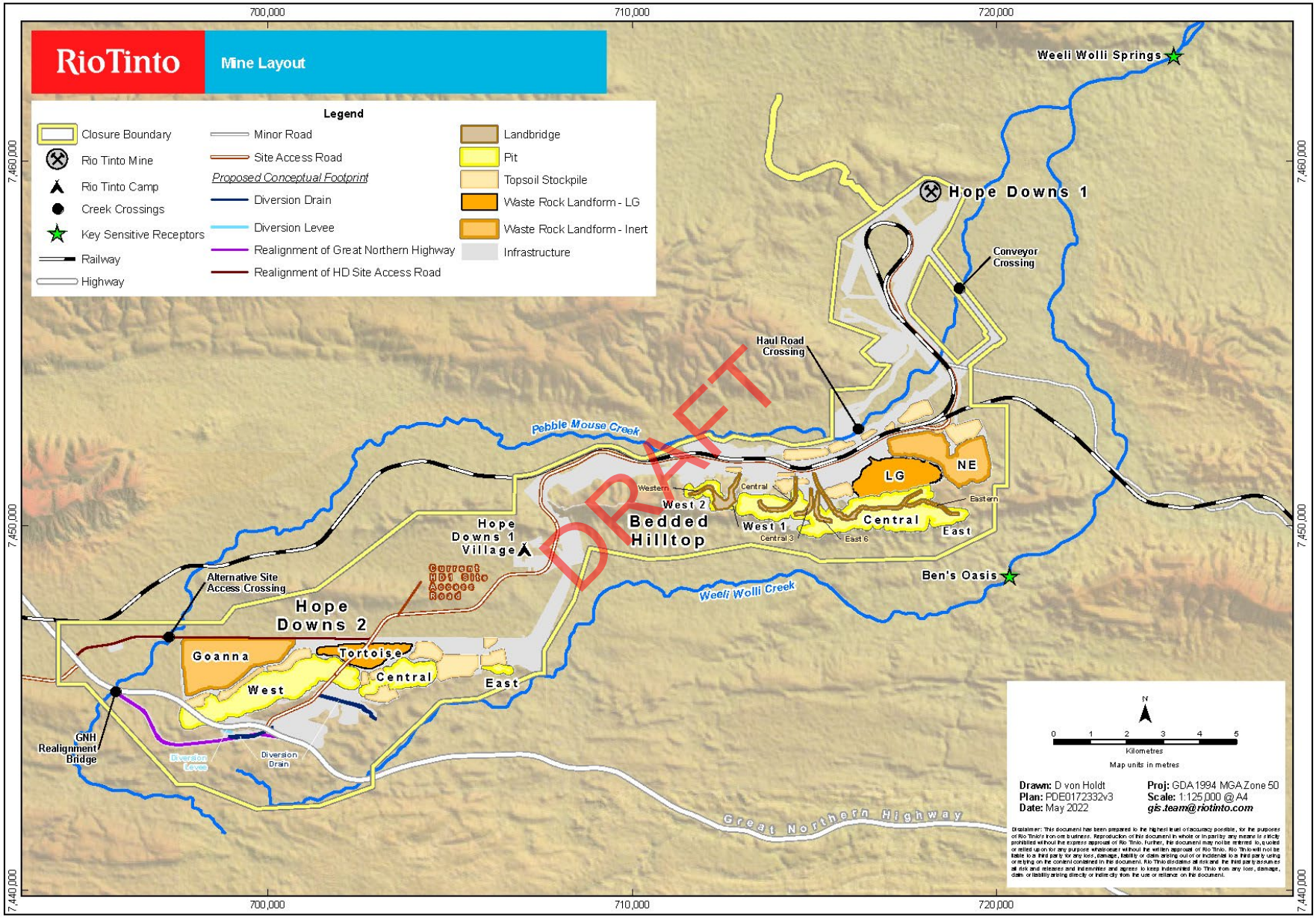

Figure 4: Mine layout

3 Identification of Closure Obligations and Commitments

The Australian mining industry has a well-established commitment to ensure that mine operations are closed with safe, stable, non-polluting landforms which are sympathetic to the surrounding landscape and that will require minimal (preferably no) ongoing maintenance post-closure.

Australian State and Territory Governments are responsible for the regulation and management of mine closure requirements for the mining industry (ANZMEC and MCA, 2000).

This section details the relevant Commonwealth, State and local requirements pertaining to the closure of the Proposal.

3.1 Commonwealth

The Commonwealth EPBC Act has established a consistent framework for environmental assessment of new proposals and variations to existing projects. Mining proposals that have the potential to significantly impact on matters of national environmental significance (MNES) are assessed for approval under this legislation. Issues related to mine closure are considered during the assessment process. Approved projects that have the potential to impact on MNES are declared a Controlled Action under the EPBC Act and are required to meet conditions of approval provided in a Decision Notice.

The Proposal was referred to the Department of Agriculture, Water, and the Environment (DAWE) to determine if assessment under the EPBC Act was required. DAWE advised on the 22 December 2021 that the Proposal would be a Controlled Action. The Proposal is being assessed via the accredited assessment process with the Western Australian Environmental Protection Authority (EPA).

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3.2 Western Australia

Department of Mines, Industry, Resources and Safety (DMIRS) is the lead regulatory agency and decision-making authority for mining projects in Western Australia under the *Mining Act* 1978 (Mining Act). DMIRS also has an advisory role in relation to the environmental management aspects of mines which are regulated under the Mining Act, State Agreement Acts and the EP Act.

Department of Water and Environment Regulation (DWER) is the lead regulator and decision-making authority under the EP Act. The EPA is the State's Government's chief advisor on environmental issues and is responsible for carrying out environmental impact assessments of significant proposals under Part IV of the EP Act.

The Department of Biodiversity, Conservation and Attractions (DBCA) protects and conserves the State's natural environment on behalf of the people of Western Australia under the *Biodiversity Conservation Act 2016* (BC Act).

Department of Jobs, Tourism, Science and Innovation (JTSI) is the lead regulator for all mining and associated activities conducted under Rio Tinto's various State Agreement Acts. The State Agreements set out the obligations of the parties in relation to mining and associated activities, including closure. The State Agreements specifically contemplate the Western Australian Government's entitlements to certain assets at closure.

3.2.1 Primary legislation

3.2.1.1 State Agreement

A State Agreement is a contract held between a mining company and the Western Australian Government that has been ratified by Parliament to become legislation. A State Agreement sets out the terms, conditions, rights and obligations of the parties in relation to the development and ongoing operation of a mining project and associated activities. The Proposal will be undertaken pursuant to the *Iron Ore (Hope Downs) Agreement Act 1992* (WA).

3.2.1.2 Mining Act

The Mining Act regulates the terms and conditions upon which exploration and mining for minerals can be undertaken within Western Australia. In 2010, amendments to the Mining Act provided for the requirement of an MCP to be submitted to DMIRS for approval as part of a Mining Proposal and in any other circumstances as outlined in Section 84AA of the Mining Act.

3.2.1.3 Environmental Protection Act

The EP Act outlines environmental management requirements for mining projects in Western Australia. Under Part IV the EP Act any proposal that may result in a significant impact to the environment must be referred under Section 38 (s38) to DWER, who set the level of assessment, undertake assessment of the proposal, and prepare a report and recommendations for the Western Australian Minister for the Environment. If approved, the Minister will issue a Ministerial Statement (MS) granting approval to implement the proposal subject to the conditions prescribed in the MS, including the requirement and timing for submission of MCPs to DMIRS, DWER and other relevant stakeholders. DMIRS is the primary agency responsible for reviewing MCPs.

The Proposal was referred under Part IV of the EP Act on 24 August 2021 and a Public Environmental Review (PER) level of assessment was determined by the EPA on 29 October 2021.

3.2.1.4 Aboriginal Heritage Legislation

The *Aboriginal Heritage Act 1972* (AH Act) protects all Aboriginal heritage sites in Western Australia, whether or not they are registered with the Department of Planning, Lands and Heritage (DPLH).

Consent is required from the Minister for Aboriginal Affairs under s. 18 of the AH Act for any activity which will adversely impact Aboriginal heritage sites. Authorisation can also be granted under s. 16 to enter, excavate, examine or remove anything on an Aboriginal heritage site (e.g., for archaeological purposes). Sites within the closure boundary are discussed in Section 5.1.2.

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3.2.1.5 Native Title

The Commonwealth *Native Title Act 1993* (NT Act) recognises the rights and interests of Aboriginal and Torres Strait Islander people in land and waters according to their traditional laws and customs. Native Title includes areas where title holders have exclusive rights and interests as well as areas where non-exclusive rights and interests exist. Traditional Owner rights recognised under the NT Act within non-exclusive areas generally include the right to:

- access, remain and move about, and camp and erect shelters and structures for that purpose;
- hunt and fish, gather and use traditional resources, and take and use water;
- engage in cultural activities and transmit knowledge;
- visit, care and protect places of cultural and spiritual importance; and
- conduct ceremonies and rituals.

The Proposal closure boundary intersects non-exclusive areas of the relevant Native Title Determinations.

3.2.2 Primary guidelines

3.2.2.1 Guidelines for Preparing Mine Closure Plans

DMIRS developed the industry guidance document *Statutory Guidelines for the Preparation of Mine Closure Plans*. This guideline was originally released in June 2011, revised in May 2015, and subsequently became a statutory guideline in March 2020.

The guideline adopts the objectives and principles of the Strategic Framework, whilst providing further description of how MCPs in Western Australia can meet the objectives and principles. It also outlines a planning process that aims at ensuring that a mine can be closed, decommissioned and rehabilitated in an

ecologically sustainable manner, consistent with agreed post-mining outcomes and land-uses, without unacceptable liability to the State.

All Mining Proposals for new projects need to be accompanied by an MCP.

The EPA and DMIRS undertake parallel assessment of MCPs if the Proposal requires approvals under Part IV of the EP Act and the Mining Act.

3.2.2.2 Other guidelines and industry standards

This MCP has been prepared in consideration of the relevant aspects from the following closure guidelines and industry standards:

- Mine Closure: Leading Practice Sustainable Development Program for the Mining Industry (2016a) (Department of Industry, Science, Energy and Resources (DISER).
- Mine Closure and Completion Handbook (DISER, 2016b).
- Preventing Acid and Metalliferous Drainage Handbook (DISER, 2016c).
- Mine Rehabilitation Handbook (DISER, 2016d).
- DRAFT Guidance Note – Environmental Risk Assessment for Mining Proposals and Mine Closure Plans (DMIRS, 2019).
- Guidance – How to prepare a Mine Closure Plan in accordance with Part 1 of Statutory Guidelines for Mine Closure Plans in Western Australia (DMIRS, 2020).
- Environmental Objectives Policy for Mining in Western Australia (DMIRS, 2020b).
- Guideline for safety bund walls around abandoned open pit mines (Department of Industry and Resources (DoIR), 1997).
- Integrated Mine Closure: Good Practice Guide (2019). International Council of Mining and Metals, International Committee of Mining and Minerals (ICMM).
- Mine Rehabilitation in the Australian Minerals Industry (2015). Mineral Council of Australia (MCA).
- A Framework for Developing Mine-site Completion Criteria in Western Australia (Western Australian Biodiversity Science Institute, Young *et al*., 2019).
- A review of mine rehabilitation condition setting in Western Australia. The Western Australian Biodiversity Science Institute, Kragt *et a*l (2019).

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3.3 Legal obligations

A Proposal closure obligations register was compiled in 2021 and is presented in Appendix 1. It contains details of legal obligations from the following instruments:

- *Iron Ore (Hope Downs) Agreement Act 1992* (WA);
- Miscellaneous Licence issued under the Mining Act pursuant to the *Iron Ore (Hope Downs) Agreement Act 1992*; and
- special leases and easements issued under the *Land Administration Act 1997 (WA*) pursuant to approval under the *Iron Ore (Hope Downs) Agreement Act 1992 (WA)*.

The register also identifies legislation, standards and guidelines that may not apply to this site specifically, but that may be relevant to closure of mine sites generally.

This MCP has been prepared to support an environmental impact assessment for the Proposal and any additional obligations that may arise through this process. All new obligations will be documented in the next update of this MCP, and then as applicable, in each subsequent update.

A Health, Safety, Environmental and Quality Management System (HSEQMS) will assure compliance with legal obligations throughout LoM operations. At this stage it is assumed that the HSEQMS process utilised during operations will continue to be employed to govern closure implementation and the post-closure monitoring period prior to relinquishment.

The Proposal is located on land the subject of the Nyiyaparli, Banjima and Ngarlawangga Native Title Determinations (refer Section 5.1.1). Rio Tinto has registered Indigenous Land Use Agreements (ILUAs) with the Nyiyaparli, Banjima, and Ngarlawangga Traditional Owners in respect of this area, and is committed to ongoing consultation regarding the assessment, operation, progressive rehabilitation, and the ultimate closure of the Proposal.

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4 Stakeholder Engagement

4.1 Consultation program

Rio Tinto recognises that regular and ongoing stakeholder engagement is a key part of mine closure planning as it ensures that the views and expectations of stakeholders are understood by the mine operator, and that these are considered and managed during the operational phase and through to the planning and implementation phases of closure. The ability to build relationships and to work collaboratively and transparently with Traditional Owners of the land on which we operate, and our host communities is critical to Rio Tinto's long-term success regarding rehabilitation and closure.

Rio Tinto has commitments for consultation with stakeholders, these are embedded in both the Rio Tinto's *Mine Closure Standard* (2021) and *Community and Social Performance Standard* (2015). These standards are aligned with principles from the Australian and New Zealand Minerals and Energy Council and the Minerals Council of Australia (ANZMEC/MCA, 2000). Consultation commences at appropriate times during the early stages of exploration planning and will continue until the final relinquishment of the site.

As part of this process all likely impacted stakeholders are identified and recorded in a register, a summary of which is shown below in Table 4-1. This register is used to ensure relevant and timely communications are held with stakeholders across a broad range of topics relevant to the mining operations, including closure. Regular consultation is conducted with key stakeholders via a variety of forums, for example various State and Local Government agency briefing meetings and Traditional Owner consultation forums (Section 5.1). The level of closure specific content and detail will increase as closure approaches.

A closure consultation register for the Proposal is maintained and a copy as at the time of writing is included in Appendix 2. This register is used to ensure stakeholder feedback is tracked and monitored to ensure that appropriate actions are taken to address these issues in a timely manner.

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Table 4-1: Proposal key stakeholder list

Category	Stakeholder
Commonwealth	• Department of Agriculture, Water and the Environment (DAWE)
State	• Department of Water and Environmental Regulation (DWER) • Department of Mines, Industry Regulation and Safety (DMIRS) • Department of Jobs, Tourism, Science and Innovation (JTSI) • Department of Biodiversity Conservation and Attractions (DBCA) • Department of Planning, Lands and Heritage (DPLH) • Department of Primary Industries and Regional Development (DPIRD) • Department of Health (DOH)
Traditional Owners	• Karlka Nyiyaparli Aboriginal Corporation (representing the Nyiyaparli people) • Banjima Native Title Aboriginal Corporation (representing the Banjima people) • Ngarlawangga Aboriginal Corporation (representing the Ngarlawangga people)
Local	• Shire of the East Pilbara • WA Police – Pilbara • Main Roads Western Australia • Pilbara Development Commission • Pilbara Regional Council • Pilbara Inland Chamber of Commerce and Industry
Non-government	• Joint Venture partners • BHP
Community	• Pilbara Aboriginal Businesses

Category	Stakeholder
	• Regional communities, including Newman • Marillana pastoral station
Internal	• Rio Tinto iron ore employees and contractors

4.2 Closure Stakeholder Engagement strategy

An overview of the closure stakeholder engagement to be undertaken throughout the life of the site is presented in Table 4-2.

The focus of this consultation will be to:

- Identify the key issues and concerns regarding rehabilitation and closure of the Proposal.
- Where practicable, address key issues and concerns in the project planning and design stage, to avoid, reduce or manage impacts.
- Establish agreed management actions through SCHMP and other management plans to inform operations and ongoing closure planning and consultation.
- Where practicable, allow for adjustments to the design and/or management of proposed rehabilitation and closure activities to address concerns or issues raised by key stakeholders.
- Provide information to key stakeholders regarding the progress of progressive rehabilitation and closure planning.
- Identify expectations for, and progress towards, agreement on post-mining land use(s) and closure outcomes.

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Table 4-2: Closure engagement strategy for key stakeholders

Stakeholder	Engagement Forum and Timing	Focus
Traditional Owners; Karlka Nyiyaparli Aboriginal Corporation (KNAC); Banjima Native Title Aboriginal Corporation (BNTAC); Ngarlawangga Aboriginal Corporation (NAC);	Local Implementation Committee (LIC) meetings (twice a year). Life of Mine Planning (LOMP) meetings (twice a year) Dedicated Cultural Heritage meetings (several times per year) Ad hoc meetings: to discuss matters of priority or concern. Meetings as required.	Consultation to support the drafting of the initial mine closure plan to accompany the ERD. Consultation to support compliance driven closure plan updates. Progressive rehabilitation and technical studies updates. Targeted closure planning engagement to support and further refine: • closure strategies and completion criteria; • post-mining land use and closure outcomes; • outline potential business opportunities linked to closure.
JTSI, DWER, DMIRS;	Rio Tinto Closure Regulator Engagement Forum, meetings held three to four times per year. Meetings as required.	Consultation to support three yearly updates to MCPs. Agenda may include: • progressive rehabilitation. • technical studies updates; and • completion criteria.
DBCA, DPLH;	DBCA have requested targeted consultation to be held when closure planning impacts their areas of responsibilities. Meetings as required.	Targeted closure planning engagement to commence during Order of Magnitude (OoM) closure studies to support further refinement of closure strategies and completion criteria.

Through a range of forums, including forums established under the Native Title Agreements (NTA), consultation with each of the Traditional Owner groups in respect of land access; Proposal development; heritage surveys; environmental management; and other issues relevant to the Proposal will be undertaken.

These forums and meetings include, but are not limited to:

- Local Implementation Committee (LIC) meetings which involve face to face meeting to discuss key issues and reach decisions on a range of topics relevant to Traditional Owners. This forum includes company senior leaders, invited subject matter experts, and Traditional Owner representatives and advisors.
- Life of Mine Planning (LOMP) meetings which involve face to face meeting to discuss and provide updates to Traditional Owners on exploration, studies/projects, mining, and closure activities. Key topics include management of water and the environment.
- Dedicated Cultural Heritage meetings which involve face to face meetings to discuss, in detail, cultural heritage identification, management and approvals.
- Environmental monitoring and management, including on-ground consultation to participate in monitoring and management activities.
- Ad hoc meetings: to discuss matters of mutual priority and concern. These meetings often take place 'on-country' with support from internal and external Subject Matter Experts (SME), Traditional Owner Elders and Aboriginal Corporation staff.

Additional requirements for consultation with KNAC are included in Table 11 of the Social and Cultural Heritage Management Plan (SCHMP) developed in collaboration with Nyiyaparli for the Proposal (Rio Tinto 2023). One of the SCHMP objectives is to "ensure mine design, rehabilitation and closure incorporates Nyiyaparli People's social surroundings values and preserves, protects and manages those values in the area in cooperation with Nyiyaparli People". The SCHMP details specific management actions, monitoring and timing to achieve this objective. Refer to Table 11 of the SCHMP for more information.

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4.3 Targeted stakeholder consultation

As this is the first MCP for the Proposal, engagement regarding closure of the site has been limited. However, engagement with Traditional Owners and key stakeholders regarding the deposits, the conceptual mine layout, highway realignment and other topics have occurred and will be ongoing as part of Social Surroundings consultation with relevant Traditional Owner groups and other community stakeholders to inform the environmental impact assessment for the Proposal.

Main Roads WA, BHP Limited, and other Government agencies have also been engaged regarding the Proposal (Appendix 2). Rio Tinto will continue these consultations with key stakeholders over the life of the Proposal with closure remaining an ongoing point of discussion.

Ongoing engagement with Traditional Owners regarding the Proposal and the closure strategy and outcomes is required to ensure a shared understanding of the planned Proposal as well as the key social and cultural values within the vicinity of the Proposal which will require protection and management during its planning, operation, and closure.

Key areas for consultation include:

- project design and closure planning;
- identification and protection of social and cultural heritage values;
- repatriation of salvaged artefact material;
- land access during and after closure;
- consideration of retaining or re-purposing infrastructure;
- consideration of plant species selection for rehabilitation; and
- business and employment opportunities.

5 Baseline Closure Data and Analysis

This section provides a summary of relevant baseline and operational studies, surveys and data, with key knowledge base reports appended. Rio Tinto will use this information to assist in the development and on-going refinement of completion criteria and effective mitigation and management of identified risks leading up to, and during, the closure implementation phase.

The HD2 closure knowledge database (Appendix 3) is a record of all the baseline studies, models and interpretations, which have been completed for the development of the Proposal that are relevant to closure planning. The knowledge may be specific to the site or generally applicable to the Pilbara region; and includes information on the performance of closure-related trials completed at other Pilbara mining operations (when appropriate).

Identified closure knowledge gaps are identified in each section and summarised in Section 6. The knowledge gaps are aligned with the Closure Risk Register (Appendix 4) and associated actions captured in the Closure Action Register (Appendix 5).

SOCIAL SETTING

5.1 Aboriginal culture and heritage

Rio Tinto recognises and respects the significance of Australia's cultural heritage, and in particular the cultural heritage of Aboriginal people who have traditional ownership of, and/or cultural connections to, the land on which it operates.

Extensive archaeological and ethnographic surveys have been undertaken within the closure boundary, along with dedicated Social Surroundings consultation to understand broader social and cultural values. This work has informed Rio Tinto's understanding of the social and cultural values of the area. The ongoing consultation with Traditional Owner groups has also informed the Proposal design to avoid impacts to significant social and cultural values, sites, and places, as well as identify options to reduce and manage impacts through the implementation, operation rehabilitation and closure phases of the Proposal. Closure works consider issues such as post-closure access requirements to culturally significant sites and appropriate storage and return of any materials salvaged during mining operations.

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5.1.1 Native Title determinations

The closure boundary is on land subject to three Native Title determinations (Figure 3), being:

- Nyiyaparli People Native Title determination (WCD2018/008), covering the majority of the Development Envelope (the Nyiyaparli section), which is administered by Karlka Nyiyaparli Aboriginal Corporation (KNAC) on behalf of the Nyiyaparli People. KNAC holds determined native title rights on behalf of the Nyiyaparli People.
- Banjima People Native Title determination (WCD2014/001), which relates to two discrete portions in the north of the Development Envelope (the Banjima section). The Banjima Native Title Aboriginal Corporation (BNTAC) holds determined native title rights on behalf of the Banjima People.
- Ngarlawangga People Native Title determination (WCD2016/007), which relates to a portion in the southwest of the Development Envelope (the Ngarlawangga section), which is managed by the Ngarlawangga Aboriginal Corporation (NAC) on behalf of the Ngarlawangga People (see **Figure 3** for comparative area sizes).

The long history of Aboriginal land use within the closure boundary reflects the deep cultural significance of this area to Nyiyaparli, Banjima and Ngarlawangga people. These Traditional Owner groups have a shared responsibility to protect and care for this country, and the respective Native Title Determinations recognise each Traditional Owner group's non-exclusive right to continue to access, use and enjoy country.

Rio Tinto has entered into Native Title Agreements with each of these three Traditional Owner groups in respect of the use of the land the subject of the Proposal. In addition, Rio Tinto has registered Indigenous Land Use Agreements (ILUAs) with the Nyiyaparli, Banjima and Ngarlawangga People in respect of the land

subject to the Proposal (and more broadly) which address the Future Acts provisions of the *Native Title Act 1993*.

5.1.2 Ethnographic and archaeological values

Archaeological and ethnographic surveys have been undertaken for the Proposal, with the participation and involvement of the relevant Traditional Owner groups, who have identified sites and made recommendations on the significance and management of each site. Surveys to date have recorded archaeological and ethnographic sites in the region including artefact scatters; quarries; rock shelters; scarred trees; rock art and other significant cultural values. There are 113 known archaeological and ethnographic sites within the HD2 closure boundary, 29 of which have been registered or lodged for assessment under the *Aboriginal Heritage Act* 1972.

As surveys continue, additional cultural and heritage places are likely to be identified. Archaeological and ethnographic surveys and consultations are ongoing and will continue during the assessment of the Proposal and beyond, which will add to the existing knowledge of heritage and cultural values within the area.

A summary of the ethnographic and archaeological values located within the Proposal closure boundary and relevant to closure of the Proposal is provided below:

- The Proposal closure boundary is located within a storied landscape that is active in Banjima, Ngarlawangga, and Nyiyaparli culture. Nyiyaparli Law (mangun) explains how the hills, plains, rivers, and waterholes as well as people, plants and animals were created by the ancestral spirits in the Kukutpa, the Dreamtime. The area holds a deep cultural significance to Nyiyaparli, Banjima and Ngarlawangga people and they are responsible for the land.
- The Djadjiling Range, which stretches along the northern edge of the Proposal closure boundary, is associated with a number of song lines important within Nyiyaparli, Banjima and Ngarlawangga culture. Rock shelters in the Djadjiling Range such as Jundaru and to a lesser extent Djadjiling Rock shelter (HS-A1 and HD07-3A-PAD13) preserve unusually dense and diverse archaeological assemblages from the period of initial occupation, between 50,000 to 35,000 years ago (Cropper and Law 2018b). The archaeological assemblage from this period indicates that people visited these shelters intermittently and only for short periods.
- Facing Djadjiling Range on the opposite side of the broad valley containing Pebble Mouse Creek (PMC) is BHT. In the upper gullies and hidden rock shelters of this range are walled cavities. These difficult-to-reach places were used to store sacred implements and objects or as burial sites.
- Near the northern portion of the Proposal, a series of sinkholes have been identified. They are linked through dreamtime stories to sinkholes associated with Wirlawarli (Weeli Wolli Spring).
- Other sites of particularly high significance within the HD2 closure boundary include a large heritage complex (HOPE4-07) and a rock shelter (BDH16-03) with unique archaeological features such as hand stencils and incised rock art.
- Water is at the centre of Traditional Owner life, culture and spirituality and is recognised by Traditional Owners as a critical element of country, and cultural and ecological landscapes. Within the Proposal closure boundary, water flows through Pebble Mouse Creek to the north where it terminates in the WWC north of the HD1 operation. The WWC headwaters are located south of the HD2 deposit, within the Proposal closure boundary, and flow northwards towards the Fortescue River 60 km to the northeast.
- WWC is a highly significant waterway that runs through the southern portion of the Proposal closure boundary. Evidence of past human occupation (in the form of material remains such as stone tools and evidence of stone quarrying) along this section of WWC has been found and recorded as part of archaeological and ethnographic surveys.

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- On the southern edge of the Proposal closure boundary, on an upper tributary of Weeli Wolli Creek near a semi-permanent waterhole, is the Wonmanna Rock Art site (DPLH ID 11917), a significant collection of engravings recognised as a Protected Area under the *Aboriginal Heritage Act* (1972) and on the Register of the National Estate (ID 016192). Figure 5 displays the current Registered Aboriginal Sites and Other Heritage Places within the Proposal closure boundary (DPLH 2021).
- Social and cultural heritage values for Nyiyaparli are documented in the HD2 SCHMP (Rio Tinto 2023). Developed in collaboration with Nyiyaparli for the Proposal, the SCHMP's purpose is to describe management for Nyiyaparli People's social and cultural values with the potential to be impacted by the Proposal. Additionally, ACHMPs will be developed with Traditional Owner groups where direct impacts to Special Places including heritage sites are identified as being significantly impacted. Refer to Section 5.1.6 for more information.

5.1.3 Closure implementation affecting heritage sites

Management of cultural heritage values will be conducted through processes established under the relevant Native Title Agreements. Closure planning considers how salvaged artefacts will be managed long term. Consultation will be ongoing with Traditional Owner throughout the life of the Proposal to identify cultural heritage sites and places, determine which sites should be preserved in situ, and which sites may be impacted and will require salvage, and the appropriate process for this.

While cultural heritage sites and places will be considered during landform design and planning (which includes rehabilitation designs), there is potential for heritage sites to be impacted because of closure implementation i.e., footprint encroachment, resulting from landforms such as waste rock landforms being reshaped to final design parameters or being located within the potentially unstable pit edge zone (PUPEZ) and therefore inaccessible due to being within abandonment bunds. As options on engineering and rehabilitation designs are narrowed as the site approaches closure, any potential for sites to be impacted will be identified and managed in consultation with the relevant Traditional Owner groups and in accordance with appropriate procedures. Heritage surveys, and any future assessments or clearances that are required to facilitate closure implementation will be conducted in collaboration with the Traditional Owner groups.

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5.1.4 Heritage management

As detailed in Section 5.5.3, safety bunding is required around potentially unstable pit edge zone for pits. An assessment has not been undertaken to determine if the conceptual bund locations would impede access to key heritage site post-closure. Consultation is ongoing with Traditional Owner groups to identify the cultural heritage sites and places which are to be preserved in situ and to which access is required, during the life of the project. This work will inform assessments in future stages of closure planning to ensure acceptable and safe access is available where possible. Discussions with Traditional Owner groups around the placement of development infrastructure will also be on-going during all phases of the project to ensure site access requirements are continually considered and updated in closure planning.

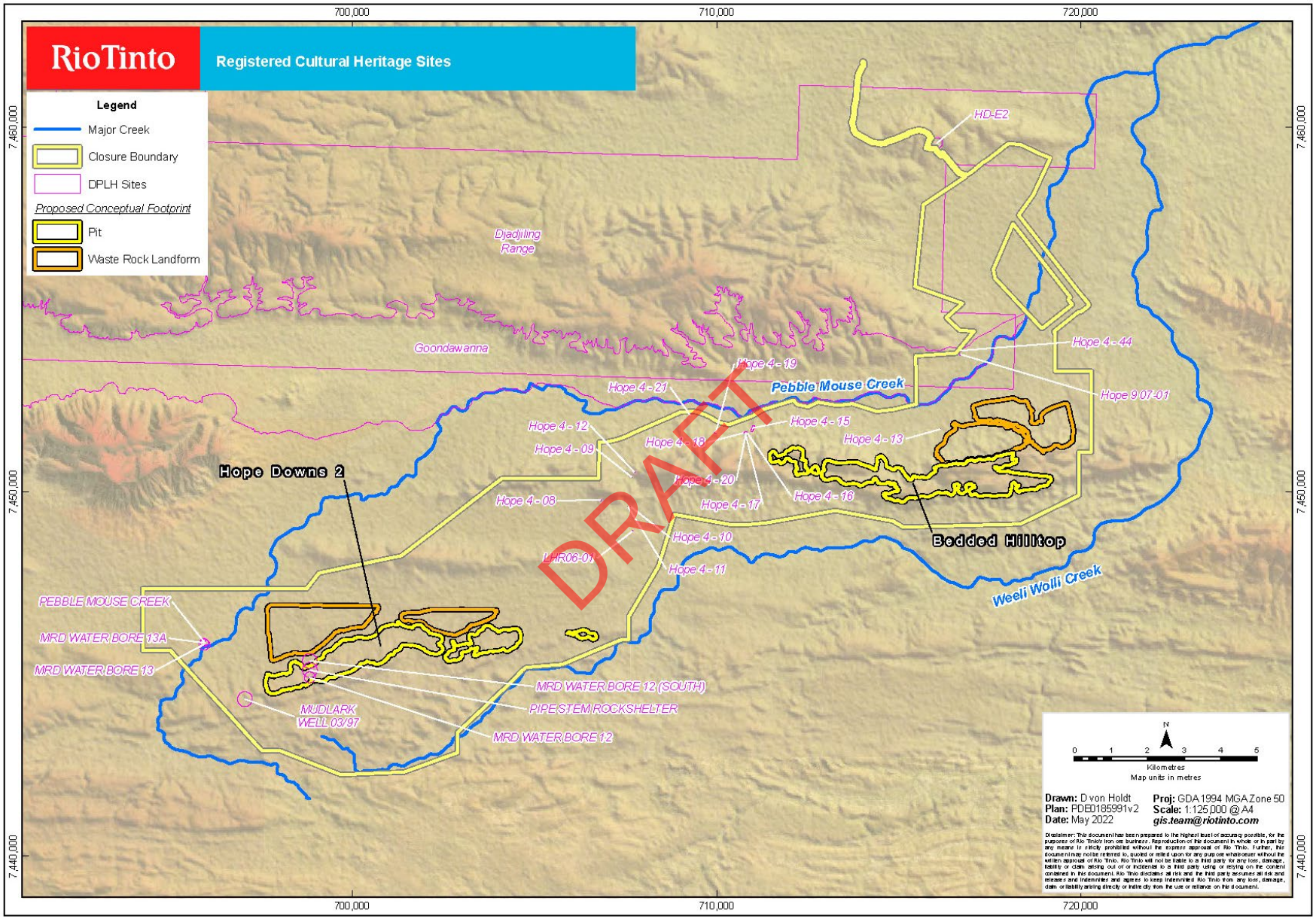

Figure 5: Registered Cultural Heritage Sites

5.1.5 Social surroundings

Aboriginal social and cultural heritage can include tangible values embodied in the landscape and specific places and sites, as well as intangible values related to cultural associations Traditional Owner have with an area – which may include, for example, traditional hunting and gathering activities, learning, teaching, ceremony, healing activities and enjoyment of country. Understanding places and cultural associations with country which are particularly important and help to prioritise areas to be avoided where possible and inform the design of other mitigation strategies.

Consultations during the development of the Proposal have considered social surroundings factors required under the EP Act. These consults included identifying important social and cultural values, work to develop options to avoid, reduce or manage impacts to these values and closure planning discussions regarding the proposed closure strategy and planning, closure outcomes and the MCP.

These consultations were undertaken with representatives of the Nyiyaparli, Banjima and Ngarlawangga Traditional Owner groups. Additional consultations were undertaken with Nyiyaparli as the majority of the Proposal is located on land that falls within the Nyiyaparli People's Native Title Determination.

Concerns expressed by the Traditional Owner groups to date relate to the practical, spiritual and cultural value of water, the potential impacts of dust and noise, restricted access to country, and the cumulative impacts of mining operations in the vicinity of the Proposal and across each Traditional Owners country. Some of the key concerns identified by the Traditional Owner in respect of these values are summarised below:

- **Water management and water quality** including the effects of diversions, groundwater drawdown and use for dust control, and cumulative impacts of water abstraction on local aquifers and changes to water flows within the WWC catchment. The Traditional Owners identify WWC and WWS as places of extremely high spiritual and cultural value. The potential effects of the proposed HD2 creek diversion and HD2 waste dumps on WWC have been raised as concerns. In particular, the effects of dust from the waste dumps, other activities associated with the Proposal on creeks and waterholes, as well as the use of water for dust suppression, are also significant concerns.
- The **impacts of dust** accumulating in water features and along drainage lines. Concern also exists about the effect of dust emissions on amenity, animals, plants and people.
- **Access to country**, particularly heritage sites and places and other areas of importance such as WWC. Access needs to be easy, year-round and unrestricted (i.e., by permit systems, fences, gates etc.). Related concerns include the condition, location and safety of the current road to WWC, and some hunting and camping areas becoming inaccessible.
- **Cumulative effects** of the Proposal with other mining operations has been raised by Traditional Owner groups. This concern relates to effects on water, including cultural responsibilities that apply in maintaining water flows between neighbouring groups' lands, as well as cumulative impacts to country as are result of pit voids, waste rock landforms and other impacts which will remain after closure.

Other points raised in consultation by Traditional Owners to date include:

- the desire for impacts to country (including through infrastructure, pit voids and waste rock landforms) to be reduced as much as possible;
- an interest in rehabilitation and the rehabilitation process; and
- business and employment opportunities during rehabilitation and closure activities.

Broadly, these groups seek to ensure these values are considered during closure, and that their country is returned to them in a way which reinstates social, cultural and environmental values as much as possible. Further consultation and surveys are planned to continue to build understanding and appreciation of social and cultural values for the Proposal and how to incorporate them into closure planning.

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Additional social and cultural heritage values for Nyiyaparli are documented in the SCHMP. One of the objectives is to ensure mine design, rehabilitation and closure considers Nyiyaparli People's social surroundings values and as far as practicable preserves, protects and manages those values in the area in cooperation with Nyiyaparli People.

5.1.6 Management of heritage sites and social and cultural values

There are several highly significant heritage sites and important social and cultural values that will require management during operations and closure implementation, and which will be considered as part of the closure planning process. These include:

- PMC is an upper tributary of WWC, and as such any development which impacts either waterway or their catchment areas are included in consultations for the Proposal. The Proposal will include construction of two crossings over a section of this creek to link with the current HD1 operation, as well as two potential additional new crossings for the potential realignment of GNH and a new mine access road. Ongoing consultation with Traditional Owners regarding potential impacts to PMC will provide an opportunity for stakeholders to recommend culturally appropriate management measures.
- The highly significant HOPE4-07 and BDH16-03 heritage sites are located within the Proposal, and the conceptual mining footprint has been altered to avoid direct impacts these sites. Geotechnical assessments at relevant features will occur during operations to assess and manage susceptibilities to vibrational impacts associated with blasting. Implementation of a 100m buffer around BDH16-03 will minimise indirect impacts from the mine associated with dust. Access to these sites will made available post-closure. The HOPE4-07 heritage complex is located to the north of WWC, southwest of the HD2 deposit. Consultation with Nyiyaparli Traditional Owners is ongoing in respect of this complex to inform additional management measures.
- The main hill at the BHT deposit, which has intrinsic aesthetic value, providing a sense of place, and the southern façade of the hill will be retained to reduce impacts to visual amenity including from WWC.

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Ongoing consultation with each Traditional Owner group regarding heritages sites and social and cultural values will inform the design of the Proposal and inform closure strategies and outcomes.

The SCHMP, jointly developed with the Nyiyaparli people, includes agreed processes and commitments in respect of the management of broader social and cultural values. Given all mining activities (mine pits and waste rock landforms) are located on Nyiyaparli country, significant impacts have been assessed for Nyiyaparli country. Closure planning will be completed in reference to the SCHMP for additional information and management of these values. The SCHMP is expected to complement, not replace, or duplicate the management and monitoring of significant impacts to factors. The SCHMP addresses social surroundings in so far as to meet the requirements of Part IV of the EP Act. The SCHMP does not replace or duplicate this MCP. The next major update of the MCP will include additional consideration of Special Places as mentioned in the SCHMP and the ACHMP, once available, to inform closure planning.

Significant impacts to Ngarlawangga country would relate to the re-alignment of GNH. Once final alignment of the GNH is determined, an SCHMP will be co-developed with the Ngarlawangga people if the re-alignment impacts Ngarlawangga country.

No SCHMP has been developed for Banjima Country given the part of the Proposal located on Banjima country is limited to infrastructure located on areas of existing disturbance associated with HD1, predominantly transport, ore handling and ancillary (such as power and communications). ACHMPs will be developed with Traditional Owner groups where direct impacts to Special Places, including heritage sites, are identified as being significantly impacted. Where Aboriginal heritage sites cannot be avoided heritage surveys will be used to support a transitional section 18 application under the AH Act and/or an Aboriginal Cultural Heritage Management Plan (ACHMP) subject to the requirements ACH Act section 10-10-5. The purpose of an ACHMP is to manage heritage sites and places with each group and in accordance with the relevant legislation. A Proposal specific ACHMP will be developed in consultation with the Nyiyaparli People

which identifies processes to be followed with regards to Special Places including heritage sites to be avoided.

As no significant impacts have been identified for Banjima, no ACHMP is required for HD2 impacts to Banjima Country.

Heritage sites and social and cultural values of high significance will be managed *in situ* where possible, with Blast Management Plans implemented where required to prevent indirect impacts such as those associated with vibrations and fly-rock.

To ensure appropriate management of risk associated with these social values, the risk title "696240 - Implementation of the closure strategy does not achieve the required cultural heritage outcomes." will be amended to include social values. The risk will be evaluated to ensure that causes, consequence, controls and actions are suitable to reflect the change, and will be included in the next major update of the MCP.

Consultation and collaboration with the Nyiyaparli, Banjima and Ngarlawangga Traditional Owners will be maintained in established forums throughout the life of the operation to ensure that proposed closure strategies address cultural requirements, and that closure outcomes for the site remain appropriate.

5.1.7 Closure access management

Post-closure access to culturally significant sites and places and repatriation of any materials salvaged during mining operations need to be considered as part of closure planning. The repatriation of artefacts following closure of the Proposal has not yet been discussed with the Banjima, Ngarlawangga or Nyiyaparli Traditional Owners but will be included in ongoing consultation. Whilst this MCP does not include specific strategies for maintaining or restoring cultural values, it does recognise that post-closure access to some sites will be required and that where possible these areas will need to be made safe for this purpose. Specific strategies have not yet been developed in recognition that detailed consultation on closure has not yet occurred with Banjima for Rio Tinto to understand their priorities, to inform closure options and align and manage closure expectations.

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Sites situated within zones of instability or abandonment bunds will be managed to avoid inadvertent post-closure impacts or isolation through lack of access. Where sites are unable to be appropriately managed in-situ, further consultation and mitigation will be undertaken with Traditional Owners and the relevant governmental departments.

As part of closure planning, detailed consultation will occur with Traditional Owners, for Rio Tinto to understand their priorities, to inform closure options and align and manage closure expectations. Consultation is intended to include:

- the repatriation of salvaged artefacts;
- management and protection of heritage sites during closure implementation;
- how to facilitate meaningful and beneficial post-mining land access and use by Traditional Owner, including the proposed placement of pit abandonment bunds; and
- how to promote meaningful opportunities to include Traditional Owners, Pilbara Aboriginal People and Pilbara Aboriginal Businesses in closure related work.

Specific engagement with each Traditional Owner group will occur to communicate access restrictions to certain areas of the site due to the potential for geotechnical instability associated with pit crests. Site access will be determined in consultation with Traditional Owners and communicated in a post-closure site access plan to ensure that areas of geotechnical instability associated with pit voids are well understood.

Post-closure access for Nyiyaparli People is addressed in Table 11 of the SCHMP, and states that the MCP is to include provision for installation and/or maintenance of access to Special Places, sites and places of social and cultural importance post-closure, wherever safe and practicable.

These consultations will continue as the site progresses through operations towards closure and be further defined in each iteration of the MCP.

5.1.8 Implications for closure and knowledge gaps

The locations of culturally significant sites and places are considered in closure planning in terms of landform closure strategies and final footprints, water management, and post-closure access requirements. Post-closure monitoring also includes monitoring of culturally significant sites and places were relevant and appropriate. Culturally significant plant species are also a consideration in development of rehabilitation seed mixes.

Closure implications associated with Aboriginal cultural heritage (Section 5.1) include:

- Management of potential mining and closure impacts of water, dust, noise, access to country, culturally significant plants and animals and cumulative impacts that can continue to affect the post-closure land use.
- Restricted access to cultural heritage sites that potentially impact intergenerational cultural heritage.
- Long-term indirect impacts to cultural heritage sites from changes to geotechnical stability, surface water movement and sediment transport require consideration in development of closure strategies.
- Additional social and cultural heritage values for Nyiyaparli are documented in the HD2 SCHMP Closure planning should be completed with reference to the SCHMP for additional information and management of these values.

Closure knowledge gaps associated with Aboriginal cultural heritage impacts, as summarised in Table 6-1, include:

- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments.
- Stakeholder engagement strategy and communications plan to be prepared for community, regulators, and internal audience.
- Undertake specific closure stakeholder engagement to determine social and cultural heritage values to be maintained at the closure of the HD2 and BHT deposits, include salvage and repatriation of sites.
- Undertake visual impact assessment of HD2 and BHT deposits final landform configuration and visibility from GNH and other key vantage points or points of cultural heritage importance.
- Develop seed mix(es) HD2 and BHT deposits in line with progressive rehabilitation targets and consultation with stakeholders.
- Develop consultation tools to assist in communicating closure strategy with stakeholders.
- Schedule consultation with stakeholders over the life of asset to consult on closure strategy options and opportunities.
- Consultation with Traditional Owners on key heritage locations and access requirements post-closure to contribute to the final closure landform or landscape.
- Consultation on closure outcomes, completion criteria and measurement tools.
- Consultation on the final closure landform or landscape and opportunities for Traditional Owners to get involved in closure planning and/ implementation.
- Social and cultural heritage values regarding Special Places for Nyiyaparli, as documented in the HD2 SCHMP, will be incorporated in the next major update of the MCP.

The risk title regarding cultural heritage will be reworded and evaluated to ensure that closure outcomes consider social values in the next major update of the MCP.

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5.2 Socio-economic aspects

Broader socio-economic aspects which will need to be considered in closure planning include impacts to the amenity of the general population. As the region is sparsely populated and there are no town sites and communities in the immediate vicinity of the Proposal, consideration of amenity will be largely restricted to the effect on users of the GNH and tourists and locals accessing higher nearby viewpoints.

Approximately 900 people are anticipated to work at the Proposal which will operate solely as Fly-In Fly-Out (FIFO) utilising the privately-owned airstrip situated at Rio Tinto's West Angelas iron ore mine. Personnel will be housed in a fully serviced accommodation facility at HD1 Village that is covered in the scope of the HD1 MCP, which will also cover any additional facilities installed as an extension to the village. As a result, there is little direct social interaction between the workforce and any surrounding communities.

Mining activities are anticipated to continue at a similar rate within the wider region after the mine ceases to operate. Thus, employment opportunities and mine related services are not anticipated to be significantly impacted by closure of the mine.

Closure of the Proposal will have minimal impact on the Newman town site, therefore the Newman town site is not considered further in this MCP.

Work required for the implementation of closure has the potential to provide economic benefits for local communities including Traditional Owner groups. A closure strategy for HD2 is to "Explore opportunities to partner with Traditional Owners to implement, maintain and monitor rehabilitation, where possible." This may include work such as rehabilitation of disturbed areas, seed collection for rehabilitation and monitoring of rehabilitation sites (refer to Sections 11 and 12 for more information). These opportunities will be considered as part of the Closure engagement strategy for key stakeholders (Table 4-2).

In the SCHMP developed in collaboration with Nyiyaparli, Table 11 indicates that where possible RTIO will invite KNAC to collaborate on the identification and development of opportunities to support Nyiyaparli engagement in closure activities including: seed collection; research and knowledge sharing; and monitoring.

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5.2.1 Implications for closure and knowledge gaps

Closure implications associated with the socio-economic setting include:

- GNH users may be impacted by the closure of the Proposal, particularly as a result of changes to landforms and visual amenity.
- Local communities may be impacted by closure of the Proposal, particularly regarding cessation of opportunities for employment and business opportunities.
- Mining activities are anticipated to continue at a similar rate within the wider Pilbara region after operation of the Proposal ceases, however, Rio Tinto will implement strategies to manage any workforce impacts.
- Closure consultation with Traditional Owners throughout the life of the mine will explore opportunities to partner with Traditional Owners to implement, maintain and monitor rehabilitation, where possible

Closure knowledge gaps associated with socio-economic impacts, as summarised in Table 6-1, include:

- Potential social and economic impacts to be assessed including amenity, public health associated with closure activities, loss of employment and business opportunities.
- Consult with stakeholders to address any potential socio-economic impacts post-closure.
- Undertake visual impact assessment of HD2 and BHT deposits final landform configuration and visibility from GNH and other key vantage points or points of cultural heritage importance.
- Investigate opportunity to allow safe access for viewing/observation of post-closure landform to deter unauthorised access to site.

- Develop consultation tools to assist in communicating closure and potential socio-economic impacts with stakeholders.

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PHYSICAL ENVIRONMENT

5.3 Climate

5.3.1 Local climatic conditions

The closest official Bureau of Meteorology (BOM) weather recording station is at Newman Aerodrome (Station 007176). Climatic information has been captured from this site since 1971 and provides a long-term climate record for the local region. In addition to this, an automatic weather station is maintained at the nearby HD1 operation.

The regional climate can be characterised as arid tropical with two distinct seasons: a hot, wet summer (October – April) and a mild, dry winter (May – September) (BoM 2022). Mean daily maximum temperatures range from 40°C in summer to 22°C in winter Figure 6).

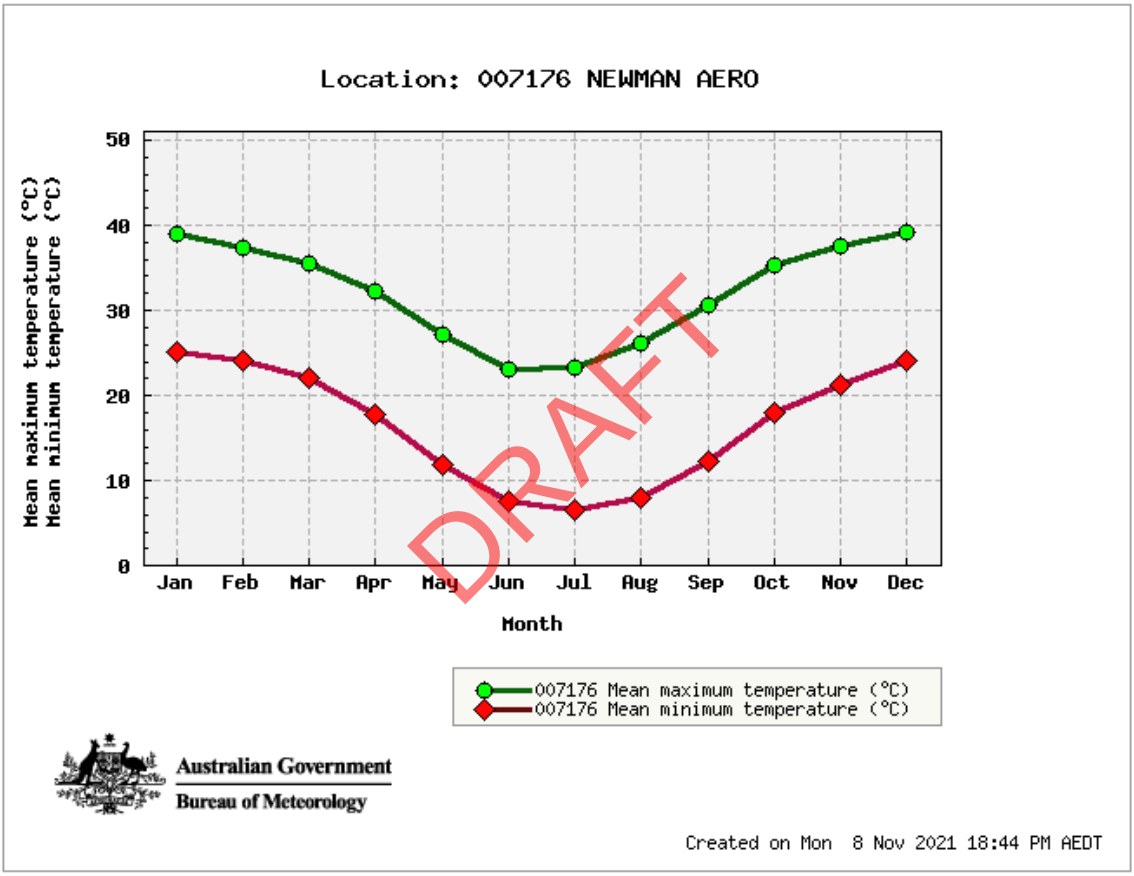

Figure 6: Mean monthly temperatures Newman Aerodrome (1996 – 2021)

Precipitation is driven by summer cyclonic activity, with the lowest average rainfall typically occurring between August and October, with the highest average rainfall falling between December and February (Figure 7).

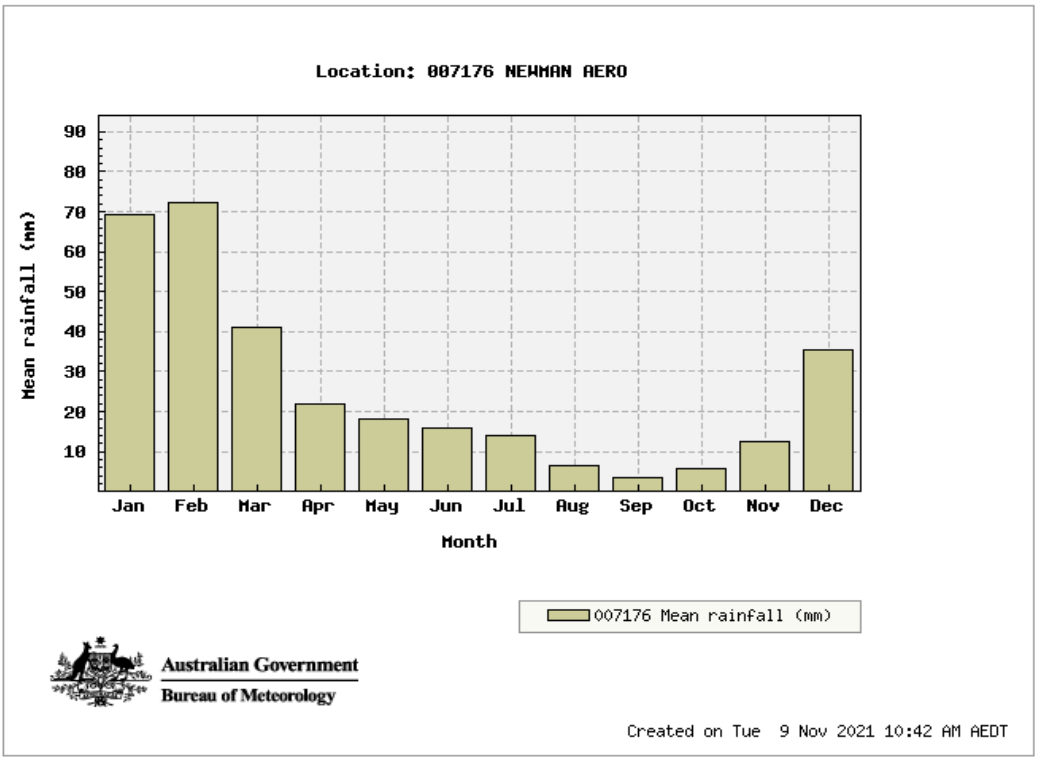

Figure 7: Mean, median and 2021 monthly rainfall at Newman Aerodrome (1971 to 2021)

Precipitation is highly variable throughout the Pilbara, with adjacent areas often receiving varying rainfall volumes throughout the wet season. Annual rainfall records also show significant variation, being driven by the number and intensity of cyclones affecting the region (Figure 8).

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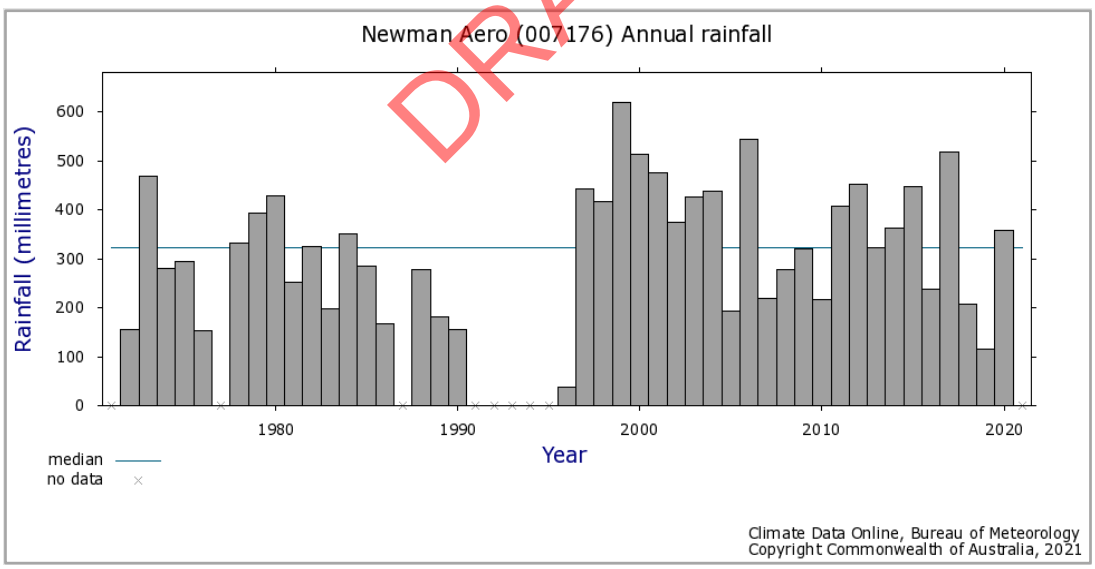

Figure 8: Historical annual rainfall at Newman Aerodrome (1971 – 2020)

The north and north-western coastline of Australia has experienced more tropical cyclones than elsewhere on mainland Australia. Tropical cyclones occur between November and April, with most observed during the late summer. Tropical cyclones can produce damaging wind gusts in excess of 150 km per hour, with heavy rains resulting in regional flooding. Seven tropical cyclones are typical off the Pilbara coast each year, with three expected to make landfall.

Evaporation rates in the region greatly exceed rainfall, which is typical for similar climate conditions around Australia. Average annual pan evaporation rate is 3200-3600 mm/year.

5.3.2 Climate change

Rio Tinto accepts the current view of the Intergovernmental Panel on Climate Change's (IPCC) that global warming is unequivocal, human influence is clear and physical impacts are unavoidable (IPCC, 2022). Rio Tinto understands that climate change will amplify existing risks in mining, port and rail operations in the Pilbara region and recognises a responsibility to act by focusing on a reduction in greenhouse gas emissions (particularly with the use of low emissions technology); and increasing resilience to physical climate change impacts.

For the Pilbara region, climate conditions for 2030 and 2090 are forecast by the Commonwealth Scientific and Industrial Research Organisation (Watterson et al., 2015) to be:

- hotter (both averages and extremes) and drier e.g., in 2030 forecast warming of 0.6°C to 1.5°C;
- potential evapotranspiration will increase in all seasons as warming progresses;
- higher sea levels;
- tropical cyclones may decrease in number, but increase in intensity and duration over the same period; and
- more unpredictable characteristics of other climate-related hazards, including flooding, storm surges and wildfires.

Climate change is a complex issue, with inherent uncertainty about the timing, pace, and severity of possible impacts. Based on climate change projections rainfall reduction will be relatively small in the Pilbara, however, an increase in intensity of extreme rainfall events coupled with the expected rise in temperatures and potential evaporation may have a large impact on the hydrology of the Pilbara region (Charles et. al., 2015).

Risks from climate change to the stability of landforms, mobilisation of contaminants and re-vegetation are some of the identified vulnerabilities. The materialisation of these climate projections is likely to make successful rehabilitation in the Pilbara more challenging.

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5.3.3 Implications for closure and knowledge gaps

Closure implications associated with climate include:

- Optimal timing of rehabilitation works to maximise germination following seeding.
- Waste Rock Landform design to consider the intensity of rainfall events, climatic variation, and the potential for extreme rainfall events.

Closure knowledge gaps associated with climate include:

- Landform evolution modelling will be required to confirm the optimal final Waste Rock Landform design, including physical waste characterisation.
- Flood modelling of the closure landform to consider climatic variation and the potential for extreme rainfall events.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.

5.4 Biogeographic setting

5.4.1 Bioregions

Bioregions for the Australian content have been created as part of a national classification of ecosystems. There are currently 89 bioregions and 419 sub-regions in Australia. Each region is based on similarities in climate, geology, landform, native vegetation and species information.

The Proposal lies within the Pilbara Craton, a bioregion defined by the Interim Biogeographic Regionalisation for Australia (IBRA). The Pilbara bioregion is divided into four subregions: Chichester, Fortescue Plains, Hamersley and Roebourne Plains.

The Proposal is in the Hamersley sub-region (Hamersley PIL03), which is described as "*Mountainous area of Proterozoic sedimentary ranges and plateaus, dissected by gorges (basalt, shale and dolerite). Mulga low woodland over bunch grasses on fine-textured soils in valley floors, and Eucalyptus leucophloia over Triodia brizoides on skeletal soils of the ranges. The climate is semi-desert tropical, average 300 mm rainfall, usually in summer cyclonic or thunderstorm events. Winter rain is not uncommon. Drainage into either the Fortescue River (to the north), the Ashburton River to the south, or the Robe River to the west*" (Kendrick 2001).

5.4.2 Land systems

Land systems of the Western Australian rangelands have been mapped and described by the department of Agriculture and Food outing the distributions and providing comprehensive descriptions of biophysical resources, including soil and vegetation condition. A total of 102 land systems occur in the Pilbara bioregion covering 181,723 km^2. Nine land systems associated with the Pilbara Bioregion occur within the HD2 closure boundary, with the Newman land system the most common, accounting for approximately 39% of the total area (Astron, 2019). The land systems present within the HD2 closure boundary are presented in Figure 9.

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5.4.3 Implications for closure and knowledge gaps

Closure implications associated with landscape include:

- Final landforms will be designed to be sympathetic with the aesthetic values of the surrounding landscape.

There are currently no known closure knowledge gaps associated with land systems.

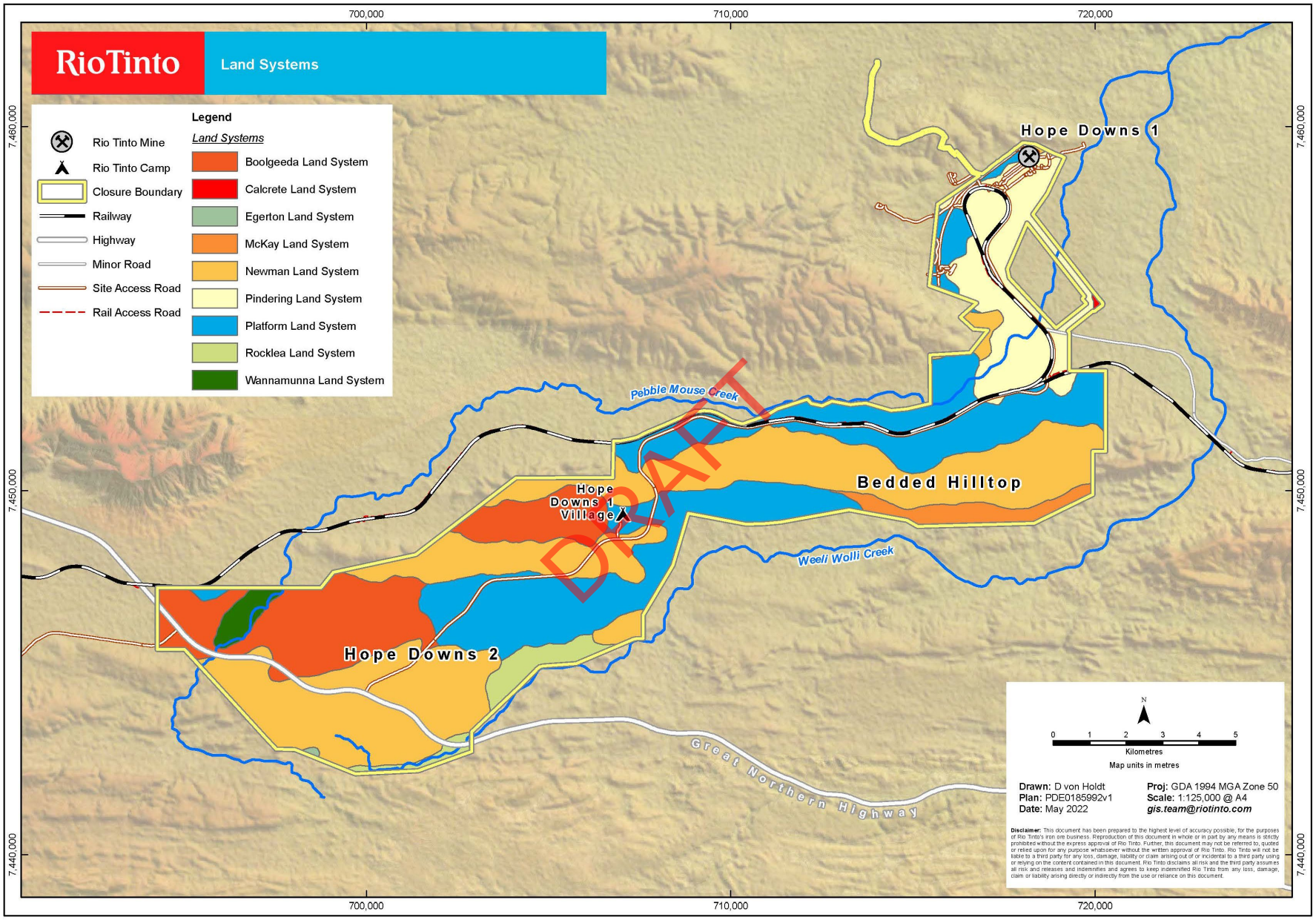

Figure 9: Land systems

5.5 Geology

The Proposal is situated at the south-eastern corner of the Pilbara Craton. The cratonic basement comprises Archean granite-greenstone and is overlain by the Archean-Proterozoic rocks of the Hamersley Basin. These rocks can be divided into three stratigraphic groups: the Fortescue, Hamersley and Turee Creek groups, with the Hamersley Group forming the outcrop at the Proposal.

The Hamersley Group is a sedimentary sequence comprising Banded Iron Formations (BIF), shales and dolomites, with minor felsic volcanic and extensive dolerite dykes and sills. The group contains the Brockman Iron Formation and the Marra Mamba Iron Formation, which together, host most of the known major iron ore deposits in the Pilbara.

The HD2 deposit is a Marra Mamba type ore deposit lying directly adjacent and beneath the GNH, approximately 3 km east of the West Angelas mine turn-off. It consists of east to west trending Marra Mamba Iron Formation, which is mineralised in two places, separated by approximately 2 km. Mineralisation is predominantly contained in the Newman Member but also includes detrital and West Angelas Shale units.

HD2 deposit mineral waste material is contained in the following units:

- Detritals;
- West Angelas Shale;
- Newman;
- MacLeod; and
- Nammuldi.

The BHT deposit is a Brockman type ore deposit in contrast to the other Marra Mamba deposits in the area. The deposit is an east to west striking Brockman Iron Formation ridge. The geology is typically flat throughout the hilltop with some gentle folding. Mapped synforms and antiforms can be seen immediately north of the range front, and the buried Brockman mineralisation extends to >200 m in places, overlain by a detrital sequence containing some mineralised material. Figure 10 shows the dominant geological units and general landscape position for the HD2 deposit, with BHT detailed in Figure 11.

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BHT deposit mineral waste material is contained in the following units:

- Detritals;
- Whaleback Shale;
- Dales Gorge;
- Footwall Zone;
- Mount McRae Shale;
- Mount Sylvia; and
- Wittenoom Formation.

Mineral waste generated at the Proposal is subsequently categorised with respect to the geological origins of the material. More detail on the erodibility of these materials is discussed in Section 5.7.

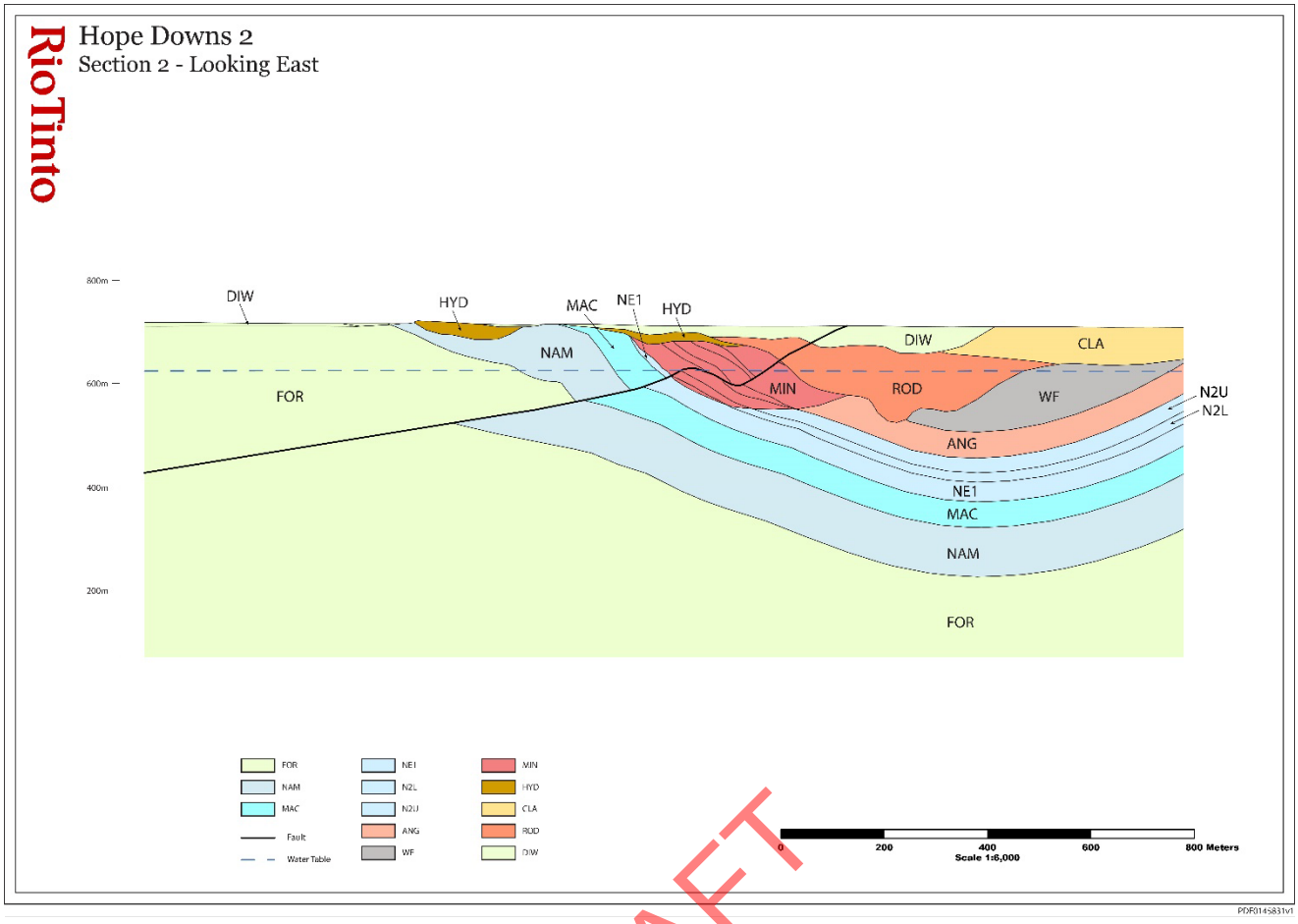

Figure 10: HD2 cross section (looking east)

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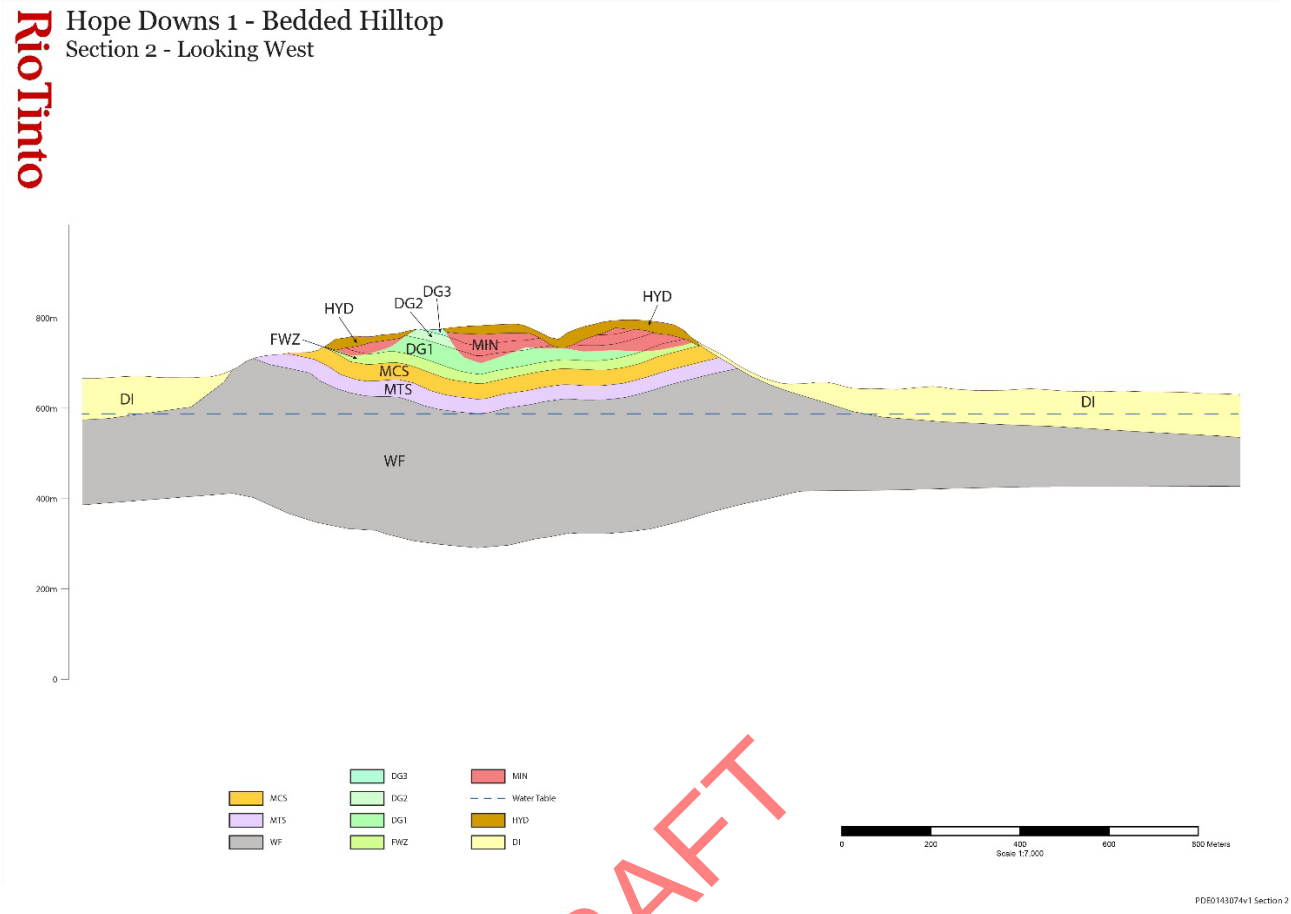

Figure 11: BHT cross section (looking west)

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5.5.1 Geotechnical stability

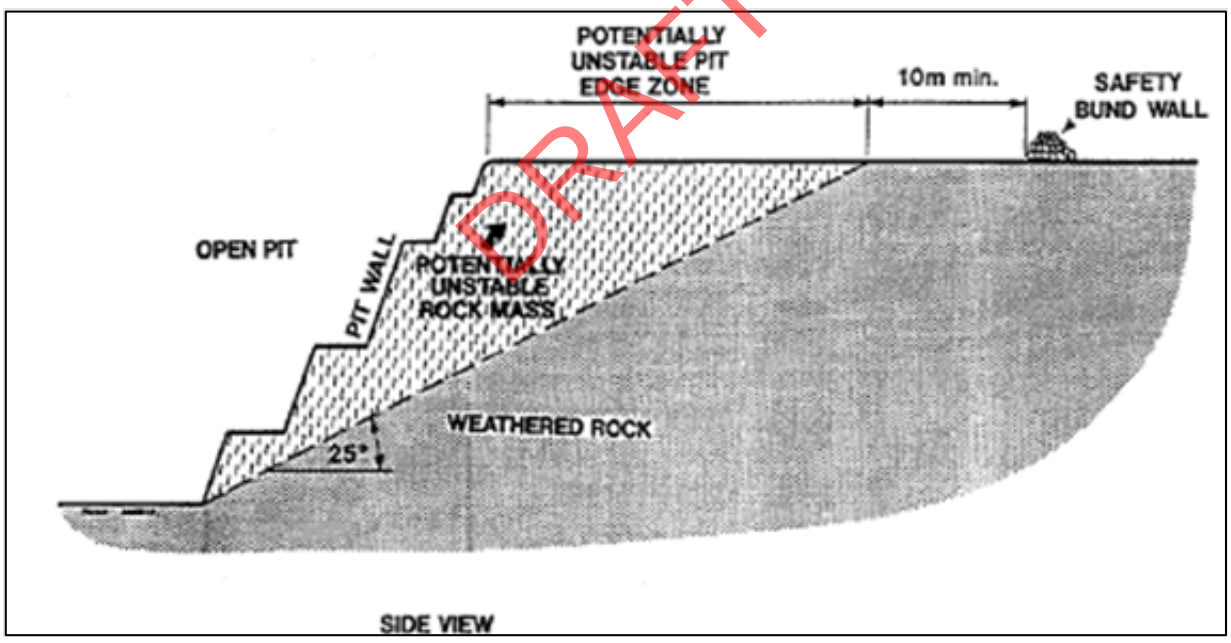
There is no intent to reshape or rehabilitate in-pit areas at HD2 and BHT deposits, and the remaining pit walls will be retained in the same configuration as when mining ceases.

Whilst opportunistic backfill of pits may occur, pit voids will remain after closure. As the pits are AWT, permanent pit lakes will not form, although water may pool temporarily at the base of the voids following heavy rainfall. It is recognised that there will be some degree of geotechnical instability, and that walls will have the potential to collapse in some areas. These areas of potential instability are referred to as the Potentially Unstable Pit Edge Zone (PUPEZ).

5.5.2 Potentially Unstable Pit Edge Zone

Determination of the PUPEZ is based on the angle method described in the former Department of Industry and Resources (now DMIRS) guideline *Safety Bund Walls Around Abandoned Open Pit Mines* (DoIR, 1997). The rock mass units spanning all of Rio Tinto Pilbara operations are categorised in general, as 'weathered' from this guideline, using the conservative assumption that all pit walls are embedded into weathered rock.

A 25° line from the pit toe or decoupling berm is projected to the surface topography. Where backfilling occurs, the pit toe may be considered from the surface of the backfilled area. In addition to this, a 10 m offset from the 25° projection line on the surface is included, plus a 5 m wide and 2 m high abandonment bund. The point at which this projection line intersects the topography back to the pit crest, is termed the potentially unstable pit edge zone (PUPEZ). Figure 12 illustrates the zone of instability methodology used for all pits, adopted from the guideline. The PUPEZ is refined over time with pit design, backfill design and mine plan changes.



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Ref: DoIR, Safety Bund Walls Around Abandoned Open Pit Mines, 1997

Figure 12: Example of zones of instability

Potential zones of geotechnical instability have been identified around the conceptual HD2 and BHT deposit pits covered within the scope of this MCP (Figure 13 and Figure 14). All waste rock landform and stockpile positions will be located outside the PUPEZ boundary to maximise waste rock landform and pit crest stability post-closure. Geotechnical assessments for wall stability and PUPEZ are conducted as part of mine design reviews, however, it is recognised that the true nature of the geology will only be understood once mining has been completed, and this could influence the stability of the pit wall. Geotechnical instability will be assessed throughout the life of the operation and site-specific assessments will be conducted to inform closure strategy and abandonment bund alignments for closure implementation.

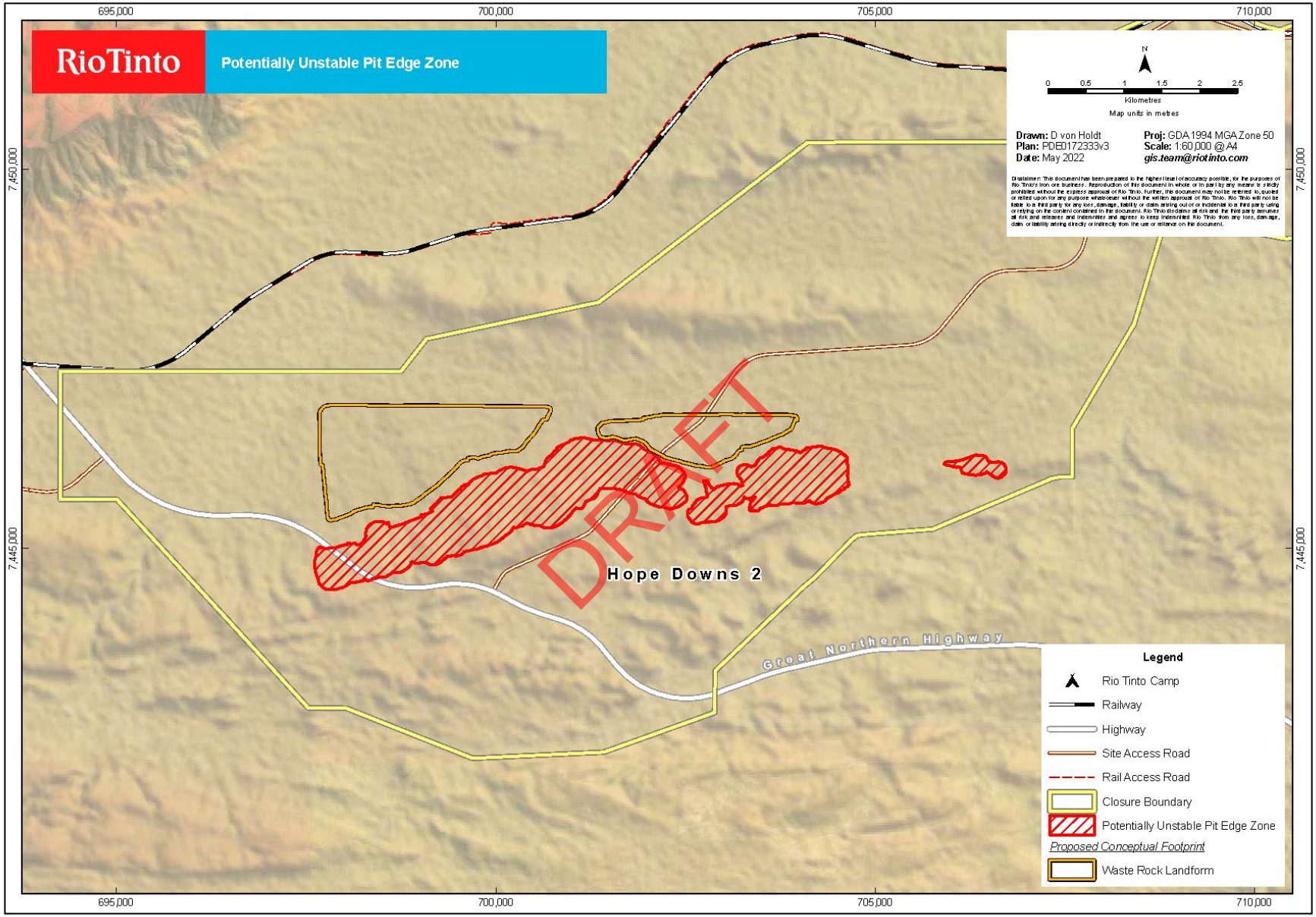

Figure 13: HD2 deposit potentially unstable pit edge zone

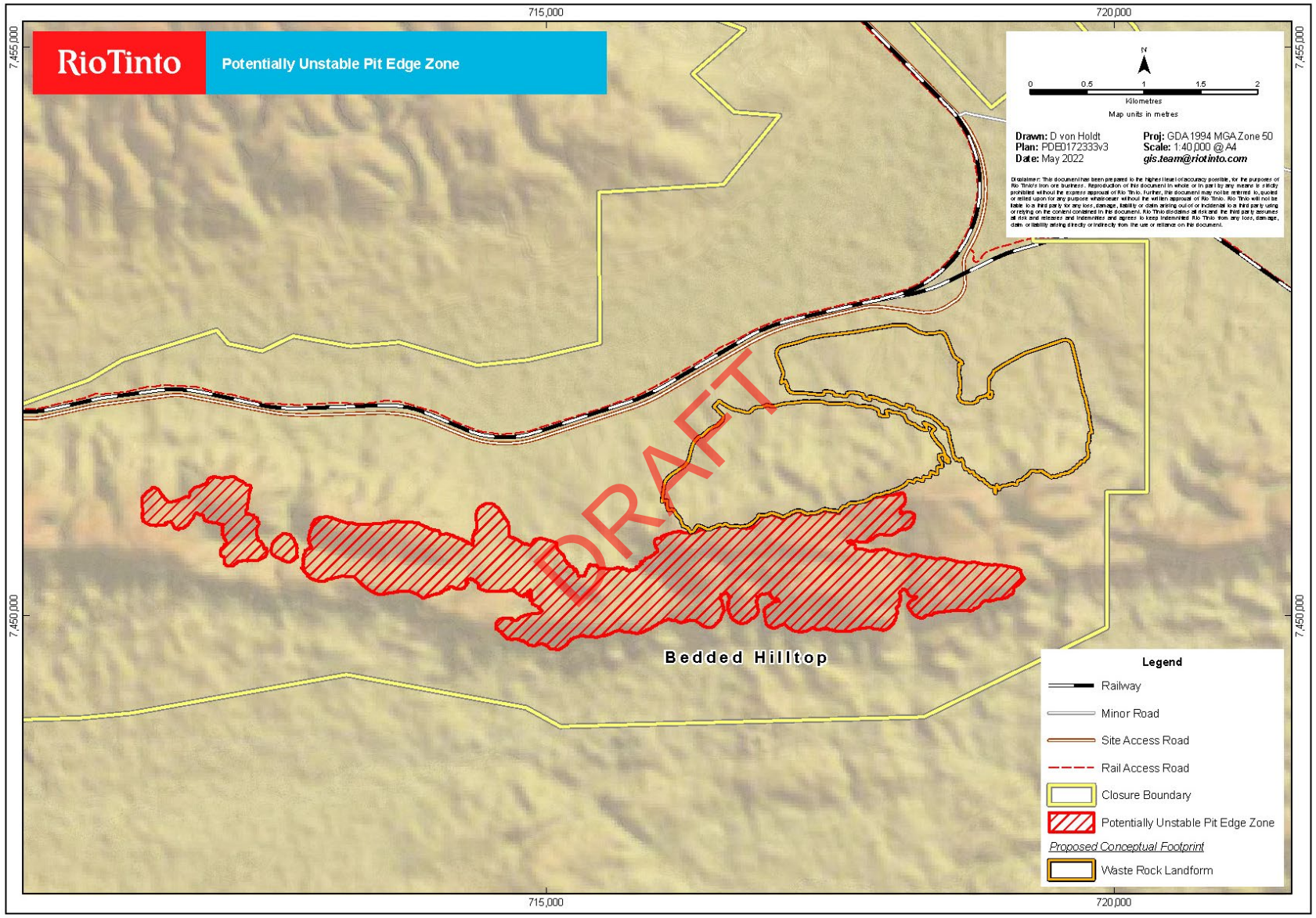

Figure 14: BHT deposit potentially unstable pit edge zone

5.5.3 Implications for closure and knowledge gaps

Closure implications associated with geotechnical stability include:

- Consideration of geotechnical stability risks in the development of closure strategies.
- Rehabilitated waste rock landform footprints will need to be located outside the predicted PUPEZ.
- Development of post-closure access plans, abandonment bund location and designs are informed by the predicted PUPEZs.
- Abandonment bunds will be established outside of the PUPEZ to limit access to pit voids.
- Abandonment bunds will require adequate volumes of competent low erodibility mineral waste which will need to be segregated and stockpiled during LoM.

Closure knowledge gaps associated with geotechnical stability, as summarised in Table 6-1, include:

- Evaluate planned post-closure pit wall stability for HD2 and BHT deposits pits to determine if mitigation is required to prevent wall collapse and PMC creek capture.
- The zone of geotechnical instability or PUPEZ will be revised and updated for HD2 and BHT deposits in each iteration of the MCP to reflect any changes to the mine plan, understanding of the closure landscape and to address any updated flood modelling.
- The location of the proposed pit abandonment bunds for the HD2 and BHT deposits will be revised and updated in each iteration of the MCP to reflect any changes to the mine plan, understanding of the closure landscape and to address any updated flood modelling.
- Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required.
- Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters.
- Site specific geotechnical assessments will be completed for rehabilitation designs of final closure landforms for HD2 and BHT deposits to confirm closure landform safety and stability.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.

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5.6 Public access

5.6.1 Risk of inadvertent access

The issue of public safety is mainly related to potential for members of the public to inadvertently access pit voids (or areas of potential instability surrounding pits) post-closure. Open pits are designed to be stable during the life of the mining operations but may not be stable in the long term as materials weather and erode, leading to instability of sections of the pit walls. These failures would pose significant risks to people if they were to access these areas in vehicles or on foot. As with waste landforms, designs for restricting public access need to be developed on a case-by-case basis after considering a range of factors such as:

- Accessibility of the site (e.g., proximity to towns/major roads/areas of interest).
- Nature of the surrounding landscape (e.g., pits abutting steep natural slopes, floodplains, water courses).
- The availability of suitable material to construct structures (e.g., material for abandonment bunds/ rock structures).
- Pit geology and geometry (e.g., natural stability of the pit, pit backfill).
- The post-closure land use (e.g., preventing cattle from surrounding pastoral leases inadvertently accessing pit voids).
- The location of heritage sites (e.g., sites which may require access post-closure).

The HD2 deposit straddles the GNH, which is proposed to be realigned to allow mining, and therefore, considered a heightened risk in relation to community and/or tourist attention.

Access will also need to be maintained to:

- WWS and WWC;
- third party tenure; and
- significant heritage/cultural sites.

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5.6.2 Abandonment bunds

A review of all planned pit and waste rock landform interactions at HD2 and BHT deposits was undertaken to check compliance to the angle method described in the guideline (DoIR, 1997). The purpose of the guideline is to reduce the likelihood of injury or fatality should a person inadvertently access the pit in a vehicle. These guidelines require a 5 m wide by 2 m high abandonment bund be placed at a minimum distance of 10m around a completed pit outside the PUPEZ.

Using this approach, conceptual abandonment bund locations (in yellow) around the PUPEZ (in blue) have been developed and are presented in Figure 15, Figure 16 and Figure 17.

- For the HD2 deposit conceptual abandonment bunds surround all pit areas, due to flat terrain.
- For the BHT deposit, which is positioned within a range, most of the pit wall is elevated between 50 and 100 m, and slopes are greater than 27 degrees in most instances. As such, terrain around the range is very steep, resulting in the pit crest being inaccessible and abandonment bunds unmanageable around the majority of the pit crest. For the purposes of conceptualisation, bunds have only been nominally located to restrict access in areas where terrain is not a significant barrier.

These conceptualisations are high level, and site-specific geotechnical assessments and consultation with key stakeholders will need to be undertaken to identify the appropriate abandonment bund locations for both deposits. Tasks have been included in the closure task register (Appendix 5) to complete geotechnical assessments, consult with stakeholders and confirm appropriate abandonment bund locations once mining commences.

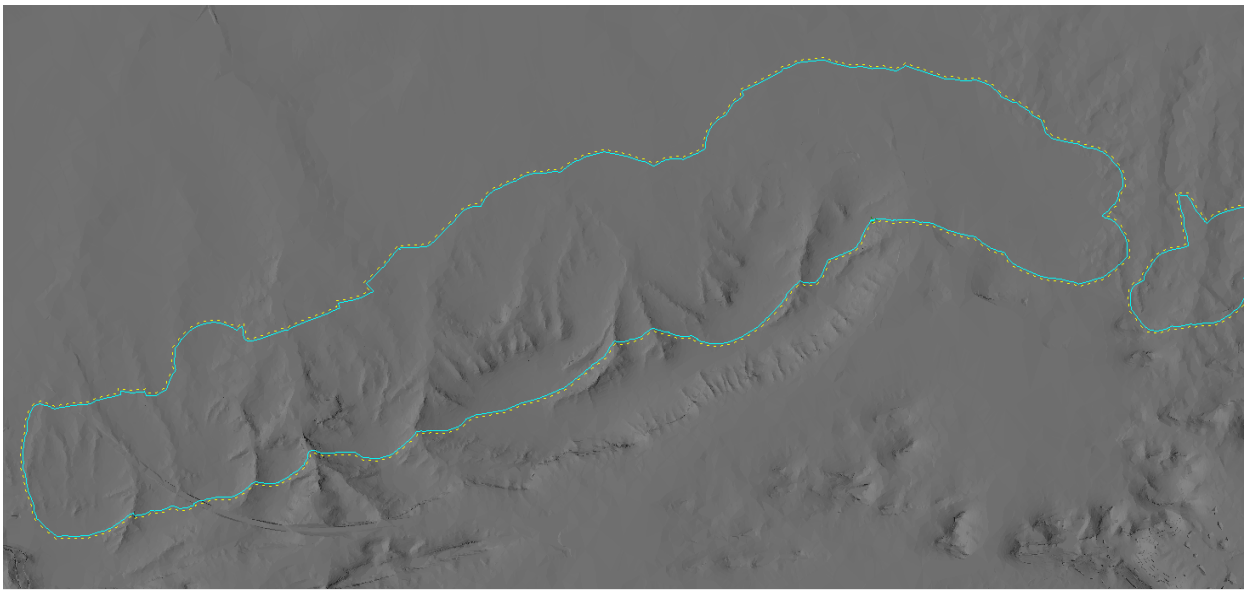

Figure 15: Conceptual HD2 deposit (west and central pits) abandonment bund locations

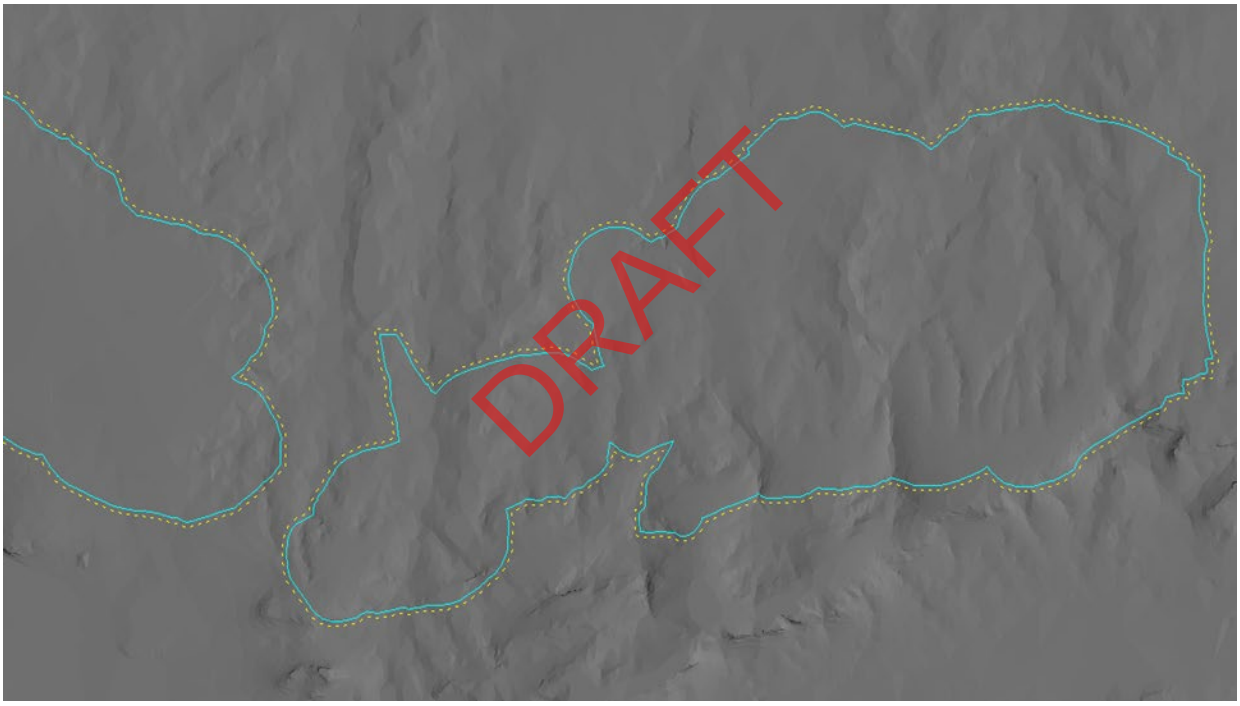

Figure 16: Conceptual HD2 deposit (east pit) abandonment bund locations

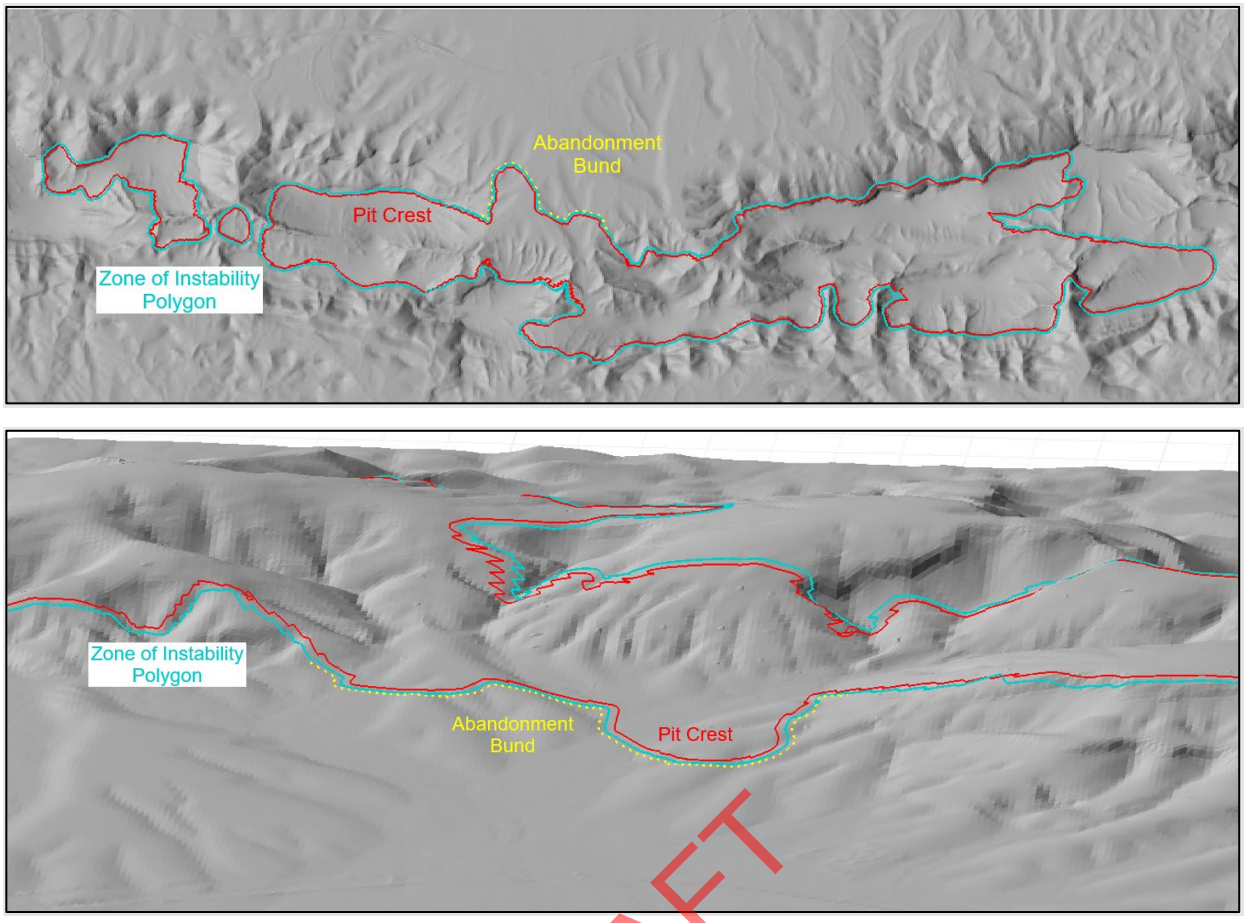

Figure 17: Conceptual BHT deposit abandonment bund locations (in yellow)

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5.6.3 Implications for closure and knowledge gaps

Closure implications associated with inadvertent access include:

- Abandonment bunds will only be placed in areas with potential access exposure and in conjunction with the following additional methods for limiting access to pits:
  - remove or block roads where appropriate (e.g., windrows);
  - use of large, competent rocks to prevent vehicular access but allowing surface water flows;
  - enable safe access to specific areas where required (e.g., sites of cultural heritage significance);
  - install gates along roads that need to be accessed (e.g., to facilitate monitoring); and/or
  - install appropriate signage.
- Abandonment bund location and construction will consider creek flood inundation zones and surface water flows to ensure long-term post-closure stability.
- Abandonment bund location and construction will consider cultural heritage locations and public access routes to ensure long-term post-closure access.
- Rehabilitation of tracks that are not required for monitoring and/or maintenance post-closure, and installation of physical barriers (e.g., earthen bunds / windrows) where appropriate to prevent access.
- Installation of a locked gate on the main access road (and the alternative unsealed access road if it is required to remain post-closure) for the duration of the post-closure monitoring and maintenance period.

- Rehabilitation of all access roads prior to relinquishment and installation of physical barriers (e.g., earthen bunds / windrows), unless the State wishes the roads to remain accessible for whatever reason.

Closure knowledge gaps associated with inadvertent access, as summarised in Table 6-1, include:

- Consultation with Traditional Owners on key heritage locations and access requirements post-closure to contribute to the final closure landform or landscape.
- Consultation with the State on preferences with regards to final closure landform and public access to the post-closure landscape. This will be determined through ongoing consultation during the life of the operation.
- Assess opportunities to allow safe access for viewing/observation of the post-closure landform near the highway to deter unauthorised access to site. If this is considered appropriate to key stakeholders, details will be included in further updates to this MCP.
- Assess the expected post-closure access to the site, and include the installation of additional control measures, where appropriate.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.

5.7 Mineral waste characteristics and inventory

Developing a comprehensive understanding of the types and volumes of materials that will remain at the completion of mining of the Proposal is critical for the effective design, construction and rehabilitation of the closure landforms. Rio Tinto has a well-developed process for the collection, analysis and characterisation of different material types, throughout the life of the asset. Long-term material behaviour can also be predicted through characterisation of representative waste types and correlation to similar waste materials present at other sites.

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5.7.1 Physical characteristics

The key physical property of mineral waste material that is applicable to the closure landform design is its susceptibility to erosion, commonly described as the material's erodibility.

Erodibility can be defined in different ways depending on the erosion prediction tool; however, Rio Tinto considers erodibility of mineral waste using the following two means:

- Erodibility ranking using the Revised Universal Soil Loss Equation (RUSLE), which broadly classifies mineral waste units by erosion risk - low, medium or high.
- Erodibility modelling using the Water Erosion Prediction Project (WEPP) runoff simulation and erosion model to define material-specific landform designs for each mineral waste unit.

5.7.2 Erodibility ranking

The RUSLE seeks to broadly rank mineral waste types into one of three levels of erodibility – low, medium, or high. The RUSLE is an empirical equation that calculates long-term annual erosion rates using five factors that are multiplied together. Two of these factors, erodibility (K-factor) and cover (C-factor), are specifically related to the material. The remaining three describe the rainfall and slope conditions. The K-factor describes the erodibility of the fines fraction (<2 mm diameter) excluding the coarse fraction (>2 mm). The C-factor describes the impact that different surface conditions have on erosion. For this ranking system, surface rock cover is a surface condition that reduces erosion potential.

The RUSLE erodibility ranking system was developed by considering the particle size distribution (PSD) of the fines fraction and the rain-armoured rock cover levels for 36 mineral waste samples from across the Pilbara mine sites. These samples had a wide range of PSD and rock cover levels. Results of this analysis showed that K-factors for the materials assessed are consistent with highly and very highly erodible materials. By themselves, they do not explain the observed differences in erosion potential of the waste materials being managed at the mine sites. However, when the impact of rock cover was included using the C-factor, it was shown that rock cover strongly influenced material erodibility and could explain the observed differences in erosion potential between materials. Mineral waste materials that had rock cover levels >70% were ranked as low erodibility and had an erodibility factor (K-factor multiplied by C-factor) of <0.0009. Waste materials with rock cover levels of 30-70% were ranked as medium erodibility and had an erodibility factor ranging from 0.006-0.0009. Waste materials with rock cover levels <30% were ranked as high erodibility and had an erodibility factor >0.006, as summarised in Table 5-1.

Table 5-1: Erodibility classification of mineral waste

Material classification	Rock Cover Level	K factor (fine fraction <2mm erodibility)	Erodibility factor (K-factor x C-factor)
Low	>70%	High	<0.0009
Medium	30-70%	High	0.0006-0.0009
High	<30%	High	>0.006

The RUSLE ranking system is used to broadly guide rehabilitation planning. For example, materials ranked as low erodibility contain appreciable competent, hard rocks suitable for placement on the outer surface of waste landforms to provide long term erosion protection. Waste materials ranked as medium erodibility can also be placed on the outer surface, however, there are likely more limitations in terms of the batter shapes (e.g., lower lift heights and/or batter angles) that are needed to ensure acceptable erosion rates are met. High erodibility ranked waste materials, where present in large proportions, require the application of conservative rehabilitation design parameters (e.g., low lift heights and/or gradients) or selective placement of more erosion resistant waste to prevent unacceptable erosion.

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5.7.3 Erodibility modelling

Although the RUSLE ranking system provides broad guidance, it is not used to define the landform designs that are adopted. This is done through physical measurement of the erodibility parameters that are used in conjunction with site-specific climate data within the WEPP runoff/erosion model. The Rio Tinto Pilbara WEPP model predicts runoff, erosion, and deposition for hillslopes and catchments, using inputs generated from rainfall stimulation plots using waste rock lithologies and a 100-year climate sequence developed from BoM weather stations, from sixteen Rio Tinto Pilbara mines.

The outputs of the WEPP model are compared to acceptable long-term soil erosion rates. Work completed by Landloch Pty Ltd (2018), on behalf of the Pilbara Rehabilitation Group, established an acceptable long-term erosion rate of 6t/ha/yr. which is consistent with the rates of soil renewal and naturally occurring erosion, and consistent with a surface with a low tendency for rill and gully erosion.

5.7.4 Erosion ranking

The erodibility potential of waste types for the Proposal have been assessed using extrapolation from equivalent material at similar sites, most specifically from HD1. Several materials specifically sourced from HD1 stockpiles were recently tested, including a Detrital sample, a Limonite (a type of Detrital) sample, and two samples of Mount Newman Member rock-type. Previous testing for a Hydrated Zone waste and two other samples of Detrital also exist for HD1. Three examples of Dales Gorge material are available from Tom Price and Western Turner Syncline, and two examples of West Angelas Shale and one Detrital example is also available from West Angelas and Marandoo. These materials broadly characterise 84% of the waste types identified at the HD2 and BHT deposits. Table 5-2 lists the HD2 and BHT deposits and

overall Proposal waste material types and percentages of total mineral waste predicted to be generated during operations along with erodibility characterisations. These materials will be used to are used to inform rehabilitation parameters adopted across the Proposal.

A portion of the material to be contained within waste rock landforms is characterised as low erodibility (competent), although within individual waste rock landforms, varying proportions of medium to high erodibility material are expected to occur. For the Proposal, 58% of waste material is of low erodibility (competent), with 37% characterised as high erodibility (soft) and 5% medium or undefined erodibility. The erodibility characterisation for the HD2 and BHT deposits varies considerably.

- HD2 deposit has 69% of waste material characterised as high erodibility (soft), with 23% characterised as low erodibility (competent) and 8.5% currently characterised as medium or undefined erodibility.
- BHT deposit is conversely comprised of 90% low erodibility (competent), 8% high erodibility (soft) and 2% medium or undefined erodible waste material.

The erosion classification of individual landforms is included in Appendix 6 and the material characterisation report (Landloch, 2020) for the Proposal can be found in Appendix 7.

The materials characterisation work completed specifically for the Proposal (2020) notes that generally material types at HD1 and HD2 perform similarly to those across the Pilbara, with the following exceptions:

- Detritals geological unit can achieve a uniform gradient of 20 degrees and height of 7 m.
- Some detrital strands are more erosion resistant, specifically Colluvium detritals and, Rounded detritals (col and di) geozones and Limonite detritals achieving maximum stable heights of 15 m at 20 degrees.
- Newman member materials are more erosion resistant and are stable at geometries of 20 degrees at 15 m lift heights.
- Hydrated material is more erosion resistant than average, stable at geometries of 20 degrees at 20 m lift heights.

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Current landform designs are based on waste material characterisation and additional findings (Appendix 6). Further work is planned to understand the strand-specific characteristics of detritals, prior to updating landform designs accordingly. Landform design is further discussed in Section 5.7.

The parameters for waste and soil samples derived from HD1 sampling are consistent with parameters measured from reference soil sites located across other Rio Tinto mine sites; WEPP-predicted erosion for site-specific material was found to be similar to erosion predicted using Pilbara-wide parameter values more commonly used to determine landform designs. Therefore, it is concluded that batter geometries generated using the Pilbara-wide erodibility parameters will be suitable for use across the Proposal. Details of mineral waste present across the Proposal are summarised in Table 5-2 and Table 5-3.

Table 5-2: Waste material erodibility characterisation by type (HD2 and BHT deposits)

Waste Type	Unit	Erodibility	HD2 deposit	HD2 deposit	BHT deposit	BHT deposit	Proposal	Proposal
		High - Low	(kt)	%	(kt)	%	(kt)	%
West Angelas Shale	ang	High	58,848,388	24	0	0	58,848,388	11
Detritals - Clay	cla	High	10,761,129	4	0	0	10,761,129	2
Detritals - poorly unconsolidated	di	High	56,790,523	23.5	2441805	1	59,232,328	11
Detritals - moderate unconsolidated	dm	High	2,187,343	1	2140889	1	4,328,232	1
Detritals	li	High	1,813,770	<1	3965283	1	5,779,053	1
Mount McRae Shale	mcs	High	0	0	6979056	3	6,979,056	1
Detritals - pisoliths	pi	High	0	0	5180946	2	5,180,946	1
Red Ochre Detritals	rod	High	39,992,407	16.5	0	0	39,992,407	8
Whaleback Shale	WS	Medium	0	0	1,247,637	<1	1,247,637	<1
Detritals - Cemented	ca	Low	72,699	<1	2804473	1	2,877,173	1
Dales Gorge Member	dg	Low	0	0	210,275,696	77	210,275,696	41
Footwall Zone	fwz	Low	0	0	32837768	12	32,837,768	6
MacLeod Member	mac	Low	17,484,930	7	0	0	17,484,930	3
Newman Member lower	n2l	Low	5,838,414	2.5	0	0	5,838,414	1
Newman Member upper	n2u	Low	7,964,493	3	0	0	7,964,493	2
Nammuldi Member	nam	Low	5,497,420	2	0	0	5,497,420	1
Newman Member	ne1	Low	19,853,867	8	0	0	19,853,867	4
Undefined	rock	Undefined	14,531,765	6	4729015	2	19,260,780	4
Wittenoom Formation	wf	Undefined	343,105	<1	0	0	343,105	<1
Mt Sylvia Formation	mts	Undefined	0	0	128739	0	128,739	<1
Fortescue Group	for	Undefined	400,701	<1	0	0	400,701	<1
Total			**242,380,956**	**100**	**272,731,307**	**100**	**515,112,263**	**100**

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Table 5-3: Waste material erodibility characterisation summary (HD2 and BHT deposits)

Erodibility	Total waste (kt)*	Total waste (%)
Low	302,049	58%
Medium	841	<1%
High	142,742	37%
Currently undefined	69,479	5%
Total	**515,111**	**100%**

*Minor difference between the kt totals in Table 5-3 and Table 5-4 is due to rounding.

5.7.5 Batter selector tool

Rio Tinto and Landloch Pty Ltd undertook an extensive project in 2010-2012, along with several detailed studies since that time, to source erodibility data for a range of materials across Rio Tinto's Pilbara mine sites. The establishment of a database defining the erosion characteristics of the predominant mineral waste units has defined stable landform batter geometries used to directly inform waste rock landform design and rehabilitation planning.

The Batter Selector Tool (BST) uses these erosionally stable batter geometries to develop 3D rehabilitation landform designs that considers long-term erosional stability. The batters within the BST are predicted to have long-term average annual erosion rates (averages over the entire batter) of <5t/ha/y, and long-term peak erosion rates (at any point on the slope) of <10 t/ha/yr. These values are set such that the potential for rill initiation is limited, therefore significantly reducing the occurrence and development of more significant erosion features, such as gullies. In addition to height, gradient and profile shapes, the BST sets minimum berm widths and back sloping angles that have been developed from WEPP predictions of runoff and erosion to determine the required berm catchment capacities.

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The BST provides individual waste rock landform design options that would result in stable slopes that meet the Rio Tinto landform design guidelines, by considering site specific rainfall and the waste types within an individual WRL. The preliminary closure designs, using the BST, for WDs and LG stockpiles at the Proposal are presented in Appendix 6. These designs will be refined and updated once physical characterisation of mineral waste units from the Proposal have been completed.

5.7.6 Principles of waste rock landform design

Mineral waste rock landforms and landbridges located on mine sites that are operated by Rio Tinto are designed and rehabilitated in accordance with Rio Tinto's Landform Design Guidelines, which provides guidance on the objectives of waste rock landform design, which is to achieve dumps that are:

- safe;
- stable;
- vegetated;
- non-polluting;
- compatible with the agreed post-mining land use;
- progressively rehabilitated;
- appropriate surface treatments; and
- links to other relevant internal and external guidance material.

These Guidelines are updated on a regular basis to incorporate lessons from research, studies and rehabilitation implementation projects. The most significant update occurred in 2012, to provide design

criteria for waste rock landforms and landbridges based on the specific waste types present. This was the result of several years of materials testing and landform evolution modelling studies of wastes typically found in the Pilbara, with design recommendations based on the assumption that an average erosion rate of 5t/ha/year (with a maximum of 10 t/ha/year) will be acceptable. Further studies have since been undertaken on additional waste types, and this resulted in further minor updates in 2014, 2016 and 2019. An ongoing sampling campaign commenced in 2020/21 to further refine material characterisation across Rio Tinto' Pilbara sites. This work will inform closure planning for the Proposal and final landform design. Any changes to landform design for the Proposal will included in subsequent MCP submissions. This work will also inform The Landform Design Guidelines and updates will be made as required.

A comprehensive summary of materials characterisation for the Proposal and across the Pilbara is presented in Section 5.7 (Appendix 7). Ongoing materials characterisation work will continue as the site commences operations and progresses towards closure. It should be noted that erosion modelling is conducted on the conservative assumption that slopes are not vegetated, however, vegetation is expected to establish on all slopes, thereby further reducing the erosion potential.

5.7.7 Erodible mineral waste management

As outlined in Section 5.7, a significant faction of the mineral waste across the Proposal is comprised of geological units that are generally classified as being of high erodibility (e.g., detritals, shales) with the more competent BIF geology that is common elsewhere in the Pilbara present in lower proportions. However, there is a significant proportion of hydrated material available, particularly associated with the BHT deposit, which is classified as having low erodibility. An action is included in the closure task register (Appendix 5) to undertake further waste characterisation to better define dump erosion potential.

The primary landform design approach proposed for both the HD2 and BHT deposits is the batter and berm style landform. The slope angle, berm width and batter height proposed is based on the expected erodibility and physical characteristics of the dominant waste type/s within the landform.

The Landform Design Guidelines (RTIO, 2020) indicate that if competent material (i.e. low or medium erodibility) is present in appreciable volumes within a waste landform, or is used to cap the outer surface, then a linear berm and batter design with specifications as presented in Table 5-4 will ensure the HD2 and BHT deposit waste rock landforms and landbridges are appropriately stable post-closure. Management options have been reviewed with respect to the mine sequence, considering frequency of occurrence of highly erodible waste material, availability of pits for in-pit backfill, availability of materials for capping and stockpile requirements for capping.

One or more of the following closure management approaches will be employed for highly erodible waste:

- selective handling to ensure encapsulation of more erodible waste;
- placement of material into exhausted pits;
- placement of low erodibility material on the outer surface of the landform (wrapping); and/or
- appropriate landform design parameters (including shallower batter angles and wider berms, lower lift heights).

The proportion of high (high to moderate detritals) erodibility material varies across the Proposal with some areas having a higher proportion of competent material present (HD2 deposit waste has a higher content of highly erodible material compared with BHT deposit waste). It should be noted that the current landform design for the HD2 deposit waste rock landforms consider erosion resistant detritals as described in Section 5.7.4, with designs favouring a conservative approach of maximum 7 m lift heights where a high (>50%) percentage of highly erodible material is present (Table 5-4). Erodibility studies to date indicate that where West Angeles Shale is included in high proportions a maximum of 5 m lifts is recommended, however this material is not present in significant quantities at HD2 or BHT deposits. Further work is underway to understand the strand-specific characteristics of detritals and the geological units prior to updating landform designs accordingly (Appendix 6Appendix 6).

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Table 5-4: Waste rock landforms rehabilitation berm and batter design specifications

Design specifications	Low erodibility material	High erodibility material
Maximum slope angle of lift	20°	20°
Maximum height of lifts	20 m	7 m
Minimum berm width	10 m	10 m
Minimum berm angle	11° (back sloping)	11° (back sloping)

Inert waste rock landforms at the HD2 deposit have significantly higher quantities of highly erodible material; 69% of waste material is characterised as high erodibility (soft), with 23% characterised as low erodibility (hard) and 8.5% currently characterised as medium or undefined erodibility. Conceptual waste rock landform designs have been based on high erodibility landform design criteria (Table 5-4) and known materials characterisation, further work is required once the HD2 deposit commences operations to characterise waste and identify appropriate storage. Table 5-5 outlines the conceptual rehabilitation parameters of the HD2 deposit waste rock landform at closure.

Table 5-5: HD2 deposit rehabilitation parameters

Landform name	Waste volume (Mm^3)	Slope angle (°)	Lift height (m)	Berm width (m)	Berm slope (°)	Footprint (ha)
HD2 DP_NW (Goanna)	174	20	7	10	3	269
HD2 DP_NC (Tortoise)	34	20	7	10	3	77

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Inert waste landforms at the BHT deposit are conversely comprised of 90% low erodibility (hard), 8% high erodibility and 2% medium or undefined erodible waste material. The conceptual dump designs have been based on low erodibility landform design criteria (Table 5-4) and known materials characterisation, further work is required once BHT commences operations to characterise waste and identify appropriate storage. Table 5-6 outlines the conceptual rehabilitation parameters of BHT deposit waste rock landforms at closure.

Table 5-6: BHT deposit rehabilitation parameters

Waste landform name	Waste volume (Mm^3)	Slope angle (°)	Lift height (m)	Berm width (m)	Berm slope (°)	Footprint (ha)
BHT DP_NELG	125	20	20	10	11	207
BHT DP_NEWD	83	20	20	10	11	206

Waste rock landform designs have been derived based on slope design parameters from the Landform Design Guidelines, taking into consideration material characteristics and recommendations as specified in Appendix 6. All external landforms that remain at closure will conform to the Rio Tinto Landform Design Guidelines including active management of water infiltration and/or shedding from both upper and lower surfaces, and perimeter bunding to prevent ponding of water at the toe. There may be changes to final landforms in future iterations of the MCP due to future changes in the LoM Plan, backfilling requirements, abandonment bunds and material characteristic testing; these designs are therefore subject to change.

No rehabilitation of in-pit waste rock landforms or in-pit landbridges is proposed where the waste landform has no potential to impact on the ex-pit environment (i.e., any sediment generated will be fully contained

within an internally draining pit) and contains only inert material. No re-profiling of pit walls or rehabilitation of pit floors is proposed. Rehabilitation of the final surface of landbridges planned to remain at closure will occur in accordance with standard procedures, as per the requirements for inert waste rock landforms. Landbridges for the Proposal is a key waste landform risk for the BHT closure landform. Rio Tinto has commissioned landform evolution modelling (LEM) to review the technical challenges associated with these landforms. Further work in landbridge and closure landform design is planned prior to the next submission of the MCP. Therefore, conceptual landbridge rehabilitation strategy is presented in Table 5-7 and rehabilitation parameters in Appendix 6, and presented in Figure 46. A task to complete LEM and update closure landform designs has been added to the closure task list in Section 6.

Table 5-7: BHT landbridge rehabilitation strategy

Landbridge name	Waste volume (Mm^3)	Rehabilitation strategy	Footprint (ha)
BHT LB_West	6.0	The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.	38.6
BHT LB_CEN	0.7	This landbridge is in pit and does not require a rehabilitation design as will be fully removed at closure.	12.5
BHT DP_Central 3	0.9	The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.	8.2
BHT LB_East 6	1.6	The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.	10.1
BHT LB_East	1.67	The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.	38.6

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Low grade ore will be stockpiled in a separate location (see Figure 4) on-site for future use; however, market conditions change over time and there is potential that the stockpiles will remain in-situ at the completion of mining. Therefore, Rio Tinto will manage the stockpiles as if they are waste rock landforms and plan to rehabilitate them if required. These stockpiles have been included in the material inventory presented in Section 5.8.3.

Conceptual closure landform rehabilitation design criteria are detailed in Appendix 6, based on site-specific assessment of materials. A multi-disciplinary pit and waste rock landform design sign-off process is conducted, which considers landform design guidelines and provides rehabilitation designs where appropriate. Performance of rehabilitation designs will be reviewed during the life of the mine.

5.7.8 Geochemical characteristics

Rio Tinto has undertaken an extensive program of geochemical testing over several years to understand the risks associated with the exposure of various waste units common to mining operations in the Pilbara (Rio Tinto 2008), including low Sulphur materials that have traditionally been considered to present a low Acid and Metalliferous Drainage (AMD) risk but may pose a Neutral Metalliferous Drainage (NMD) risk. This knowledge has been used to develop a geochemical risk assessment process (Green and Borden, 2011), which:

- identifies materials commonly associated with geochemical risks (materials characterisation);

- establishes Sulphur content as an indicator of acid generation potential;
- undertakes static testing of materials to identify materials with AMD potential (e.g., acid base accounting, multi-element analysis); and
- undertakes kinetic testing of materials identified as having AMD potential.

This information is used in combination with the position of the material relative to the proposed final pit shell to estimate the amount of potentially reactive material per block of material mined to determine an overall geochemical risk for the deposit.

An AMD risk assessment has been completed for the Proposal in 2020 (Appendix 9) which includes all relevant waste lithologies present at the site, and analyses have been completed in accordance with the Rio Tinto standards and processes. Test work has included Acid Base Accounting (ABA), total Sulphur and multi-element analysis, mapping the black Mount McRae Shale against the final pit designs and mining models and mapping the position of samples relative to the water table.

5.7.9 Total Sulphur and geochemical characterisation

To date 151,258 waste samples have been analysed for sulphur content; with 89,006 samples (including 29,978 in pit samples) analysed at the HD2 deposit and 62,252 samples (including 21,786 in pit samples) analysed at the BHT deposit (Appendix 9 and Appendix 10). Of these, majority of the samples located at depth below the approved pit shells (i.e., in below water table, BWT deposits) contain Sulphur with concentrations >0.3%. The proposed AWT mining activities will not disturb these materials and therefore there is no requirement to manage AMD/NMD risks from these high Sulphur materials. It should be noted that the pit shells might change over time and updates to the geological and mining models will be made; therefore, closure strategies regarding this aspect may change to maintain the environmental outcome.

As detailed in Appendix 8 and Appendix 9, subsequent to the total Sulphur analysis, geochemical characterisation (acid base accounting) has been undertaken on 96 drill hole waste rock samples from 10 different stratigraphic units (53 samples from the BHT deposit and 43 samples from the HD2 deposit) to date (Appendix 9). Of these, 10 samples were lignite material, which showed the greatest potential for acid generation and metal release, with all samples classed as Potentially Acid Forming (PAF). For the remaining 86 samples, two samples, one from the Dales Gorge Member and one from the Footwall Zone, were classed as PAF in a low capacity (<5kg H2SO4/t) to generate acidity. The 20 Wittenoom Formation samples were all classed as Non-Acid Forming (NAF) and had considerable Acid Neutralising Capacity (ANC). The remaining 64 samples were classified as NAF or Uncertain.

Following the ABA testing, a total of 25 samples, including 4 PAF lignite samples, were subjected to a static 2:1 DI (de-ionised) water leach test. All the PAF samples generated acidic leachates (pH ~2.4) with the highest Electroconductivity (EC) range (2,610 – 24,900 µS/cm) and solute concentrations. The NAF samples generated circum-neutral leachates with low solute concentrations and most of the other metals and metalloids recorded levels at or slightly above the limits of detection. It should also be noted that leach testing results can't be directly correlated with the conditions experienced when mining of these materials, as the solid to liquid ratios are likely to vary as a result of climatic factors and material volumes (Appendix 8).

The geochemical characterisation therefore indicates that the AMD risk for the Proposal overall is expected to be low. Any changes to the mine plan over time will require a re-evaluation of this risk and appropriate actions to ensure it remains low. Further testing of BHT (detrital) lignite materials is required once mining commences.

5.7.10 PAF operational management

Although the AMD risk posed by mining landforms and pit voids for the Proposal is considered low, where the black Mount McRae Shale is unexpectedly intersected during mining, PAF management may be required. Rio Tinto operations comply with the *Spontaneous Combustion and Acid Rock Drainage (SCARD)*

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Management Plan, Rio Tinto 2021b V7 (Appendix 11) in the event PAF is identified during mining operations.

The *SCARD Management Plan* (Rio Tinto, 2021a) outlines the process for ongoing assessment of waste rocks to identify PAF rock types that have not been previously flagged during ore block modelling, and the procedures for PAF material segregation, storage, and operational accountabilities for PAF material management to avoid environmental, safety and health risks.

5.7.11 Fibrous minerals

Naturally occurring fibrous minerals can be found in many parts of Western Australia but are particularly prominent in the BIF of the Pilbara. At Rio Tinto's Pilbara operations, fibrous minerals are generally encountered in waste material from BWT Marra Mamba Iron Formation but have also been encountered in other stratigraphic units including the Brockman and Joffre Iron formations. Fibrous minerals may also occur as clasts found within overlying alluvium cover. Fibrous minerals pose a risk when fibres of a respirable size become airborne and are inhaled. The *Rio Tinto Iron Ore (WA) Fibrous Minerals Management Plan* (FMMP) (Rio Tinto, 2020a) describes guidelines for the management of fibrous minerals encountered during mine production and at closure, such as the encapsulation of intersected fibrous mineral waste in non-fibrous mineral waste within a waste rock landform.

Riebeckite is the most common mineral associated with fibrous minerals encountered at the Proposal. Riebeckite is usually found in fresh (unweathered) BIF. The asbestiform variety of riebeckite is crocidolite, or blue asbestos. The presence of riebeckite does not necessarily pose a fibrous mineral risk, but it is a precursor mineral to crocidolite, therefore, there exists a likelihood of encountering crocidolite. If present, crocidolite seams would primarily occur within the unmineralised Marra Mamba Iron Formation. In addition, crocidolite may also occur in BIF clasts found within the overlying alluvium cover.

Fibrous mineral waste is not expected to be exposed during operations based on the current life of mine plan at the HD2 or BHT deposits.

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5.7.12 Implications for closure and knowledge gaps

Closure implications associated with mineral waste characteristics and inventory include:

- Final landform designs will be based on the physical characteristics of the waste material. Based on the volume of high erodibility waste rock at the HD2 deposit, stockpiling of rock armouring material will be required. In addition, abandonment bund material will be incorporated into mine design reviews to ensure this material is stockpiled and available at closure.
- The geochemical assessment of waste rock will be reviewed and updated periodically or following changes to the pit design.
- Based on the low risk of both PAF, metal-enriched and fibrous mineral waste, it is not currently anticipated that stockpiling of rehabilitation materials with specific characteristics to enable encapsulation will be required.

Closure knowledge gaps associated with mineral waste characteristics and inventory, as summarised in Table 6-1, include:

- Site specific physical waste characterisation will be progressively undertaken when each mineral waste unit becomes available during mining operations.
- Include HD2 and BHT deposit materials in updates of the BST.
- Undertake further testing of BHT (detrital) lignite materials when geological units become available during mining operations as per the SCARD management plan.
- Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters.

- Revise waste rock landform rehabilitation and overall closure landform designs based on physical waste characterisation, BST parameters, hydrological and ecological factors and stakeholder consultation as required.
- Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.

5.8 Soils

Topsoil is an important factor in achieving high quality rehabilitation results. Characterisation of properties provides an indication of their potential impacts on vegetation establishment, growth and landform stability; although it is important to recognise soils may be altered as part of mining processes. Appropriate characterisation can also help ensure soils with adverse properties are avoided in rehabilitation.

In the Pilbara, hills and rock ridges which represent the surface expression of the Marra Mamba Iron Formation, have extensive areas without soil cover and the soils that do occur are shallow and skeletal. Rocks of this formation weather very slowly, and any soil which does form tends to be transported into the surrounding valleys and plains due to the sparse vegetation cover and erosion force of heavy rains derived from thunderstorms and cyclones.

The soils on slopes, although having had more time to develop than the soils of the adjacent ridges, are still influenced by the parent rock and may be shallow and stony sands or loams. On pediments, older pediplains and alluvial plains, hard alkaline red loamy soils tend to be dominant, and may be considered as the regional mature soil type. The surface of these areas may contain a layer of small gravel, derived from the more resistant rocks in the area.

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In 2021 a topsoil soils assessment was conducted for soils collected as part of exploration drilling locations for both the HD2 and BHT deposits; the assessment collected a total of 38 samples (23 and 15 respectively) across both deposits (Landloch 2022). The assessment analysed the physical and chemical properties of the soils for the purposes of rehabilitation post-closure.

Soils collected at the HD2 deposit reside within the Newman, Platform, and Boolgeeda land systems, while those identified at the BHT deposit are located only within the Newman land system. Soils within these land systems are broadly characterised below:

- Newman land system soils are predominantly classified as stony soils, with smaller proportions of red shallow loams and red shallow sands.
  - Stony soils tend to be shallow with physical rooting depths no more than 0.5m. They have circum-neutral pHw, low salinity, loam to clay loam textures, and very high coarse fragment abundance.
  - The red shallow loams have similar properties except for low coarse fragment abundance. The red shallow sands are similar except for low coarse fragment abundance and a loamy sand to clayey sand texture.
- Platform land system soils are predominantly stony soils (similar to those of the Newman system) and red loamy earths. The red loamy earths are similar to the stony soils except they tend to be deeper and have low coarse fragment abundance.
- Boolgeeda land system soils are commonly red shallow loams or red/brown non-cracking clays.

- Red shallow loams tend to be shallow with physical rooting depths no more than 0.5m. They have circum-neutral pHw, low salinity, sandy loam to clay loam textures, and low to moderate coarse fragment abundance.
- The red/brown cracking clays also have a shallow rooting depth due to increased clay content and chemical limitations in soils deeper than ~0.3m. They have neutral to alkaline pHw, low salinity, and low coarse fragment abundance. Surface soils have a sandy clay texture, with subsoils becoming light to medium clays. Sodicity increases with depth in the non-cracking clays and becomes high in soils deeper than ~0.3m.

The soils present at HD2 and BHT can be summarised as follows:

- Circum-neutral to alkaline pHw.
- Low salinity.
- Loam to clay loam textures, with loamy sand and clay textured soils also present but less common.
- Variable coarse fragment abundance, with stony soils have >90% coarse fragments and the loam and clay textured soils within the Boolgeeda land system having <10% coarse fragments.
- Clay subsoils within the Boolgeeda land system may be sodic and prone to dispersion. This is a potential issue for HD2 only as the Boolgeeda system is not present at BHT.

The results of the physical and chemical soils analysis completed for the HD2 and BHT deposits is provided in Table 5-8. The soils are non-sodic and typically acid to neutral in the upper 200mm (defined as topsoil) of the profile with subsoils being neutral to alkaline. Trace element analysis does not indicate any potential deficiency or toxicities. Results are represented here as a range; further soils assessments will be conducted during construction and operational phases of the project as required. The soils analysis report is available in Appendix 8.

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Table 5-8: Comparison between soils from HD2 and BHT deposits

Analysis		Unit	HD2 deposit	BHT deposit
Physical	Soil texture (<2 mm soil fraction)	NA	Sand, clay, loam	Stony soils loam
	Coarse material content (%)	%	10 - 79	42 - 70
	Fine Fraction	%	17 - 90	42 - 77
	Coarse Sand	%	19.7 - 44.8	21 - 58
	Fine Sand	%	33.8 - 57.9	23.6 - 42.3
	Silt	%	4.7 - 14.1	33.3 - 53.7
	Clay	%	13.1 - 28.3	1.5 - 6.9
	Plant Available Water (PAW adjusted)	mm/m	60 - 180	10 - 21.2
	Plant Available Water (PAW adjusted)	mm/m	17 - 148	75 - 120
	Saturated hydraulic conductivity (Ksa)t	mm/hr	4 - 29	22 - 60
Chemical	pHw	pH units	4.61 - 7.95	5.08 - 7.16
	pHCa	pH units	3.81 - 7.15	4.75 - 7.37
	EC 1:5	dS/m	0.1 - 0.9	0.01 - 0.33
	Exchangeable Sodium Percentage (ESP)	%	1.0 - 10	1.8 - 8.9
	Exchangeable Magnesium Percentage (EMP)	%	14 - 32	17 - 41
	Chloride (Cl)	mg/kg	12.6 - 656	16.6 - 126
	Electrochemical Stability Index (ESI)	NA	00 - 0.1	0.00 - 0.03

Analysis		Unit	HD2 deposit	BHT deposit
	Total Nitrogen (N)	mg/kg	131 - 1252	664 - 1004
	Ammonium – (NH4)	mg/kg	<0.2 - 10.4	<2 -13.2
	Nitrate – (N03)	mg/kg	1.06 - 232	1.46 - 7.13
	Organic Carbon (C)	%	0.5 - 1.5	0.4 - 1.7
	Total Phosphorous (P) P	mg/kg	225 - 601	329 - 654
	Average Phosphorous (P) P	mg/kg	8.5 - 42.2	13.3 - 30.2
	Average Potassium (K)	mg/kg	67.5 - 302	63.3 - 105
	Average Sulphur (S)	mg/kg	6.5 - 23	3.7 - 41
	Trace Copper (Cu)	mg/kg	0.8 - 3.7	0.4 - 1.3
	Trace Manganese (Mn)	mg/kg	Dec-59	8.5 - 49
	Trace Zinc (Zn)	mg/kg	0.5 - 4.1	0.5 - 0.9
	Extracted Calcium (Ca)	mg/kg	1.8 - 7.4	1.2 - 4.6
	Extracted Magnesium (Mg)	mg/kg	0.7 - 2.7	0.7 - 1.7
	Extracted Potassium (K)	mg/kg	0.1 - 1.2	0.1 - 0.3
	Extracted Sodium (Na)	mg/kg	0.1 - 0.4	0.1 - 0.7
	Extracted Aluminium (Al)	mg/kg	0.0 - 0.3	0.0 - 0.2
	Effective Cation Exchange Capacity (ECEC)	mg/kg	1.8 - 7.4	2.4 - 7.3

A summary of suitability of the material as growth media is provided in Table 5-9, further detail is provided in Appendix 8. Further work will be undertaken throughout the LoM to assess and manage soils.

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Table 5-9: Summary of suitability of topsoil as growth medium

Property	HD2 deposit	BHT deposit
pHw, pHCa	Suitable, though there are a significant amount of low pH materials that may reduce nutrient availability and biological activity. This reduction did not reduce fertility to unsuitable levels.' Field/pot trials to confirm this is recommended. Lime could be used to increase pH if shown by trials to be needed.	Suitable. Only 1 of 15 samples had slightly low pH and 1 of 15 samples had slightly high pH.
Salinity, chloride	Suitable	Suitable
Structural stability	Often unstable (52% of samples)	Infrequently unstable (27% of samples)
Fertility	Often low total N Often low available K	Very often low total N Sometimes low available K
Plant available water	Suitable	Suitable
Saturated hydraulic conductivity	Suitable	Suitable

5.8.1 Soil inventory

Topsoil is a limited resource in the Pilbara with topsoil recovery often being restricted due to the nature and terrain of the landscape. The objective of soil management is to maximise the collection of topsoil and

subsoil, and to store it in such a way as to maximise its viability and productivity for subsequent use in rehabilitation.

Topsoil and subsoil are managed in accordance with the *Rio Tinto Iron Ore Soil Resource Management Work Practice* (Rio Tinto 2020b) to ensure appropriate volumes are available for rehabilitation activities. Where practical, a minimum of 200 mm of topsoil and up to 600 mm of subsoil is collected when new ground is disturbed. Long-term locations for soil stockpiles have been identified and incorporated into the mine plan (Figure 4) with stockpile height limited to 2 m high to maintain viability.

Where practical, a minimum of 200 mm of topsoil and 600 mm of subsoil is collected (where possible) when new areas are disturbed. Reconciliations of topsoil volumes are undertaken to confirm that sufficient material is available to spread across the rehabilitated area, assuming a spreading depth of 200 mm.

Current collection rates at HD1 (a suitable proxy for soil collection at HD2 and BHT) show that approximately 30% of the expected volume is recovered and stockpiled, with the remainder unrecoverable due to terrain restricting accessibility or the unavailability of soil on outcropping rock formations. Table 5-10 provides projected soil inventory for HD2 (as of December 2019), assuming recovery rates of 30% remain consistent over time.

Table 5-10: Predicted LoM soil balances for the HD2 (BHT and HD2 deposits)

Topsoil parameters	Future predicted clearing and recovery
Topsoil volume (m^3)	2,716,800
Subsoil volume (m^3)	4,370,400
Total soil volume (m^3)	7,087,200
Total disturbance area (ha)	4,900.01
Pit areas not rehabilitated (ha)	965.89
WRL requiring rehabilitation (ha)	939.24
Landbridges requiring rehabilitation (ha)	62.88
Infrastructure area requiring rehabilitation (ha)	2932.14
Completed rehabilitation (ha)	NA
Area requiring topsoil (ha)	3,934.11
Soil volume required 200mm (m^3)	7,035,000
Soil Surplus (m^3)	52,200
Soil Surplus (%)	0.7%

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The HD2 and BHT deposits are predicted to have sufficient soil resources to complete rehabilitation works at closure; however, alternative growth media (AGM) may need to be considered (Section 5.8.2) if recovery rates fall below the 30% factor applied due to anticipated topographic constraints.

Broadly, to maximise prospects of successful outcomes each progressive rehabilitation project is assessed to determine the type and amount of soil (or alternative media) used. This assessment could include:

- soil inventory at the time of rehabilitation.
- landform and rehabilitation type.
- potential for trials.
- distance to soil stockpiles; or
- potential upcoming rehabilitation projects.

5.8.2 Alternative growth media

In 2010, a study was commissioned by Rio Tinto into the use of mine waste materials as an AGM for rehabilitation. The study reviewed soil, tailing and mineral waste characteristics from select Pilbara mining operations, to identify material combinations that may be suitable as a topsoil substitute or supplement in cases where topsoil may be insufficient for rehabilitation requirements. In these cases, topsoil would be applied to high priority areas such as waste landforms and lower priority areas such as laydown areas may receive AGM.

The study showed plant-available nutrients held within the waste materials, although variable, was characteristically low and comparable to natural soils in the region. Most of the waste materials had macro- and micro-nutrient concentrations within the range or above the levels measured in benchmark Pilbara topsoil and rehabilitated soils. The pH and phosphorus-buffering index of most waste materials were also comparable to that of the benchmark topsoil materials.

In general, Pilbara mineral wastes were non-saline and non-sodic, with no sample presenting above the 15% threshold for exchangeable sodium percentage (ESP), the indicator of high sodicity. The soil structure of waste materials was relatively stable, with only slight or no dispersion upon re-moulding, indicating a relatively stable structure that is not easily degraded, and were not prone to hard setting. However, estimated plant available water content of the waste materials ranged from <3% to >25%.

Subsoil samples from HD1 (expected to have soils analogous to the Proposal) were within acceptable ranges to be used as AGM when compared to Pilbara soils except for gravel content. While gravel content was found to be lower than typical Pilbara topsoils, it was very similar to HD1 topsoil samples (both between 0-5%). It was concluded that subsoil sample particle size distribution was very similar to the topsoil parameters measured, and therefore, considered suitable for use as AGM. A lower gravel content may also offer benefits with regards to soil water holding capacity.

Whilst rehabilitation areas have generally performed better with topsoil application, absence of topsoil does not necessarily mean that rehabilitation will fail, or that completion criteria will not be achieved. AGM trials have been conducted on waste rock landforms rehabilitation without topsoil application (for example the Channar 84 East 5 trial completed in 2021) and are performing strongly against most success indicators. Further trials using detrital waste material as an AGM have begun at Tom Price (MMW4 waste rock landform and Section 5.15). Initial observations indicate stability and early growth.

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As discussed in Section 5.8.1, it is predicted there will be adequate topsoil and subsoil resources available for rehabilitation of the HD2 deposit, but further work may be needed to explore the use of AGM at the BHT area due to topographic factors potentially affecting soil recoveries. Therefore, investigations will continue to be undertaken to support rehabilitation efforts at the HD2 and BHT deposits.

5.8.3 Rehabilitation materials inventory

Often during rehabilitation activities, erodible, fibrous and PAF materials are planned to be encapsulated as part of making the site safe and stable. The materials required for these encapsulation purposes often require specific characteristics described below. Many of the external waste rock landforms contain a high proportion of erodible material, which has been accounted for in proposed landform design parameters (Section 5.7.7). Competent material with low erodibility will be stockpiled in low-grade (LG) waste rock landforms at the HD2 and BHT deposits, which can be rehandled at closure if capping of external waste rock landforms is required. Materials suitable for armouring (Table 5-11) at HD2 and BHT deposits will be segregated and stockpiled during operations for rehabilitation purposes. Preliminary calculations have been completed including rock armouring of HD2 waste rock landforms slopes and abandonment bunds, further work is required once mining commences, an action is listed in Table 6-1 and Appendix 5.

Table 5-11: Rehabilitation materials (competent rock)

Waste type	Use	Location	Volume (Mm3)
Newman Member	Armouring of erodible waste rock landforms	Tortoise HD2	1.4
Dales Gorge	Armouring of erodible waste rock landforms	NW_LG BHT	210

5.8.4 Implications for closure and knowledge gaps

Closure implications associated with soils include:

- The predicted soil balance indicates a surplus if all available topsoil can be harvested. In the event the predicted volume is not realised, Rio Tinto will consider the suitability of subsoil as an AGM.
- Rehabilitation materials inventory is necessary to support long-term landform stability and progressive rehabilitation.

Closure knowledge gaps associated with soils, as summarised in Table 6-1, include:

- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments.
- Update the topsoil balance for estimated topsoil recovery annually once mining commences.
- Complete subsoil characterisation work when vegetation clearing commences as required.
- Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.

5.9 Contaminated sites

Rio Tinto maintains registers for potentially contaminating activities and known or suspected contaminated sites which have been formally reported under s11 of the *Contaminated Sites Act 2003* (WA). The registers are informed by regular review of operations and where required preliminary or detailed site investigations to assess contaminants associated with such activities and assess their risk of harm to human health, the environment and environmental values. Potentially contaminating activities and land uses as described in the 2014 (former) Department of Environmental Regulation guideline '*Assessment and management of contaminated sites'* (DoE, 2014*)*, that may be associated with mining activities onsite include, but not limited to:

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- automotive repair workshops (light and heavy machinery);
- substations and transformers;
- fertiliser and explosives storage;
- landfill sites;
- mineral processing, mining, screening and crushing facilities;
- rail transport corridors;
- hydrocarbon storage, handling and dispensing facilities;
- sewage wastewater treatment plants and irrigation areas; and
- disturbance of potentially acid forming materials during mining.

All potentially contaminating activities and land uses identified on the site register are managed as part of the ongoing mining operation. Prior to closure as part of the decommissioning process, a contaminated site assessment will be undertaken. Based on this assessment, specific plans will be developed to remediate or manage contaminants, where required, to support the final land use.

No locations within the HD2 closure boundary have been reported under the *Contaminated Sites Act 2003* (WA), as would be expected for a greenfield development.

5.9.1 Implications for closure and knowledge gaps

Closure implications associated with contaminated sites include:

- Ensuring that contamination risks have been assessed prior to the closure of the Proposal.

Closure knowledge gaps associated with contaminated sites, as summarised in Table 6-1 include:

- Undertake Preliminary Site Investigation 5 years prior to closure.
- Undertake Detailed Site Investigation 2 years prior to closure.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.

These knowledge gaps are required to be addressed to inform post-mining land use planning and understanding of any required remediation activities.

5.10 Hydrogeology

The HD2 and BHT deposits are associated within two distinct aquifers, referred to as the HD2 and BHT aquifers (Figure 18 through to Figure 22). These aquifers are localised and conceptually understood to be compartmentalised at HD2 where groundwater availability is primarily limited by the vertical extent (thickness) of the aquifer, and as bounded, and 'bathtub-like' at BHT.

These aquifers can be grouped into two main types:

- HD2 aquifer - the Wittenoom aquifer type comprising the karstic dolomite within the Bee Gorge and Paraburdoo Members of the Wittenoom Formation and the mineralised and/or fractured zones of the underlying Mount Newman Member of the Marra Mamba Iron Formation; and
- BHT aquifer - the Brockman Iron Formation aquifer type comprising the mineralised zones of the Dales Gorge Member and Joffre Member where fractures are encountered.

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In general, Wittenoom Formation aquifers are typically regional in scale and variably connected while Brockman Iron Formation aquifers are typically local scale and most often association with iron ore enrichment (Rio Tinto, 2022).

At the HD2 deposit the Marra Mamba Formation abuts the regionally extensive Wittenoom Formation (Figure 19 and Figure 21). The water table is located within both these formations and generally below the detrital deposits. Groundwater in the Marra Mamba Iron Formation (Mount Newman Member) is expected to be in hydraulic connection with the adjacent Wittenoom Formation effectively forming a single aquifer.

At the BHT deposit, the aquifer is located within the mineralised Dales Gorge Member of the Brockman Iron Formation, which hosts a localised and predominantly isolated aquifer. The Mount McRae Shale forms an aquitard around the majority of the Mineralised Brockman Iron Formation isolating the groundwater held in the BHT area from the regional Wittenoom aquifer. It is considered that a small area in the north of the deposit is connected to the regional aquifer due to eroding of the Mount McRae Shale at this location (Figure 19 and Figure 21). Compartmentalisation is observed at the eastern boundary of the aquifer by a 44 m head difference occurring across a pair of dykes to the east of the Baby Hope (HD1SW) area of the HD1 operation (Rio Tinto, 2022).

The direction of groundwater flow across the Proposal is predominately to the northeast, essentially mimicking the surface water drainage system that occurs in this area. Groundwater recharge is expected to occur at surface drainage features following rainfall and creek flow events.

The depth to groundwater ranges between approximately 50m and 100m throughout most of the Proposal area, depending on topography (Figure 18 to Figure 20). These depths are generally greater than those which would typically support groundwater dependent vegetation (>15 m below ground level). The depth to

groundwater is shallower (approximately 40 m) below ground surface along WWC and PMC where they cross the eastern boundaries of the aquifer. A high level of compartmentalisation occurs within the fractured rock Wittenoom aquifer. Head changes between 13 m (south-eastern boundary) and 38 m (western boundary) have been observed either side of restricted flow boundaries present within the aquifer.

The HD2 deposit pre-mining groundwater elevations range from 629mAHD to 625mAHD (Wittenoom aquifer). A pre-mining groundwater elevation of 625 m AHD is considered as appropriate for the deposit. At the BHT deposit, groundwater gradients are relatively flat across the aquifer with the groundwater elevation ranging between 595mAHD in the west and 593mAHD in the east. A pre-mining groundwater elevation of 594mAHD is considered appropriate for the deposit (Rio Tinto, 2022).

5.10.1 Groundwater dependent hydrology

The surface water present at Ben's Oasis is understood to be groundwater fed. The source of the groundwater is likely to be predominantly from a southern catchment, disconnected from the HD2 deposit area and local storage associated from the immediate sub-catchment geology that surrounds Ben's Oasis. Ben's Oasis is interpreted as a zone of outcropping Wittenoom Formation of negligible primary permeability, forcing groundwater to discharge at surface. As outlined above, groundwater in the BHT deposit area (held in the Mineralised Brockman Formation) is hydraulically isolated from the surrounding Wittenoom aquifer and from Ben's Oasis (Figure 18).

Groundwater flow within the Wittenoom Formation is impeded between HD2 deposit and Ben's Oasis by a southwest trending dyke near the HD1 village (Figure 19). A 13 m head difference on either side of the dyke has been observed, indicating a restricted flow boundary. Groundwater levels near to Ben's Oasis have been measured at 618mAHD (July and December 2021) and therefore approximately four metres higher than groundwater levels measured in monitoring bores immediately to its west.

This conceptual understanding of the groundwater underlying the Proposal suggests it is unlikely that changes to the HD2 and BHT aquifers from borefield extraction for operational supply will impact Bens Oasis. Monitoring of Bens Oasis will be ongoing throughout operations to ensure abstraction activities do not impact the groundwater dependent ecosystem (GDE) (Rio Tinto, 2022).

WWS is also not considered to be connected to the aquifers at the HD2 deposit due to the presence of a southeast trending dyke located to the east of the BHT area (Figure 18) (Rio Tinto, 2022).

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5.10.1 Groundwater quality

The groundwater is fresh; with salinity is typically about 1000 µS/cm EC, and slightly alkaline. Salinity (as EC) ranges from approximately 183 to 2,960 µS/cm, pH ranges from 6.54 to 8.9. Parameters tested for are within Australian Drinking Water Guidelines (NHMRC, NRMMC, 2011) excepting Arsenic (As) concentrations of 0.011 and 0.017 mg/L and Manganese (Mn) concentrations of up to 0.703 mg/L have been recorded. Water quality data ranges for the HD2 and BHT aquifers, obtained from groundwater sampling and laboratory analyses (Rio Tinto, 2022) are included in Table 5-12.

Table 5-12: Groundwater quality ranges for Proposal

Groundwater Quality Parameter	HD2 aquifer	BHT aquifer
Alkalinity CaCO3 (mg/L)	90 - 337	160 - 378
Cond EC LAB (uS/cm)	666 - 2960	183 - 346
Hardness (CaCO3) (mg/L)	411 - 1240	341 - 421
pH (pH Units)	6.54 - 8.69	741 - 815
Dissolved Oxygen (O2) (% Sat)	49 - 98.2	33.5 - 92.5
Total Dissolved Solids (TDS) (mg/L)	496 - 2300	474 - 856

Groundwater Quality Parameter	HD2 aquifer	BHT aquifer
Total Suspended Solids (TSS) (mg/L)	<5 - 280	<5 - 6190
Antimony (An) (mg/L)	<0.001 - 0.001	<0.001
Arsenic (As) (mg/L)	<0.001 - 0.001	<0.001 - 0.017
Barium (Ba) (mg/L)	0.001 - 0.01	0.218 - 0.426
Beryllium (Be) (mg/L)	<0.001 - 0.001	< 0.001
Boron (B) (mg/L)	0.2 - 0.31	0.19 - 0.33
Bromide (Br) (mg/L)	<0.05 - 0.762	0.356 - 1.08
Cadmium (Cd) (mg/L)	<0.05 - 0.00224	<0.001
Chloride (Cl) (mg/L)	78 - 240	78 - 232
Chromium (Cr) (mg/L)	<0.001 - 0.001	<0.001
Cobalt (Co) (mg/L)	<0.001 - 0.029	<0.001 - 0.003
Copper (Cu) (mg/L)	<0.001 - 0.001	<0.001
Fluoride (Fl) (mg/L)	0.2 - 0.4	0.3 - 0.7
Iron (Fe) (mg/L)	<0.05 - 3.11	<0.05 - 4.19
Lead (Pb) (mg/L)	<0.001 - 0.001	<0.001
Magnesium (Mg) (mg/L)	42 - 164	47 - 61
Manganese (Mn) (mg/L)	0.001 - 0	0.006 - 0.703
Mercury (mg/L)	0.001 - 0.004	<0.00004
Molybdenum (Mo) (mg/L)	<0.001 - 0.001	<0.001
Nickel (Ni) (mg/L)	<0.001 - 0	<0.001 - 0.002
Nitrate (NO3) (mg/L)	<0.01 - 5.22	<0.01 - 0.07
Nitrite (NO2) (mg/L)	<0.01 - 0.01	<0.01
Total Nitrogen (TN) (mg/L)	0.3 - 0.9	<0.1 - 0.4
Total Phosphorous (TP) (mg/L)	<0.01 - 0.27	<0.01 - 0.19
Potassium (K) (mg/L)	8 - 31	10 - 14
Selenium (Se) (mg/L)	<0.01 - 0.01	<0.01
Sodium (Na) (mg/L)	47 - 216	41 - 104
Sulphate (SO4) (mg/L)	60 - 1320	1 - 115
Zinc (Zn) (mg/L)	<0.005 - 4.25	<0.005 - 0.131

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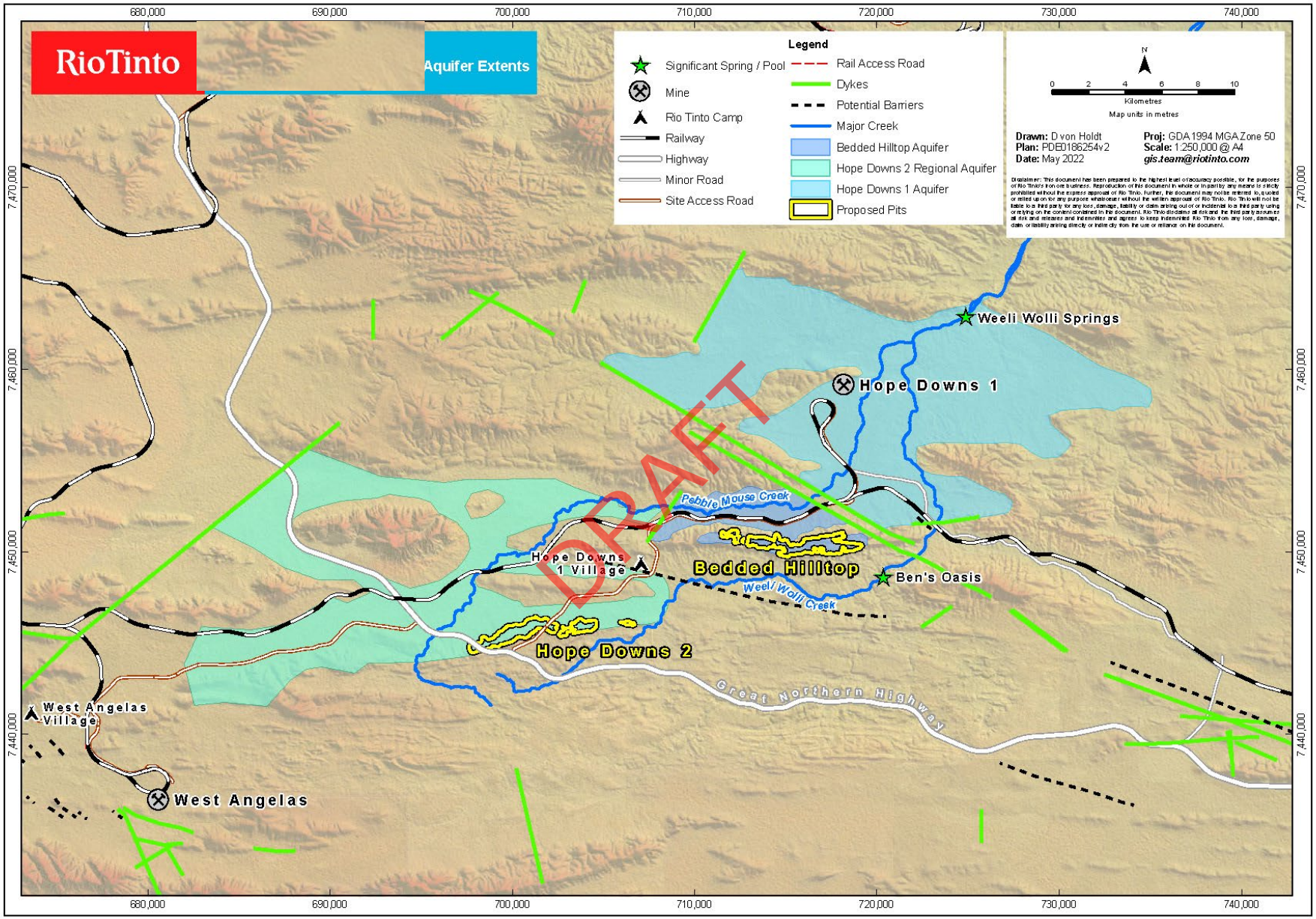

Figure 18: Proposal groundwater aquifer extents

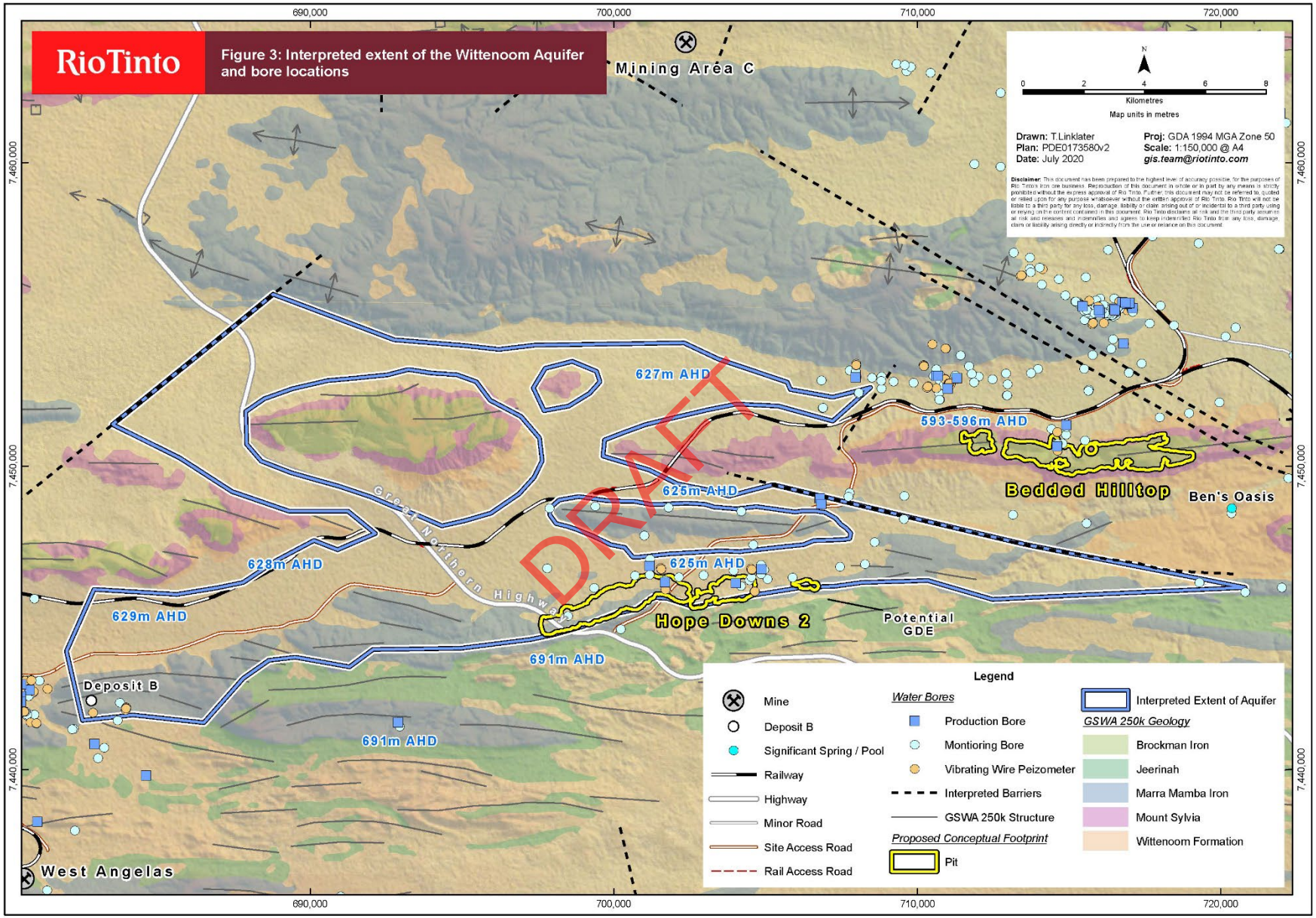

Figure 19: HD2 aquifer and water levels (mAHD, 2020)

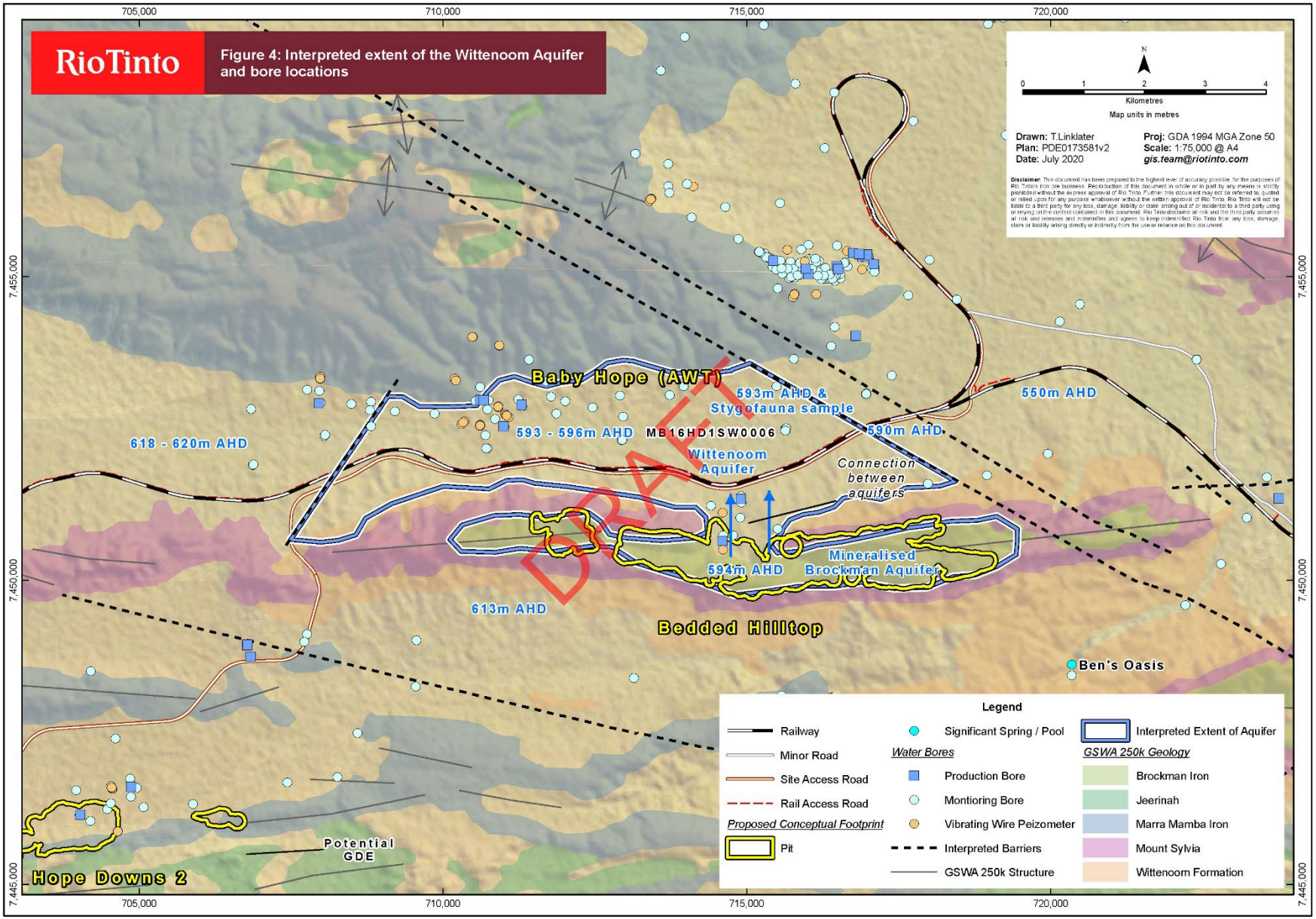

Figure 20: BHT aquifer and water levels (mAHD, 2020)

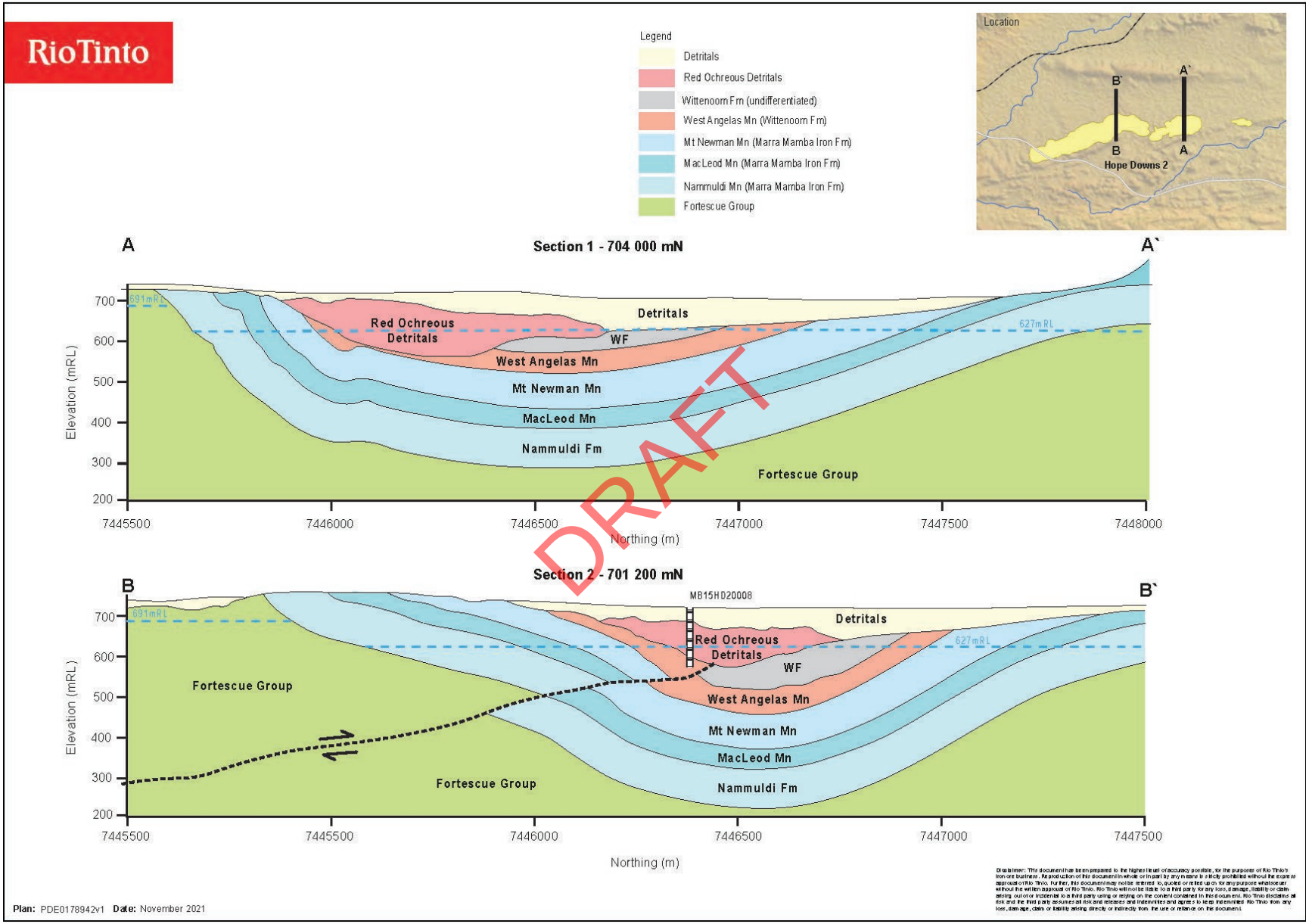

Figure 21: HD2 hydrogeological cross sections

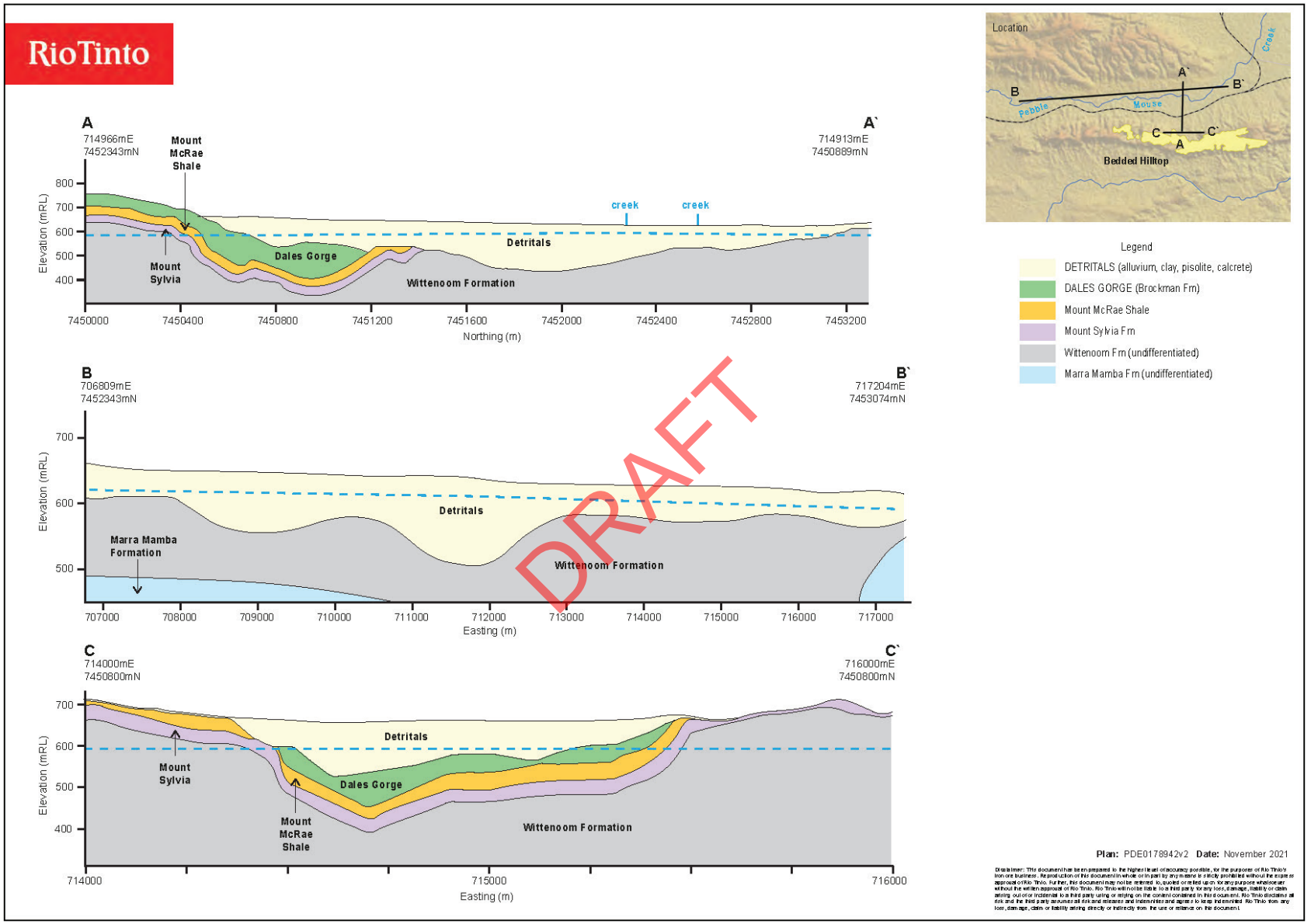

Figure 22: BHT hydrogeological cross sections

5.10.2 Groundwater use

Groundwater abstraction to dewater pits for mining (dewatering) is not required for the Proposal. Groundwater abstraction is assessed only for the purpose of providing a project water supply. Groundwater abstraction is not expected to impact areas beyond the local aquifer extents due to the presence of definable aquifer boundaries; namely structural groundwater flow barriers (regional and local dykes) and low permeability units (the Mount McRae Shale, the Fortescue Group and high silica zones such as the area between the HD2 and BHT aquifers). Abstraction of groundwater for construction and operational purposes is required, including dust suppression. Hydrogeological investigations have been undertaken in the Proposal area between 2015 and 2021.

To meet mine water demand, groundwater is to be sourced from existing and future production bores local to the HD2 deposit and bores currently used to supply the HD1 Village (potable water supply). Production water may also be sourced from dewatering at the HD1 operation.

Groundwater is currently abstracted from the Wittenoom aquifer to supply water for the HD1 Village. The abstraction bores for this camp are located approximately 2.5 km north of the closest part of the BHT deposit and are located within the same aquifer. Abstraction from these bores commenced in 2006, the total annual abstraction is generally close to the annual licence allocation of 500,000 kL (GWL No. 161143 (6)).

Groundwater levels recorded approximately 200 m south of the abstraction bores have declined by around 2 m over the 12-year period of abstraction, indicating a relatively minor and localised effect. Dewatering carried out at Deposit B (West Angelas), located approximately 10.6 km southwest of HD2 closure boundary has caused localised drawdown within the aquifer which extends approximately 2 km north of Deposit B.

Groundwater abstraction from these sources is not expected to impact areas beyond the local aquifer extents due to the presence of the definable aquifer boundaries (Figure 18). Additional monitoring bores have been installed across the surrounding area. Rio Tinto (2022) details the impact of groundwater abstraction for the Proposal.

The catchment created by the mine voids will serve to focus rainfall runoff and thus recharge, resulting in localised ponding at their base following heavy rainfall, which will dissipate via infiltration and evaporation shortly after the event.

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5.10.3 Implications for closure and knowledge gaps

Closure implications associated with groundwater include:

- Drawdown of the aquifers due to groundwater supply abstraction over the LoM may result in changes to hydrogeological regimes, groundwater quality and subterranean fauna habitat and may require management in the post-mining period.

Closure knowledge gaps associated with groundwater, as summarised in Table 6-1, include:

- Complete final options assessment for water source and impacts for HD2 and BHT deposits.
- Update closure hydrogeological model with new conceptualisations for HD2 and BHT deposits water supply options.
- Complete closure hydrogeological water quality model for HD2 and BHT deposits once water supply options are agreed with stakeholders.
- Update the conceptual hydrogeological model for HD2 and BHT deposits final closure landform 5 years from closure.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

5.11 Hydrology

The Proposal is located within the upper reaches of the WWC catchment that forms part of the Fortescue River Region (Figure 23). WWC has a total catchment area of approximately 4,770 km^2 to Waterloo Bore gauging station and drains north into the Fortescue Marsh. The upper reaches of the WWC catchment include Pebble Mouse Creek (PMC), a major tributary of WWC with a catchment of 340 km^2. The HD2 and BHT deposits are both located between PMC to the north and the main channel of WWC to the south. The creek lines both intersect the edges of HD2 tenure, with PMC headwaters commencing south of the HD2 deposit and the creek line skirts the west of the HD2 deposit, heading north-east. WWC headwaters commence to the south of the HD2 deposit and head north-east towards BHT deposit and then north toward WWS (Figure 23). The creek lines both intersect the edges of HD2 tenure and there are several areas where the Proposal infrastructure footprint crosses PMC.

Modelling of the WWC catchment in 2021 (Appendix 12) identified that the development of the Proposal will reduce the WWC catchment area by approximately 45 km^2, based on the proposed placement of the pits and waste rock landforms. This is equivalent to 3.5% of the contributing catchment area to WWC and this percentage of flows is not considered a significant impact to the WWC catchment. Surface water management within the closure boundary of the Proposal is discussed in Section 5.11.3.

5.11.1 Surface water quality

Surface water quality sampling has not yet been undertaken for the PMC and WWC waterways adjacent to the Proposal. Seasonal inundation is ephemeral, and no flowing water has been recorded in PMC or WWC recently during surveys of the area. This has been identified as a closure knowledge gap and will be rectified, an action is listed in Section 5.11.6 and Table 6-1.

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5.11.2 Weeli Wolli Spring and Ben's Oasis

The management of downstream flows is key to minimising impacts to sensitive receptors. Two sensitive environmental receptors have been identified in proximity to the Proposal, WWS and Ben's Oasis (Figure 23).

WWS is located approximately 7 km downstream of the confluence of PMC and WWC, to the northeast of the Proposal (Figure 23). The Spring was naturally groundwater fed (pre-mining) due to a geological barrier where high permeability rock units meet low permeability rock units, forcing groundwater to rise to the ground surface. WWS is currently maintained by discharge of surplus water from dewatering at the HD1 operation. Upstream of the permanent flowing portion of the spring are several permanent and semi-permanent pools scattered over 2 km. WWS also receives surface flows as it is within the main channel of the WWC. These catchment flows would reach WWS only in rare flood events associated with cyclones and are unlikely to have a significant impact on WWS. Mining is AWT avoiding pit dewatering and surplus water management. No other impact to WWS is anticipated.

Ben's Oasis is a significant environmental feature on WWC, which is located approximately 2 km from the BHT area and 15 km east of the HD2 area of the HD2 deposit (Figure 23). It is understood that Ben's Oasis is supported via groundwater expression (refer to Section 5.10.1) but also receives surface flows as it is within the main channel of the WWC. Ben's Oasis is in an area where the Wittenoom Formation is interpreted to outcrop allowing the discharge of groundwater at surface. Based on modelling completed in 2021 the estimated area of the WWC catchment contributing surface water flows to Ben's Oasis is approximately 420 km^2. The HD2 pits and waste rock landforms will reduce the catchment reporting to Ben's Oasis by approximately 6 km^2. However, the proposed HD2 levee and diversion drains (Figure 25) would contribute an additional 5 km^2 of catchment to Ben's Oasis (Section 5.11.3). Therefore, the net contributing catchment area is expected to be reduced by 1 km^2, equivalent to 0.2% of the total catchment.

Modelling completed in 2021 indicates that catchment reductions due to the Proposal mining activities will result in small reductions in surface water runoff (1% at WWS and 1.1% at Ben's Oasis) and are expected to have an insignificant impact on the flow regime at either of these locations. Assessment of the potential for sediment to be transported from the Proposal to WWC, indicates that sediment is likely to concentrate

at the culverts which will limit transport of sediment further downstream; therefore, the Proposal is considered unlikely to impact water quality at WWS. Further information is detailed in Appendix 12 and Appendix 13.

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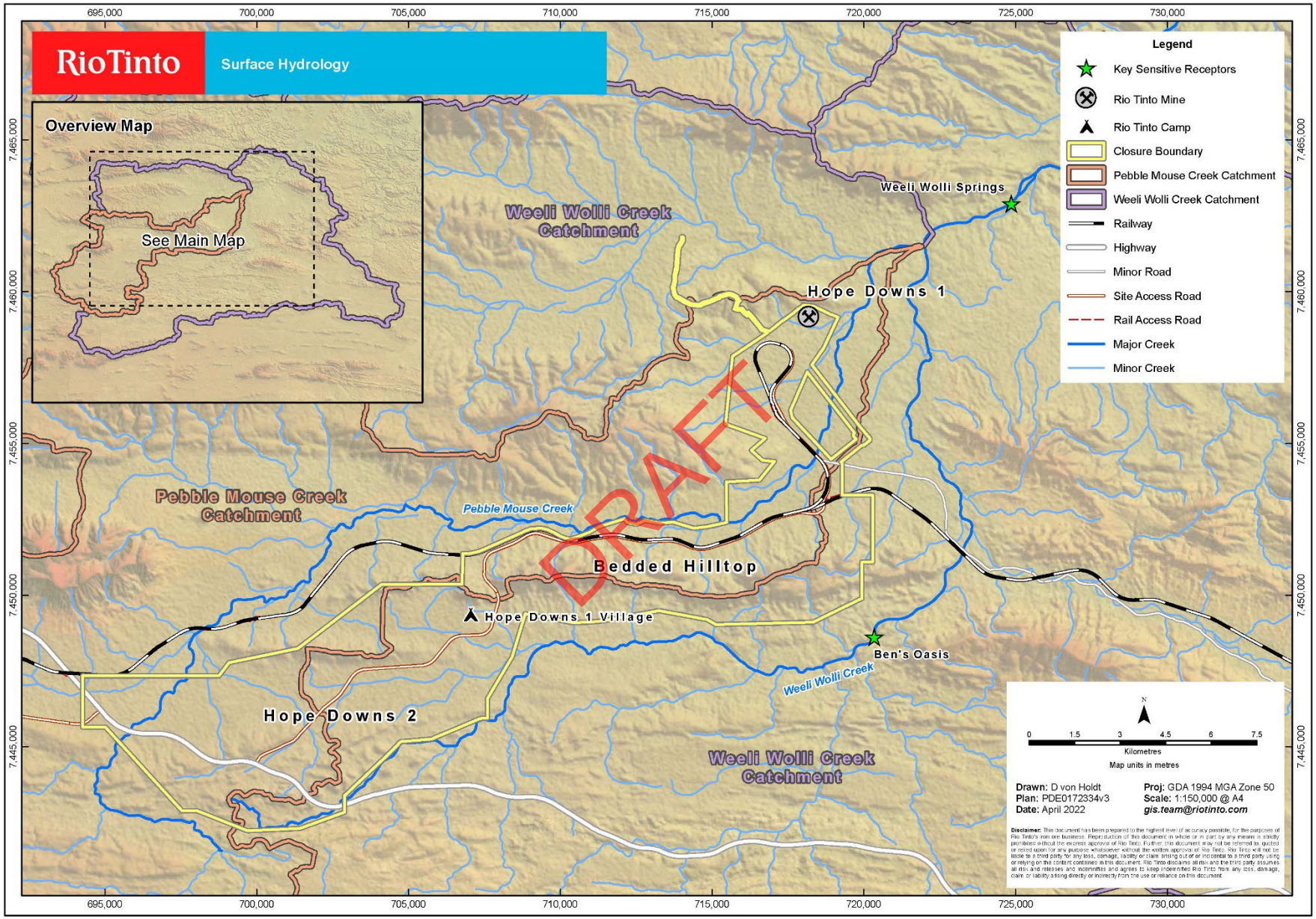

Figure 23: Surface Hydrology of Proposal

5.11.3 Surface water management

To manage the flow of surface water within the WWC catchment, several surface water management structures have been proposed. These include several PMC crossings during operations, and a diversion drain and levee to maintain flows post-closure.

During operations an engineered crossing of PMC will be constructed to connect the Proposal to the crushing facilities at HD1, referred to as the haul road crossing (Figure 24). This crossing comprises a haul road with culverts to ensure low flows are not impeded and has been designed for the modelled flow rate of 1:20 Annual Exceedance Probability (AEP) with final engineering designs for construction shown in Figure 24. Three further crossings (a conveyor crossing and two alternative access crossings) may be added to the project scope; however, these are proposed for removal at closure if constructed, and have not been included in the flood modelling completed on the closure landform. Flood modelling (Appendix 12) predicted effects on these watercourses included a slight loss of runoff which is expected to have little effect on the flow regime at either WWS or Ben's Oasis and is therefore not expected to have significant impact on the environmental and heritage values of these features during operations.

The attenuation of surface water upstream of the PMC crossing is predicted to result in an increase of flood depths of 1 m immediately upstream of the culverts in a 1:100 AEP event. Flow in this area would quickly disperse and is not expected to cause a significant change in the hydrological regime of the creek. Removal of this crossing at closure will reinstate flows closely to the natural system conditions.

To manage surface water flows during operations and post-closure a permanent diversion levee and two permanent diversion drains (Figure 25) will be installed to divert flow from a tributary in the PMC catchment towards WWC. This will maintain the catchment flows to WWC and prevent flows from being captured within the HD2 closure boundary. These have presently been designed to convey flows up to 1:100 AEP flows during operations. Flood modelling has been conducted on the proposed operational and closure landforms to inform flood risk and priority locations (Section 5.11.5). Assessment of the final landforms (i.e., using the post-closure landscape) is required in future updates to this closure plan to ensure that the surface water management structures are appropriate to manage flow post-closure. This is addressed as an action in the closure risk assessment and task list (Appendix 4 and Appendix 5).

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The rare (1:100 AEP) and extreme (1:10,000 AEP) flood risks associated with the closure of HD2 and BHT are considered relatively low (Section 5.11.5). Conceptual closure landform designs have been generated to support this MCP; however detailed designs for rehabilitation are yet to be developed. As part of future closure planning Rio Tinto will design, upgrade and/or construct landforms which will improve landform stability over closure time frames (Appendix 10). Where post-closure surface water management structures remain, detailed engineering designs that are safe, stable and non-polluting and based on appropriate flood events will be completed as part of closure studies.

To enable safe mining (e.g., pit development), drainage works will be required to permanently divert surface water flow that would normally drain into PMC to WWC. Physical design and construction of major surface water management structures is guided by the Rio Tinto Environmental Design Principles for Permanent Facilities and the Rio Tinto Standard Specification for Stormwater Drainage. These principles aim to:

- ensure the long-term safety and stability of engineered landforms;
- ensure local drainage is reinstated so that impacts on local hydrology is limited; and
- ensure the latest design practice and monitoring evidence are used to guide design.

Minor drainage works will be required at closure to reinstate natural flow paths through disturbed areas prior to revegetation. This includes:

- removing culverts;
- reinstating minor surface water flow systems, preferable along pre-disturbance flow paths;
- undertaking minor landscaping to recreate appropriate creek bed slopes and banks; and

- implementing localised surface water controls on large flat disturbed areas, to manage incident rainfall and local catchment run-on / run-off.

In general, re-instated and constructed drainage will be designed in accordance with the following guidelines:

- The final profile of the constructed drainage line will consist of a flat base and sloped banks to allow for free drainage.
- The channel width will be determined based on the estimated volume of water anticipated to flow down the channel. In areas where friable, easily erodible material exists, or where there is the potential for high flow velocities, it may be necessary to cover the base of the constructed channel with competent rock.
- Where possible, the channel will be designed to meander so constructed channels have characteristics like the surrounding region, e.g., are not all linear features.
- The constructed channel will be blended in with any natural drainage lines.

5.11.4 Principles of landform location

Constructed landforms will consider the surrounding hydrology of the area, as they can have an impact on catchments both upstream and downstream of their location. Waste rock landforms and other landforms can act as a diversion or dam for upstream surface water, reducing flow to the downstream catchment. Likewise, these landforms can erode with surface water flow, destabilising the landform and impacting the downstream environment with sediment.

Landform design and location guidelines have been adopted when completing new designs. Waste rock landforms and other landforms are generally built outside the 1:100 AEP floodplain, consider material characterisation and often include surface water management structures such as diversions, bunds, and surface water retention cells. Ponding at the landform toe during rain events can be managed using rock armouring at the base of the landform. Bunding at the landform toe will also mitigate water ponding and divert water over a greater area increasing infiltration. The impacts of the final landform design on surface drainage flows at a site level will require assessment prior to final closure planning.

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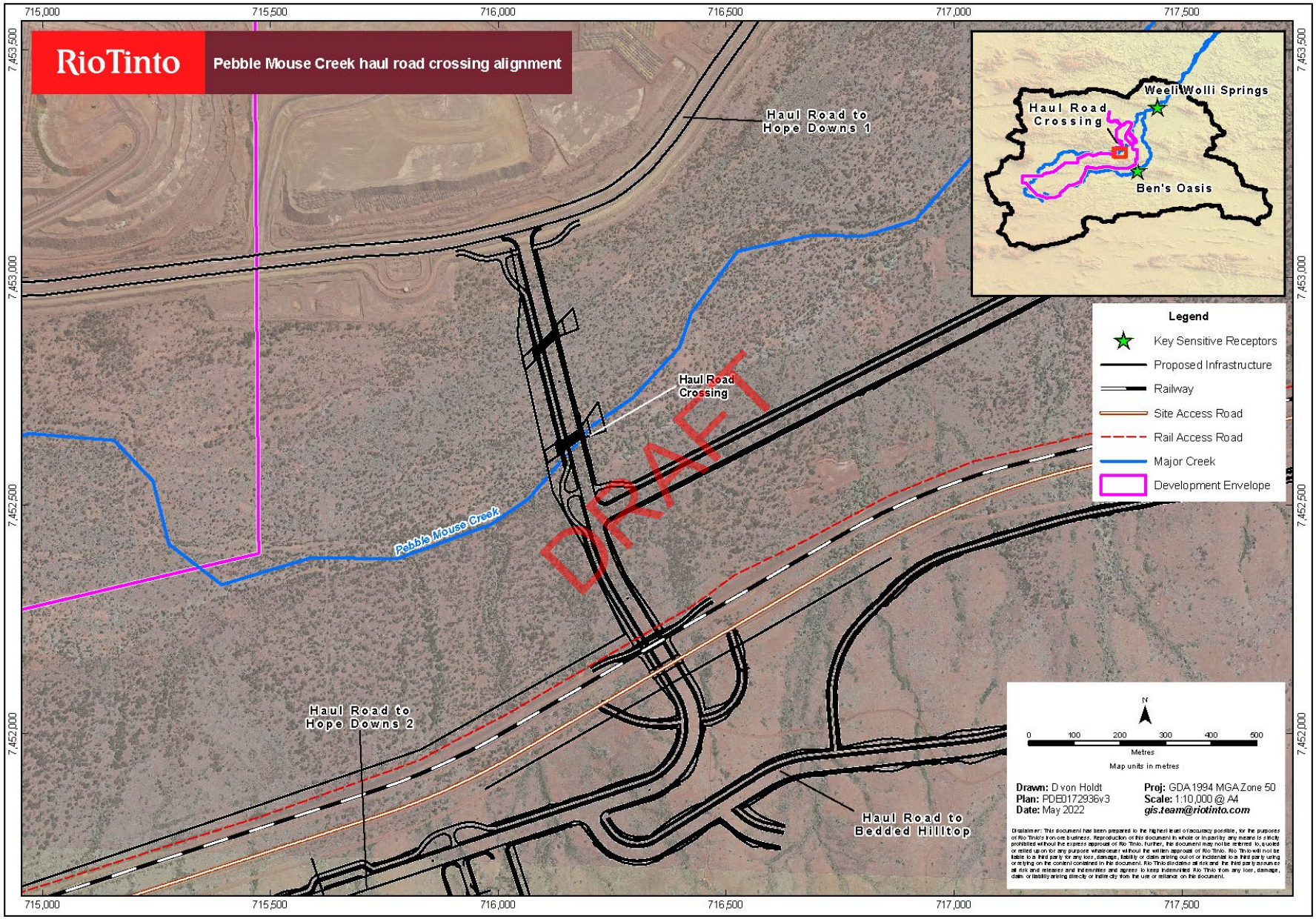

Figure 24: PMC Floodway alignment (PMC crossing)

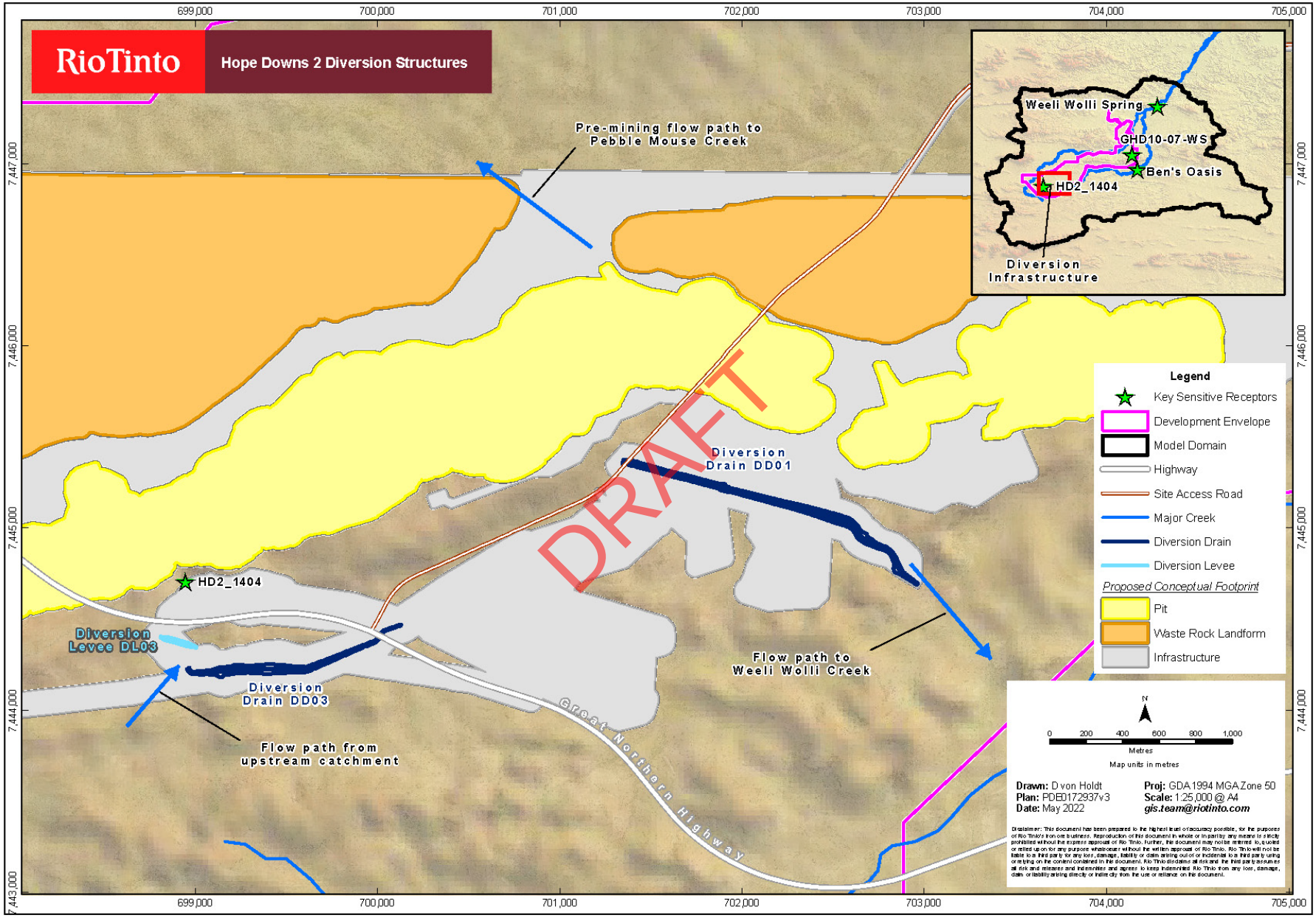

Figure 25: HD2 diversion levee and drains

5.11.5 Hydraulic Flood Modelling

The methodology and results from the most recent flood modelling for the Proposal is detailed in Appendix 12. When considering the flood hazard associated with rare to extreme events, it is important to recognise the uncertainty and limitations in estimating flood events with a very low probability of occurrence. The uncertainties involved with the flood estimation process increase with increasing size of the flood. Events of between 1:100AEP and 1:10,000AEP are termed “very rare” but are considered within the range of largest direct observations and the credible limit of extrapolation (limit of plausible extrapolation from other sources of information). Extreme events are in the range between 1:10,000AEP event and the Probable Maximum Flood (PMF) and represent the range of floods which borders on the ‘unknowable’, where even a high level of expertise cannot substantially reduce the level of uncertainty.

The PMF is a design concept that notionally represents the upper limit on flood magnitude but for which an AEP cannot be readily assigned. Although it is possible to produce an estimate of the PMF and simulate the associated flood hydraulics, this needs to be viewed in an appropriate context. There is no precedent for events of this magnitude in a catchment of this size in Australia or globally. Furthermore, the probability of the Probable Maximum Precipitation (PMP) event occurring in a catchment this size (1,340 km^2) is 1:1,000,000; however, the probability of the PMF cannot be reliably estimated as it requires both the PMP rainfall and extremely wet antecedent catchment conditions to coincide. Furthermore, it is possible that a catchment may change its behaviour when subjected to extreme rainfalls, with geomorphological mechanisms and changes in storage and routing behaviour possible. Extreme floods can be landscape altering even in the natural (undeveloped) environment which can in turn alter the magnitude of the flood flows. Typically, estimates of the PMF would only be applied in very limited circumstances, for example, in the design of spillways for water or tailings dams which fall into a high-risk category.

The situation of the Proposal, being of higher elevation, upstream of a flood plain and outside the floodplains of either creek (WWC and PMC), reduces the overall flood risk significantly. The flood risk associated with the Proposal is very low, no impacts to downstream flows and low risk of creek capture by the remaining HD2 pit void are expected due to surface water management structures. Because of the reasons described above, it is suggested that the following events are appropriate for use in assessing performance of operational flood protection and inform closure planning:

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- The 1:100AEP flood can be reliably estimated using the methods adopted and is appropriate for use in floodplain assessments for operational infrastructure.
- The 1:1,000AEP flood is considered a rare event, however it is a realistic event to use when identifying risks associated with greater than design flood events for closure, as it falls within the credible limit of extrapolation, and below the world maximum flood envelope curve (for WWC catchment).
- The 1:10,000AEP flood is considered a very rare event. As an extreme case, the 1:10,000AEP flood event may be considered, as this event is at the upper end of the credible limit of extrapolation and falls just above the envelope curve. However, as the Proposal is located upstream of sensitive receptors and flood management controls are required to manage surface water and maintain long term catchment flows, the 1:10,000AEP is a minimum requirement for assessing the risks associated with the management of surface water.

Using methods outlined in Australian Rainfall and Runoff (ARR, 2019), flood estimation of the upper WWC catchment was undertaken to provide site-wide estimates of design floods for rare to very rare events for the HD2 and BHT deposits at closure (Appendix 12).

A two-dimensional hydraulic model was developed using “TUFLOW” software to characterise the surface water flow regime of WWC and PMC in reference to the surrounding landscape. Modelling results, presented in Figure 26 through to Figure 28 (HD2 deposit) and Figure 29 through to Figure 31 (BHT deposit), show that the deposits are not subject to riverine flooding or within the 1:100AEP or 1:1000AEP flood plain for PMC or WWC. Catchment hydrological modelling (RORB) was combined with the 2D hydraulic modelling (TUFLOW) to characterise the surface water flow regime across tenure at the HD2 and BHT

deposits. Design flood quantiles were developed for the 1:2 AEP through to 1:100 AEP event during operations and then the 1: 100AEP up to the 1:10,000AEP events for the closure landform using a flood frequency analysis (FFA) at DWER Tarina flow gauge and Monte Carlo simulation applied to a RORB model, which was calibrated to streamflow records at the same gauging station. Only the modelling results are presented for the closure landform, are presented in Figure 26 through to Figure 28 (HD2 deposit) and Figure 29 through to Figure 31 (BHT deposit).

Initial modelling for the safe operation of the Proposal (1:2 AEP through to 1:100 AEP completed in 2020) (Rio Tinto 2020) indicated that the attenuation of surface water upstream of the PMC crossing is predicted to result in an increase of flood depths of above 1m immediately upstream in the major events. These flood waters will quickly disperse and are not expected to cause a significant change in the hydrological regime of the creek during operations. The crossing is planned to be removed at closure to allow the natural flow regime to return to PMC. These modelling results also indicated that during operations there would be little or no risk to topsoil stockpile storage locations from significant flooding and little to no risk to pit or landform stability even for the rare event (1:100AEP). This modelling also highlighted PMC catchment flows entering the pit at the HD2 deposit during the rare event (1:100AEP), however because of the diversion levee and drain proposed, the risk is reduced during operations and post-closure.

Modelling of flood risks for the closure landform across both deposits (shown in Figure 26 through to Figure 31), considered rare (1:100AEP) through to very rare (1:10,000AEP) events. This modelling showed that the HD2 diversion levee and drains, designed to direct flows from a tributary creek of PMC to WWC, will overtop in the 1:1000AEP and 1:10,000AEP event scenarios (Figure 26 through to Figure 28). These drainage structures will need to be designed to withstand a minimum 1:1000AEP event at closure, to avoid the loss of flows from the WWC catchment and maintain the integrity of the diversion levee and drains. Further work is required in modelling flows to understand if these flows would negatively affect the WWC downstream and sensitive receptors within the creek line, namely WWS.

Modelling of flood risks for the closure landform also highlighted relatively low flood risks associated with the pit and waste rock landform closure designs at the HD2 and BHT deposits. Ponding against the DP_NW (Goanna) waste landform at HD2 deposit is likely to infiltrate quickly across the toe of the waste landform (Figure 26 through to Figure 28), however some capping of the landform may be required at closure to manage erosion. Ponding is also visible on the top of the BHT waste rock landform, against the BHT pit wall in all three event scenarios (1:100AEP through to 1:10,000AEP). The waste material within this landform is unlikely to be affected by this ponding, as the material is competent or of low erodibility. Landform evolution modelling (LEM) of these landforms is planned for the HD2 and BHT deposits and the results of this modelling will be used to inform rehabilitation and management of surface water at closure.

Understanding water and drainage systems and their significance to the Traditional Owner's is an ongoing focus within Rio Tinto to ensure the successful management of cultural heritage values. Outcomes from this ongoing work may influence future revisions of this MCP. Post-closure management is discussed in Section 5.11.3.

5.11.6 Implications for closure and knowledge gaps

Closure implications associated with surface water include:

- Surface water flows for the Proposal will require post-closure management to ensure closure outcomes minimise impacts and support the closure strategy.
- Flood modelling indicates that some areas of the pits in each deposit will intercept surface flows under flood conditions, as well as landforms impeding flows, referring to operational 1:100 AEP.
- Topsoil stockpile areas are placed outside the 1:100 AEP flood inundation zone.
- Flood management structures will be implemented to enable the HD2 deposit to be mined safely and maintain downstream flows into WWC in the long term.
- Surface water quality for PMC and WWC to inform closure strategy.

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Closure knowledge gaps associated with surface water, as summarised in Table 6-1, include:

- Undertake hydrological water quality sampling of PMC and WWC prior to commencing mining of the HD2 and BHT deposits.
- Update surface water modelling for PMC creek diversion in line with changes to landform design and closure strategy for HD2 deposit (1:100AEP, 1:1000AEP and 1:10,000AEP).
- Upgrade of drainage designs for permanent closure drainage structures (PMC) where required, in line with flood risk assessments (1:100AEP, 1:1000AEP and 1:10,000AEP).
- Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters.
- Undertake hydrological modelling (1:100AEP, 1:1000AEP and 1:10,000AEP) of updated landbridge closure strategy and designs.
- Undertake hydrological modelling of abandonment bund alignment and final closure landform for HD2 and BHT deposits (1:100AEP, 1:1000AEP and 1:10,000AEP).
- Determine required engineering flood mitigation structures for HD2 and BHT deposit's closure landforms.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

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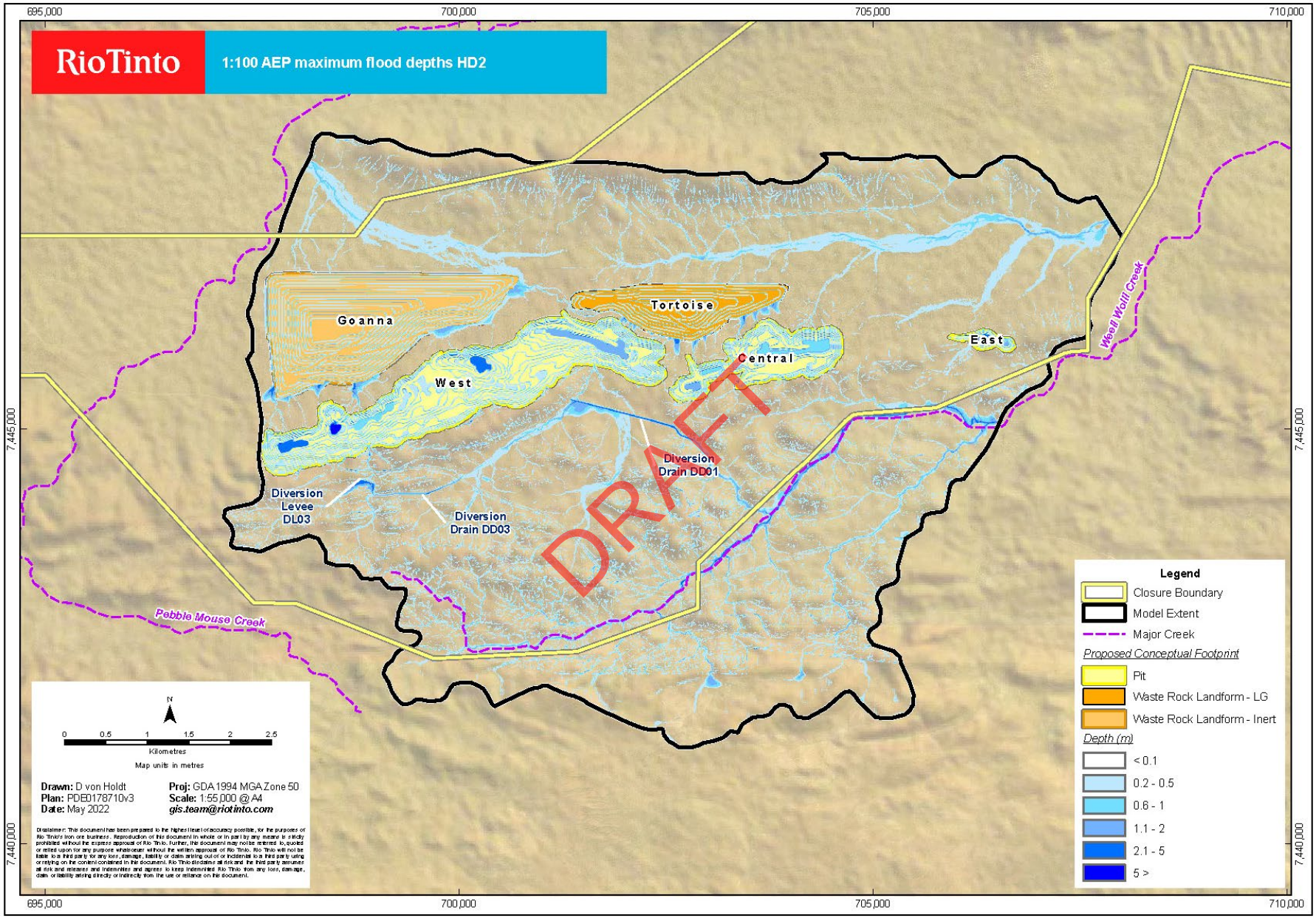

Figure 26: 1:100 AEP maximum flood depths HD2

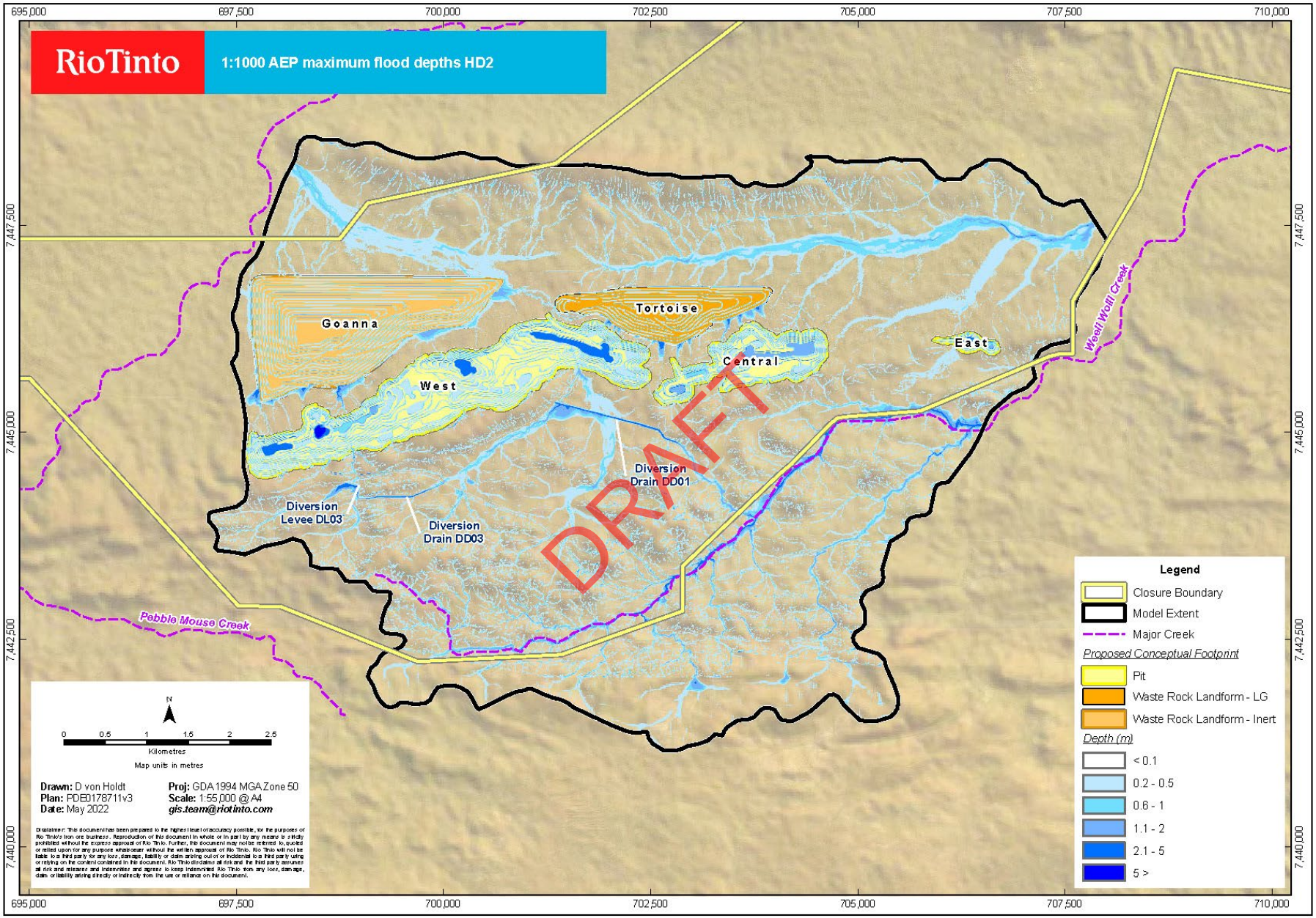

Figure 27: 1:1000 AEP maximum flood extents HD2

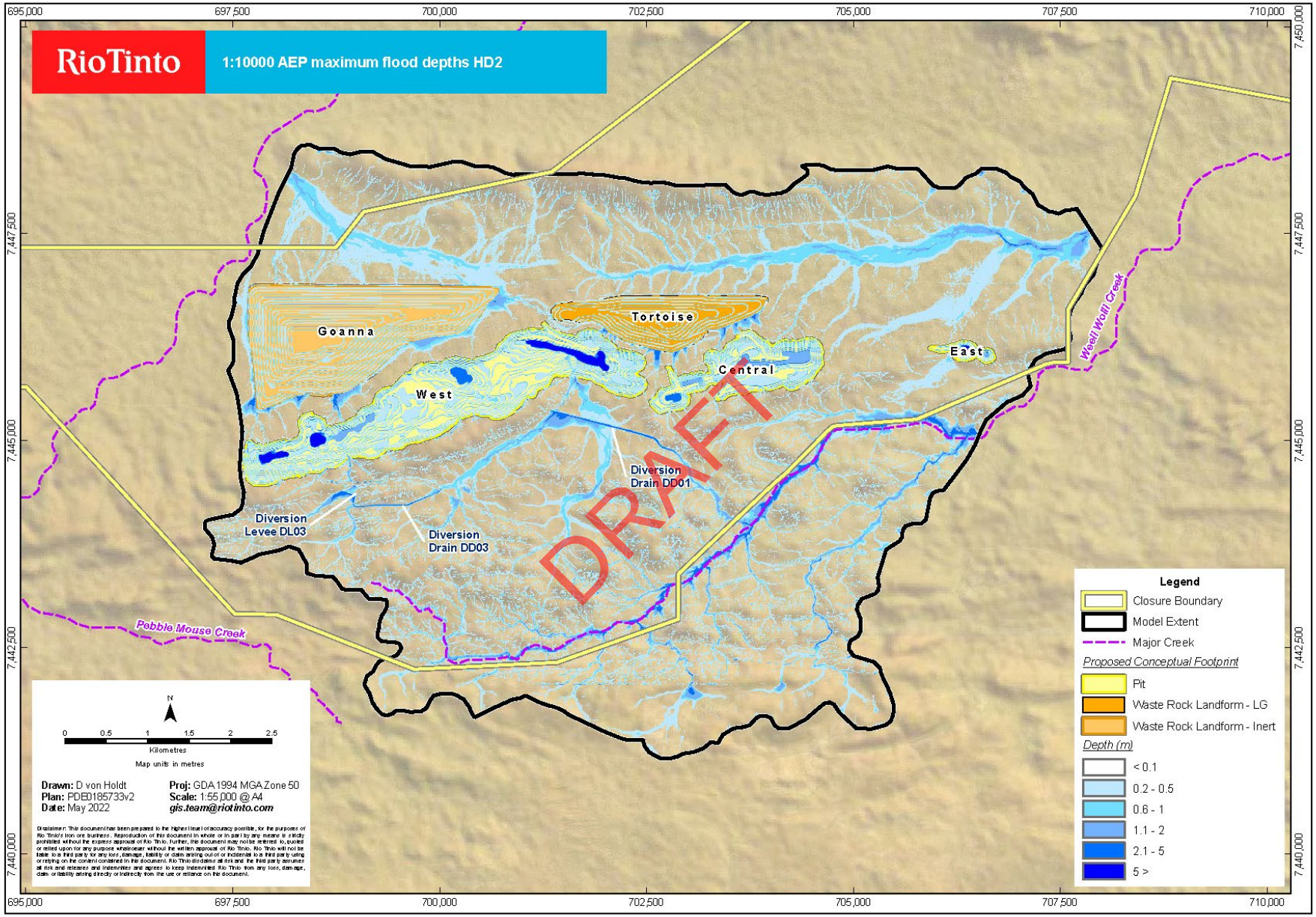

Figure 28: 1:10,000 AEP maximum flood depths HD2

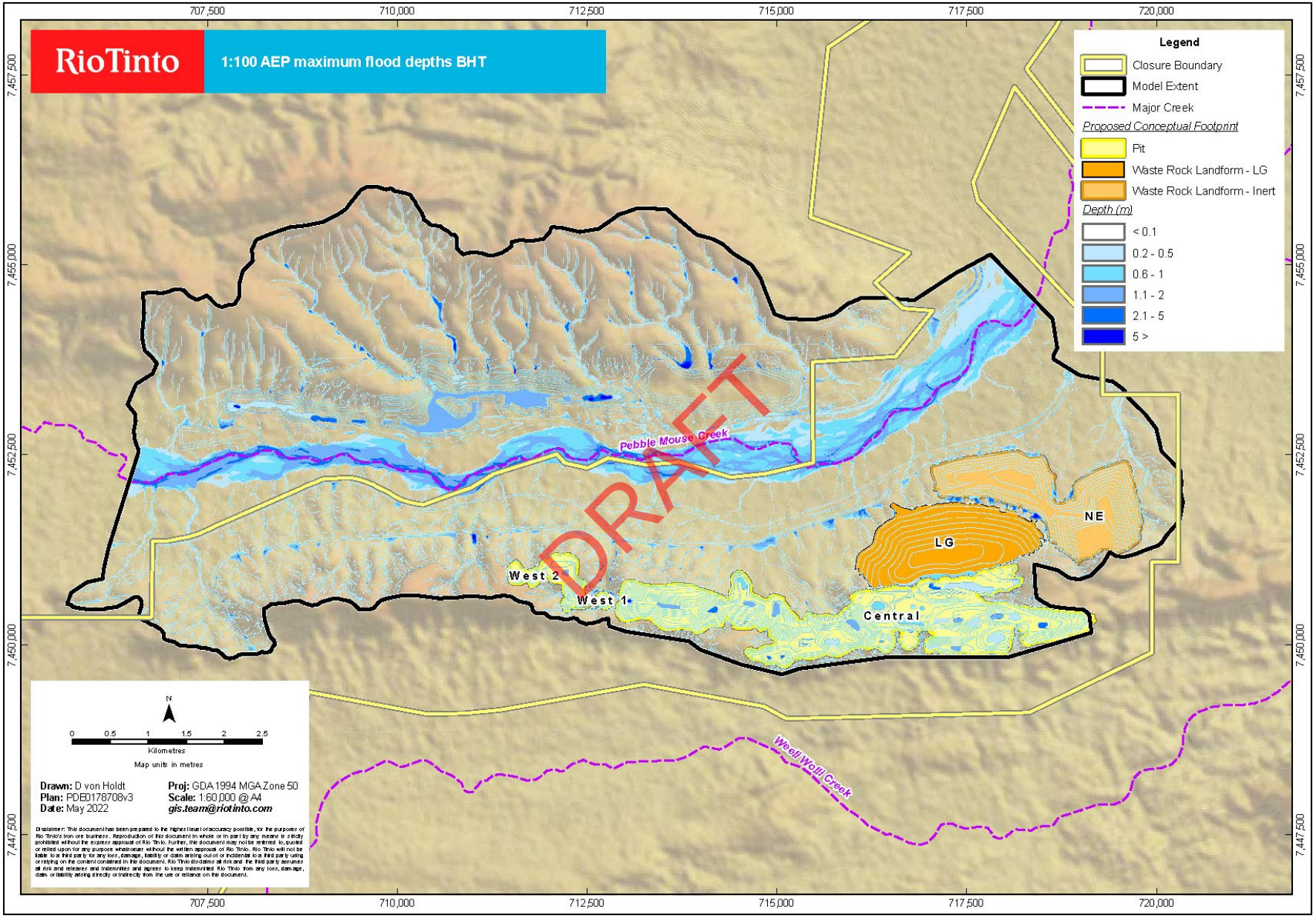

Figure 29: 1:100 AEP maximum flood depths BHT

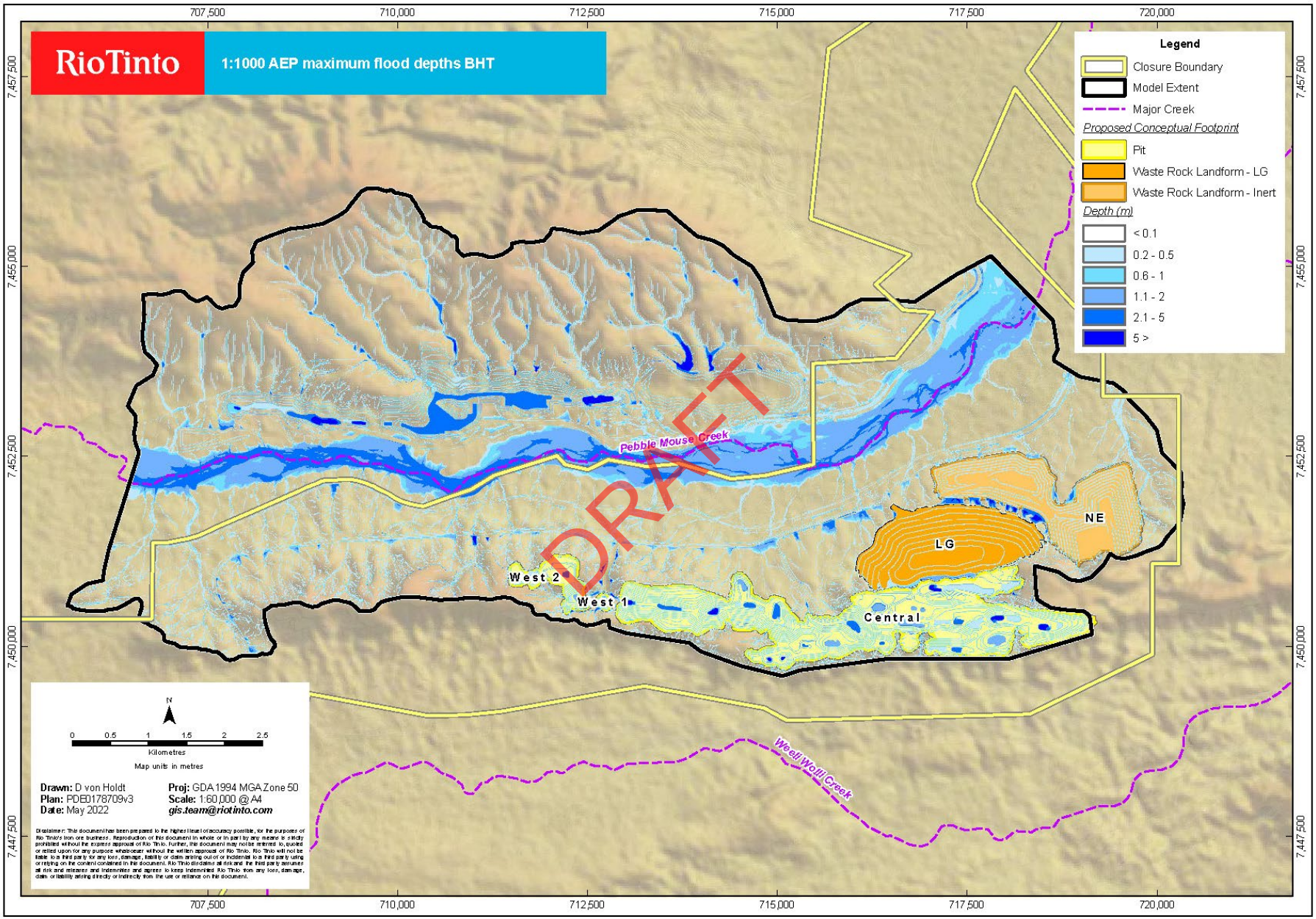

Figure 30: 1:1000 AEP maximum flood depths BHT

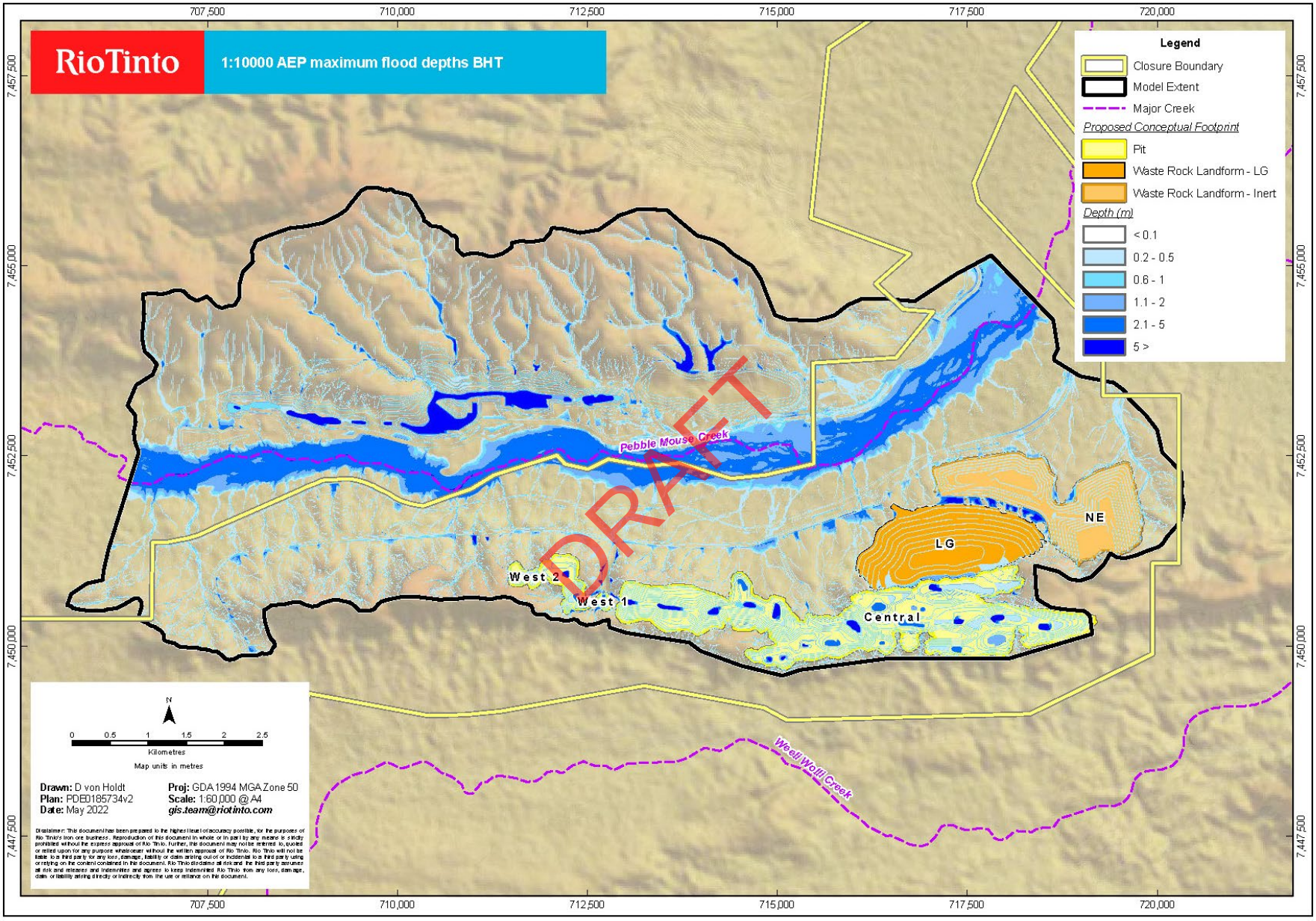

Figure 31: 1:10,000 AEP maximum flood depths BHT

BIOLOGICAL ENVIRONMENT

5.12 Conservation significant areas

5.12.1 National Parks

The nearest major conservation reserves to the Proposal closure boundary include:

- Karijini National Park (KNP), the eastern portion of which is approximately 25 km northwest of the Proposal closure boundary, while portions of the Western Rail Corridor are located adjacent to the KNP.
- Proposed Fortescue Marsh National Park, approximately 64 km north of the Proposal closure boundary.
- Mungaroona Range Nature Reserve, approximately 72 km to the north-west of the Proposal closure boundary.
- Millstream-Chichester National Park, approximately 156 km to the north-west of the Proposal closure boundary.

5.12.2 Threatened and Priority Ecological Communities

There are no Threatened or Priority Ecological Communities (TEC / PECs) located within the Proposal closure boundary, although the following PEC is in proximity.

- WWS Community (P1) the buffer is located approximately 9.7 km northeast of BHT deposit and approximately 23.7 km of HD2 deposit.

The Proposal is not expected to impact the conservation status of any flora or fauna species, populations, or fauna habitat. This includes changes to abundance, species diversity, geographic distribution and / or productivity of flora at species or ecosystem levels.

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5.12.3 Implications for closure and knowledge gaps

Closure implications associated with conservation significant areas include:

- Exclusion zones around conservation significant areas will be maintained through the decommissioning and closure implementation phases.
- Conservation significant areas are key values in the landscape and factor into closure planning related to post-closure land use, access to the landscape and closure outcomes.

Closure knowledge gaps associated with flora and vegetation, as summarised in Table 6-1, include:

- Conservation significant areas will be considered in closure planning with reference to post-closure land use, access to the landscape and closure outcomes.
- Conservation significant areas will be considered in closure planning with reference to post-closure land use, access to the landscape and closure outcomes.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

5.13 Flora and vegetation

Astron (2019a) completed a detailed flora and vegetation survey including three phases of survey from 2017 to 2019. Flora survey coverage is shown in Figure 32.

5.13.1 Priority flora

A total of 411 native flora taxa from 161 genera, belonging to 52 families have been recorded within the Proposal closure boundary with *Acacia* (37 taxa) the dominant genus with others *Eremophila* (16 taxa) and *Senna* (16 taxa) (Astron, 2019).

Table 5-13 lists the Threatened and Priority flora that have been identified at the Proposal and which have high biodiversity value based on their conservation status. No Threatened flora species listed under the Commonwealth EPBC Act, or the State BC Act have been recorded within the Proposal closure boundary. The species distribution is presented in Figure 32 through to Figure 35.

While mining activities may directly impact individuals of these species, it is not expected they will affect any given species, considering the regional distribution. Seeding of Priority species is not currently considered in rehabilitation planning, as discussed further within this MCP.

Table 5-13: Significant flora identified at the Proposal

Flora taxon	Conservation status WA	Habitat comments
Eremophila sp. West Angelas (S. van Leeuwen 4068)	P2	Very steep hillslopes, base of breakaways. High in the landscape
Aristida lazaridis	P2	Plains, drainage lines, associated flood out areas.
Hibiscus sp. Gurinbiddy Range (M.E. Trudgen MET 15708)	P2	Near summit of hills, high in landscape, gorges. gullies
Acacia subtiliformis	P3	On rocky calcrete plateaux, rocky slopes.
Eremophila naaykensii	P3	High in the landscape, cliff tops, gorge tops, steep rocky slopes.
Goodenia sp. East Pilbara (A.A. Mitchell PRP 727)	P3	Calcrete flats and rises
Grevillea saxicola	P3	Low rocky hills and associated slopes, foot slopes and drainage features.
Rhagodia sp. Hamersley (M. Trudgen 17794)	P3	Mulga plains, south facing slopes of ironstone hills.
Triodia sp. Mt Ella (M.E. Trudgen 12739)	P3	Amongst rocks and outcrops, east and southeast facing gorge slopes, south facing breakaways.
Acacia bromilowiana	P4	Rocky hills, breakaways, scree slopes, gorges, creek beds.
Lepidium catapycnon	P4	Hill top, slopes and drainage features.
Ptilotus mollis	P4	Stony hills and screes, hillslopes below small breakaways.

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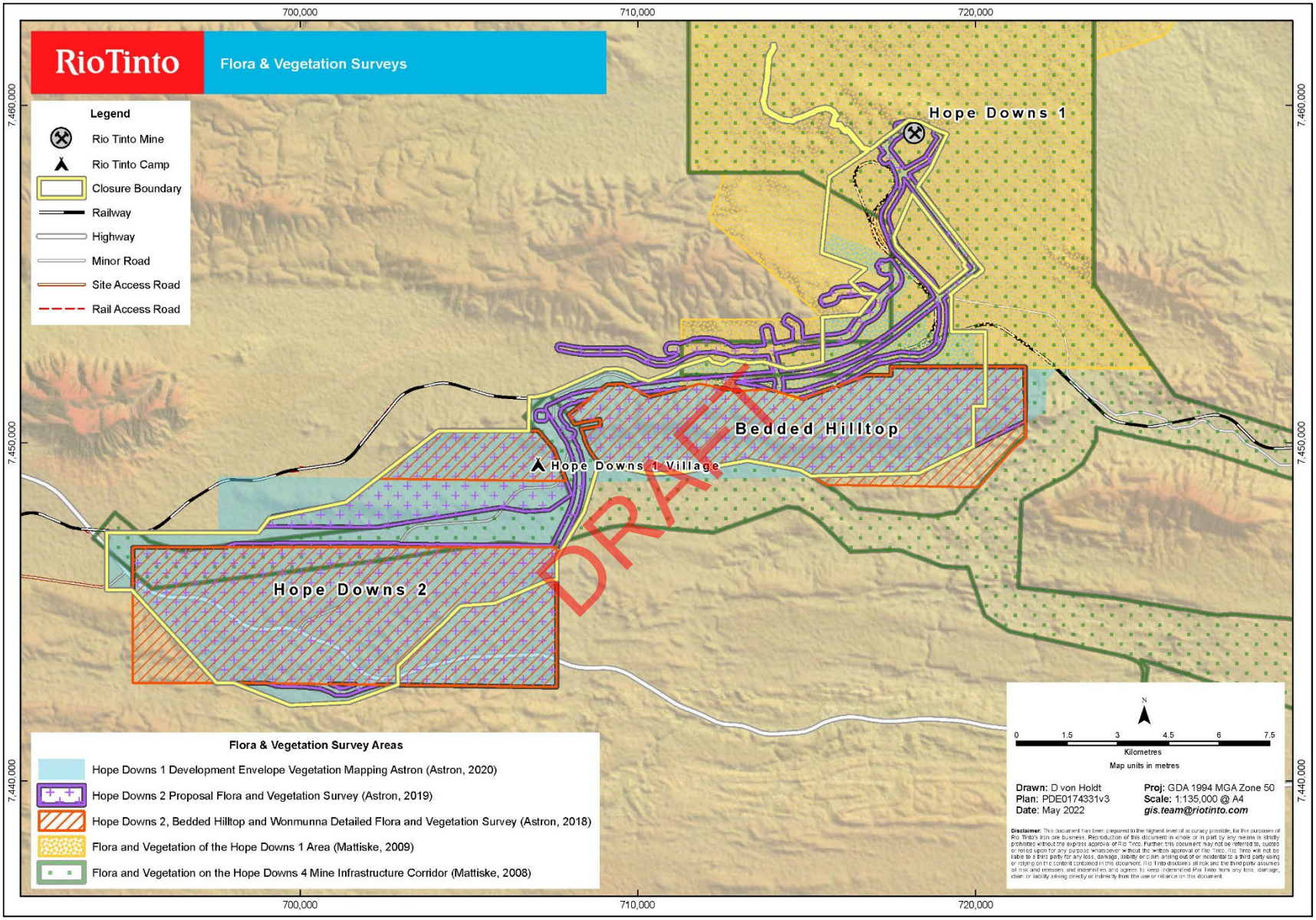

Figure 32: Flora and vegetation surveys

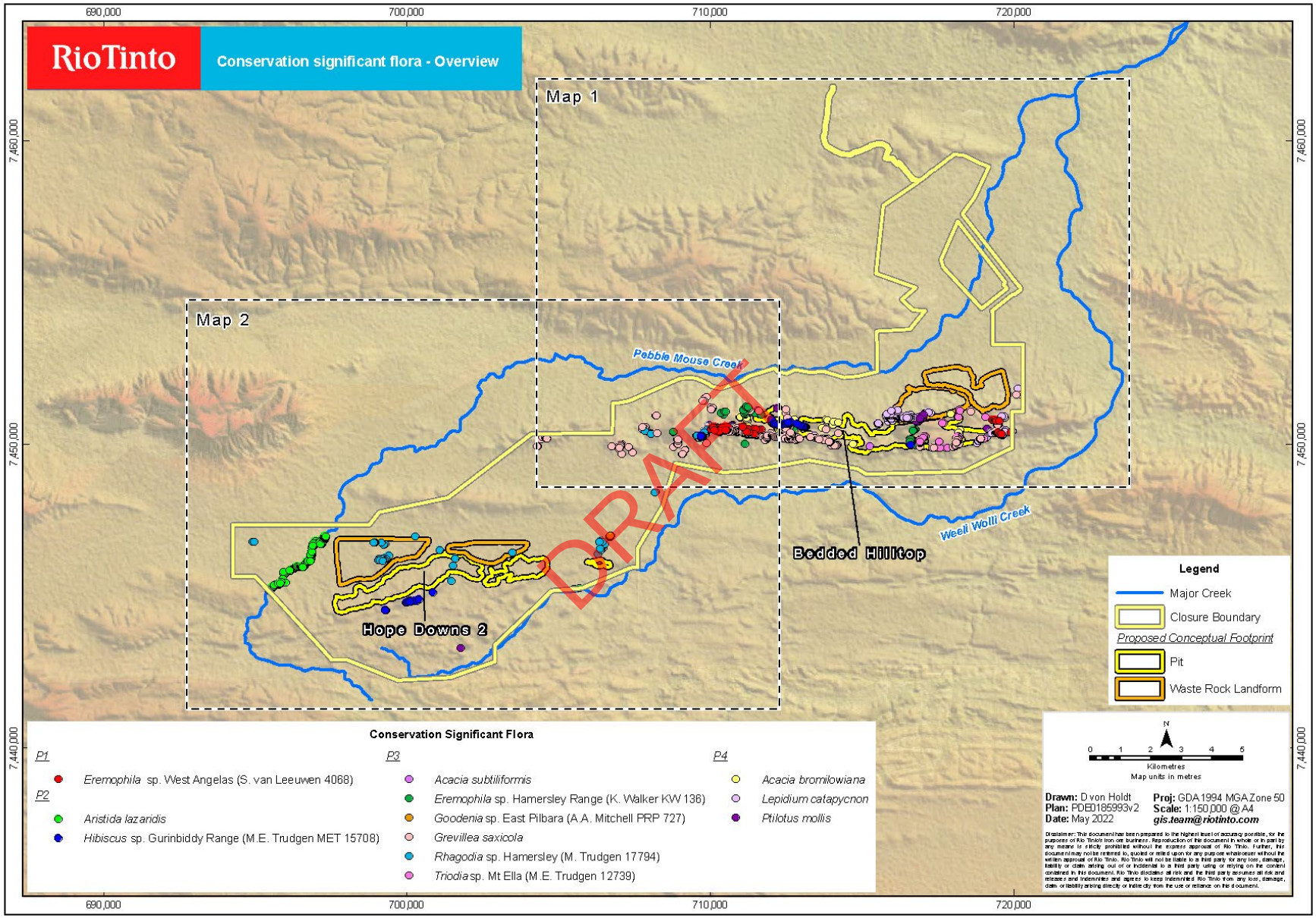

Figure 33: Significant flora records - Overview

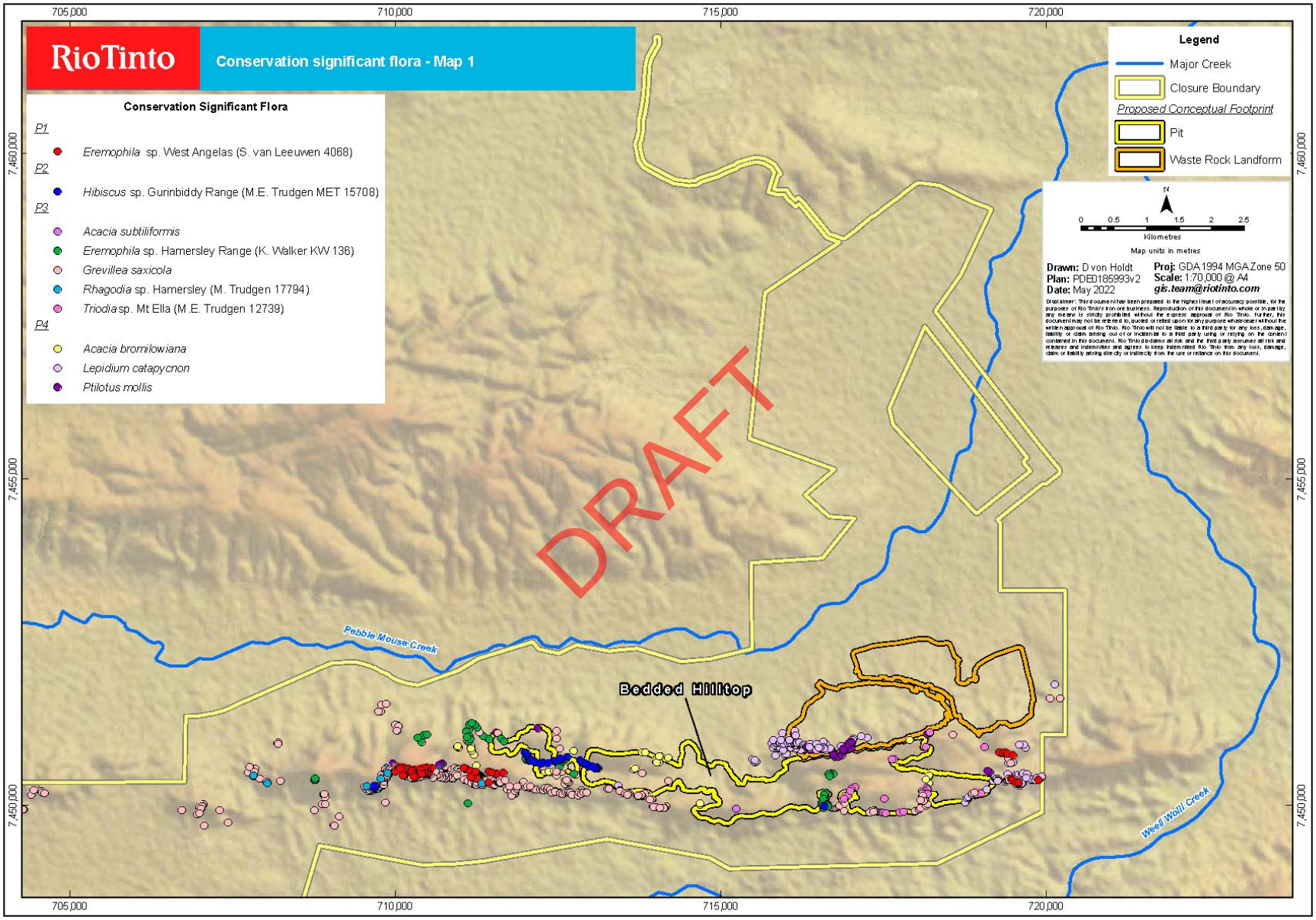

Figure 34: Significant flora (map 1)

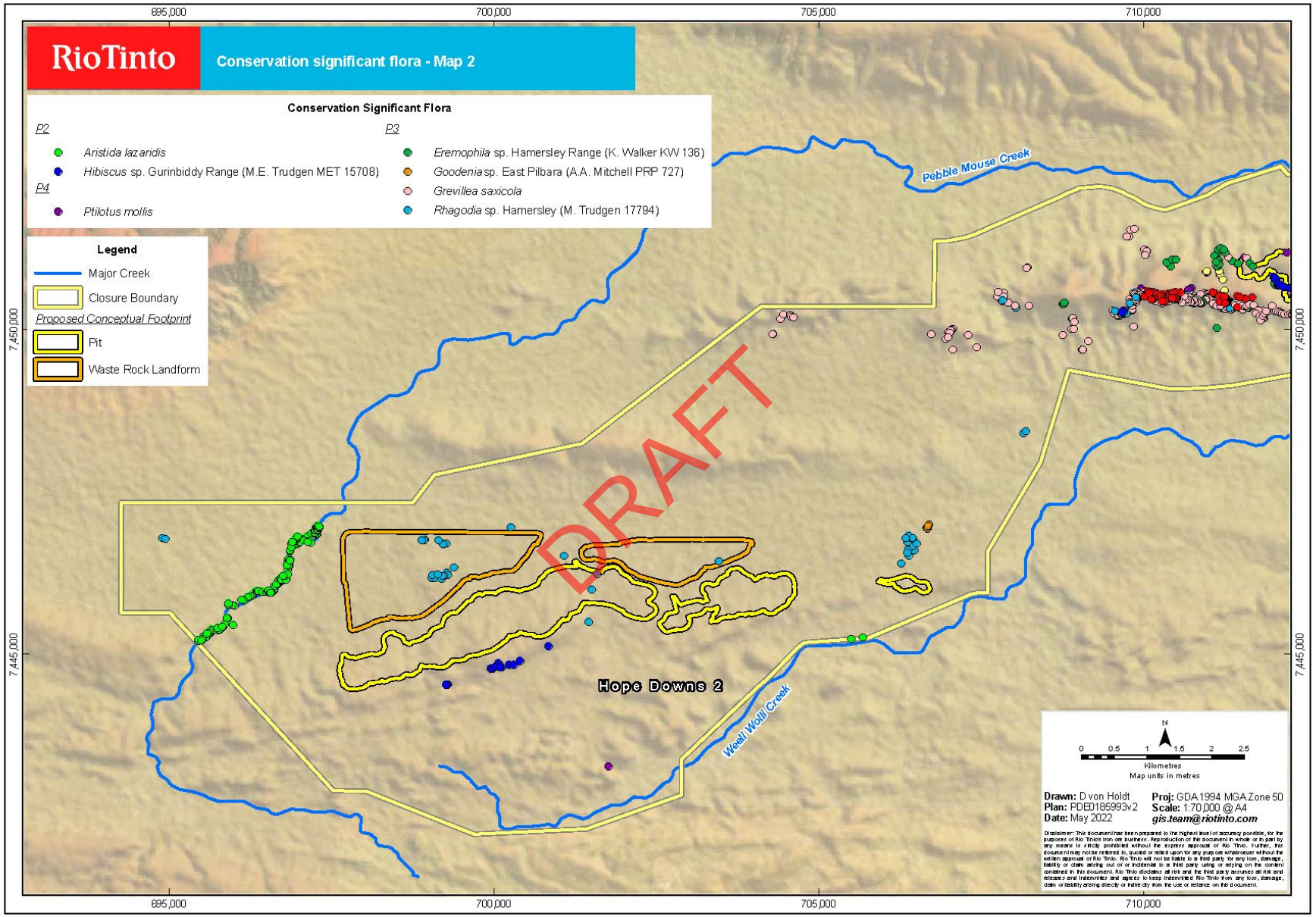

Figure 35: Significant flora (map 2)

5.13.2 Vegetation communities

Two vegetation units, H2 (associated with hill tops and hill slopes) and D4 (associated with drainage line habitat), within the Proposal were rated as of high local significance (Astron 2019).

- H2 (Hills and Slopes #2) occurs on the south-facing upper slopes of BHT and supports Priority flora in relatively dense populations, in particular P2 *Eremophila* sp. West Angelas (S. van Leeuwen 4068) and P3 *Eremophila naaykensii* (Astron, 2019a). The vegetation was found to be in Very Good to Excellent condition and largely unaffected by recent fires, indicating the unit may act as refuge habitat for conservation significant flora, as such it may also be threatened by fire, which kills mulga stands and/or prevents regeneration. The unit also has an affinity with the ecosystem at risk 'lower-slope mulga', further supporting its high local conservation significance rating (Astron, 2019).
- D4 (Drainage #4) occurs on larger drainage lines, including at Pebble Mouse Creek and supports the facultative phreatophyte species *Eucalyptus camaldulensis* subsp. *obtusa* and *E. victrix*. The vegetation was assessed as Good to Very Good condition and in some of the upper reaches of Weeli Wolli and Pebble Mouse Creeks, supports an additional conservation significant flora taxa, P2 *Aristida lazaridis* (Astron, 2019a). Riparian vegetation equivalent to the D4 unit is generally well represented within the locality, and the Hamersley sub-region. The high local significance is predominantly attributed due to this unit representing the larger drainage habitats of the Proposal as well as the key habitats potentially supporting potential GDEs. Furthermore, a significant portion of the significance rating attributed to this unit by Astron (2019a) is afforded due to it supporting the P2 species *Aristida lazaridis* in some areas. *A. lazaridis* is only detected in association.

Nine vegetation units, D7, D8, P1, P2, P3, P4, H1, H6 and H7 (associated with drainage line, plains, and hills and slopes habitat), were considered to be of moderate local significance (Astron, 2019). The justification for this classification is as follows:

- D7 (Drainage #7) supports populations of *Aristida lazaridis* (P2).
- D8 (Drainage #8) is likely to represent the regional 'Valley Floor mulga' which is considered to be an EAR, and also supports a small population of *Rhagodia* sp. Hamersley (M. Trudgen 17794).
- P1 (Plains #1) is likely to represent the 'grove/inter-grove mulga, Eastern Hamersley Range', which is considered an EAR.
- P2 (Plains #2) occurs on cracking clays and alluvial plains and supports several populations of *Aristida lazaridis* (P2).
- P3 (Plains #3) supports populations of *Aristida lazaridis* (P2) and is likely to represent the regional 'Valley Floor mulga' vegetation community which is considered to be an EAR.
- P4 (Plains #4) likely to represent with the regional 'Valley Floor mulga' which is considered to be an EAR.
- H1 (Hills and Slopes #1) supports the presence of numerous Priority flora taxa, including *Eremophila naaykensii, Grevillea saxicola* and *Triodia* sp. Mt Ella (M.E. Trudgen 12739)
- H6 (Hills and Slopes #6) is likely to represent the 'Lower-Slope Mulga', which is an EAR in the Hamersley subregion due to frequent fires.
- H7 (Hills and Slopes #7) supports high number of *Hibiscus* sp. Gurinbiddy Range (M.E. Trudgen MET 15708) (P2) being recorded within the vegetation type.

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5.13.3 Invasive flora

Flora and vegetation surveys within the Proposal closure boundary have recorded a total of 17 introduced flora species (weeds) pre-disturbance (Table 5-14). The most frequently recorded weed species throughout the Proposal was *Bidens bipinnata* (Bipinnate beggartick), associated with creeks, Mulga-dominated vegetation and hillslopes. None of these species are listed as Weeds of National Significance or declared plants for the Pilbara region under the *Biosecurity and Agriculture Management Act 2007* (WA).

The DBCA Weed Species Ranking considers the potential distribution, current distribution, ecological impact, invasiveness and feasibility of control to derive a final broad qualitative weed species ranking corresponding to specific management actions.

Weeds are managed during operations in accordance with internal procedures and guidelines and includes strategies such as periodic spraying and equipment hygiene.

Table 5-14: Weed species recorded at the Proposal

Scientific name	Common name	Ecological impact	Invasiveness
Bidens bipinnata	Bipinnate Beggartick	Unknown	Rapid
Brassica tournefortii	Mediterranean Turnip	High	Rapid
Cenchrus ciliaris	Buffel Grass	High	Rapid
Cenchrus setiger	Birdwood Grass	High	Rapid
Chloris virgata	Feathertop Rhodes Grass	high	Rapid
Conyza bonariensis	Flax leaf Fleabane	No rating	No rating
Cynodon dactylon	Couch	High	Rapid
Datura leichhardtii subsp. leichhardtii	Native Thornapple	Unknown	Unknown
Flaveria trinervia	Speedy Weed	No rating	No rating
Lactuca serriola	Prickly Lettuce	No rating	No rating
Malvastrum americanum	Spiked Malvastrum	High	Rapid
Rumex vesicarius	Ruby Dock	No rating	No rating
Setaria verticillata	Whorled Pigeon Grass	High	Rapid
Sigesbeckia orientalis	Indian Weed	Unknown	Rapid
Solanum nigrum	Black Berry Nightshade	Low	Rapid
Sonchus oleraceus	Common Sow thistle	Low	Rapid
Vachellia farnesiana	Mimosa Bush	High	Rapid

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5.13.4 Implications for closure and knowledge gaps

Closure implications associated with flora and vegetation include:

- Exclusion zones around conservation significant flora species will be maintained through the decommissioning and closure implementation phases.
- The selection of reference / analogue sites and the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) to assess the performance of progressive rehabilitation.
- Optimal seed selection of rehabilitation seed mix is crucial to progressive rehabilitation and successful achievement of rehabilitation completion criteria targets.
- Undertaking rehabilitation of waste rock landforms and disturbed areas progressively, reduces the monitoring and maintenance post-closure and overall closure implementation timeframes and costs.

Closure knowledge gaps associated with flora and vegetation, as summarised in Table 6-1, include:

- Seed mixes have not been developed for the Proposal, to facilitate progressive rehabilitation. Considering the short mine life for the Proposal, flora species recorded in baseline surveys will be

used to inform rehabilitation seed mix(es). Seed mixes will be developed in consultation with stakeholders.

- The selection of reference / analogue sites and the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) have not yet been undertaken. Vegetation mapping completed for the Proposal will be used to inform the selection of reference / analogue sites and inform the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) and monitor against progressive rehabilitation
- Select reference / analogue sites for HD2 and BHT deposits to inform revegetation criteria and progressive rehabilitation.
- Implement progressive closure and rehabilitation of waste rock landforms and disturbed areas as soon as possible to reduce closure liabilities.
- Develop seed mix(es) in line with progressive rehabilitation targets and consultation with stakeholders.
- Conduct closure research and rehabilitation trials to demonstrate methodologies.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

5.14 Fauna

A series of fauna surveys were conducted within the Proposal closure boundary to inform the Part IV environmental impact assessment process, the results of which have been consolidated into an integrated report (Astron, 2019). Fauna survey coverage is presented in Figure 36.

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5.14.1 Terrestrial fauna habitat

There are eight broad fauna habitat types identified within the Proposal area prior to mining, shown in Figure 37. These habitats include Gorge and Gully, Breakaway, Minor Drainage, Rocky Hill, Low Hills and Slopes, Alluvial Plain, Mulga Woodland and Stony Plain. These habitat types are expected to be represented in undisturbed areas after closure. Characteristics of these habitat types are provided in Table 5-15.

Table 5-15: Description of pre-mining habitats identified at the Proposal

Landform	Basic description
Gorge and Gullies	Represented by deep often rocky gorges, sometimes with ephemeral or semi-permanent pools, after significant rainfall events, particularly in the BHT area. These habitats are high value providing significant shelter sites and supports a diversity of fauna species. Microhabitats include overhangs, crevices, caves, tree hollows, ephemeral, semi-permanent water. Vegetation is dominated by scattered low Mallee over tall open scrub, scattered shrubs and scattered *Triodia* hummock grasses.
Breakaway	Features breakaways or ridge lines, falling away to steep scree slope or drainage. This landscape is of high value to a low diversity of fauna species that are likely to reside in Breakaway habitats. Microhabitats include caves (roost/feed caves), cracks and crevices and sheltered leaf litter. Vegetation is typically *Eucalyptus* and *Corymbia* low open woodland over tall open shrubland and very open *Triodia* hummock grassland to open *Triodia* tussock grassland.

Landform	Basic description
Minor Drainage	Moderate value habitat characterised by open drainage areas on stony soils, with water bodies only present during times of heavy inundation. The landform supports a moderate diversity of microhabitats, with some tree hollows and woody debris, thick ground cover/vegetation and deep leaf litter. The vegetation commonly associated with this habitat is *Eucalyptus* low woodland, with scattered low trees and tall open shrubland and open tussock grassland.
Rocky Hill	Represented by stony hills on high ranges with dissected valleys and gorges. Rocky Hill habitat is of moderate value to a low diversity of fauna species that are rocky habitat specialists. Microhabitats include shallow overhangs, boulders and crevices. Vegetation is dominated by *Eucalyptus* low open woodland and low open shrubland over open *Triodia* hummock grassland.
Low Hill and Slopes	Extends over low stony hills and slopes with dissected valleys and drainage on stony soils. These habitats are of low value for a wide spectrum of fauna species. Microhabitats include termite mounds, *Triodia* hummocks, minimal leaf litter Vegetation typically consists of low open *Eucalyptus* woodland and tall shrubs over *Triodia* hummock grassland.
Alluvial Plain	Flood plain surrounding drainage areas. This habitat is of low value to a wide spectrum of fauna species. Microhabitats include dense leaf litter, termite mounds and spinifex clumps, cracking clays. Vegetation association of alluvial plains is composed of tall open *Acacia* and *Eremophila* shrubland over low open shrubland and tussock grassland.
Mulga Woodland	Represented by stands of Mulga groves on clay based stony plains. This habitat is of low value to a wide spectrum of fauna species. Microhabitats include termite mounds and minimal leaf litter. Vegetation consists of tall *Acacia* shrubland over scattered tall shrubs, open shrubland and very open *Triodia* hummock grassland.
Stony Plain	Spans broad flat low-lying plains to undulating plain on soft loamy soils. This habitat is of low value to a wide spectrum of fauna species. Microhabitats include limited leaf litter, termite mounds and spinifex clumps. The dominant vegetation is low open *Eucalyptus* woodland over scattered tall *Acacia* shrubs and *Triodia* hummock grassland.

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The Gorge/Gully and Breakaway habitats are of high value as they contain microhabitats such as caves, cracks and crevices which provide refuge and foraging opportunities. These habitat types are the most restricted of the habitat types present; however, they are not considered unique to the Proposal and are typical of the Hamersley sub-region of the Pilbara. Most of the other habitat types (excluding Mulga Woodland) are relatively common and widespread throughout the Pilbara.

Areas of cleared habitat are prevalent throughout the Proposal closure boundary because of drilling programs. Fauna habitats adjacent to these disturbed areas show evidence of edge effects including lack of connectivity, grazing and dust deposition. Elsewhere, fauna habitat condition is affected to some extent by grazing and trampling by cattle and feral camels in localised areas such as drainage lines and associated plains but is otherwise generally considered to be in Good to Excellent condition.

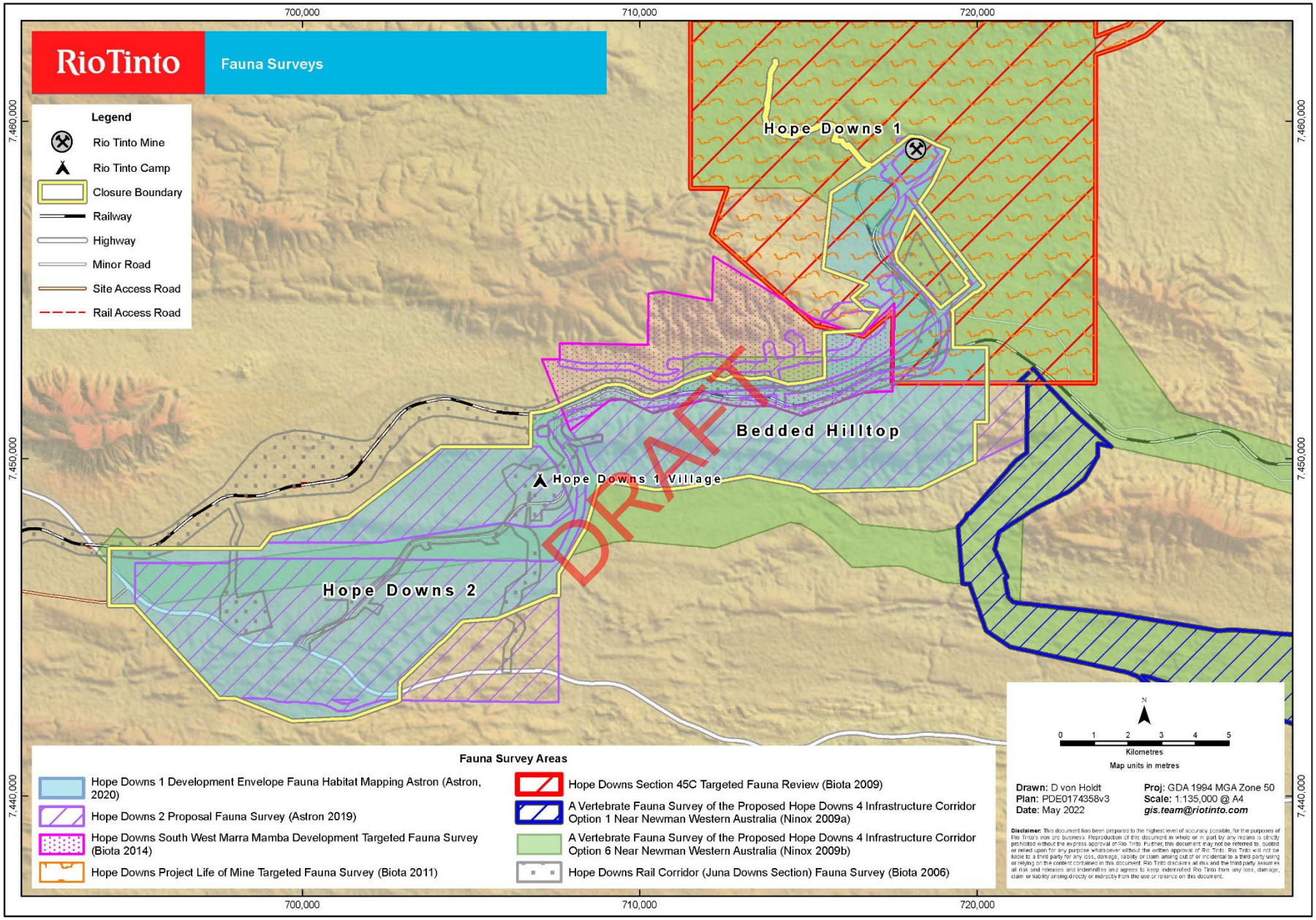

Figure 36: Fauna survey areas

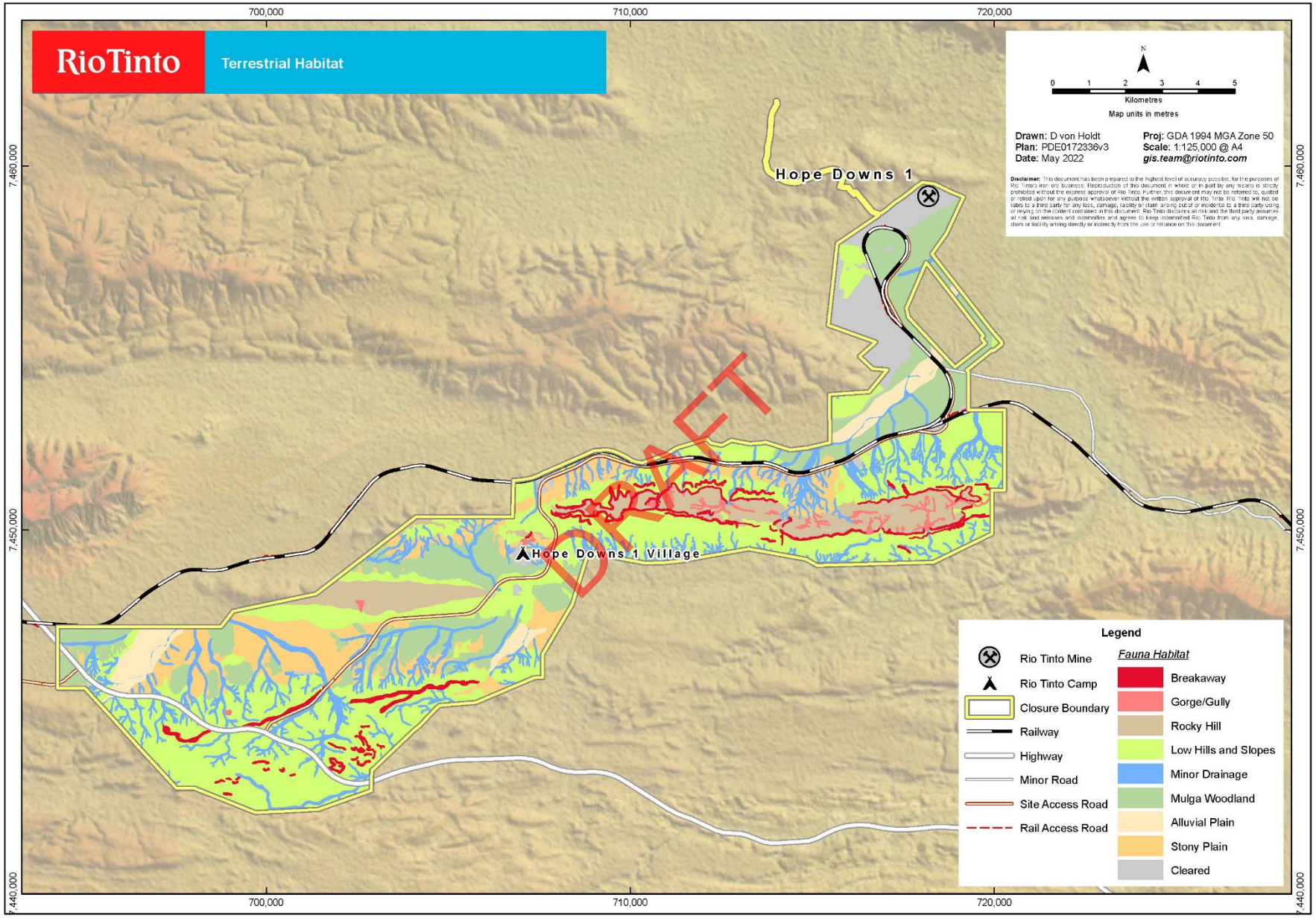

Figure 37: Terrestrial fauna habitats

5.14.2 Fauna reintroduction

The re-introduction or translocation of fauna into rehabilitated areas is not proposed as part of this MCP.

Instead, natural migration of fauna species into rehabilitated land is encouraged by creating habitats with similar composition to pre-mining communities in appropriate locations and with consideration of the post-closure soil and landforms design. Habitat elements that are considered as part of the closure landform design includes:

- vegetation known to provide preferred food or shelter preference;
- retaining and replacing woody debris;
- rapid generation and retention of leaf litter using small-scale topography (e.g., furrows created from ripping);
- introducing or leaving rocky features such as oversized waste burden or scree slopes;
- creating greater depths of friable soil (or suitable mineral wastes) for burrowing fauna;
- preserving connectivity with unmined areas, and maintaining the quality of these habitats; and
- managing feral predators and herbivores across both reference and rehabilitated areas.

Species associated with plains, drainage line or disturbed habitats have the potential to benefit from the rehabilitation of mine, due to returned or expanded habitat post-closure.

5.14.3 Significant fauna

Seven species of significance have been recorded within the Proposal closure boundary (Table 5-16). Fauna habitat and conservation significant fauna records are presented in Figure 37 through to Figure 39. A Mining Exclusion Zone (MEZ) has been added at BHT deposit to protect 233 ha of significant fauna habitat and 8.3 ha around a cave utilised by Ghost Bats. All efforts will be made leading up to and during closure to protect and maintain areas of significance in line with regulatory guidelines.

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Table 5-16: Significant fauna and its relationship to habitat across the Proposal

Fauna species	Scientific Name	Conservation status WA	EPBC Act status	Habitat occurrence
Northern Quoll	*Dasyurus hallucatus*	Endangered	Endangered	Recorded within closure boundary. Most records (ten) were recorded at the BHT deposit, with four in the HD2 deposit. The records were generally within Gorge/Gully and Breakaway habitat types.
Pilbara Leaf-nosed Bat	*Rhinonicteris aurantia*	Vulnerable	Vulnerable	Recorded at low activity levels at three out of the 23 bat detector locations. All calls were recorded from foraging individuals in Gorge/Gully and Breakaway habitats at least three hours after dusk. These records are not consistent with the presence of a permanent roost cave nearby.
Ghost Bat	*Macroderma gigas*	Vulnerable	Vulnerable	Evidence of Ghost Bat activity within the closure boundary has been recorded on multiple occasions over three survey phases, through acoustic recordings, scat recordings in nocturnal feed caves and an individual Ghost Bat sighted during spotlighting within the closure boundary. Four of these records occurred within the BHT deposit, four within the HD2 deposit and one record from the Wonmunna area, situated between the two deposits. Ten caves (including one potential maternity roost, two potential diurnal roosts and two confirmed nocturnal feeding roosts) were recorded within the closure boundary. All recorded roosts are located within the Gorge/Gully and Breakaway habitat types.
Oriental Plover	*Charadrius veredus*	Migratory	Migratory	Not recorded. However, a single individual Oriental Plover was opportunistically recorded northeast of the HD2 deposit at the HD1 camp soccer pitch. Given the species is a non-breeding visitor to Australia, no habitats present in the closure boundary support breeding of this species. Habitat types within the closure boundary likely represent suitable foraging habitat for the species, particularly when water is available after significant rainfall.
Unpatterned Robust Lerista (Robertson Range)	*Lerista macropisthopus remota*	Priority 2	-	One individual of the species has been recorded within the closure boundary. The individual was found within a Mulga Woodland habitat, with the species expected to also occur within the Alluvial Plain and Minor Drainage fauna habitats.
Letter-winged Kite	*Elanus scriptus*	Priority 4	-	One individual was recorded within the closure boundary which represents a new record for the local area, with the nearest record to Proposal being approximately 120 km north. This record is expected to reflect the species habits of translocating across landscapes in response to increased foraging resources.
Western Pebble-mound Mouse	*Pseudomys chapmani*	Priority 4	-	Three individuals were recorded within the closure boundary. Five pebble mounds were recorded within the Stony Plain, Rocky Hill and Mulga Woodland habitats.

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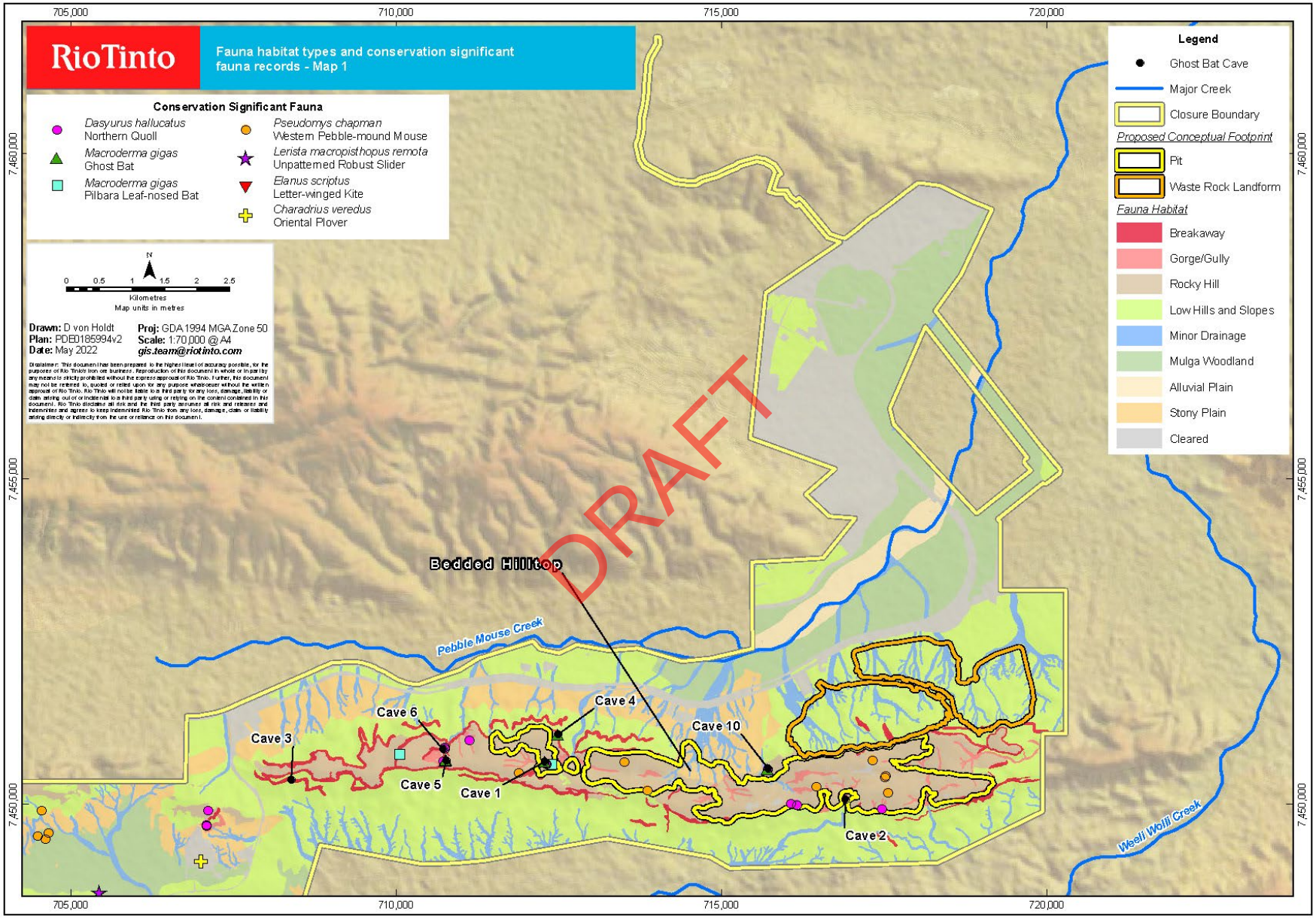

Figure 38: Fauna habitat types and significant fauna records (map 1)

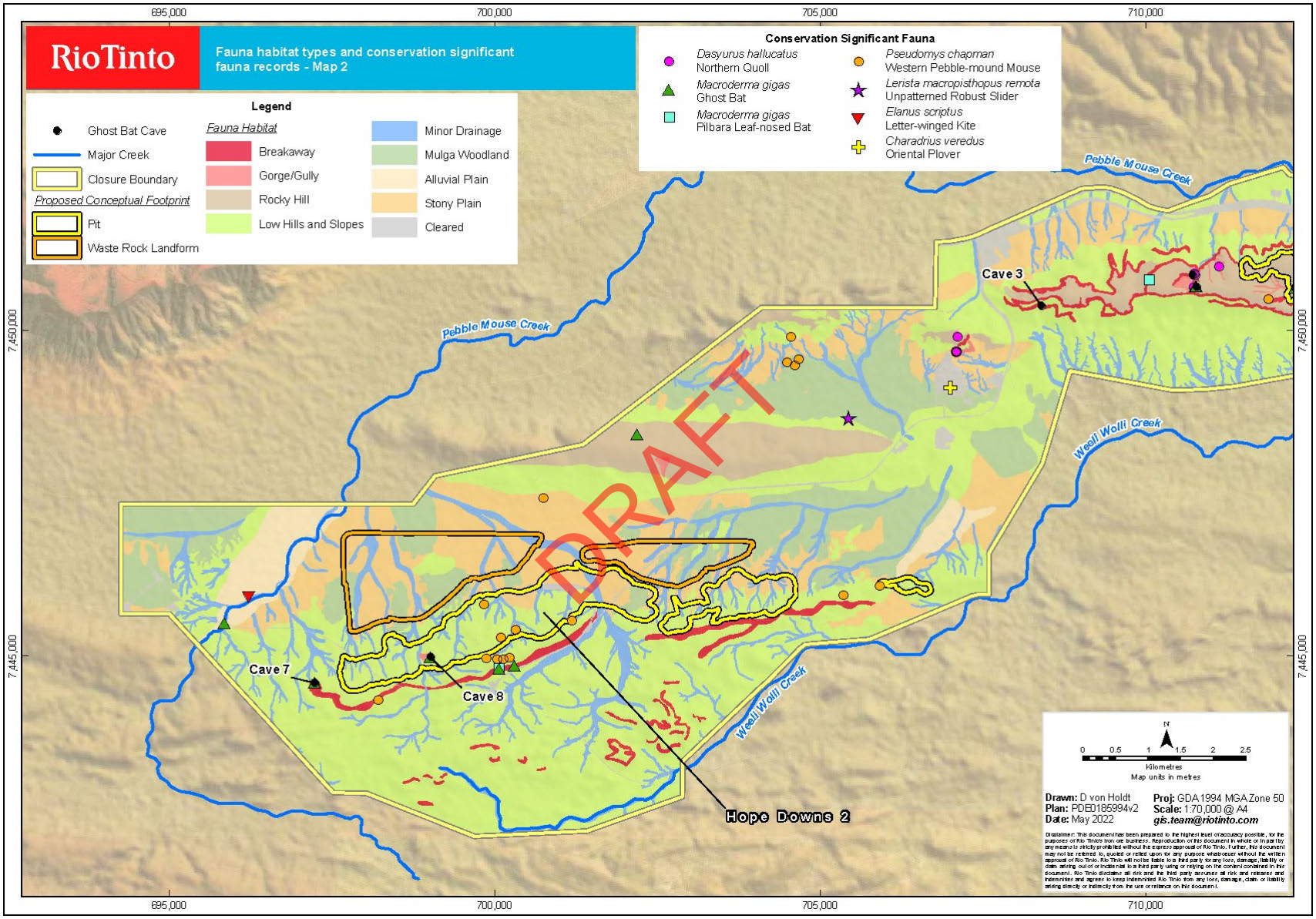

Figure 39: Fauna habitat types and conservation significant fauna records (map 2)

5.14.4 Short range endemic fauna

Short Range Endemic (SRE) fauna, which includes species of insects, arachnids, myriapods and crustaceans, have highly restricted distributions (less than 10,000 km^2) because of poor dispersal, slow growth, low fecundity or specific habitat preferences, confinement to discontinuous habitats, and highly seasonal activity patterns. The following broad fauna habitat types identified within the Proposal area have been identified as being favourable for SREs:

- Breakaway - High;
- Mulga Woodland - Moderate;
- Minor Drainage - Moderate;
- Gorge/Gully - High; and
- Rocky Hill - High.

Most of the above listed habitats are associated with an isolated east-west running ridge, resulting in most of the breakaways and rocky slopes being southward-facing, which is typically most favourable for SREs (Astron, 2019c). Although SRE suitability of the Alluvial Plain habitat was considered to be low overall

A number of surveys for SRE fauna have been conducted within the Proposal area since 2014 (Biota 2014, Astron 2019) as well as a troglofaunal survey that recorded a potential SRE (Biota 2015). In total, three Confirmed and 35 Potential SRE invertebrate taxa have been recorded within the Proposal area. Of these, 19 Potential SRE taxa are known only from within the Proposal area, ten of which are currently only known from within the proposed footprint. Only one confirmed SRE species, *Karaops banyjima* was recorded within the Proposal area (Astron 2019b).

The confirmed SRE taxon *Karaops banyjima*, was recorded from three localities in the Proposal area (Astron, 2019c), including two within Gorge/Gully habitat (being a suitable prospective habitat for SRE species) and one from within Rocky Hill habitat. All three records were outside of the Proposal conceptual footprint.

An additional taxon, *Troglarmadillo* sp. is considered a likely SRE. One record of this taxa was recorded from Gorge/Gully habitat from within the Proposal closure boundary, but outside of the Proposal conceptual footprint.

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5.14.5 Subterranean fauna

Subterranean fauna encompasses troglofauna (terrestrial subterranean fauna) and stygofauna (aquatic subterranean fauna). They both have ecological importance due to their species richness, evolutionary history and adaptation to their environment. The Proposal includes AWT mining only, therefore will not result in a significant alteration to the water table and thus stygofauna are not expected to be significantly impacted and not discussed further.

Assessment of the prospective suitability of habitat to support troglofauna has been undertaken within, and in proximity to, the Development Envelope. The extent, thickness, and connectivity of local geological habitats above water table was mapped by Rio Tinto based upon geological models. The mapping identified high confidence modelled (medium and high suitability) habitat for troglofauna comprising colluvium, Mt McRae Shale / Mt Sylvia Formation, Wittenoom Formation, Brockman Iron Formation and Marra Mamba Iron Formation.

Large areas of BHT and HD2 troglofauna habitat will remain in their in situ natural state after the development of the Proposal. At the BHT deposit, the Brockman Iron Formation will be significantly reduced in volume within the Proposal area (approximately 35% of the surface extent will remain, based on mapped surface geology), noting that suitable troglofauna habitat in the form of the Mount McRae Shale, Mount Sylvia and Wittennoom formations extend at depth and surrounding the deposits. While the connectivity of modelled habitat within BHT will decline due to the volume and location of habitat removed, this is not expected to significantly affect the persistence of the troglofauna community.

At the HD2 deposit, habitat removal resulting from mining is also not expected to be significant. Twenty three percent of habitat in the area of this deposit is predicted to be lost; however, the connectivity of habitat remaining will be similar to pre-mining conditions. Assessment of impacts to subterranean fauna habitat was undertaken within the extent of Development Envelope using a 2D approach validated by preliminary 3D habitat modelling. As a significant proportion of available habitat will remain, the ecological integrity of the troglofauna habitat is not expected to be significantly affected.

Seventeen of the 22 taxa recorded during the baseline surveys are considered unlikely to be impacted by the Proposal on the basis that their recorded distribution is outside of, or extends beyond, the proposed pits. For the remaining five taxa, all are singletons and have so far only been recorded from within the proposed pit shells. The five taxa are:

- *Eukoenia* 'sp. OES2' (Troglobite)
- *Lagynochthonius PSE96* (Troglobite)
- *Tyrannochthonius* 'sp. Biologic-PSEU001' (Troglobite)
- *Scolopendromorpha* 'sp. Biologic-CHIL001' (Troglophile)
- *Trinemura* 'sp. OES11'. (uncertain dependence on subterranean habitats).

All five troglofauna taxa listed above are expected to occur outside the proposed impact area, due to suitable habitat connectivity. There is evidence of connection between troglofauna habitats, which provides opportunity for species dispersal.

Habitat reconstruction for subterranean fauna will not be specifically targeted as part of closure implementation and rehabilitation activities, when considering closure planning for the Proposal.

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5.14.6 Introduced fauna

Feral carnivores (e.g., cats, dogs, foxes) can create locally increased predation pressure on native fauna as well as increase competition with native species for resources such as space (territory), water and food. Feral herbivores (e.g., cattle, camels, donkeys, rabbits) can also have a significant impact in Rangeland areas, such as the Pilbara. In dry times, grazing pressure reduces the abundance of palatable native species, impacting biodiversity and can create conditions that encourage weeds to grow. Foot traffic impacts the soil conditions, and in combination with over grazing, can encourage erosion. Foot traffic has also been the cause of damage to cultural landmarks and Aboriginal sites. Overgrazing and damaged soils has a flow-on effect to native fauna species that rely on this vegetation for food and shelter. Astron (2019) recorded seven species of feral mammals including:

- Cat (*Felis catus*);
- Dog/Dingo (*Canis familiaris*);
- European Cattle (*Bos Taurus*);
- Camel (*Camelus dromedaruis*);
- Donkey (*Equus asinus*);
- Rabbit (*Oryctolagus cuniculus*); and
- House Mouse (*Mus musculus*).

5.14.7 Implications for closure and knowledge gaps

Closure implications associated with fauna and habitat values include:

- All exclusion zones will be maintained through the decommissioning and closure implementation phases.
- Progressive rehabilitation of disturbed areas, no longer required for operational purposes, will be undertaken to re-establish native self-sustaining vegetation and habitat for fauna species.

- Monitoring programs of the Pilbara Ghost Bat and Northern Quoll will be refined during operations and continue through the decommissioning and closure implementation phases.
- Considering fauna habitat values will be required to ensure closure landforms align with exclusion areas and fauna habitat values.

Closure knowledge gaps associated with fauna and habitat values, as summarised in Table 6-1 include:

- Complete fauna habitat assessment of the final closure landform for HD2 and BHT deposits 5 years from closure.
- Undertake review of final closure landform and completion criteria to determine the functional habitats likely to be present post-closure.
- Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
- Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

RESEARCH & TRIALS

5.15 Rehabilitation trials, research and development

Lessons learnt from other Pilbara mining sites are used to inform and update our standard rehabilitation management practices. Implementation of such advances includes:

- Landform specific rehabilitation designs based on mineral waste characterisation and site-specific climatic conditions.
- Rehabilitation requirements considered when determining landform placement.
- Survey control of rehabilitation earthworks to the rehabilitation design.
- Improved soil and seed management practices (viability testing and pre-treatment).
- Targeted research and development scopes.
- Development of guidance documentation and management procedures.
- Development of databases to house raw rehabilitation monitoring data.
- Production of close out reports and sharing of learnings across the Pilbara mining operations.

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Although rehabilitation outcomes are largely variable, with success highly dependent on the climatic conditions and rehabilitation methods associated with works, these advances have resulted in an overall improvement in rehabilitation quality seen across the company's Pilbara operations and continue to contribute to the refinement of rehabilitation management develop successful outcomes.

Rio Tinto undertakes research and development to increase its understanding of the local natural ecosystem, optimise its rehabilitation techniques and be at the forefront of technological advances; with the over-arching goal of continually improving the rehabilitation quality it can achieve. Research and development projects range from opportunistic on ground trials, to large scale multi-partner federally funded research programs. Rehabilitation monitoring data is reviewed regularly to identify opportunities to refine rehabilitation techniques i.e., rates of recruitment from sown seed. A selection of recent research and development initiatives is summarised below.

5.15.1 Eco-Engineering solutions to improve mine-site rehabilitation outcomes

Both Rio Tinto and BHP Western Australia Iron Ore are partners in a federally funded research program investigating the rapidly developing field of Restoration Engineering, with a focus on the mining-intensive

Pilbara region of Western Australia. This Global Innovation Linkages project is led by the Kings Park Science research team and has additional partners from the University of Western Australia (UWA), Greening Australia, University of California, Brigham Young University, the University of Nevada, and Natural Resource Conservation LLC (a private US-based consultancy).

The Restoration Engineering approach partner's ecological research, focussed on best practice use of seeds from a recruitment biology point of view, with innovative ecologically guided engineering solutions focussed on the invention and modification of seeding equipment needed to deliver native seeds at scale. This project hosted a workshop in 2018, bringing together a team of local and international research scientists and industry professionals involved in the advancement of UWA's recent 'flash flaming' invention and direct seeding machine development. The project aims to:

- Critically evaluate the field limitations of current mechanised seeding techniques used in large-scale rehabilitation efforts to guide engineering modifications or new designs required to improve precision-delivery of native seeds in adverse rocky, uneven and sloped landforms.
- Design, construct, and field test prototype seed enhancement and direct seeding machines that can accommodate and efficiently deliver a wide range of seeds including those that differ in shape, size, and weight, and enhanced (primed, pelleted and coated) seeds, at broad acre scales.
- Quantify seed placement, seedling recruitment and rehabilitation performance using the engineered direct seeding machines across different mining growth media and soil types.
- Disseminate this research through peer-reviewed publications, on-ground field demonstrations on active mine sites or degraded lands and multiple conference and workshop avenues.

Whilst some knowledge within the project remains confidential in the early research phase, there have been aspects incorporated into Rio Tinto's progressive rehabilitation trial areas. These include the use of flamed seed preparation rehabilitation, spinifex pre-treatment trials and the evaluation of several new species for flaming treatment. Work has also included an engineering trial to optimise the placement of seeds under the soil surface for increased germination results. Several trials are underway in a lab testing environment and may be phased into field trials in the future.

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Opportunities to incorporate research trials into the company's progressive rehabilitation projects are undertaken where possible and incorporated into the rehabilitation monitoring program. Learnings are then incorporated into seed management and rehabilitation procedures.

5.15.2 Pilbara seed provenance

Appropriate strategies for collecting seeds as the raw genetic material for restoration activities are an important consideration for revegetation programs. Traditional approaches regarding seed collection follow a precautionary principle that advocates a narrowed definition of 'local provenance' seed. This approach has been adopted by DWER, the DMIRS and other regulatory agencies in mining-related environmental approvals in the Pilbara, where approval owners are required to use 'locally' sourced seed. This 'local' restriction often relates to geographic distance and does not take into consideration other factors related to biogeographical setting or relevant plant ecology and seed biology.

The Pilbara Seed Provenance Study was a collaboration between industry and DWER, undertaken to genetically delineate local provenance and provide clarity with respect to delimiting seed provenance zones for a suite of Pilbara species used in mine site rehabilitation and other revegetation initiatives.

Nuclear genotyping for six species *Petalostylis labicheoides, Indigofera monophylla, Corymbia hamersleyana, Acacia hilliana, Acacia pruinocarpa* and *Senna glutinosa* subsp. *glutinosa* across the Pilbara was completed. The results were finalised in 2017 and showed that several species exhibited strong patterns of population structure, indicating that each require seed to be collected from specific provenance zones, whilst others showed little to no delineation between populations, allowing for seed collection to occur across the full geographic range of the species. This knowledge contributed to addressing the uncertainty regarding seed provenance.

6 Closure Knowledge Gaps

This section provides a summary of all current closure knowledge gaps identified during the Proposal closure planning and development of the closure strategy. The Proposal closure knowledge base also informs the closure risk assessment (Section 7 and Appendix 4) and the Proposal closure action register (Appendix 5). Each iteration of this MCP will include a review and refinement of the closure knowledge gaps, which will be progressively addressed through the Rio Tinto risk management process.

Table 6-1: Current Proposal closure knowledge gaps

Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
Aboriginal culture and heritage	Agreement on key heritage locations and access requirements post-closure, final site closure outcomes, completion criteria and measurement tools. Schedule for future closure consultations over the life of Proposal.	To be progressively addressed through on-going engagement with Traditional Owners and consideration of the mine plan.	• Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments. • Stakeholder engagement strategy and communications plan to be prepared for community, regulators, and internal audience. • Undertake specific closure stakeholder engagement to determine social and cultural heritage values to be maintained at the closure of the HD2 and BHT deposits, include salvage and repatriation of sites. • Undertake visual impact assessment of HD2 and BHT deposits final landform configuration and visibility from GNH and other key vantage points or points of cultural heritage importance. • Develop seed mix(es) HD2 and BHT deposits in line with progressive rehabilitation targets and consultation with stakeholders. • Develop consultation tools to assist in communicating closure strategy with stakeholders. • Schedule consultation with stakeholders over the life of asset to consult on closure strategy options and opportunities. • Complete consultation with Traditional Owners on key heritage locations and access requirements post-closure to contribute to the final closure landform or landscape • Complete consultation on closure outcomes, completion criteria and measurement tools. • Complete consultation on the final closure landform or landscape and opportunities for Traditional Owners to get involved. • Social and cultural heritage values regarding Special Places for Nyiyaparli, as documented in the HD2 SCHMP, will be incorporated in the next major update of the MCP.

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Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
			• The risk title regarding cultural heritage will be reworded and evaluated to ensure that closure outcomes consider social values in the next major update of the MCP.
Socio-economic	Potential social and economic impacts including amenity, public health associated with closure activities, loss of employment and business opportunities.	To be progressively addressed through on-going engagement with Traditional Owners, communities, personnel and consideration of the mine plan.	• Potential social and economic impacts to be assessed including amenity, public health associated with closure activities, loss of employment and business opportunities. • Consult with stakeholders to address any potential socio-economic impacts post-closure. • Undertake visual impact assessment of HD2 and BHT deposits final landform configuration and visibility from GNH and other key vantage points or points of cultural heritage importance. • Investigate opportunity to allow safe access for viewing/observation of post-closure landform to deter unauthorised access to site. • Develop consultation tools to assist in communicating closure and potential socio-economic impacts with stakeholders.
Climate	Closure landform designs in consideration of climate change.	This knowledge gap will be reviewed in each triennial revision of the MCP.	• Complete landform evolution modelling to confirm the optimal final Waste Rock Landform design, including physical waste characterisation. • Flood modelling of the closure landform to consider climatic variation and the potential for extreme rainfall events. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
Geotechnical	PUPEZ associated with final pit voids, abandonment bund locations and surface water management implications. Inventory of rehabilitation materials (low erodibility waste) to be utilised for capping and abandonment bunding where required.	This knowledge gap will be reviewed in each triennial revision of the MCP.	• Evaluate planned post-closure pit wall stability for HD2 and BHT deposits pits to determine if mitigation is required to prevent wall collapse and PMC creek capture. • The zone of geotechnical instability or PUPEZ will be revised and updated for HD2 and BHT deposits in each iteration of the MCP to reflect any changes to the mine plan, understanding of the closure landscape and to address any updated flood modelling. • The location of the proposed pit abandonment bunds for the HD2 and BHT deposits will be revised and updated in each iteration of the MCP to reflect any changes to the mine plan, understanding of the closure landscape and to address any updated flood modelling.

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Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
			• Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required. • Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters. • Site specific geotechnical assessments will be completed for rehabilitation designs of final closure landforms for HD2 and BHT deposits to confirm closure landform safety and stability. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
Public access	Abandonment bund locations and surface water management implications. Access to the landscape and the management of inadvertent access to PUPEZ.	This knowledge gap will be reviewed in each triennial revision of the MCP.	• Complete consultation with Traditional Owners on key heritage locations and access requirements post-closure to contribute to the final closure landform or landscape • Complete consultation with the State on preferences with regards to final closure landform and public access to the post-closure landscape. This will be determined through ongoing consultation during the life of the operation. • Assess opportunities to allow safe access for viewing/observation of the post-closure landform near the highway to deter unauthorised access to site. If this is considered appropriate to key stakeholders, details will be included in further updates to this MCP. • Assess the expected post-closure access to the site, and include the installation of additional control measures, where appropriate. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
Mineral waste	Erodibility of HD2 mineral waste.	Complete waste characterisation progressively as geological units become available during operations. Landform designs to be updated as required.	• Site specific physical waste characterisation will be progressively undertaken when each mineral waste unit becomes available during mining operations. • Include HD2 and BHT deposit materials in updates of the BST. • Undertake further testing of BHT (detrital) lignite materials when geological units become available during mining operations as per the SCARD management plan.

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Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
		Identify materials to be stockpiled for abandonment bunds and rehabilitation activities.	• Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters. • Revise waste rock landform rehabilitation and overall closure landform designs based on physical waste characterisation, BST parameters, hydrological and ecological factors and stakeholder consultation as required. • Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
Soils	Soil inventory and topsoil recovery strategy and volumes.	Incorporate topsoil soils review and update annually. Undertake topsoil suitability assessment within completion criteria work (next 5 years).	• Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments. • Update the topsoil balance for estimated topsoil recovery annually once mining commences. • Complete subsoil characterisation work when vegetation clearing commences as required. • Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
Contaminated sites	Knowledge and database of potentially contaminating activities register for Proposal.	Complete PSI and DSI contaminated sites assessments 5 years from closure date.	• Undertake Preliminary Site Investigation 5 years prior to closure. • Undertake Detailed Site Investigation 2 years prior to closure. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits.
Hydrogeology	Suitability and accuracy of hydrogeological	On-going verification and refinement of the hydrogeological	• Complete final options assessment for water source and impacts for HD2 and BHT deposits.

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Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
	conceptualization and water source options.	conceptualisation of groundwater model throughout LoM, to be updated in each triennial revision of this MCP.	• Update closure hydrogeological model with new conceptualisations for HD2 and BHT deposits water supply options. • Complete closure hydrogeological water quality model for HD2 and BHT deposits once water supply options are agreed with stakeholders. • Update the conceptual hydrogeological model for HD2 and BHT deposits final closure landform 5 years from closure. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
Hydrology	Finalisation of hydrological closure strategy for pit voids, landbridges, waste landforms, abandonment bunds and surface water management structures based on refinement of flood modelling and surface water management structure designs. Surface water quality sampling is yet to be undertaken.	Surface water model to be refined throughout LoM and updated in each triennial revision of this MCP. Landbridge closure strategy to be provided in the 2024 revision of this MCP. Surface water modelling of final post-closure surfaces to be included in the MCP five years from planned closure.	• Update surface water modelling for PMC creek diversion in line with changes to landform design and closure strategy for HD2 deposit (1:100AEP, 1:1000AEP and 1:10,000AEP). • Upgrade of drainage designs for permanent closure drainage structures (PMC) where required, in line with flood risk assessments (1:100AEP, 1:1000AEP and 1:10,000AEP). • Undertake hydrological water quality sampling of PMC and WWC prior to commencing mining of the HD2 and BHT deposits. • Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters. • Undertake hydrological modelling (1:100AEP, 1:1000AEP and 1:10,000AEP) of updated landbridge closure strategy and designs. • Undertake hydrological modelling of abandonment bund alignment and final closure landform for HD2 and BHT deposits (1:100AEP, 1:1000AEP and 1:10,000AEP). • Determine required engineering flood mitigation structures for HD2 and BHT deposit's closure landforms. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

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Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
Conservation Significant Areas	Exclusion zones around conservation significant flora species will be maintained through the decommissioning and closure implementation phases.	Assessment of the conservation significant flora and fauna status to be updated within this MCP. Conservation significant areas to be considered as part of closure planning and access for closure.	• Conservation significant areas will be considered in closure planning with reference to post-closure land use, access to the landscape and closure outcomes. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
Flora and Vegetation	Optimal seed selection of rehabilitation seed mix. The selection of reference / analogue sites and the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) to assess the performance of progressive rehabilitation.	Locations of reference sites to be determined at least 8 years prior to planned closure.	• Seed mixes have not been developed for the Proposal, to facilitate progressive rehabilitation. Considering the short mine life for the Proposal, flora species recorded in baseline surveys will be used to inform rehabilitation seed mix(es). Seed mixes will be developed in consultation with stakeholders. • The selection of reference / analogue sites and the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) have not yet been undertaken. Vegetation mapping completed for the Proposal will be used to inform the selection of reference / analogue sites and inform the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) and monitor against progressive rehabilitation • Select reference / analogue sites for HD2 and BHT deposits to inform revegetation criteria and progressive rehabilitation. • Implement progressive closure and rehabilitation of waste rock landforms and disturbed areas as soon as possible to reduce closure liabilities. • Revise seed mix(es) in line with progressive rehabilitation targets and consultation with stakeholders. • Conduct closure research and rehabilitation trials to demonstrate methodologies. • Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.
Fauna	Representative fauna habitats likely to be present within the final closure landform.	This knowledge gap will be addressed as the site nears planned closure.	• Complete fauna habitat assessment of the final closure landform for HD2 and BHT deposits 5 years from closure. • Undertake review of final closure landform and completion criteria to determine the functional habitats likely to be present post-closure.

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Factor	Closure knowledge gap	Timing / Progress	Associated closure risk assessment action/s
			• Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits. • Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, soils, contaminated sites, hydrogeological, hydrological, conservation, flora and vegetation, fauna knowledge and assessments.

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7 Closure Risk Assessment

Risk assessment and management is an integral component of Rio Tinto's business framework and approach to closure planning. The objectives of risk management are to improve execution and reduce risk exposure. To achieve these objectives, Rio Tinto manages all business risks using the RSA Archer Integrated Risk Platform which provides the business with a consolidated and clear view of risks, including version and history tracking and unique identification of risks, controls and actions for tracking purposes.

Risk assessments are undertaken to qualitatively and semi-quantitively guide the selection of closure options, assess specific risk and identify controls for the design and execution of closure. Successful management of risks requires the implementation of a clear risk management strategy supported by adequate resources, a strong risk-aware culture, and maintaining an up-to-date risk register that is regularly reviewed.

7.1 Risk assessment process

All Rio Tinto closure risk assessments are facilitated by competent personnel, involving a range of technical and subject matter experts.

The aims of the closure risk assessment process are to:

- Identify potential hazards that could influence successful closure of the mine.
- Evaluate the risks given the management controls/strategies described within the MCP and consideration of the risk likelihood and consequences (using the descriptors included within the Rio Tinto HSEC 5 x 5 risk determination matrix, refer to OBJ OBJ OBJ OBJ Table 71 OBJ) to establish an overall risk class, which can range from Class I (Low) to Critical IV (Critical).
- Identify additional control measures (actions) for significant threats rated as either Class III (High) or Class IV (Critical) to ensure the residual risk rating is As Low As Reasonably Practicable (ALARP).
- Review and update risk, control effectiveness and action status.
- Communicate risk information.

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Issues are assessed against set consequence criteria (environment, health and safety, cost of closure, community trust, and compliance). Risk is evaluated based on the maximum reasonable outcome consequence and the likelihood of that consequence occurring to derive an inherent risk rating, prior to the application of controls, and a residual risk rating, inclusive of current management and commitments. The ALARP principle is to be used when determining which risk treatments to apply.

Table 7-1: Risk class determination

Likelihood	Most serious consequence				
	Very low	Low	Moderate	High	Very high
Almost certain	Class II	Class III	Class IV	Class IV	Class IV
Likely	Class II	Class III	Class III	Class IV	Class IV
Possible	Class I	Class II	Class III	Class IV	Class IV
Unlikely	Class I	Class I	Class II	Class III	Class IV
Rare	Class I	Class I	Class II	Class III	Class III

The risk classification identifies the level of management action that must be taken to mitigate the threat (Table 7-1). A risk determination of Class III or Class IV reflects a material risk that requires active management and consideration of additional control measures (Table 7-2). All actions associated with risk management and mitigation are captured in Archer and reflected in the HD2 MCP as Appendix 4.

Table 7-2: Risk management response

Risk class - threats	Management response
Class I	Risks that are below the risk acceptance threshold and do not require active management.
Class II	Risks that lie on the risk acceptance threshold and require active monitoring.
Class III	Risks that exceed the risk acceptance threshold and require proactive management.
Class IV	Risks that significantly exceed the risk acceptance threshold and need urgent and immediate attention.

A control effectiveness rating is determined for each risk to evaluate whether the control will effectively mitigate the risk. If controls are deemed Marginal or Weak, then actions are assigned to improve the control effectiveness. Rio Tinto's definitions of control effectiveness are:

- **Good** – control is considered adequately designed and is operating effectively on almost all occasions.
- **Satisfactory** – control is considered adequately designed and is operating effectively on most occasions.
- **Marginal** – control is considered inadequately designed or is only operating to partial effectiveness on most occasions.
- **Weak** – there is no control designed or the control is operating ineffectively on all occasions.

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7.2 Risk evaluation

The risks (threats and opportunities) were defined by considering the likelihood of different outcomes occurring for the Proposal given the nature of the local environment, established through collection of baseline data, and scope of the approved operations.

- The inherent risk presents the conditions that may result without implementation of controls during operations or closure.
- The residual risk was determined by considering the likelihood of the most credible consequences occurring after the nominated controls are implemented. When evaluating residual risk, Rio Tinto considers that a control cannot reduce the residual risk until it has been implemented, unless the control is a mandatory legal obligation, such as the management of inadvertent access to a pit void through the construction of abandonment bunds. A final, or treated risk, can be determined once the nominated control has been implemented, and the risk assessment will be updated accordingly.

Risk registers are reviewed and updated as conditions change. The closure risk register is also systematically reviewed and updated at least every three years in support of the update of the MCP.

7.3 Risk profile

The first Proposal closure risk assessment was undertaken in 2020 and refreshed in 2021, this updated risk assessment is presented in Appendix 4.

A summary of the current closure risk profile shows there are currently two Class II, eight Class III and one Class IV threats, a total of twelve risks associated with the closure of the Proposal. A summary of the

threat profile is presented in

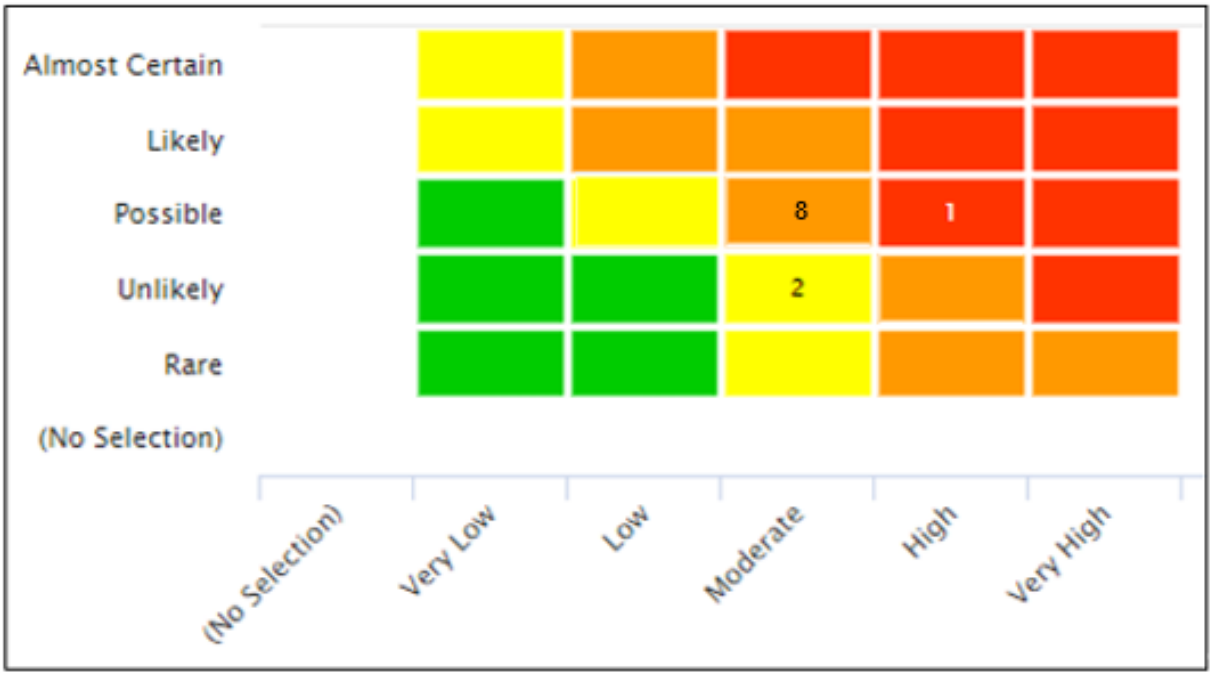

Figure 40 and Class IV and III risks are detailed below.

Actions are assigned to risks that exceed Rio Tinto's risk acceptance threshold and therefore require additional control measures to reduce the risk at closure to ALARP and an acceptable level. Actions are also assigned to address knowledge gaps where further information is required to reduce uncertainty. This would typically be the case in the early stages of operations where the detailed knowledge of an aspect may be low. These actions are captured in Table 6-1, Appendix 4 and Appendix 5.

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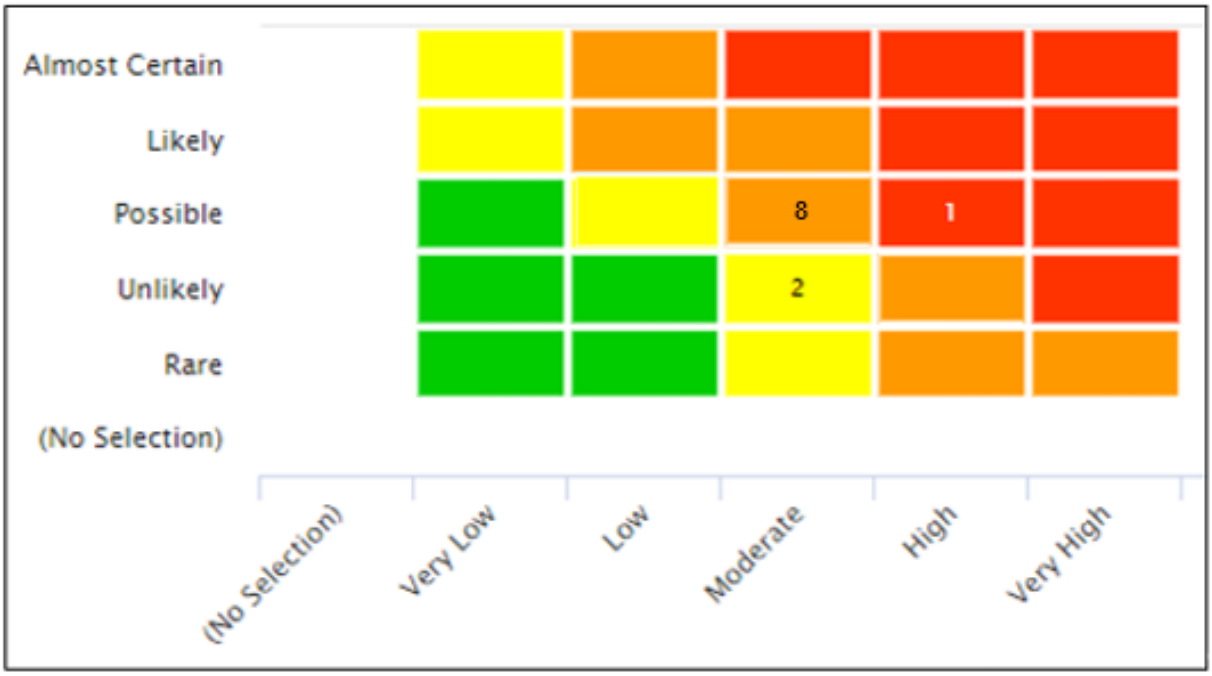

Figure 40: Proposal threat risk profile

7.3.1 Closure class IV risk

One Class IV risk was identified during the 2020 closure risk assessment:

- Risk 696068 - The safety risk for people entering the Proposal area after it has been rehabilitated and closed has not been effectively mitigated

The causes, impacts, existing controls, evaluation rationale and planned actions for each of these threats are detailed within Appendix 4.

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7.3.2 Closure class III risks

Eight Class III risks were identified during the 2020 closure risk assessment:

- Risk 696234 - Implementation of the closure strategy does not achieve the required environmental outcomes.
- Risk 696240 - Implementation of the closure strategy does not achieve the required cultural heritage outcomes.
- Risk 696247 - Consultation fails to identify and/or address stakeholder concerns.
- Risk 696032 - Inadequate management of contaminating activities at the Proposal during operations increases closure costs.
- Risk 696217 - Inadequate management of surface water results in increased closure complexity and costs.
- Risk 696208 - Failure to reach agreement with the State on suitable completion criteria for the Proposal
- Risk 696223 - Rehabilitation outcomes at HD2 do not meet closure objectives.
- Risk 974578 - Waste rock landforms and / or landbridges at the Proposal are subject to excessive erosion.

The causes, impacts, existing controls, evaluation rationale and planned actions for each of these threats are detailed within Appendix 4.

8 Management of Key Issues

Appendix 7 of DMIRS *Mine Closure Plan Guidance - How to prepare in accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans* (DMIRS 2020) lists a number of rehabilitation and closure issues that may be relevant for mine sites, including several that are identified as key issues at the Proposal. An evaluation of the relevance of each of these issues is presented in Table 8-1 and summarises data and information previously presented in Section 5 of this MCP.

Table 8-1: Relevance of potential closure and rehabilitation issues

Issue	Evaluation of issue
Key issues relevant to closure of the Proposal	
Dispersive, sodic and erosive materials	A proportion of waste material is anticipated to be of high erodibility. No dispersive or sodic waste materials have been identified.
Geotechnical stability	All final landforms will be located outside the PUPEZ. Specific design of two sections of the abandonment bund and pit crest of HD2 will be required if the temporary diversion of PMC is removed.
Inadvertent public access	Pit abandonment bunds will be constructed in accordance with the DoIR 1997 *Safety bund walls around abandoned open pit mines*. Alternative design of some sections of the pit abandonment bund may be required if temporary diversion of PMC is removed. Agreed access to the area for Traditional Owners is required post-closure.
Alteration of the hydrology and flow of surface waters	Permanent diversion of minor PMC flows to WWC is proposed. This diversion is planned to be retained after closure pending assessment of impacts to the pit crest stability of two sections of the HD2 pit. A floodway crossing of PMC is proposed north of the BHT pits. Landbridges associated with the BHT deposit remain at closure but are unlikely to affect the flow of surface water. They will be reshaped and rehabilitated.
Social and cultural heritage values	Significant social and cultural heritage values have been identified by the relevant Traditional Owners and closure strategies are required to ensure values are protected.
Hazardous materials	Hazardous materials (e.g. hydrocarbons, ammonium nitrate) will be removed prior to, or during, decommissioning activities.
Hazardous and unsafe facilities	All infrastructure will either be decommissioned and removed or legally transferred to a third-party or the State in accordance with State Agreement Act requirements.
Contaminated sites	Given the developmental phase of the HD2 mine, there are currently no known or suspected contaminated sites associated with the mining area. A preliminary sampling and investigation programme will be undertaken prior to closure to determine if any remediation measures are required. All activities will be conducted in accordance with DWER guidance, and any known or suspected site will be reported to DWER Contaminated Sites Branch.
Acid and metalliferous drainage	Geochemical waste characterisation across deposits HD2 and BHT deposits has been assessed as having a low risk of AMD generation. The mine plan will avoid the minor volumes of black Mount McRae Shale identified during resource definition drilling.
Rehabilitation materials availability	There is no topsoil or rehabilitation material deficit anticipated. A soil survey has not been conducted at HD2, and as such any chemical and physical limitations of topsoil and subsoil for use in rehabilitation have not yet been determined. The soil survey will be reported in the next iteration of the MCP and implications for soil management and use in rehabilitation will also be addressed. Regarding other rehabilitation materials, as the site is considered to have a low AMD, fibrous materials and erosive materials risk, cover and/or capping materials are not currently expected to be required for closure.

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Issue	Evaluation of issue
Challenges associated with rehabilitation and revegetation	As mining has not commenced at the Proposal limited progressive rehabilitation of resource development disturbance has occurred to date. Once rehabilitation has commenced, and the associated monitoring data becomes available, any evident challenges will be presented in the MCP.
Visual amenity	A visual amenity assessment will be undertaken during closure studies, once the final landform is refined, and again post implementation.
Key issues not relevant to the closure of the Proposal and not considered further in this MCP	
Radioactive materials	No naturally occurring radioactive materials are expected to be encountered during mining.
Fibrous materials	Fibrous minerals are not expected to be encountered during mining.
Waste fines storage facilities	There is no proposed WFSF for the Proposal.
Mine pit lakes	All mine pits are above water table and, therefore, groundwater pit lakes are not expected to form.
Dust emissions	Closure dust management will be consistent with operational dust controls. Closure implementation is not expected to require additional management measures above those adopted during operations.
Flora and fauna diversity / threatened species	Management of disturbance in proximity of conservation significant species and mining exclusion zones will be consistent with operational controls. Closure implementation is not expected to require additional management measures above those adopted during operations.
Surface water / groundwater quality	No significant impacts on surface water or groundwater quality are anticipated, groundwater quality baseline has been collected and monitoring will continue. Surface water quality sampling is highlighted as a knowledge gap and will be addressed. PMC and WWC are located outside the development envelope, excepting a crossing of PMC.
Alteration of the direction of groundwater flow and alteration of the depth to water table of the local aquifer	As all mining is above water table, there is no alteration of the groundwater flow direction beyond the local scale associated with the production borefield.
Community issues	There are no townships, remote communities or pastoral stations which will be impacted by the closure of the Proposal.

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9 Closure Planning Process

The closure planning process at Rio Tinto is an iterative process that commences during the mine development planning phase and is regularly updated and refined during the operational phase. MCPs are updated to account for changes resulting from:

- amendments to the mine plan.
- improvements of the site closure knowledge base (e.g., through daily activities, technical studies, research actions and progressive rehabilitation).
- new or amended regulation.
- changes to surrounding land uses; and
- evolving stakeholder expectations.

The review brings specialists together to discuss current performance, proposed mine changes and opportunities to improve closure outcomes. At the end of the review, improvement actions are assigned, and the MCP is updated.

A key output of closure planning is the development of a closure cost estimate. Closure provisions are subsequently integrated into business planning processes to ensure funds will be available to close the site effectively.

As part of the *Rio Tinto Closure Standard* (2021), closure studies are required at intervals as the site, or a discreet area of the site suitable for partial closure, approaches the end of mine life. Like development projects, closure studies are progressed through several evaluation stages: from OoM to Pre-Feasibility (PFS) and Feasibility (FS) level.

Progressive rehabilitation is also planned, undertaken and monitored to inform the closure planning process, as detailed in Section 11.3. The final MCP is prepared as an output of the Feasibility stage of closure study and is submitted to the relevant regulatory agencies to approve for implementation. In the final MCP, location specific management plans will be provided for each closure domain. These detailed plans cover the physical closure, dismantling and subsequent rehabilitation implementation requirements. The supporting technical reports that have been used to define the post-closure outcomes will be appended to the final MCP.

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10 Land Use, Closure Outcomes and Completion Criteria

10.1 Pre-mining land use

The Proposal is located primarily on land the subject of the Nyiyaparli native title determination, with smaller portions located on land the subject of the Banjima and Ngarlawangga Native Title Determinations. These Native Title Determinations recognise each Traditional Owner group's non-exclusive right to continue to access, use and enjoy their country.

Since European settlement, land uses in the region have also included cattle grazing, exploration, mining, and conservation.

Part of the GNH currently traverses a portion of the closure boundary and is a main regional transport route as well as being used by tourists and locals. The current HD1 mine access road also traverses the Proposal closure boundary and is one of the main ways to access WWC and WWS, which are of environmental, social and cultural significance in the region.

Aside from mining activity and associated infrastructure, the area within the Proposal closure boundary is largely undeveloped. Pastoral activity in the region has historically been limited to cattle grazing. The Proposal conceptual footprint is generally on areas of rugged terrain of low pastoral land value. There are several other mines currently proposed and operating in the vicinity of the Proposal including:

- Rio Tinto Hope Downs 1;
- Hamersley Iron – Yandi Pty Limited (HI) Yandicoogina;
- Robe River Mining Co Pty Ltd West Angelas;
- Rio Tinto Hope Downs 4;
- BHP Mining Area C (MAC);
- BHP Yandicoogina;
- Process Minerals International (wholly owned subsidiary of Mineral Resources Limited) Phil's Creek Iron Ore Mine;
- BCI Minerals Limited Iron Valley Project;
- Proposed FMG Nyidinghu Project;
- BHP Southern Flank development; and
- Mineral Resources Wonmunna Mining Area.

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10.2 Closure domains

Rio Tinto uses closure domains to group areas with common features for rehabilitation, and decommissioning requirements at closure. Detailed closure strategies for the rehabilitation and decommissioning of individual closure domains, beyond those of current standard management practices, will be documented in the final MCP to be prepared as the site approaches closure. The distribution of closure domains for the Proposal is illustrated in Figure 41.

HD2 domains include:

- pits - includes currently operating or planned pits:
  - above water table voids
- inert waste rock landforms remaining at closure:
  - inert external waste rock landforms
  - stockpiles

- landbridges.
- infrastructure areas, haul roads, ROM Pads.
- disturbed areas – all areas of disturbance that are not categorised by any of the above landform domain categories. This domain has been broken down into 'high disturbance', 'moderate disturbance' and 'low disturbance' sub-domains, based on the number of earthworks that will be required during final landscaping, to allow for more accurate closure cost estimation.
- rehabilitated areas – areas which have been progressively rehabilitated; and
- undisturbed areas that retain natural vegetation.

Proposed closure measures for each of the closure domains are included in Table 10-1 and presented in Figure 41. Designs and key criteria for all major landforms are included in Appendix 6.

Table 10-1: Proposal implementation strategies by closure domain

Domain class	Footprint	Domains	Closure measures to be undertaken where appropriate
Pits	**(ha)**		

Above water table (AWT) pits	965.89	HD2_West
		HD2_Center
		HD2_East
		BHT_West
		BHT_Center
		BHT_East
			• when and where possible undertake opportunistic backfill during operations to:
			  ○ minimise the volume of waste remaining in waste rock landforms; and/or
			  ○ manage highly erodible material.
			• no rehabilitation is proposed within the pit footprint (unless backfilled to near or above surface).
			• prior to final closure, appropriate evaluation and implementation of measures to restrict inadvertent public access.
			• construct abandonment bunds around pit perimeters, outside of the PUPEZ, as required; and
			• HD2_West pit may be partially backfilled with mine waste to facilitate the realignment (to the original location) of the GNH.

Waste Rock Landforms			•
Inert ex-pit waste rock landforms	939.24	HD2 DP_NW HD2 DP_NC HD2 LG BHT DP_ NEWD BHT NELG	• reshaping outer slopes to appropriate angles/profiles based on design criteria suitable for waste type (Appendix 6 and Appendix 7). • apply a maximum 200 mm[2] layer of topsoil (or subsoil where topsoil is unavailable); and • rip and seed using appropriate native species.
Topsoil and subsoil stockpiles	Included in infrastructure footprint area	HD2_TS_DES_01 HD2_TS_DES_02 HD2_TS_DES_03 HD2_TS_DES_04	• stockpiles are generally planned to be removed prior to, or during, closure activities. • rehabilitate underlying surface in accordance with standard procedures (as per infrastructure areas).

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[2] To maximise the value of the available topsoil a maximum depth of 200 mm is assumed across rehabilitated areas based on expected availability and machine capability. However, the intent is to optimise usage to achieve the best possible rehabilitation outcomes.

Domain class	Footprint	Domains	Closure measures to be undertaken where appropriate
Pits	**(ha)**		
		HD2_TS_DES_05	
		HD2_TS_DES_06	
		HD2_TS_DES_07	
		HD2_TS_DES_08	
		HD2_TS_DES_09	
		HD2_SS_W_01	
		HD2_SS_E_01	
		BHT subsoil and topsoil stockpiles	
Landbridges			
BHT Landbridges	62.88	LB_Central 3	• assess whether landbridge needs to be partially or completely removed considering geotechnical stability and surface water considerations. • reshaping outer slopes to appropriate angles/profiles based on design criteria suitable for waste type (5.7 and Appendix 6). • apply a maximum 200 mm[3] layer of topsoil (or subsoil where topsoil is unavailable); and • rip and seed using appropriate native species.
		LB_East	
		LB_East 6	
		LB_Central	
		LB_West	
Other domains			
Haul roads	2932.14	Haul roads	• install cross bunds where appropriate (at approximately 50m to intervals if the gradient of the reshaped road corridor is greater than 10 degrees); and • rehabilitate final surfaces in accordance with standard procedures (as per inert waste rock landforms).
BHT ROM pad		ROM pad	• remove all structures and footings that are above surface or buried within 1m of the final land surface. • utilise material for pit backfill, capping or encapsulation if required; and • rehabilitate final surface in accordance with standard procedures (as per inert waste rock landforms).
Infrastructure areas		Areas where infrastructure is located, including, but not limited to:	• retain or remove infrastructure in accordance with State Agreement requirements and stakeholder engagement. • undertake contaminated sites assessment and remediation measures, where required.

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[3] To maximise the value of the available topsoil a maximum depth of 200mm is assumed across rehabilitated areas based on expected availability and machine capability. However, the intent is to optimise usage to achieve the best possible rehabilitation outcomes.

Domain class	Footprint	Domains	Closure measures to be undertaken where appropriate
Pits	**(ha)**		
		• Vehicle workshops and fixed plant workshops • Hydrocarbon storage areas, • ANFO facilities, • Laydown areas, • Turkey's nests, • Transfer pads, • Roads • Offices. • Processing facilities • Run of mine (ROM) pads • Ore stockpile. • Conveyors, • Camps, • Fuel facilities • and any associated disturbances.	• where infrastructure requires removal, remove all structures and footings that are above surface or buried within 1 m of the final land surface. • drain pipelines and remove hazardous materials (from pipelines and elsewhere across the site) in accordance with Controlled Waste Regulations. • where linear infrastructure is removed, reinstate drainage lines where appropriate. • actively seek reuse and recycling opportunities for decommissioned infrastructure. • dispose of inert materials that are not retained, reused or recycled in an inert landfill area (may be a used pit area); and • rehabilitate final surface in accordance with standard procedures, which includes: ○ apply a maximum 200 mm[4] layer of topsoil (or subsoil where topsoil is unavailable). ○ deep rip the surface where required to address compaction; and ○ revegetate with an appropriate mix of species of local provenance.
Disturbed area – low		Various	• respread topsoil, sub-soil or alternative growth medium (if available) onto disturbed area; and • rip and seed. • The need for seeding may be reassessed closer to closure on the basis that these areas have a high probability of retaining some degree of a seed bank.
Disturbed area –moderate		Various	• recontour to remove windrows and other impediments to surface water flows. • respread topsoil onto disturbed area; and • rip and seed.
Disturbed area – high		Various	• undertake earthworks reshaping of high disturbance area. Includes cell creation and minor windrow or bund formation or removal as required. • respread topsoil onto disturbed area; and • rip and seed.
Rehabilitated areas		Various	• Will be assessed to ensure performance meets agreed completion criteria. If any areas do not meet completion criteria, they will be assessed for rehabilitation rework.

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[4] To maximise the value of the available topsoil a maximum depth of 200mm is assumed across rehabilitated areas based on expected availability and machine capability. However, the intent is to optimise usage to achieve the best possible rehabilitation outcomes.

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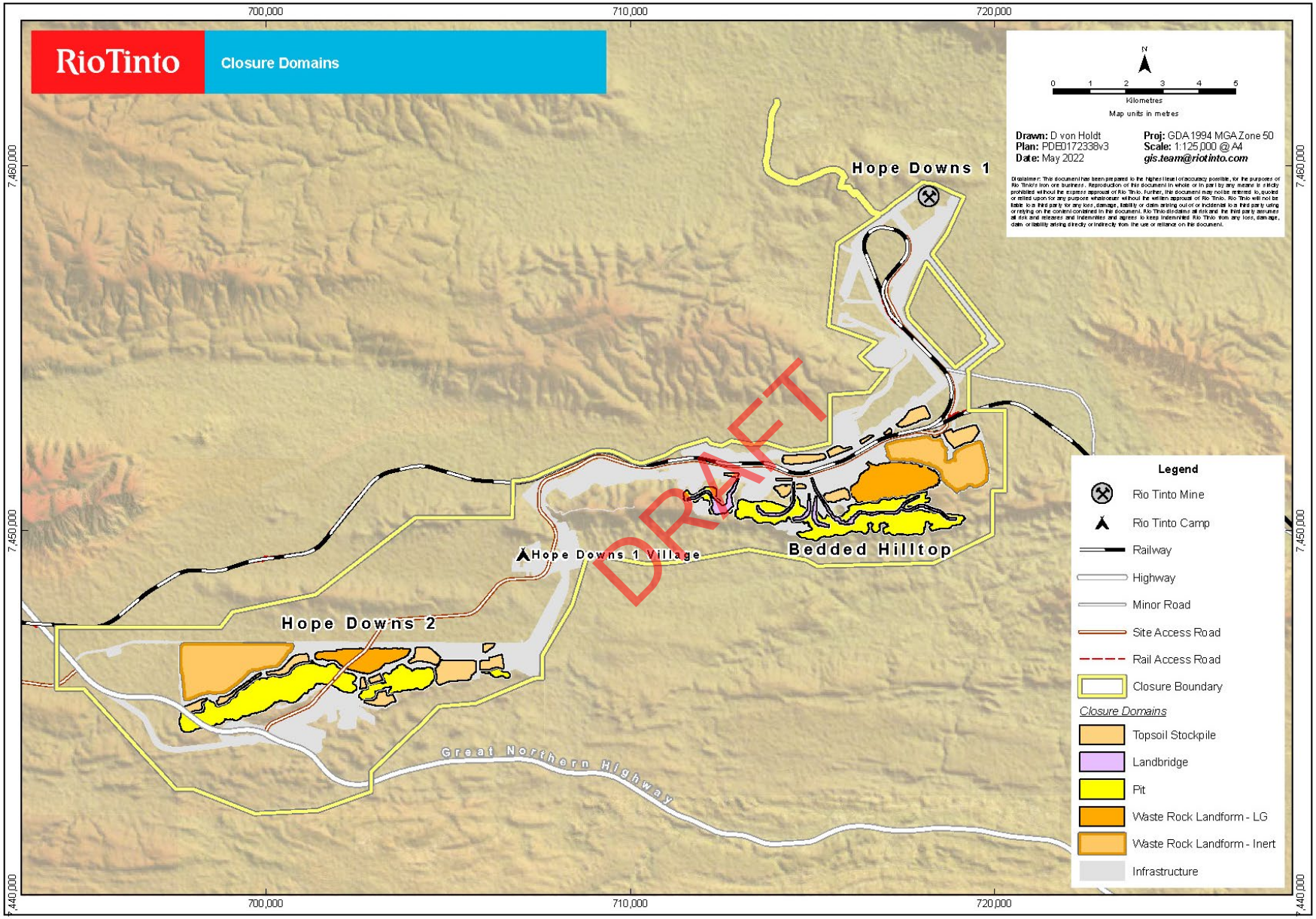

Figure 41: Closure domains

10.3 Proposed post-mining land use

The post-mining land use needs to be clearly articulated to allow for the development of specific closure outcomes, which are used in the development and formalisation of closure criteria. In accordance with the DMIRS Statutory Guidelines (DMIRS, 2020) the proposed post-mining land use should be:

- relevant to the wider regional environment.
- achievable in the context of post-mining land capability.
- acceptable to Rio Tinto stakeholders; and
- ecologically sustainable in the context of the local and regional environment.

Subject to the Native Title Determinations noted above, Traditional Owner groups continue to access and use the land the subject of the closure boundary for traditional purposes (Section 5.1), and this will be factored into post-mining land use.

Options for commercial post-mining land use are limited in the Pilbara region, with mining and pastoralism the only industries that have historically proven viable. Inland regions are sparsely populated, with the largest inland towns (such as Tom Price, Paraburdoo and Newman) established specifically to support the mining industry. Beneficial uses for the mining area (e.g., recreation or aquaculture) that might have potential in areas supported with a higher population base are unlikely to be viable.

As the current surrounding and underlying land use across the Proposal closure boundary is UCL and given the natural topography and landscape changes that will result from mining, including deep voids and constructed landforms, a pastoral post-mining land use is not considered a viable land use for the site, however closure outcomes need to consider that livestock from surrounding areas are likely to access the site inadvertently.

Rio Tinto proposes the following post-mining land use at the Proposal:

> *The site will be rehabilitated to create a safe, stable and non-polluting landscape, vegetated with native species of local provenance, that maintains environmental and cultural heritage values.*

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10.4 ALUM Classification

The proposed post-mining land use for the Proposal have been developed using the Australian Land Use Management (ALUM) Classification system, which was developed by the Australian Federal Government to describe land capability and use from an agricultural perspective. Adopting an ALUM domain approach allows closure to be undertaken in such a manner that maximises the potential future land use opportunities. These post-mining land uses will not come into effect until post relinquishment.

Under the ALUM code system HD2 will have areas classified as per Table 10-2. The site will have large areas classified as ‘Class 1 - Conservation and Natural Environments’ (ALUM 1.3.4 – Rehabilitation), which is consistent with the surrounding area’s land use of UCL. Non disturbed areas will remain ALUM 1.3.3 Residual Native Cover. Areas assigned ALUM 1.3.4 (Rehabilitation), and ALUM 1.3.3 (Residual Native Cover) will remain consistent with the surrounding area’s land use of UCL, including supporting access for social and cultural activities by Traditional Owners, where possible.

A change to pastoral activity is not considered a viable post-closure land use for the mine area due to the landforms which will remain and the nature of the mining activity undertaken. The final landform will include large pit voids and waste rock landforms, which do not provide suitable range land for grazing. Abandonment bunds are proposed for construction around the pit voids and waste rock landforms to restrict inadvertent human access to these areas. Post-mining land uses, such as grazing activities, will not be suitable for some areas of the site, such as pit voids, which will be designated ‘Extractive Industry - not in use’ (ALUM 5.8.4).

The remaining landforms and disturbed areas, once rehabilitated, will be classified as Class 1 - Conservation and Natural Environments (ALUM 1.3.4). These areas will be rehabilitated to develop safe, stable, non-

polluting, self-sustaining, functioning ecosystems, but such rehabilitation will not attempt to fully restore the pre-mining environment.

As the Proposal is situated on UCL and given its proximity to WWS and Creek, the return to UCL with rehabilitated areas supporting native vegetation is the most appropriate post-mining land use. Table 10-2 and Figure 42 outlines proposed post mining land uses for the Proposal.

Table 10-2: Post-mining land uses of the Proposal

Class	Relevant domains	Anticipated outcomes
1.3.3 Residual native cover	UCL underlying areas not cleared by the operation	Residual native vegetation not cleared by the operation. Supports access for social and cultural activities by Traditional Owners, where possible.
1.3.4 Rehabilitation	Infrastructure Areas Roads, tracks and laydown areas Stockpiles (selected areas) Surface Water Management structures Waste rock landforms, landbridges and backfill	Safe, stable non-polluting landscapes vegetated with native vegetation of local provenance. Applicable to all crown land underlying low risk rehabilitation areas. Supports access for social and cultural activities by Traditional Owners, where possible.
5.8.4 Extractive industry not in use	Pit voids	Areas will be made safe and stable with access restricted to the public where required

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The proposed post-mining land uses will continue to be refined as further investigations are completed and as additional consultation is held with stakeholders. Some examples of the alternative options for consideration post relinquishment include mining tourism and solar farming. Alternative land use options will continue to be investigated throughout the mine life, in consultation with local communities, Traditional Owner groups and other relevant stakeholders.

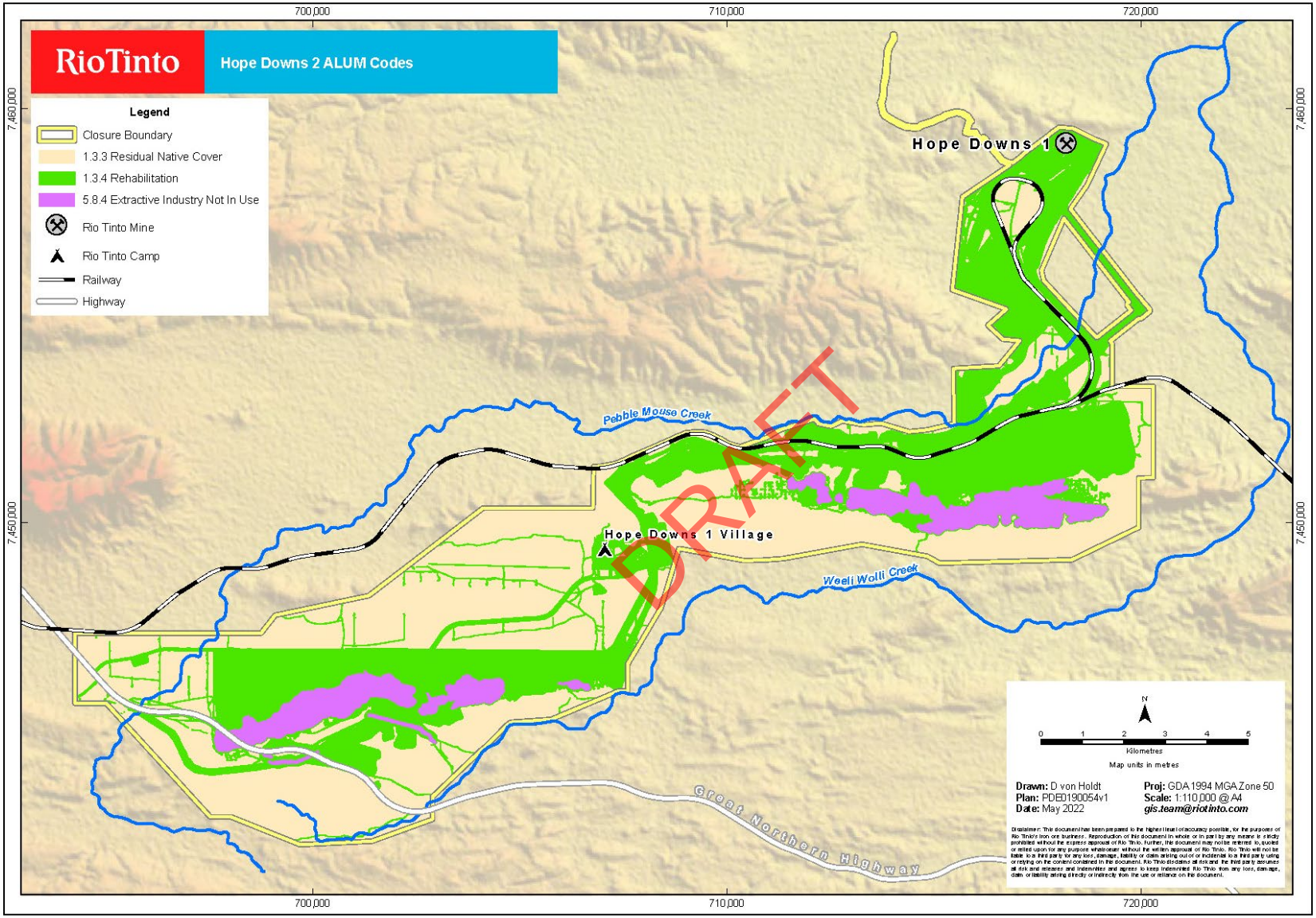

Figure 42 ALUM Codes

10.5 Closure outcomes

10.5.1 Rio Tinto vision for closure in the Pilbara

Closure outcomes have been developed with consideration of Rio Tinto's general vision for closure, which is to:

- Relinquish its mining leases to the Western Australian State Government.
- Preserve, protect and manage the social and cultural heritage values of the area in cooperation with Traditional Owners and other stakeholders.
- Develop and implement strategies for closure that consider the implications on local communities.
- Achieve completion criteria that have been developed with stakeholders and agreed with WA Government.
- Develop landforms that are safe, stable, and compatible with the surrounding environment and post-mining land use.
- Achieve environmental outcomes that are compatible with the surrounding environment.
- Implement a workforce strategy that addresses the impacts of closure on employees and contractors; and
- Achieve successful closure in a cost-effective manner.

Rio Tinto's overall goal for closure of the Proposal is to relinquish the site to the State Government. Through demonstrating that the agreed closure outcomes have been met. This will be achieved once the government and community agree that the condition of the site is compatible with an agreed post-mining land use.

Closure outcomes reflect the aspects of the MCP that government and community stakeholders agree are key to evaluating the site condition. They do not represent the full range of issues that need to be addressed upon closure; rather they represent the key outcomes against which the ability to relinquish will be assessed.

The MCP outcomes considered appropriate for the Proposal are presented in Table 10-3. Due to the early stage of the operation, these outcomes have yet to be agreed with key stakeholders and are likely to evolve in future versions of this plan as knowledge of closure issues progress and detailed closure discussions commence.

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Table 10-3: Proposed Proposal closure outcomes

Number	Outcome
1	Cultural heritage values have been preserved where possible, in consultation with stakeholders.
2	Public health and safety hazards have been appropriately managed.
3	Infrastructure has been appropriately managed.
4	The final landform is stable, and its design considers hydrological and ecological factors.
5	Vegetation on rehabilitated land is self-sustaining native species and compatible with the post-mining land use.
6	Conservation significant flora and fauna habitat is not significantly impacted by closure activities.
7	Contamination risks have been appropriately managed and do not preclude the agreed post-mining land use(s).

Note that these outcomes do not represent the full range of issues that need to be addressed upon closure of the Proposal; rather they represent the key outcomes against which the ability to relinquish will be assessed.

Preliminary completion criteria and measurement tools have been drafted for each of these outcomes and are discussed further in Section 10.6.

10.6 Completion criteria

Completion criteria are defined as the indicators used to determine whether closure outcomes have been met. They are used to measure the success of closure implementation against outcomes, and to facilitate relinquishment of mining tenure.

Completion criteria (Table 10-4) have been developed in consideration of predicted closure outcomes. Measurement processes and the associated supporting data (evidence and / or metrics), that could be used to evaluate the success of closure are also described in Table 10-4.

The completion criteria are subject to ongoing review and update, informed by the outcome from studies, monitoring and ongoing stakeholder consultation. Given the number of years until scheduled closure, the completion criteria contained in this plan should be considered preliminary only. As the site approaches scheduled closure, the completion criteria will contain more measurable and time-bound parameters.

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Table 10-4: Preliminary completion criteria

Outcome	Preliminary completion criteria	Verification process/method	Evidence
Cultural heritage values have been preserved where possible.	1) Safe access to sites of social and cultural significance is implemented as agreed with key stakeholders. 2) Key heritage sites have not been impacted by closure implementation where possible. 3) Closure strategies have been developed in consultation with Traditional Owner representatives. 4) The final landform has been subject to visual impact assessment.	• Designated access pathways have been identified and communicated. • Abandonment bund restriction areas are communicated. • Heritage survey confirms heritage sites of significance have not been impacted. • Stakeholder consultation. • Visual impact assessment. • Ethnographic survey and/or site inspection.	• Maps of designated access pathways. • Maps of abandonment bund locations. • Heritage survey report. • Consultation register. • Visual impact assessment report. • Survey report.
Public health and safety hazards have been appropriately managed.	1) Safety and health risks have been identified. 2) Measures to mitigate the identified public safety (and fauna where appropriate) and human health hazards have been agreed with key stakeholders and have been implemented. 3) Transfer of any residual liabilities is agreed with stakeholders.	• Risk assessment conducted and mitigation actions implemented. • Relevant stakeholders have been engaged on risk mitigation measures to be employed. • Independent audit(s)/review to confirm that hazard mitigation measures have been implemented. • Process for transfer of residual liabilities is documented.	• Risk assessment report. • Audit report to confirm effectiveness of controls. • Records of stakeholder engagement. • Liability transfer agreement/s.
Contamination risks have been appropriately managed.	1) Requirements under the *Contaminated Sites Act 2003* (WA) have been met for the identification, recording, management, remediation and transfer of any contaminated sites as appropriate. 2) Restriction on use as defined on the Notice does not prevent the ability to conduct agreed post-mining land use(s).	• The site has been appropriately assessed for the presence of suspected or known contaminated sites. • Suspected or known contaminated sites have been appropriately reported under the *Contaminated Sites Act 2003*. • Appropriate management measures to address contamination have been implemented.	• Contaminated sites investigation report/s undertaken in accordance with the Department of Water and Environmental Regulation *Contaminated Sites Guidelines* and the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM). • Reports submitted to the Department of Water and Environmental Regulation. • Notice of Classifications.

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Outcome	Preliminary completion criteria	Verification process/method	Evidence
The final landform is stable and considers hydrological factors.	1) No erosion features that compromise landform integrity are present and if present, erosion features are stable. 2) The final landform was designed and constructed with consideration given to its stability during intense rainfall and large flood events. 3) Final landforms are outside predicted potentially unstable pit edge zones.	• Rehabilitation monitoring program including quantitative evaluation of behaviour of rills and gullies (if required) over time. • Analysis of aerial imagery to provide qualitative analysis of landform stability. • Post-closure landform review to confirm that risks have been appropriately managed.	• Rehabilitation monitoring results. • Survey data assessment. • Post-closure landform evaluation report. • Analysis of aerial imagery.
Vegetation on rehabilitated land is self-sustaining and compatible with the post-mining land use.	1) Seed used in rehabilitation works is of local provenance[5]. 2) Native plants within rehabilitated areas are observed to flower and/or fruit. 3) Recruitment of native perennial plants is observed. 4) Species richness[6] of native perennial plants within rehabilitated areas is not less than reference sites. 5) Any weed species recorded within rehabilitation areas are present within the local area.	• Seed management plan • Rehabilitation monitoring / site inspections. • Analysis of historical monitoring data. • Analysis of weed species and richness within revegetation against baseline data.	• Rehabilitation closeout report (inclusive of seed list). • Rehabilitation monitoring reports.
Infrastructure has been appropriately managed.	1) Legal agreement to transfer residual liability completed (if required). 2) Where transfer of liability is not established, infrastructure has been decommissioned and removed.	• Appropriate agreements and transfer processes in place and communicated for any infrastructure remaining post-closure. • Decommissioning and demolition plan.	• Agreements in place with party assuming liability for infrastructure. • Visual inspection and close out report of decommissioning activities

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[5] Note: Some seed used in rehabilitation predates accurate recording of collection area. Note 2: Local is defined as Pilbara IBRA

[6] Richness is defined as the number of different species in the defined area.

11 Closure Implementation

The closure measures identified below consider the methods used to manage key risks as discussed in the previous section.

11.1 Closure work program

The Closure Work Program, documented in Table 11-1 to Table 11-6, reflect the current level of site knowledge for each closure domain. As the site is not yet operational these Closure Work Programs are considered preliminary and will be developed over the LoM to provide detailed closure implementation requirements, final landform designs, closure strategies and progress of addressing knowledge gaps.

It is intended that the Closure Work Program for each domain will form the basis of a more detailed Decommissioning and Rehabilitation Plan which will be used for closure implementation.

The Closure Work Program for each domain presents key information relevant to each domain, including:

- domain features, status and closure date.
- post-mining land use ALUM classification.
- relevant closure design information.
- closure assumptions.
- knowledge gaps.
- preliminary closure outcomes relevant to each domain.
- closure monitoring and maintenance requirements; and
- closure strategy and key tasks for rehabilitation and closure phases.

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Table 11-1: HD2 and BHT pit voids closure works program

Program Aspect	Program Summary
Domain features	Pit voids: (HD2 West, Centre, East) (BHT West, Centre, East)
Footprint (ha)	965.89
Status of domain features	Proposed
Estimated closure date	2040
Post-mining land use	5.8.4 Extractive industry not in use
Relevant preliminary closure outcomes	• Public health and safety hazards have been appropriately managed. • Cultural heritage values have been preserved where possible, in consultation with stakeholders.

Program Aspect	Program Summary

Specific closure assumptions	• Undertake opportunistic backfill during operations or post-closure to:
	  ○ minimise the volume of waste remaining in waste rock landforms; and/or
	  ○ manage highly erodible material.
	• Prior to final closure, appropriate evaluation and implementation of measures to restrict inadvertent public access.
	• Hd2_west pit may be partially backfilled with mine waste to facilitate the realignment (to the original location) of the GNH.
	• In-pit areas, including pit walls and floors, will not be rehabilitated, unless in-pit backfill is within 10 m of the natural ground level.
	• Abandonment bund will be constructed during operations, using competent NAF mineral waste.
	• All permanent ex-pit mining landforms will be located outside the PUPEZ.
	• Prior to final closure, appropriate evaluation and implementation of measures to restrict public access will be undertaken.

Landform design	• Indicative locations of abandonment bunds and WDs / LG stockpiles, based on the current mine plan, are presented in Figure 4.
Knowledge gaps	• Abandonment bund location / design requires consideration of opportunities to tie-in to natural topography or WDs; intersection with flood inundation zones under a 1:1000 AEP (as a minimum); and site access requirements for Traditional Owners. • Progressive operational backfilling opportunities to be. • PUPEZ associated with final pit voids, abandonment bund locations and surface water management implications. • Inventory of rehabilitation materials (low erodibility waste) to be utilised for capping and abandonment bunding where required.
Closure and rehabilitation materials required	• Competent NAF mineral waste for abandonment bund.
Closure monitoring and maintenance	• Access assessment. • Geotechnical monitoring. • Assessment of abandonment bund.
Closure Strategy – key tasks	
Progressive rehabilitation and closure activities	• Large, deep voids likely to remain at closure • Construction of abandonment bund as per DoIR 1997 guidelines
Decommissioning and closure	• Removal of rubbish and remaining infrastructure. • Final closure of abandonment bund and pit ramp. • Installation of signage, if required. • Monitoring / assessment as required.
Premature closure	• Access to pit made safe by construction of abandonment bund (where required) and blocking pit ramps. • Monitoring and maintenance program revised and implemented.

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Table 11-2: HD2 and BHT waste landform closure works program

Program aspect	Program summary
Domain features	• Waste rock landforms: HD2DP_NW (Goanna), • Low-grade stockpiles: HD2 DP_NC (Tortoise) • BHT Landbridge/s
Footprint (ha)	965.89, 62.88
Status of domain features	Proposed
Estimated closure date	2040
Post-mining land use	1.3.4 Rehabilitation
Relevant preliminary closure outcomes	• The final landform is stable, and its design considers hydrological and ecological factors. • Vegetation on rehabilitated land is self-sustaining and compatible with the post-mining land use. • Cultural heritage values have been preserved where possible, in consultation with stakeholders.
Specific closure assumptions	• All waste landforms are NAF and have a low risk of metalliferous drainage. • Greater than 50% of mineral waste is predicted to be high erodibility. • LG stockpiles may be processed during the LoM, however, if any remain at closure they will be rehabilitated as per WRLs. • Waste rock landforms will be located outside the PUPEZ and 1:1,000 AEP flood inundation zone of PMC. • Waste landforms will be constructed in accordance with RTIO design criteria and rehabilitated in accordance with RTIO standards and procedures. • Progressive rehabilitation of waste landforms will occur during operations where possible. • Landbridge's will be modified or removed to reinstate natural surface water flow. • Landbridges not removed at closure will be rehabilitated as per Waste Rock Landform requirements.
Landform design	Conceptual closure landform design is presented in Section11.2.
Knowledge gaps	• Erodibility of HD2 mineral waste. • Soil inventory and topsoil recovery strategy and volumes.
Rehabilitation materials required	• Topsoil for use as growth medium.
Closure monitoring and maintenance	• Post-closure landform stability monitoring • Erosion maintenance • Revegetation monitoring
Closure strategy – key tasks	
Progressive rehabilitation and closure activities	• Opportunistic progressive pit backfilling during operations may be undertaken to reduce volume of ex-pit waste landforms • Implementation of progressive rehabilitation during operations as per RTIO standards and procedures
Decommissioning and closure	• Removal of rubbish and mining infrastructure. • Re-profile batter slopes to closure design criteria. • Construct toe bunds and safety berms to design criteria. • Spread topsoil on all slopes and flat surfaces, rip and seed.
Premature closure	• Closure outcomes and completion criteria revised.

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	• Revised materials rehabilitation inventory. • Closure designs and provision revised and updated as required. • Implementation of revised rehabilitation and closure works as appropriate. • Monitoring and maintenance program revised and implemented.

Table 11-3: HD2 (HD1) and BHT processing infrastructure closure works program

Note – Proposal is utilising HD1 existing Crushers and associated infrastructure. The liability for closure of these pieces of infrastructure will be transferred to the MCP once the Proposal is approved.

Program aspect	Program summary
Domain features	Conveyor between BHT and HD1, Transfer pads, haulage roads and laydown areas
Footprint (ha)	Included in infrastructure footprint - 2932.14
Status of domain features	Proposed
Estimated closure date	2040
Post-mining land use	1.3.4 Rehabilitation
Relevant preliminary closure outcomes	• Public health and safety hazards have been appropriately managed. • Infrastructure has been appropriately managed. • Contamination risks have been appropriately managed and do not preclude the agreed post-mining land use(s). • Vegetation on rehabilitated land is self-sustaining and compatible with the post-mining land use. • Cultural heritage values have been preserved where possible, in consultation with stakeholders.
Specific closure assumptions	• All recoverable ore has been processed. • Unless transfer to an agreed third party, decommissioning and disposal of processing infrastructure will occur. • Chemicals and hazardous materials are appropriately removed and managed prior to decommissioning phase. • Processing infrastructure will be decommissioned, removed and disturbance rehabilitated. • Removal of below-ground infrastructure will occur to a depth of 1 m • Infrastructure will be salvaged, recycled or buried on-site as appropriate.
Landform design	• Conceptual landscape design will be included as information becomes available for revised versions of the MCP.
Knowledge gaps	• Third party transfer or sale of non-processing infrastructure. • Contaminated sites investigation at closure. • Soil inventory and topsoil recovery strategy and volumes.
Rehabilitation materials required	• Topsoil
Closure monitoring and maintenance	• Erosion monitoring • Revegetation monitoring
Closure strategy – key tasks	
Progressive rehabilitation and closure activities	• Implementation of progressive decommissioning and rehabilitation during operations as per Rio Tinto standards and procedures.
Decommissioning and closure	• Retain or remove infrastructure in accordance with State Agreement Act requirements and stakeholder engagement. • Drain pipelines and remove hazardous materials in accordance with Controlled Waste Regulations. • Where infrastructure is removed, reinstate drainage lines where appropriate.

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	• Undertake contaminated sites assessment and remediation measures, if required. • Dispose of inert materials that are not retained, reused or recycled in an inert landfill area (may be a used pit area). • Spread topsoil, rip and seed
Premature closure	• Closure outcomes and completion criteria revised. • Revised materials rehabilitation inventory. • Closure designs and provision revised and updated as required. • Implementation of revised rehabilitation and closure works as appropriate. • Monitoring and maintenance program revised and implemented.

Table 11-4: HD2 and BHT non-processing infrastructure closure works program

Program aspect	Program summary
Domain features	Vehicle workshops and fixed plant workshops, hydrocarbon storage areas, ANFO facilities, laydown areas, turkey's nests, transfer pads, roads, offices. camps, fuel facilities and associated disturbances.
Footprint (ha)	Included in infrastructure footprint - 2932.14
Status of domain features	Proposed
Estimated closure date	Final closure 2040
Post-mining land use	1.3.4 Rehabilitation
Relevant preliminary closure outcomes	• Public health and safety hazards have been appropriately managed. • Infrastructure has been appropriately managed. • Contamination risks have been appropriately managed and do not preclude the agreed post-mining land use(s). • Vegetation on rehabilitated land is self-sustaining and compatible with the post-mining land use. • Cultural heritage values have been preserved where possible, in consultation with stakeholders.
Specific closure assumptions	• Unless transfer to an agreed third party, decommission and rehabilitation of infrastructure will occur.
Landform design	Conceptual final landform design for this domain is not currently available and will be prepared and provided in revised versions of this MCP.
Knowledge gaps	• Third party transfer or sale of non-processing infrastructure. • Contaminated sites investigation at closure. • Soil inventory and topsoil recovery strategy and volumes.
Rehabilitation materials required	• Topsoil
Closure monitoring and maintenance	• Erosion monitoring • Revegetation monitoring
Closure strategy – key tasks	
Progressive rehabilitation and closure activities	• Implementation of progressive rehabilitation during operations as per RTIO standards and procedures.
Decommissioning and closure	• Retain or remove infrastructure in accordance with State Agreement Act requirements and stakeholder engagement. • Drain pipelines and remove hazardous materials in accordance with Controlled Waste Regulations. • Where infrastructure is removed, reinstate drainage lines where appropriate.

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	• Undertake contaminated sites assessment and remediation measures, if required. • Dispose of inert materials that are not retained, reused or recycled in an inert landfill area (may be a used pit area). • Spread topsoil, rip and seed
Premature closure	• Closure outcomes and completion criteria revised. • Revised materials rehabilitation inventory. • Closure designs and provision revised and updated as required. • Implementation of revised rehabilitation and closure works as appropriate. • Monitoring and maintenance program revised and implemented.

Table 11-5: Linear infrastructure closure works program

Note - Rail: utilised from the Hope Downs 1 operations. The liability for closure of this infrastructure will be transferred to the MCP once the Proposal is approved.

Program aspect	Program summary
Domain features	Powerlines, pipelines, communications cable (as required).
Footprint (ha)	Included in infrastructure footprint - 2932.14
Status of domain features	Proposed
Estimated closure date	2040
Post-mining land use	1.3.4 Rehabilitation
Relevant preliminary closure outcomes	• Public health and safety hazards have been appropriately managed. • Infrastructure has been appropriately managed. • Contamination risks have been appropriately managed and do not preclude the agreed post-mining land use(s). • Vegetation on rehabilitated land is self-sustaining and compatible with the post-mining land use. • Cultural heritage values have been preserved where possible, in consultation with stakeholders.
Specific closure assumptions	• Unless transfer to an agreed third party, decommissioning and rehabilitation of infrastructure will occur.
Landform design	Conceptual final landform design for this domain will be prepared and provided in revised versions of this MCP.
Knowledge gaps	• Contaminated sites investigation at closure. • Soil inventory and topsoil recovery strategy and volumes. Soil inventory and topsoil recovery strategy and volumes. • Management plan for the section of rail that intercepts the WAMA to be developed for closure.
Rehabilitation materials required	• Topsoil • Cover materials if / as required.
Closure monitoring and maintenance	• Erosion monitoring • Revegetation monitoring
Closure strategy – key tasks	
Progressive rehabilitation and closure activities	• Implementation of progressive rehabilitation during operations as per Rio Tinto standards and procedures.
Decommissioning and closure	• Retain or remove infrastructure in accordance with State Agreement requirements and stakeholder engagement. • Undertake contaminated sites assessment and remediation measures, if required.

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	• Where infrastructure requires removal, remove all structures and footings that are above surface or within 1m of the final land surface. • Drain pipelines and remove hazardous materials in accordance with Controlled Waste Regulations. • Where infrastructure is removed, reinstate drainage lines where appropriate. • Actively seek reuse and recycling opportunities for decommissioned infrastructure. • Dispose of inert materials that are not retained, reused or recycled in an inert landfill area (may be a used pit area). • Spread topsoil, rip and seed.
Premature closure	• Closure outcomes and completion criteria revised. • Revised materials rehabilitation inventory. • Closure designs and provision revised and updated as required. • Implementation of revised rehabilitation and closure works as appropriate. • Monitoring and maintenance program revised and implemented

Table 11-6: Roads and other disturbance closure works program

Program aspect	Program summary
Domain features	• Topsoil stockpiles: HD2: TS1, TS2, TS3, TS4, TS5, TS6, TS7, TS8. • Topsoil stockpiles: BHT: TS1, TS2, TS3, TS4, TS5, TS6, TS7, TS8, TS9, TS10. • Subsoil stockpiles HD2: SS1. • Subsoil stockpiles BHT: SS1, SS2.
Footprint (ha)	• Included in infrastructure footprint - 2932.14
Status of domain features	• Haul roads, roads, tracks: proposed • Borrow pits and laydowns: proposed • PMC diversion drain and levee: proposed • Topsoil and subsoil stockpiles: stockpiling proposed
Estimated closure date	2040
Post-mining land use	1.3.4 Rehabilitation
Relevant preliminary closure outcomes	• Vegetation on rehabilitated land is self-sustaining and compatible with the post-mining land use. • Cultural heritage values have been preserved where possible, in consultation with stakeholders.
Specific closure assumptions	• Linear infrastructure will be rehabilitated unless ownership is transferred to a third party. • Disturbance will be rehabilitated to according to relevant Rio Tinto standards and procedures.
Landform design	Conceptual final landform design will be presented in revised versions of the MCP as available.
Knowledge gaps	• Resolution is required regarding retention of linear infrastructure. • Soil inventory and topsoil recovery strategy and volumes. Soil inventory and topsoil recovery strategy and volumes.
Rehabilitation materials required	• Topsoil
Closure monitoring and maintenance	• Erosion monitoring • Revegetation monitoring
Closure strategy – key tasks	

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Progressive rehabilitation and closure activities	• Implementation of progressive rehabilitation during operations as per Rio Tinto standards and procedures.
Decommissioning and closure	• Retain or remove infrastructure in accordance with State Agreement requirements and stakeholder engagement. • Undertake contaminated sites assessment and remediation measures, if required. • Where infrastructure requires removal, remove all structures and footings that are above surface or within 1m of the final land surface. • Where linear infrastructure is removed, reinstate drainage lines where appropriate. • Actively seek reuse and recycling opportunities for decommissioned infrastructure. • Dispose of inert materials that are not retained, reused or recycled in an inert landfill area (may be a borrow pit, or mined pit area); and • Spread topsoil, rip and seed.
Premature closure	• Closure outcomes and completion criteria revised. • Revised materials rehabilitation inventory. • Closure designs and provision revised and updated as required. • Implementation of revised rehabilitation and closure works as appropriate. • Monitoring and maintenance program revised and implemented.

11.2 Closure landscape

The post-closure landform is the final expected landform at the completion of the closure measures outlined in Section 11.1. A conceptual image of landforms at the end of mining and post-closure for the Proposal is included in Figure 43 through to Figure 46. This landscape is likely to change as the Proposal commences construction and moves into the operational phase, and in response to regulator and stakeholder feedback on the proposed closure strategies within this MCP. Updates will be presented in each future iteration of this MCP in consultation with key stakeholders.

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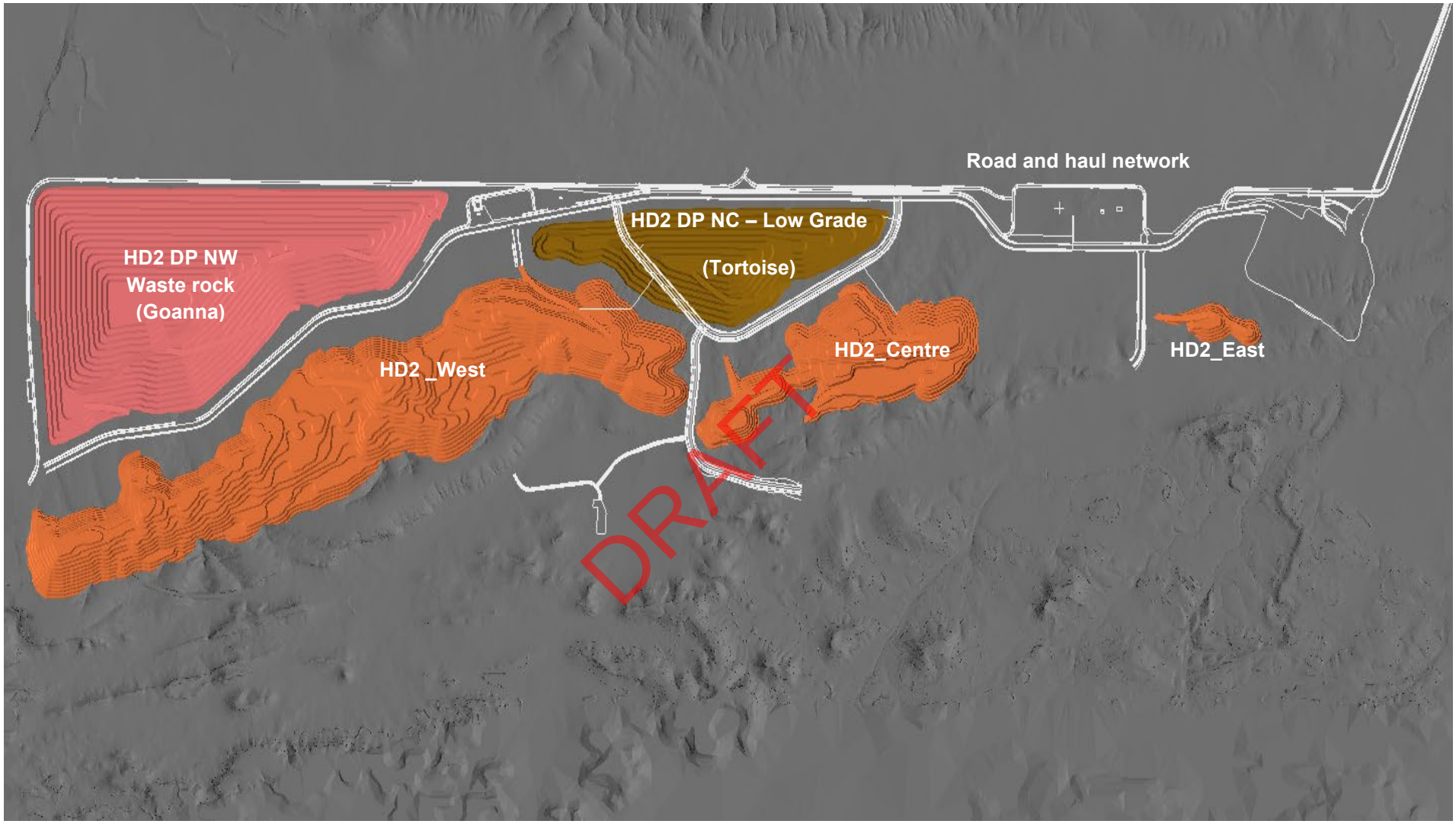

Figure 43: Conceptual layout of the HD2 deposit at completion of mining (mineral waste in pink, low grade material in brown, pits in orange)

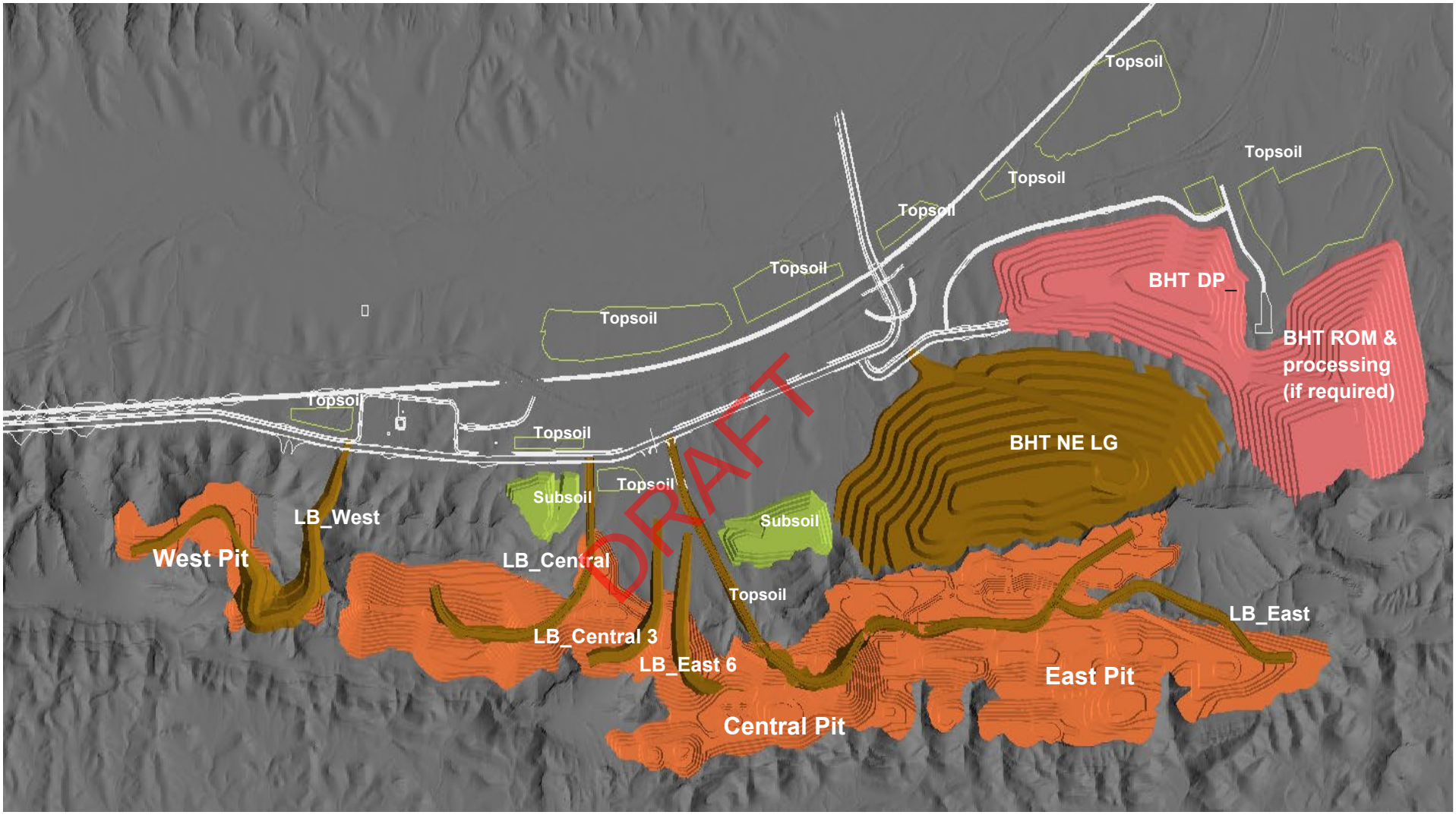

Figure 44: Conceptual layout of BHT deposit at completion of mining (mineral waste in pink, low grade material in brown, pits in orange)

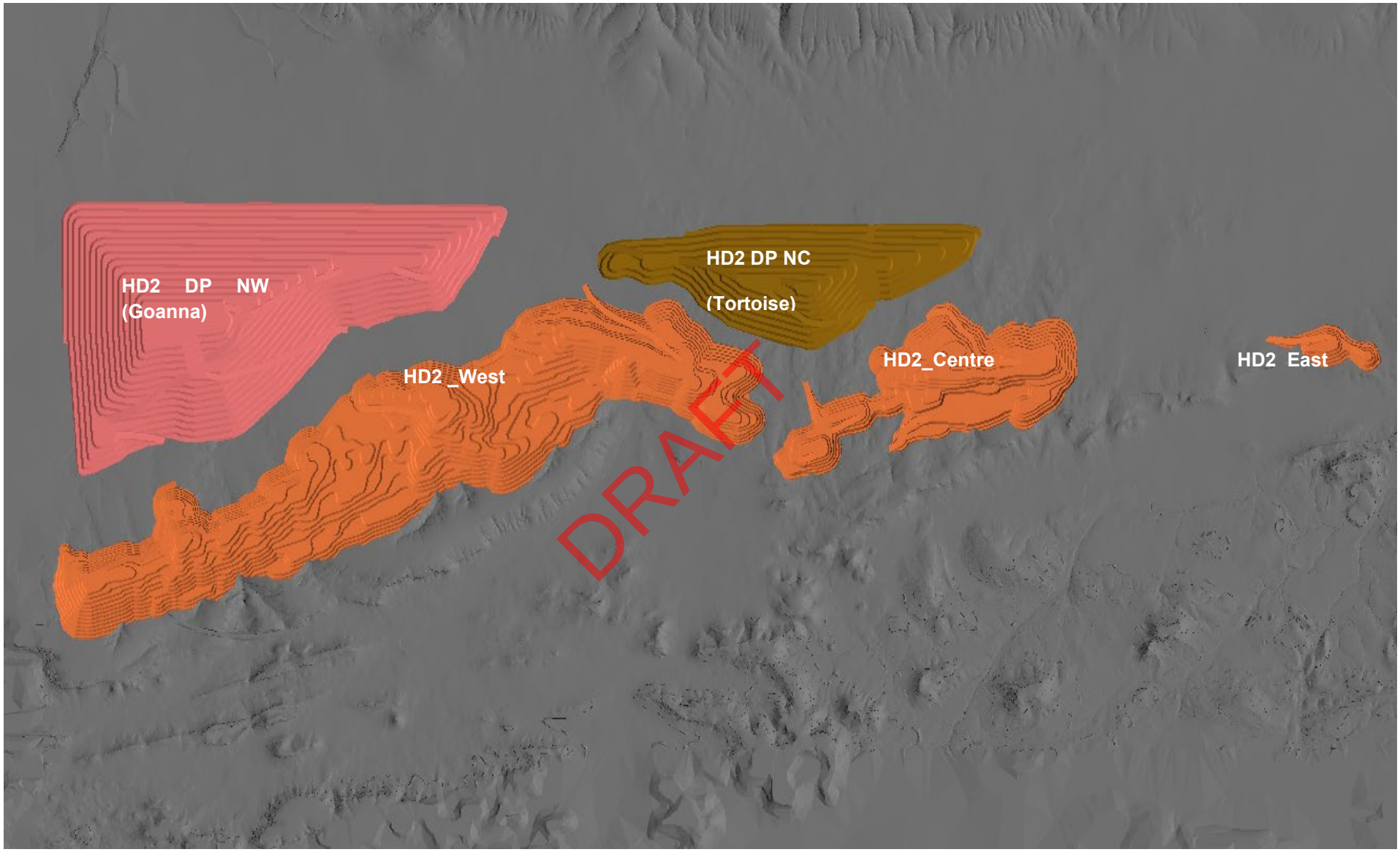

Figure 45: Conceptual layout of HD2 deposit at completion of rehabilitation activities (mineral waste in pink, low grade material in brown, pits in orange)

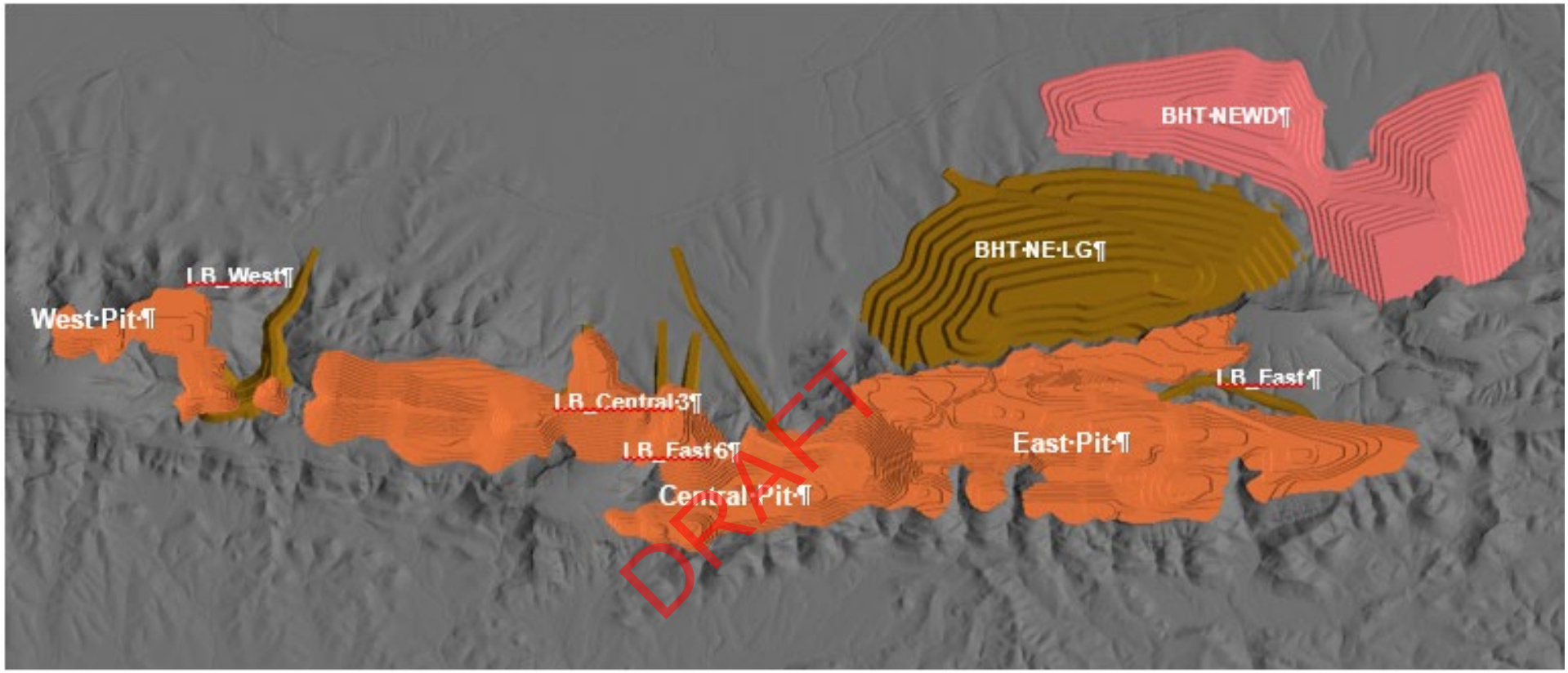

Figure 46: **Conceptual layout of BHT deposit at completion of rehabilitation activities (mineral waste in pink, low grade material in brown, pits in orange). Note – Only landbridges outside the pit areas will remain at closure.**

11.3 Progressive rehabilitation

As operations have not commenced for the Proposal, opportunities for progressive rehabilitation have not presented themselves to date. The mining sequence and short mine life will require that most waste rock landforms are in use until closure. However, tracks, borrow pits and other disturbance areas will be progressively rehabilitated in alignment with rehabilitation planning processes.

11.3.1 Rehabilitation planning

Rio Tinto has formal processes for identifying areas which are no longer required for operational activity and are therefore available for rehabilitation. However, mine plans are dynamic and subject to continuous revision, and rehabilitation may need to be re-disturbed for mining or operational use. Progressive rehabilitation opportunities are reassessed regularly as part of the planning process.

Rehabilitation is classified based on the extent of disturbance, or high, moderate, or low disturbance, Rehabilitation classifications are based on the closure domains and will be presented in progressive rehabilitation performance reporting in future iterations of the Proposal MCP. These classifications are broken down in the following subsections.

11.3.1.1 Low impact disturbance areas

Areas where vegetation has been cleared and there has been minimal disturbance to the soil profile are classified as low impact disturbance areas; examples include laydown areas, linear infrastructure (pipelines, tracks etc.), topsoil stockpile footprints and exploration disturbance. Rehabilitation of such areas involves spreading of topsoil where available and ripping of the area to relieve compaction. Seeding may occur if topsoil is not available.

11.3.1.2 Moderate impact disturbance areas

Areas requiring minor earthworks to either return the area to natural relief or create a compatible landform consistent with the surrounding natural relief and topography are classified as moderate impact disturbance areas. Examples of moderate impact areas include airstrips, buildings, infrastructure, mine roads and borrow pits. Typically, rehabilitation of such areas involves re-contouring, application of topsoil, ripping, and sometimes seeding.

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11.3.1.3 High impact disturbance areas

High impact disturbance areas require extensive earthworks to either return them to natural relief or create a compatible landform consistent with the surrounding landforms and topography. Typically, such areas contain concrete footings that require cracking and covering with fill, voids that need to be filled with waste rock, and significant reshaping and contouring to create the required relief. Examples include accommodation camps, fuel farm facilities, haul roads, bridges, dams, power stations and processing plants. Constructed landforms, such as waste rock landforms and waste fines storage facilities, are also highly disturbed areas that require significant earthworks to achieve stable rehabilitation designs.

11.3.2 Rehabilitation implementation

Rehabilitation is conducted in accordance with the *Rio Tinto Iron Ore Rehabilitation Handbook* (2016) which is reviewed and updated periodically to reflect changes in industry standards, reflect new knowledge obtained through research and development, and to adopt learnings from ongoing rehabilitation projects. The Handbook addresses:

- soil resource management;
- rehabilitation techniques;
- local provenance species seeding practices; and
- Records, data management and on-going monitoring.

11.3.3 Seeding practices

Locally collected seed is required to assist in revegetation and the creation of a self-sustaining ecosystem as the viability of the seedbank within stockpiled topsoil deteriorates. In addition, the stockpiled topsoil may not contain the seeds of all the target species of its new location / habitat.

Seed mixes for rehabilitation are of local provenance, which for the Proposal is defined as 200km and within the same IBRA subregion. Specific seed mixes are selected to provide a range of species taking into consideration landscape position and slope. In areas where erosion risks are identified, seed mixes may be modified to include or increase the portion of species that provide rapid cover.

Rio Tinto purchases seeds from commercial seed suppliers, with emphasis on ensuring that these are appropriate local provenance species. Seeds are stored in purpose-built, climate-controlled storage facilities to maximise long term viability.

The inclusion of rare and threatened flora species in rehabilitation programmes is limited by the following factors:

- habitat preference - preference for drainage lines, gullies, calcretes or other habitat not suitable or similar to those likely to be present in the rehabilitation landscapes.
- abundance - very few populations or small populations from which to source seed.
- difficult taxonomy / unresolved taxonomy issues and thus status of species highly uncertain.
- growth form - e.g., short-lived annual species with preference for growth under woodland canopies.
- seed production - some species do not regularly produce seed.
- propagation methods - some species are not able to germinate from seed and cuttings are required which is not a suitable method for broad scale application in an arid environment.
- availability of seed at the time when rehabilitation occurs; and/or
- seed dormancy.

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Given these issues, the focus of rehabilitation programs is to restore vegetation complexes that include the more common species present in the habitat type, and to achieve a diverse range of strata. Seed mixes may include species of conservation significance if they are available, but presence of these species in rehabilitation areas is more likely to result from natural recruitment from surrounding areas.

11.3.4 Local reference sites

Reference sites are used when assessing the progress of rehabilitation works carried out at Rio Tinto's Pilbara mine sites. Reference sites are usually representative of the 'natural' undisturbed landscape surrounding the mine site or rehabilitated area. Such sites should consist of the target vegetation community and terrain and provide an example of what the rehabilitated area may achieve over time. Reference site data also assists in planning further rehabilitation programmes i.e., seed lists, and in the development of completion criteria. Reference sites will be installed at HD2 in a variety of locations to represent key current and future landform types and across the range of site vegetation types and structures. The reference sites will be chosen strategically to achieve both good representation as well as to remain in areas least likely to be disturbed and will be presented in the next revision of the MCP. Appropriate rehabilitation monitoring reference sites will be established as the rehabilitation and monitoring programs develop for HD2.

11.4 Rehabilitation performance

As operations have not commenced at the Proposal opportunities for progressive rehabilitation have not presented themselves to date, however some progressive rehabilitation has been undertaken to date associated with exploration activities (Figure 47). Rio Tinto has extensive experience in rehabilitating similar landforms to those expected to be present in the post-mining landscape at the Proposal across the Pilbara, including at the nearby and analogous HD1 and HD4 operations. A summary of progressive rehabilitation performance at HD1 is provided below with additional information on rehabilitation activities at HD4.

Progressive rehabilitation has taken place at other Rio Tinto sites in the Pilbara and selected areas are detailed in Section 11.3, these areas have some contextual similarities to the Proposal and learnings will be transferred where applicable.

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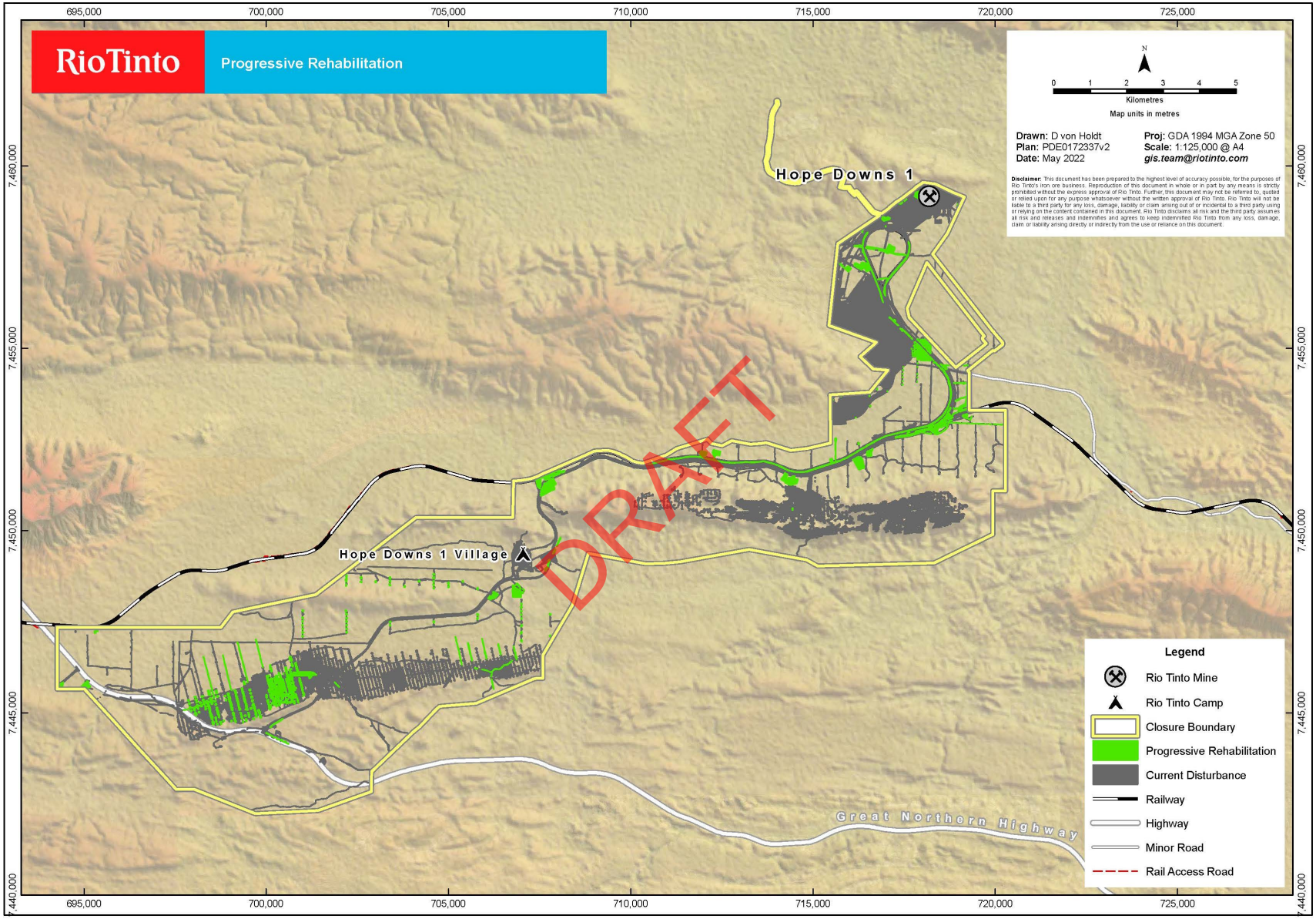

Figure 47: Progressive rehabilitation

11.4.1 HD1 Borrow pits

At the HD1 operation, an area of approximately 144 ha has been rehabilitated to date, these areas include borrow pits, old landfill and service pads.

Rehabilitation of borrow pits located around HD1 was undertaken in 2007. A monitoring program based on 51 monitoring points was established across the rehabilitated borrow pits in 2010.

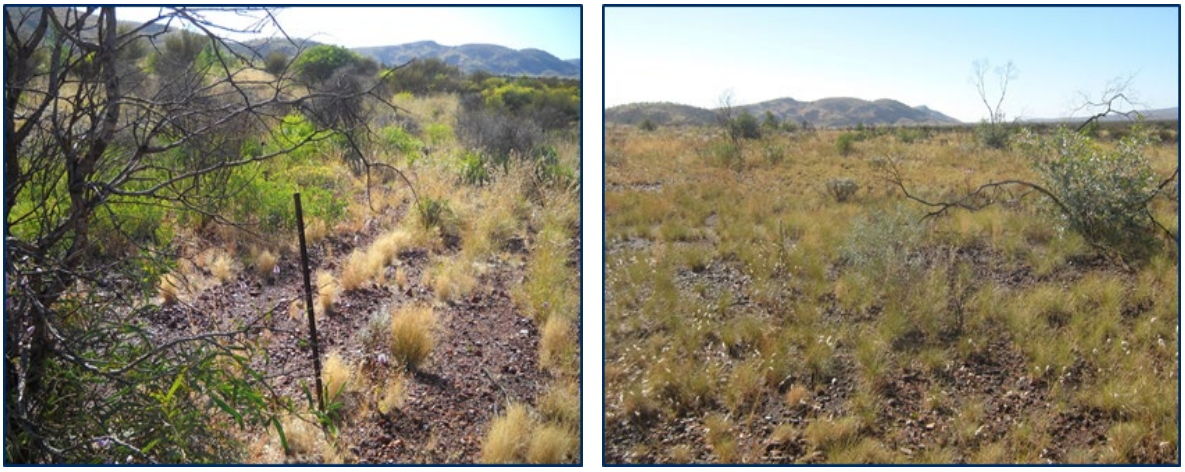

Figure 48: HD1 Borrow Pit rehabilitation outcomes (left) and control areas (right)

Results from annual rehabilitation monitoring indicate that all except two borrow pit sites are stable, erosion has been noted at the two exceptions. Vegetation at the sites appears to be in good condition. Plant species number and perennial plant density have increased, and the overall canopy cover has increased at most sites. Data analysis shows that many of the rehabilitated sites compare favourably with reference sites in terms of plant abundance and species composition. Sites rehabilitated by installation of topsoil only were found to have higher number of species in comparison to some reference sites. It is thought this could be the result of viable seeds in the topsoil seedbank and natural re-colonisation from neighbouring vegetation communities.

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Based on monitoring data, it can be inferred that in general the vegetation of the rehabilitated borrow pit sites is well established with the number of species expected to increase over time through natural re-colonisation from surrounding areas (Figure 48).

11.4.2 Old landfill and service pads

Two sites at HD1 extend over the Old Landfill and Service Pad sites that were rehabilitated in 2013 and first monitored in 2014. Both sites appear stable, although some breaks in the bank at the Old Landfill have been noted. The Old Landfill site was rehabilitated using topsoil and the introduction of seeds at 4.95 kg/ha. The survey data show that the Old Landfill site is still in an early stage of establishment with a low plant cover. However, due to the wide range of seeds in the uppermost soil layer, seedlings from diverse species have been observed. It was also noted that cattle grazing was impacting native grasses (Figure 49).

Vegetation at the Service Pad site is relatively well established with a good species diversity and abundance despite being recently rehabilitated (Figure 50). This outcome has been attributed to the area having only been partially cleared, facilitating re-colonisation from adjacent vegetation.

Figure 49: HD1 Landfill rehabilitation outcomes (2014 and 2017)

Figure 50: HD1 service pad rehabilitation outcomes (2014 and 2017)

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Weeds are absent at both sites, but there is a risk the presence of cattle may lead to the spread of invasive plant species to the Old Landfill.

Overall, species composition and extent of bare areas at both the Old Landfill and Service Pad sites were comparable with most reference sites. Species abundance and perennial cover are expected to increase over time as no major threats to the establishment of the native vegetation have been recorded.

11.4.3 Tom Price Marra Mamba East

Rehabilitation success across the Pilbara has been variable, with well-developed vegetative systems observed in some areas, and limited rehabilitation outcomes in others. Rehabilitation techniques have improved markedly over the last decade, and learnings from landform configuration improvements, usage of growth media and seeding have been incorporated into more recent rehabilitation projects.

Rehabilitation sites completed recently which are similar to conceptual dumps at the Proposal include Marra Mamba East (MME) waste rock landform at Tom Price and the Brockman 2 Pit 6 waste rock landform. Both rehabilitation areas contained non-polluting waste types of a similar character to the majority waste makeup of waste rock landforms in the Proposal and the outcomes of these projects can be applied to landforms at the Proposal.

The MME waste rock landform at Tom Price was rehabilitated in 2018 to a 5 m lift, 18 linear degree slope angle and 10 m berm configuration (Figure 51). The majority material types within the dump were highly erodible West Angelas Shale members interspersed with some blocky BIF material. Rock capping was also used on one batter slope of the rehabilitated landform to provide additional protection for a significant cultural site present close to the toe of the final landform. Topsoil was not applied to the rehabilitated slope due to low quantities available at Tom Price Operation, and in effect this project is a trial to determine how

successful vegetation growth would be in the absence of topsoil. Appropriately treated seed was applied at a rate of 8 kg/ha.

Figure 51: Tom Price MME re-profiled waste rock landform

Some of the lessons learnt from the design and tender process include material availability and quality, design changes to improve practicality and seeding techniques. These lessons are all being incorporated into the rehabilitation design process to provide better closure outcomes.

MME waste rock landform rehabilitation was less than two years old at the last monitoring point and had not yet established native perennial vegetation. Poor vegetation establishment at the MME waste rock landform is considered to be likely related to low rainfall in the region in the 12 months prior to the 2019 monitoring assessment. Erosion features are also present on the dump and require continued monitoring.

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11.4.4 Brockman 2 Pit 6

Rehabilitation works on the Brockman 2 Pit 6 waste rock landform were completed in 2017, with a resultant landform consisting of four lifts of varying heights, and a total footprint of 9.7 ha (Figure 52). Earthworks were performed by pushing the existing angle of repose slopes out to 20 linear degrees; with 20 m, 15 m and 10 m lift heights and 10 m back sloping berms for the final design. An unmanned aerial vehicle (UAV) was used to survey the dump and ensure it was conforming to the design with a tolerance of +/-200 mm. Once the final surface was confirmed as conforming to the design, topsoil was spread on the surface to a depth of 100 to 200 mm (including berms along contour). Deep ripping and seeding were completed with a dozer mounted seeder and with a multi-tine ripper without wings. A seed mix of local native species was sown on the same pass as ripping.

Two rehabilitation transects were installed at Pit 6 waste rock landform in 2018: one on the upper lift and one on the second lift. The area received rainfall well below average in the year preceding rehabilitation activities, and no significant rainfall in the months following seeding. Species richness and density were comparable to or exceeded the reference sites, indicating successful early establishment of the rehabilitation. High species richness is characteristic of new rehabilitation areas, and often declines as the rehabilitation matures.

Some erosion was already present on the rehabilitation surface, and continued monitoring will determine whether these features stabilise or increase in severity over time. The annual weed *Rumex vesicarius* (Ruby Dock) was present at both transect sites however contributed little cover in 2018. This weed will continue to be managed via the operational weed management programme. It is likely to take some years before the rehabilitated sites approach the reference sites in terms of structure, composition and associated parameters, however early signs are indicating a self-supporting ecosystem

Figure 52: Brockman 2 Pit 6 revegetation 2017 (left) and 2019 (right)

Learnings from this project contribute to improvements in Rio Tinto's rehabilitation implementation processes to prevent similar issues occurring in future projects. These include the recommendation that an unmanned aerial vehicle fly over is completed prior to any rehabilitation design commencing, topsoil haulage scheduling and optimised resourcing to prevent re-handling of material, and machine requirements with regard to adequate ripping and contouring local reference sites.

11.5 Unexpected closure

Unexpected or premature closure of the Proposal may result in modifications of the proposed mine closure strategies detailed in this MCP and its subsequent revisions.

In the event of unexpected or premature closure, revision and update of the closure risk assessment would occur to determine key areas for closure works and any change in residual risk from premature closure. Outcomes of the review will be used to prioritise closure tasks. A revision and update of the MCP inclusive of decommissioning requirements will be completed to address changed circumstances and gain approval from relevant key stakeholders where strategies may require amendment.

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These plans would require the following as a minimum:

- stakeholder engagement to communicate the amended closure strategy and address stakeholder concerns.
- review closure outcomes and completion criteria to determine any which may be difficult to achieve in given premature closure. Communicate these with relevant key stakeholders to determine a way to resolve issues.
- amended landform designs for all permanent landforms and mining voids where the proposed design could no longer be met.
- review of topsoil and other rehabilitation materials balances to determine any deficiencies in materials, and options to address this.
- undertake contaminated land assessment, and where required, remediation works, of all areas of the site used for storage or utilise hazardous materials.
- update the final void groundwater model where the proposed extent of mining did not occur to determine if the closure strategy requires amendment.
- finalise any rehabilitation or closure trials to determine if findings are adequate to implement.
- review and update monitoring and maintenance requirements.

- revision and update of the closure cost estimate to determine any financial constraints associated with altered designs or deficit of rehabilitation materials.
- address all safety obligations required under Sections 42 and 88 of the Mines Safety and Inspection Act 1994 (WA) relating to mine suspension or abandonment. One of those obligations is to notify the relevant DMIRS District Inspector before a mining operation is suspended or abandoned.

11.6 Decommissioning

A Decommissioning Plan will be developed based on the Closure Work Programs presented in Section 11.1 for implementation and stakeholder approval where required.

Once ore processing has been completed, decommissioning of equipment and facilities prior to removal of those items not identified to remain post-closure will be undertaken. Equipment and facilities that will not remain post-closure will either be dismantled for reuse or resale, or demolished for on-site disposal, with the approach selected being based on economic conditions at the time of closure. Contaminated land assessments will be undertaken following removal of infrastructure, or within the vicinity of infrastructure to be handed over to a third party. Where required, remediation activities will occur and the monitoring and maintenance requirements within the MCP updated.

Final landforms will be constructed, including any installation of covers, placement of topsoil, abandonment bunds and surface drainage structures. Where required, soil amendments will be made, and seed mixes spread.

Groundwater production and monitoring bores not required for the post-closure monitoring program, or being handed over to a third party, will be decommissioned to meet DWER requirements.

Monitoring activities will commence within the required timeframes following completion of rehabilitation activities. Revision and update of the closure cost estimate will occur, to determine any financial constraints associated with altered designs or deficient materials.

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12 Closure Monitoring and Maintenance

The primary purpose of closure monitoring is to assess whether the agreed closure completion criteria have been met for the Proposal. A specific monitoring program will be finalised as the site approaches closure, and this current plan outlines the principles that will be employed rather than specific details.

12.1 Phases of monitoring

For the purposes of this plan, monitoring is assumed to be conducted in several phases including:

- baseline monitoring, which is conducted as operations expand into new mining areas. Results that are relevant to closure are summarised in the environment knowledge base.
- operational monitoring, which occurs throughout the life of the mine, in line with regulatory requirements and the Rio Tinto operational standards. Results that are relevant to closure are incorporated in the environment knowledge base when it is reviewed.
- pre-closure monitoring, which occurs as the site approaches closure to underpin assessment of post-closure performance.
- closure monitoring, which is conducted during the period of active site closure (approximately two years following the cessation of mining); and
- post-closure monitoring, which is conducted on a regular basis, for at least 10 years or until either:
    - there is a demonstration that closure criteria have been met and that the site is able to be relinquished; or
    - parameters being monitored reach a steady state.

This plan considers pre-closure, closure and post-closure monitoring, while baseline monitoring informs the closure knowledge base and development of closure strategies.

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12.2 Preliminary monitoring program

The closure monitoring program will be finalised during the detailed closure planning stages as the site approaches closure. However, the program could be expected to include such components as indicated in Table 12-1. Specific and appropriate monitoring will be conducted to ensure data is obtained to allow assessment of performance against completion criteria (Section 10.6). The monitoring program will be sufficiently flexible to enable adjustments to be made if results indicate that more, or less monitoring is warranted at any phase. Specific parameters within each aspect are to be defined.

Table 12-1: Preliminary plan for closure monitoring

Aspect	Phase		
	Pre-closure	During closure implementation	Post-closure
Erosion monitoring	✓	✓	✓
Rehabilitation (vegetation) monitoring	✓	✓	✓
Groundwater level monitoring	✓	✓	✓
Groundwater quality monitoring	✓	✓	✓
Surface water quality monitoring	✓	✓	✓
Contaminated sites assessment	✓	✓	
Heritage survey	✓	✓	
Visual impact assessment	✓		✓
Geotechnical stability	✓	✓	

12.3 Rehabilitation monitoring

The purpose of the rehabilitation monitoring program is to evaluate successional development of the rehabilitation, and thereby provide useful feedback for the improvement of rehabilitation techniques, and to help assess progress towards long term rehabilitation goals. Monitoring also provides information which can be used to set realistic and achievable completion criteria. This objective can be achieved by examining changes in key parameters over time and comparing results from the rehabilitation with those from corresponding reference sites in undisturbed areas.

Reference sites, also known as control sites or analogues, are positioned within remnant native vegetation representative of the local area. Such sites should contain the vegetation community commensurate with those existing at the rehabilitated site prior to disturbance and be situated in a similar topographical position within the landscape, and as such serve as an indicator of what the rehabilitated area may achieve over time. However, suitable references sites may not be available for all rehabilitation sites as landforms undergoing rehabilitation are often highly modified, and in such cases references sites provide a guide only. Reference site data also assists in planning aspects of the rehabilitation program i.e., seed lists and the species of which they comprise.

Rehabilitation monitoring is completed in the cooler months (June to September) each year. The monitoring program design (i.e., monitoring technique and frequency) for each rehabilitated area considers the following factors:

- the level of complexity of the rehabilitation and therefore rehabilitation quality risk i.e., waste rock landforms are high risk; exploration rehabilitation is low risk.
- regulatory monitoring requirements.
- rehabilitation age.
- rehabilitation quality.
- rehabilitation area size.
- part of a rehabilitation trial area.
- natural disturbance i.e., fire, cyclonic rainfall.
- safe access for monitoring personnel; and
- efficient use of monitoring resources.

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Several rehabilitation monitoring techniques are used which are usually matched to the level of rehabilitation quality risk. For example, the intensive quantitative method is used on high-risk waste rock landform areas. The techniques used are summarised below.

12.3.1 Vegetation, fauna habitat and erosion quantitative method

Vegetation monitoring involves permanent transects up to 100 m in length, comprised of 2 m x 2 m quadrats at intervals of 5 m. Within each quadrat, numbers of all native perennial plant species and weeds are counted, and their % cover estimated. Total native perennial plant cover is assessed by dividing the 2 m section along the transect baseline into eight, 25 cm sections and recording the number of these that have no cover of any native perennial plant species. A subjective assessment of total native perennial plant cover (%), for plants rooted within the quadrat, is also recorded for each quadrat. Notes are taken of the general condition of the rehabilitation, including new disturbance and fire damage. A photograph is taken from both the start and end point of each transect.

Fauna and habitat monitoring involve estimating litter cover, noting rocks and logs in each quadrat along the same transect, and then doing a whole of transect assessment of grazing extent, native animal scats, ant numbers present, and indicators of native animal activity.

Erosion monitoring involves identifying gullies (i.e., rills greater than 30 cm deep) along the same transect, but extended to 150 m, recording the location of each gully and measuring their total width and depth at the deepest point. If erosion is identified elsewhere in the rehabilitation area, then an erosion specific transect would be installed on a representative section of the gully and total width and depth at the deepest point recorded. A photograph is taken of each measured gully. This intensive quantitative method is used on high disturbance areas such as waste landforms.

12.3.2 Rehabilitation quality assessment

Rehabilitation Quality Assessments (RQAs) are used on low to moderate disturbance areas, historical rehabilitation with no monitoring history, or on areas too small for transects. They can also be used in combination with the above transect methods on large rehabilitation areas to manage monitoring resources efficiently. The purpose is to gain an overview of the rehabilitation quality including erosion, growth medium, vegetation cover, species richness, vegetation structure, plant density, weed presence and general condition. Each characteristic is compared between the rehabilitation and local undisturbed native vegetation and given a score according to the RQA field book guidelines. A representative photograph is taken of both the rehabilitation and reference areas.

12.3.3 Water monitoring

Water monitoring during closure will focus on confirming water quality downstream. Rio Tinto will seek to engage with other industry stakeholders to discuss the potential for data sharing with emphasis on a better understanding of the potential impacts to Ben's Oasis. A specific program of monitoring will be developed prior to decommissioning.

12.3.4 Heritage surveys

Heritage assessments are undertaken prior to closure to ascertain potential cultural heritage impacts of closure implementation and inform the development of alternative strategies if required. Assessments are also undertaken post-closure to confirm that implementation has been undertaken in an appropriate manner.

The SCHMP will also set out consultation processes in respect of broader social and cultural values, throughout the life of mine and prior to closure.

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12.3.5 Visual impact

Visual impact assessment will be undertaken prior to closure to ascertain any potential visual impacts of the closure implementation and inform the development of alternative strategies if required.

12.3.6 Post-closure maintenance

Post-closure, maintenance will continue as required until it is determined that the closure outcomes have been met or it is otherwise agreed with Government to allow relinquishment of the site.

13 Financial Provisioning for Closure

Rio Tinto considers specifics of the closure cost estimate to be commercially sensitive information. This section outlines the general process used to develop the closure cost estimate.

13.1 Principles of Rio Tinto closure cost estimation

Closure cost estimates are determined based on methods outlined in the Rio Tinto Closure Standard and the Rio Tinto Accounting Policy. Closure costs are considered in two formats:

- Present Closure Obligation (PCO) which is indicative of costs associated with closure of the mine given its current footprint, this accounts for the progressive development of a site over time.
- Total Projected Closure (TPC) cost which predicts the cost (in current terms) associated with closure at the end of the life of the mine. The TPC includes areas that are not currently approved, but that feature within the life of mine plan and that are considered likely to be developed in the future.

The cost estimates consider the following components[7]:

- pre-closure studies.
- decommissioning (i.e., removal of infrastructure)[8];
- final landform construction.
- rehabilitation and biodiversity management.
- heritage management.
- workforce management (i.e., training costs and redundancy payments)[9];
- monitoring costs.
- costs associated with the development of the final closure plan.
- costs associated with undertaking a final shutdown of operations [12].
- allowance for failed rehabilitation or pollution that may necessitate rework of rehabilitation areas.
- assignment of indirect costs in accordance with Rio Tinto Accounting Policy; and
- a contingency factor.

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13.2 Closure cost estimation methods

The closure cost estimation methodology is based on methods outlined in the Rio Tinto Closure Standard and Rio Tinto Accounting Policy, with the level of accuracy increasing as the site approaches closure[10]. The closure cost estimates are conducted based on the most recent information of mine plans and infrastructure. Closure costs estimate are generally undertaken by specialist external consultants. The PCO estimate for

[7] Costs associated with decontamination are assessed during closure plan development but are costed separately as they are classified as operating costs, not closure costs.

[8] The decommissioning cost estimate assumes that infrastructure will be demolished and buried on site. The site is sufficiently remote that deconstruction for the purposes of materials salvage and recycling is likely to be cost prohibitive. However, opportunities for salvage and recycling will be sought as the site approaches closure.

[9] Workforce management costs are only included in the TPC.

[10] The level of accuracy applied to Rio Tinto estimates is as follows:

- greater than 10 years from closure: ±30%.
- between 10 years and 5 years from closure: ±20%; and
- less than 5 years from closure: ±15%.

each site is revised on an annual basis to account for incremental mine development during the year. As part of Rio Tinto assurance processes these cost estimates are audited by external financial auditors annually to ensure adequate processes to generate the provisions are maintained. The TPC estimate is typically revised whenever a formal closure plan review is conducted (usually 3-yearly) to capture any changes to LoM design.

Note that for commercial reasons the actual estimate is not documented in this closure plan.

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14 Management of Information and Data

The management of baseline, closure risks and issues data, as well as legal and other obligations and stakeholder consultation records is critical to the management of closure planning and implementation activities. The following data management systems support the management of this data to inform closure planning for the Proposal.

14.1 Information Management System (IMS)

Rio Tinto operates a comprehensive document management system, with electronic records of all key information and data. The document system, known as the Information Management System (IMS) is linked to other business units within the Rio Tinto group of companies, and processes are in place to ensure that the data contained within this system is appropriately backed up and protected. Each document stored within this system is given a unique document number which identifies the document and enables it to be accessed. This system will continue to operate following site closure, and all relevant data will be retained according to appropriate data retention requirements.

An audit will be conducted prior to closure to ascertain whether there is any additional information stored in hard copy form at the site. Such data will be scanned and entered into the IMS to ensure that it is appropriately retained post-closure.

14.2 Closure knowledge base

The closure knowledge database (CKB) is a knowledge management process designed to bring closure related research and monitoring outcomes together into one searchable location. It uses a single-entry form to capture where the report is stored, and how and where the research can be applied for all new ongoing and completed closure related studies. This information is then managed by the Closure team within a secure database. An extract from the CKB which summarises technical information relevant to the Proposal is attached as Appendix 3.

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14.3 EnviroSys

EnviroSys is an environmental database that is used by Rio Tinto to manage environmental and hydrogeological data. The tool is used to store, monitor, and analyse those parameters and report trends on data collections.

Data collected currently includes:

- groundwater – biological, chemical, field, levels, production.
- marine water – biological, chemical, field.
- soil chemistry.
- surface water – biological, chemical, field, levels, production.
- tonnes and moisture.
- rehabilitation monitoring.
- water meters; and
- weather (rainfall, temperatures etc.).

EnviroSys is used to support the building of closure knowledge bases, as well as ensure compliance with operating licenses pertaining to data management. At closure this data would be appropriately stored to allow for review of post-closure completion criteria.

14.4 ARCHER

The Archer system is a centralised database of all operational and closure risks. This database is used by Rio Tinto to manage risks and address actions to progress closure related planning during the life of mining.

Archer currently stores risks, controls and actions and the system functionality also enables the user to rate the effectiveness of these risks and controls, as well as verify actions have been completed.

The Proposal closure risk register is currently stored in Archer, with closure planning actions aiming to address knowledge gaps highlighted in this closure plan. As indicated in Section 7, quarterly review of actions and controls is undertaken for the life of the asset.

14.5 Tenement management system (TMS)

TMS is a system used to store tenement, licencing, permitting and other land management data, as well as legal and other obligations. This database is maintained to inform the Legal Obligations Register of the MCP (Appendix 1) and will continue to be updated as changes to legal obligations associated with land management change.

14.6 Dynamics 365

Dynamics 365 is a system used to capture stakeholder feedback and consultation records. This system also enables the user to set actions to address responses to feedback and enquiries. All consultation minutes and reports will be stored in IMS and record of these stored in Dynamics 365. This system is used to collate feedback for planned consultations regarding the Proposal and to collate consultation records for inclusion in the Proposal MCP. These records can be reviewed in the Stakeholder Consultation Register (Appendix 2).

15 Reviewed Mine Closure Plans

This is the first MCP completed for the HD2 Proposal. Table 15-1 outlines Rio Tinto's response to EPA Services comments (DWERDT704549 and APP-0013051) received 27th June and 6th October 2023 on the preliminary draft HD2 MCP (versions April and August 2023), as a supporting document and appendix to the HD2 ERD to support a Part IV. Changes and updates as indicated are reflected in this MCP (October 2023).

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Table 15-1: Summary of regulator feedback and Rio Tinto responses to the revised Mine Closure Plan

Rio Tinto response to EPA comments (DWERDT704549 and APP-0013051) received on the Hope Downs 2 Mine Closure Plan (versions April - August 2023). Updates reflected in the HD2 MCP (October 2023)	
EPA Services comments	**Rio Tinto response**

It is noted that the Hope Downs 2 proposal will require State Agreement approval and that DMIRS is an advisory body for the MCP (see comments above).
Actions
• Update the dates on the MCP document.
  ○ The MCP document is dated April 2023 although the corporate endorsement date is 13 July 2022.
  ○ Clarify why the MCP refers to a closure date of 2033 although Hope Downs 2 life of mine is expected to be 15 years from 2025.
  ○ Clarify why the MCP does not include infrastructure that is included in Hope Downs 1, however Hope Downs 2 will use Hope Downs 1 infrastructure and the life of mine extends past the Hope Downs 1 end of life of mine.
	The dates in the MCP will be updated to reflect the corporate endorsement, and the latest mine life dates (2025-2040).
	The closure boundary for the HD2 proposal includes infrastructure from HD1, including HD1S ROM and associated infrastructure. The closure boundary shows overlap of Baby Hope waste dumps at HD1 due to the HD2 Proposal use of the BH haul roads to transport ore to HD1 infrastructure as mentioned above. Once HD2 is approved, this HD1 infrastructure will be reassigned as HD2 infrastructure. The MCP text will be reviewed and amended to clarify this.
	The reference to West Angelas is included because it is a requirement of the DMIRS Guidelines for the Preparation of Mine Closure Plans to list the current underlying tenure of proposal extent. The re-alignment of the Great Northern Highway will not be constructed under the L47/52 tenure,

• Update details in the MCP Closure obligations to refer to Hope Downs 2 – currently refers to West Angelas not Hope Downs 2.	rather, in consultation with Main Roads WA, suitable tenure will be sought. The footnote in section 1.2 has been amended to reflect that L47/52 is considered part of the scope of the Rio Tinto West Angelas Closure Plan. Once the realignment route is finalised, this tenure may be removed from the scope in future updates to this MCP as new tenure will be acquired to address this. Tenement conditions associated with L47/52 are therefore included in Appendix 1 – HD2 Closure Obligations Register.
<u>Section 5.7.7 Erodible mineral waste management and Table 5-4</u> The conceptual WRL designs proposed at this early stage comprise multiple lifts with relatively narrow (10 m) back sloping (11 degrees) berms. This creates the potential for those berms to fill up with sediment and create a failure point post-closure. The risk is mentioned at length in the Landloch paper titled "*Hydrological function of berms within a waste landform design: Mine Closure 2016* – AB Fourie and M Tibbett (eds) © 2016 Australian Centre for Geomechanics, Perth, ISBN 978-0-9924810-4-9. For 10 m wide berms with a 5% back slope in the Pilbara setting a time frame of 63 years is estimated from water erosion prediction project (WEPP) model before the capacity is reached and failure may likely occur. • **Actions** • Review the proposed conceptual WRL designs. • Provide a design life for those features to indicate at what point the berm capacity is likely to be exceeded and explain how that risk will be mitigated. • Consider in the risk assessment, the elimination of the risk created by the construction of the berms.	WRL slope designs have been determined from application of the RTIO Batter Selector Tool, a purpose built tool informed by years of sampling and testwork of key stratigraphies across the Pilbara, including Greater Hope Downs. Parameters generated from testwork provided inputs into the WEPP model, along with site specific climate sequences – in this case the HD1 and HD2 climate sequence. The Batter Selector Tool outputs slope parameters that would result in stable slopes by considering site specific rainfall and the waste types within an individual WRL. Additionally, landform evolution modelling was completed for HD2 to inform WRL design. This modelling utilised an average erosion rate for the batter geometry, which was calculated and converted to a cumulative erosion volume for a 300 year period. A period of 300 years was selected because the DMIRS mine closure guidance for considering closure criteria and performance indicators states that the "identified completion criteria and associated performance indicators must be able to demonstrate that rehabilitation is progressing as anticipated, particularly where mathematical modelling is utilised to predict long term (usually 300 years or longer) environmental performance (e.g. waste rock landforms)." (DMIRS 2020). In following these processes, the proposed conceptual WRL designs are considered appropriate.
<u>Section 5.8.1 Soil inventory</u> **Action** • It is more pragmatic to state that the topsoil stockpiles will be paddock dumped (to minimise further disturbances) instead of stating a 2m height limit (depending on trucks used). ○ The height of the topsoil stockpiles is a function of the height of the truck bins used to carry out the topsoil haulage and dumping post stripping (~2 m height with a Moxy and ~4 m height if using a Haulpack).	Comment noted: the 2m height limit is the nominal height as documented within the *Rio Tinto Iron Ore Soil Resource Management Work Practice* (Rio Tinto 2020b). As noted, in some cases stockpile heights may be higher than this depending on the machinery used.
Section 5.8.1 Soil inventory, Table 5-10 Predicted life of mine (LoM) balances for Hope Downs 2 (BHT and HD2) **Action** • Table 5-10 should include estimated soil losses that occur during the stripping/haulage and stockpiling of topsoil (~5%).	Comment noted: the soil volumes in Table 5-10 assume a soil recovery rate of 30% this estimate already factors in soil losses during stripping and recovery.
Section 5.8.2 Alternative growth media **Action**	Comment noted: Excess stemming material will be considered for use as alternative growth media if available.

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• Include stemming material (if a surplus is created) is another potential source of suitable alternative growth media.	
Section 5.8.3 Rehabilitation materials inventory • The MCP recognises that waste material produced will have variable erodibility properties and that the less erodible, competent material will need to be segregated and stockpiled during operations for rehabilitation purposes (Table 5-11). **Actions** • Include the requirement to log, track, record and reconcile where the waste is dumped as the individual WRL's are constructed. • Close tracking and recording of this detail for individual truck dumps is crucial to allow for the best possible WRL closure design to be implemented and consider changes that will necessarily occur as the project progresses. • Include this information in section 11.5 (Unexpected Closure) also.	Noted: RTIO is currently investigating how existing mine systems may be used to track the movement of beneficial (competent) waste materials. Learnings from this work will be applied across RTIO managed operations, including HD2.

Section 5.13.3 Invasive flora and 5.13.4 implications for closure and knowledge gaps.
The proposal is adjacent to, and is linked to, existing mining operations and includes area disturbed by exploration works (see figure 47 progressive rehabilitation, current disturbance).
Actions
• Consider and provide invasive flora in a broader and contemporaneous context to inform the weed risk assessment:
  ○ The flora surveys used to document weeds are pre-disturbance and most likely do not reflect the current situation. As an example, it is most likely that Kapok Bush (a very common weed of disturbed areas and roadsides in the Pilbara) is already present in the project area, yet not recorded in table 5-14.
• Provide the reference to the weed species ranking used in the assessment:
  ○ It is noted that the DBCA weed species ranking includes priority weed species that may not be relevant to most mining operations in the Pilbara (for example, Cotton Palm is rated as high risk for its potential to invade Millstream Chichester National Park).
  ○ Use a weed priority listing that reflects the potential for certain weed species to invade disturbed and rehabilitated mining landscapes, rather than the potential for species like WoNS to invade areas that are essentially undisturbed with significant conservation values (also see comments above in flora and vegetation).
  ○ It is also noted that rehabilitation success on Pilbara mine sites is impacted by problematic weeds Kapok, Buffel Grass, Ruby Dock and Calotropis (where present).
	Noted: Baseline surveys were undertaken in 2019/2020. At this time the survey area was adjacent to existing Baby Hope and Hope Downs 1 mining operations. Flora and vegetation surveys within the Proposal closure boundary have recorded a total of 17 introduced flora species (weeds) pre-disturbance (Table 5-14 of the MCP).
	To inform appropriate management of weed species, both the WoNS and DBCA Weed Species Ranking have been used. DBCA Weed Species Ranking considers the potential distribution, current distribution, ecological impact, invasiveness and feasibility of control to derive a final broad qualitative weed species ranking corresponding to specific management actions. RTIO is not aware of any Pilbara specific guidance for weed species. If such guidelines exist then, these will be considered.
	The ERD recognises the potential impact that weeds have to conservation values and includes mitigation and management measures in Table 6-21. Management of weeds is also addressed in the EMP. Weed management includes commitments to engage a consultant to develop a survey and control program to ensure a robust approach to identifying and managing introduced species within the Development Envelope that focuses on high-risk areas (e.g., environmental value, existing weed presence, status of weeds that are present, and potential for further transfer/dispersal e.g., waterways and high trafficable areas).
	To manage weeds in rehabilitation sites, weed species are identified during rehabilitation monitoring work and appropriate controls implemented as required. Monitoring of rehabilitation sites is conducted to assess impact of problem weeds and control measures are implemented as required. Monitoring of weeds in rehabilitation sites is described in Section 12.3.1 of the MCP.

Section 11.5 (Unexpected Closure). Management of project changes.	Noted: Please refer to comment above regarding Section 5.8.3 of the MCP.

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Action
• See comments for Section 5.83 above:
  ○ Having a record and understanding of waste characteristics, precise location and date for individual truck dumps as WRLs are constructed is crucial.
  ○ This allows for the best possible WRL closure design to be implemented and take into account changes that will occur as the project progresses including unexpected closure type scenarios, or when pits, and corresponding WRL, do not progress as initial project expectations.	

MCP Appendix 4 HD2 Closure Risk register. Waste dumps and or land bridges at HD2 are subject to excessive erosion (974458) Rehabilitation outcomes at HD2 do not meet closure objectives. **Action** • Update the existing controls for waste rock management to include a requirement to track and record what type of waste rock (based on block model understanding followed by in-pit validation) is dumped in which location of the various WRLs. This will minimise the overall risks of excessive erosion occurring as well as help design the most optimal final closure slope based on 'as-dumped' data and inevitable project changes over time.	Noted: Please refer to comment above regarding Section 5.8.3 of the MCP.
Appendix 6 HD2 Landform Design Criteria BHT LB West, BHT LB Central 3, BHT LB East 6 and BHT LB East - The external portion will have an updated rehabilitation design completed prior to approval of the project, designs and landforms evolution modelling are underway and planned for completion in 2023. **Actions** • Present in more detail, the proposed rehabilitation designs that are contemplated for the portions of the land bridges that are proposed to stay in-situ and be rehabilitated. • Typically, land bridges are required for haulpacks to reach elevated areas and the rehabilitation of the ramps can result in impacts to surface water or result in slopes left at angle-of-repose (to avoid the former) that cannot be successfully rehabilitated.	Rehabilitation designs for the proposed remaining sections of landbridges are shown in Appendix 6 of the MCP. Further review and design of these landbridges is to be conducted and updated designs will be provided in the next major revision of the MCP. Significant work is undertaken during design to assess impact of hydrological impact of landbridges on surface water flow during operations and at closure. Where significant risks remain at closure, landbridges will be removed or altered to minimise impacts on surface water flows.

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17 Appendices

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Appendix 1: Closure Obligations

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HOPE DOWNS 2 CLOSURE OBLIGATIONS REGISTER
APPROVAL CONDITIONS

Mining Act 1978	
Tenement No. L47/00052	
Condition No.	**Closure conditions**
4	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
11	At the completion of operations, all buildings and structures being removed from site or demolished and buried to the satisfaction of the Executive Director, Environment Division, DMP.
15	On the completion of operations or progressively when possible, all waste dumps, tailings storage facilities, stockpiles or other mining related landforms must be rehabilitated to form safe, stable, non-polluting structures which are integrated with the surrounding landscape and support self sustaining, functional ecosystems comprising suitable, local provenance species or alternative agreed outcome to the satisfaction of the Executive Director, Environment Division, DMP.
20	Management of mine closure is to be undertaken in accordance with the Mine Closure Plan (Reg ID 75896) "West Angelas Closure Plan" dated 11 April 2018 signed by Santi Pal, and retained on Department of Mines, Industry Regulation and Safety File No. EARS-MPMCP-75896 as Doc ID 6012188.
24	A Mine Closure Plan is to be submitted in the Annual Environmental Reporting month specified in tenement conditions in the year specified below, unless otherwise directed by the Executive Director Resource and Environmental Compliance Division, Department of Mines, Industry Regulation and Safety. The Mine Closure Plan is to be prepared in accordance with the Department's "Guidelines for Preparing Mine Closure Plans" 2020.
Tenement No. M282SA (Mining lease issued pursuant to State Agreement)	
Condition No.	**Closure conditions**
n/a	No closure conditions

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CLOSURE OBLIGATIONS REGISTER
COMMITMENTS

Formal Commitments	
Iron Ore (Hope Downs) Agreement Act 1992	
Clause No.	**Closure obligations**
7 (1)	The Company shall subject to the EP Act and the provisions of this Agreement submit to the Minister on or before 30 June 1998 to the fullest extent reasonably practicable its detailed proposals (including plans where practicable and specifications where reasonably required by the Minister) with respect to the production of iron ore from the area or areas approved pursuant to subclause (1) of Clause 6 and the transport and shipment of iron ore produced which proposals shall make provisions for the Company's workforce and associated population required to enable the Company to mine and recover iron ore from the mining lease and transport and ship the iron ore and shall include the location, area, lay out, design, quantities, materials and time programme for the commencement and completion of construction or the provision (as the case may be) of each of the following matters, namely : (m) an environmental management programme as to measures to be taken, in respect of the Company's activities under this Agreement, for rehabilitation and the protection and management of the environment.
16 (1) & (2)	(1)The Company shall in respect of the matters referred to in paragraph (m) of subclause (1) of Clause 7 and which are the subject of approved proposals, carry out a continuous programme of investigation research and monitoring to ascertain the effectiveness of the measures it is taking both generally and pursuant to such approved proposals for rehabilitation and the protection and management of the environment. (2) The Company shall during the currency of this Agreement submit to the Minister at yearly intervals commencing from the date when the Company's proposals are approved or determined (except those years in which a comprehensive report is required to be submitted) a brief report concerning investigations research and monitoring carried out pursuant to subclause (1) and the implementation by the Company of the elements of the approved proposals relating to rehabilitation and the protection and management of the environment in the year ending two calendar months before the due date for the brief report and, at three yearly intervals commencing from such date a comprehensive report on the result of such investigations research and monitoring and the implementation by the Company of the elements of the approved proposals relating to rehabilitation and the protection and management of the environment during the three year period ending two calendar months before the due date for the comprehensive report and the programme proposed to be undertaken by the Company during the following three year period in regard to investigations research and monitoring pursuant to subclause (1) and the implementation by the Company of the elements of the approved proposals relating to rehabilitation and the protection and management of the environment.

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38 (1), (2) and (3)	(1) On the cessation or determination of this Agreement — (a) except as otherwise agreed by the Minister the rights of the Company to in or under this Agreement and the rights of the Company or of any assignee of the Company or any mortgagee to in or under the mining lease and any other lease licence easement grant or other title or right granted hereunder or pursuant hereto (but excluding townsite lots which have been granted to or acquired by the Company and \Iron Ore (Hope Downs) Agreement Act 1992 Schedule 1 Iron Ore (Hope Downs) Agreement which are no longer owned by it) shall thereupon cease and determine but without prejudice to the liability of either of the parties hereto in respect of any antecedent breach or default under this Agreement or in respect of any indemnity given under this Agreement; (b) the Company shall forthwith pay to the State all moneys which may then have become payable or accrued due; (c) save as aforesaid and as otherwise provided in this Agreement neither of the parties shall have any claim against the other of them with respect to any matter or thing in or arising out of this Agreement. (2) Subject to the provisions of subclause (3) upon the cessation or determination of this Agreement except as otherwise determined by the Minister all buildings erections and other improvements erected on any land then occupied by the Company under the mining lease or any other lease licence easement grant or other title made under or pursuant to this Agreement shall become and remain the absolute property of the State without the payment of any compensation or consideration to the Company or any other party and freed and discharged from all mortgages and other encumbrances and the Company shall do and execute all such deeds documents and other acts matters and things (including surrenders) as the State may reasonably require to give effect to the provisions of this subclause. (3) In the event of the Company immediately prior to the cessation or determination of this Agreement or subsequently thereto desiring to remove any of its fixed or movable plant and equipment or any part thereof from any part of the land occupied by it at the date of such cessation or determination it shall give to the State notice of such desire and thereby shall grant to the State the right or option exercisable within 3 months thereafter to purchase in situ such fixed or moveable plant and equipment at a fair valuation to be agreed between the parties or failing agreement determined by arbitration under this Agreement.
39	Nothing in this Agreement shall be construed to exempt the Company from compliance with any requirement in connection with the protection of the environment arising out of or incidental to its activities under this Agreement that may be made pursuant to the EP Act.

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CLOSURE OBLIGATIONS REGISTER

RELEVANT LEGISLATION

Relevant Legislation	
Closure planning and implementation requires consideration of general legislative requirements beyond those that apply to a specific site. A list of potentially	
Australian Commonwealth Legislation	**Western Australian State Legislation**
Environmental Protection and Biodiversity Conservation Act 1999	*Environmental Protection Act 1986*
Native Title Act 1993	*Environmental Protection Regulations 1987*
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	*Environmental Protection (Controlled Waste) Regulations 2004*
Workplace Relations Act 1996	*Environmental Protection (Unauthorised Discharges) Regulations 2004*
	Contaminated Sites Act 2003
	Contaminated Sites Regulations 2006
	Conservation and Land Management Act 1984
	Mining Act 1978
	Mining Regulations 1981
	Parks and Reserves Act 1895
	Rights in Water and Irrigation Act 1914
	Wildlife Conservation Act 1950
	Aboriginal Heritage Act 1972
	Aboriginal Affairs Planning Authority Act 1972
	Mines Safety and Inspection Act 1994
	Mines Safety and Inspection Regulations 1995
	Occupiers Liability Act 1985
	Criminal Code Compilation Act 1913

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CLOSURE OBLIGATIONS REGISTER
GUIDELINES AND STANDARDS

Relevant Guidelines and Standards	
Closure planning and implementation requires consideration of relevant guidelines and standards, some of which may have regulatory consequence through being referenced in regulatory documents. A list of key guidelines and standards that are routinely considered is provided below, but is not exhaustive due to the breadth of the closure planning discipline. This closure plan has been prepared so as to be considered with relevant content of these guidelines and standards.	
Guideline or Standard	**Author**
Guidelines for the Preparation of Mine Closure Plans (2020)	Western Australian Department of Mines and Petroleum and
Leading Practice Sustainable Development Program for the Mining Industry - Mine Closure and Completion (2006)	Commonwealth Department of Industry Trade and Resources
Mine Rehabilitation Handbook (1998)	Minerals Council of Australia
Guideline for the Assessment of Environmental Factors: Rehabilitation of Terrestrial Ecosystems (2006)	Western Australian Environmental Protection Authority
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)	Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council
Mine Void Water Resource Issues in Western Australia (2003)	Western Australian Water and Rivers Commission
Contaminated Sites guideline series	Western Australian Department of Environmental Regulation
Environmental Notes on Mining: Acid Mine Drainage (2009)	Western Australian Department of Mines and Petroleum
Environmental Notes on Mining: Waste Rock Dumps (2009)	Western Australian Department of Mines and Petroleum
Safety Bund Walls Around Abandoned Open Pit Mines (1997)	Western Australian Department of Industry and Resources
Global Acid Rock Drainage Guide (2014)	International Network for Acid Prevention
Australian Standard 2601: The Demolition of Structures (2001)	Standards Australia
Australian Standard 4976: The Removal of Underground Petroleum Storage Tanks (2008)	Standards Australia
Demolition Work Code of Practice (2015)	Safe Work Australia

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Appendix 2: Closure Consultation Register

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Start date	Stakeholder	Consultation Type / Forum	Information provided by Proponent (summary for ERD and MCP)	Stakeholder Response/ Comments	Proponent Response (summary)	Key feedback for Closure Planning
22/05/2018	Weeli Wolli Creek Co-Management Board (now Weeli Wolli Creek Advisory Committee)	Meeting	Introduction to the Project, including scope and proposed timing.	NA	NA	Discussion of early Project design
5/09/2018	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli Heritage Sub-Committee meeting	Cultural heritage survey update provided for HD2 and BHT. Discussion of the deposits and planned heritage work.	NA	NA	Discussion of early Project design
6/09/2018	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli LIC meeting	Introduction to the Project, including the HD2 and BHT deposits and two potential ore transport options (haul and conveyor). Studies will continue to investigate the most cost-effective way of transporting ore from these deposits. Proposed first ore dates will depend on ongoing studies work.	KNAC expressed concerns that with Bedded Hilltop coming online, access to Weeli Wolli Creek (WWC) may become blocked. KNAC requested updates on access to WWC at future LIC meetings.	KNAC and the Nyiyaparli people will be kept informed about the progress of the Studies (i.e. new deposits) – particularly through the LIC forum.	Project design and closure planning will need to maintain access to Weeli Wolli Creek.
10/10/2018	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga LIC meeting	Introduction to the Project, including the portion potentially within the Ngarlawangga native title determination	NA	NA	NA
3/04/2019	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli Heritage Sub-Committee meeting	Cultural heritage survey update provided for HD2 and BHT. Discussion of the BDH16-03 very significant site and that additional geotechnical assessment will be required if blasting is to occur within 300m of the site. The cultural values of BDH16-03 were discussed in detail.	NA	NA	Protection of BDH16-03 to be considered in closure planning.
4/04/2019	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli LIC meeting	The Order of Magnitude study phase is complete and the Pre-feasibility stage will commence later in 2019. HD2 and BHT are within the Nyiyaparli native title determination and heritage survey work will continue to cover the proposed pits, waste dumps and infrastructure areas.	NA	NA	NA
23/09/2019	BNTAC/ Banjima Traditional Owners	USB	Copies of the biological reports undertaken in respect of the Project area, as well as an explanatory memo were provided to BNTAC	NA	NA	NA
23/09/2019	BNTAC/ Banjima Traditional Owners	Meeting with BNTAC staff	Overview of Project, including that HD2 and BHT are on Nyiyaparli country, but that ore will be processed at the existing plant on Banjima country. Overview of biological survey outcomes. Overview of proposed Assessment on Referral Information approval process and timeline for the Project.	The potential interaction of the Proposal with Weeli Wolli Creek is likely to be a concern. BNTAC requested that information about the Proposal be presented to the Weeli Wolli Creek Advisory Committee. BNTAC are looking at cumulative impacts of mining in the Pilbara.	The Proponent advised that above water table mining only is proposed so there should be no impact to Weeli Wolli Creek. It is proposed to build a crossing over Pebble Mouse Creek and modelling will be completed to ensure there are no downstream impacts to Weeli Wolli Creek. The Proponent confirmed it would present information about the Proposal to the Weeli Wolli Creek Advisory Committee. The Proponent will provide a copy of the referral to BNTAC at the time of submission to the EPA and will continue to consult with BNTAC.	NA
25/09/2019	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga LIC meeting	Overview of Project, noting that the only portion of the Project on Ngarlawangga country is the potential diversion of part of Great Northern Highway to develop the full extent of the HD2 deposits. An overview of the Project scope was provided including that it involves above water table mining only of the HD2 and BHT deposits, external waste dumps, water supply and associated infrastructure, transport of ore (via conveyors or haulage) to HD1 for processing , access tracks and roads, rail crossing, and the potential diversion of part of Great Northern Highway on to Ngarlawangga country. Discussion of the proposed Assessment on Referral Information approvals process and timeline for the Project	Ngarlawangga are concerned about the impact of the potential Great Northern Highway diversion on their country and would like more information about the proposed highway alignment footprint. Ngarlawangga are interested in a scoping session to define the consultation pathway.	The Proponent will provide a copy of the referral to NAC at the time of submission to the EPA and will continue to consult with NAC.	NA

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Start date	Stakeholder	Consultation Type / Forum	Information provided by Proponent (summary for ERD and MCP)	Stakeholder Response/ Comments	Proponent Response (summary)	Key feedback for Closure Planning
26/09/2019	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli LIC meeting	Overview of Project, including that it involves above water table mining only of the HD2 and BHT deposits, external waste dumps, water supply and associated infrastructure, transport of ore (via conveyors or haulage) to HD1 for processing , access tracks and roads, Pebble Mouse creek crossing, rail crossing, and the potential diversion of part of Great Northern Highway onto Ngarlawangga country. Discussion of the proposed Assessment on Referral Information approval process and timeline for the Project and update on biological survey work and outcomes.	KNAC requested that the referral be provided to for it to review.	The Proponent will provide the referral and ERD to the group at the time of submission to the EPA and will continue to consult with KNAC.	NA
16/10/2019	KNAC/ Nyiyaparli Traditional Owners	Meeting	Overview of Project and timing, and proposed approvals process and consultation. Discussion included that the Project involves above water table mining only of the HD2 and BHT deposits, and as a result dewatering will not be required. Discussion of water courses within the Development Envelope, along with known environmental values, including the known MNES. The Proponent advised that additional biological reports are being prepared and will be provided to KNAC for review. The Proponent provided an update on the proposed approvals process and timing.	Nyiyaparli raised concerns about maintaining access to sites during construction, operation and closure (particularly Weeli Wolli Creek) and the importance of protecting water. Suggestions regarding sharing of information to support social surroundings. Nyiyaparli are keen to undertake additional fieldwork and surveys with the Proponent, especially to identify important plants and bush foods.	The Proponent will share biological information and undertake desktop assessment with on country verification in 2020. Access to Weeli Wolli Creek by Traditional Owners will be considered as part of mine planning. Updated maps showing water sources and rockshelters to be provided to KNAC to assist its desktop review of the Proposal. Common names of flora and fauna (and images) to be added to maps ahead of the next consultation. The Proponent indicated that it is keen to schedule additional surveys and fieldwork with Nyiyaparli people starting in February or March 2020.	Discussion of early Project design and environmental approvals process. Protection of watercourses and maintaining access to sites (particularly Weeli Wolli Creek) will need to be considered in mine design and closure planning.
12/11/2019	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga Board of Directors meeting	An overview of the Project was provided to the Ngarlawangga Board of Directors, noting that the only portion of the Project on Ngarlawangga country is the potential diversion of part of Great Northern Highway. An overview of the Project scope was provided including that it involves above water table mining only of the HD2 and BHT deposits, external waste dumps, water supply and associated infrastructure, transport of ore (via conveyors or haulage) to HD1 for processing , access tracks and roads, rail crossing, and the potential diversion of part of Great Northern Highway on to Ngarlawangga country. Discussion of the proposed Assessment on Referral Information approvals process and timeline for the Project. An overview of the biological survey outcomes to date was also provided.	The Ngarlawangga Board asked if the potential diversion of Great Northern Highway will be surveyed. NAC asked what impact the highway diversion will have on Ghost Bats,	The Proponent said heritage surveys will be conducted over the area of the potential diversion of the Great Northern Highway, and that it is not currently clear what impact the diversion may have on Ghost Bats, but that it would try to avoid disturbance to the bats where possible. The Proponent will provide biological reports to NAC for review, and is available to attend further meetings to discuss the Proposal. The Proponent will continue to consult with NAC in respect of the Proposal.	Discussion of early Project design and environmental approvals process. Protection of important plants and animals will need to be considered in mine design and closure planning.
19/11/2019	BNTAC/ Banjima Traditional Owners	Banjima LIC	An overview of Proposal and biological survey outcomes was presented to the LIC, including that it will involve above water table mining only at HD2 and BHT, permanent external waste dumps, water supply from a small borefield and the transport of ore to HD1 for processing. Infrastructure required by the Proposal will include a crossing over Pebble Mouse Creek, access tracks and roads, a rail crossing and the potential diversion of part of Great Northern Highway. Discussion of the proposed Assessment on Referral Information approvals process and timeline for the Project. An overview of the biological survey outcomes to date was also provided.	BNTAC noted that the Proponent presented information about the Proposal to BNTAC previously and this has been shared with the elders. Banjima LIC members noted that HD2 and BHT are on Nyiyaparli country but the ore will be processed on Banjima country.	The Proponent will provide biological reports to BNTAC for review, and is available to attend further meetings in respect of the Proposal and related issues.	Discussion of early Project design and environmental approvals process.
24/02/2020	Weeli Wolli Creek Advisory Committee	Weeli Wolli Creek Advisory Committee meeting	Overview of the Proposal and summary of environmental studies to date. NB Committee did not meet quorum.	The Committee noted that continued access to Weeli Wolli Creek will be an important consideration, and Traditional Owner consultation will be appreciated.	The Proponent will continue to engage with Traditional Owners in respect of the Project and maintaining access to Weeli Wolli Creek, including via LICs and other forums.	Discussion of early Project design. Maintaining access to Weeli Wolli Creek will need to be considered in mine design and closure planning.
16/04/2020	KNAC, BNTAC, NAC	Email	The Proponent provided an explanatory memo and copies of the updated biological reports.	NA	NA	NA
1/07/2020	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli Executive Committee meeting	Overview of the Project and summary of the approvals process.	NA	NA	NA

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Start date	Stakeholder	Consultation Type / Forum	Information provided by Proponent (summary for ERD and MCP)	Stakeholder Response/ Comments	Proponent Response (summary)	Key feedback for Closure Planning
19/08/2020	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga LIC meeting	Overview of the Project scope including that it involves above water table mining only of the HD2 and BHT deposits, external waste dumps, water supply and associated infrastructure, transport of ore (via conveyors or haulage) to HD1 for processing , access tracks and roads, rail crossing, and the potential diversion of part of Great Northern Highway on to Ngarlawangga country. New crossings of Pebble Mouse Creek will be required to transport ore to HD1. Overview of biological surveys completed to date and outcomes and initial visual impact assessment work. Discussion of the Social Surroundings consultation sought with Ngarlawangga. Discussion of the approvals process.	Request for more information about Ghost Bats. Copies of additional biological reports to be provided to NAC.	The Proponent is happy to meet with NAC and provide additional information about Ghost Bats. Additional biological reports were provided to NAC in October.	NA
21/08/2020	KNAC/ Nyiyaparli Traditional Owners	Teleconference with KNAC staff	Overview of the Project and approvals process and timing. Discussion of the Social Surroundings consultation sought with Nyiyaparli.	NA	NA	NA
17/09/2020	BNTAC/ Banjima Traditional Owners	Meeting with BNTAC staff	Overview of the Project and approvals process and timing. Update on biological reports. Discussion of the Social Surroundings consultation sought with Banjima.	BNTAC noted that ore will be processed on Banjima country and that Banjima should be compensated for this impact. BNTAC asked for more information about water use at HD1 and that water will be a focus for Banjima in future consultation. BNTAC also asked if traffic will increase in frequency.	The Proponent and BNTAC have agreed an approach for further discussions about compensation. Information about water use at HD1 was provided to BNTAC. The Proponent advised that the process rate will be similar to now so traffic will be about the same frequency.	Discussion of early Project design and that water use and management will be important to consider in project design and closure planning.
23/09/2020	BNTAC/ Banjima Traditional Owners	Delivery of USB with information	Additional biological reports and explanatory memos provided	NA	NA	NA
25/09/2020	NAC/ Ngarlawangga Traditional Owners	Meeting with NAC staff and representatives to plan pre-fieldwork meeting	Discussion and planning of Social Surroundings consultation sought and proposed timing. Planning of pre-fieldwork meeting held on 9 October 2020.	This will be a collaborative approach to capture information for the Proponent to feed into the mine design and approval but also to make sure Ngarlawangga capture the information and knowledge for the group.	NA	NA
1/10/2020	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli LIC meeting	Overview of the Project and approvals process and timing. Information on the HD2 Project, closure strategy and objectives. Discussion of the proposed Social Surroundings consultation to feed into the approvals process. The Proponent is seeking Nyiyaparli feedback to include in the Project design and the approvals process, and would like to get feedback on the ore transport options (haul road or conveyor) and location of the proposed Pebble Mouse Creek crossing. Initial information about the closure planning process.	Protecting water and heritage sites and places is important - especially Weeli Wolli Creek and maintaining the flow of Pebble Mouse Creek. Free and safe access to Weeli Wolli Creek needs to be considered in planning. The proposed waste rock landform near Weeli Wolli Creek is too close. Impacts to water and cumulative impacts to water are a concern. Nyiyaparli requested the Proponent work with other mining companies in the area on a combined water management approach. Nyiyaparli want to be involved in environmental surveys and monitoring work. Nyiyaparli ladies and their plant knowledge should also be included in survey work (both environmental surveys and ethnobotanical surveys). Nyiyaparli want to be consulted about closure of the Project, and an opportunity to explain to Rio Tinto what they would like.	Feedback included in ongoing project revision work, and to inform ongoing consultation. The water rock landform south of the HD2 pit was removed in subsequent mine designs and access to Weeli Wolli Creek will be maintained as part of the Project design. Access to Weeli Wolli Creek will also be supported during construction of the Project. The Proponent is developing a framework to work with BHP on water management. Ethnobotanical work with Nyiyaparli ladies has commenced and will continue. Closure consultation is ongoing as the project design is refined and developed.	Discussion of early Project design and that the waste rock landform south of the HD2 pit is too close, and that water use and management will be important to consider in project design and closure planning, along with maintaining access to Weeli Wolli Creek. Additional closure consultation is required for the Proponent t better understand closure planning for the Project and provide input. An agreed closure consultation process will be part of the SCHMP.
2/10/2020	KNAC/ Nyiyaparli Traditional Owners	Social Surroundings pre-fieldwork workshop	Whole-day workshop with KNAC staff and representatives and Nyiyaparli Traditional Owners. Discussion of the approvals process and timing and what 'Social Surroundings' is. Discussion of the Project scope and timing, including surface and ground water and water supply options, proposed Pebble Mouse Creek crossings, and the proposed surface water diversion near the proposed HD2 pit. Discussion of initial closure planning and outcomes and heritage survey work to date. Discussion of key social and cultural values in the Project area. Discussion of the Social Surroundings consultation sought to inform the Project and support the approval. Scoping for the first in-field consultation planned for late October 2020.	Key issues raised by the Nyiyaparli Traditional Owners to be considered in the Project design and discussed further included impacts to waterways and water flows, water use and management, increased dust and noise, impacts to heritage sites, access to country, ground disturbance and other impacts to country, closure and rehabilitation (including opportunities to backfill), Nyiyaparli involvement in environmental and other monitoring and business development and employment opportunities. Meeting feedback also captured in the first Social Surroundings Short Report (provided in December 2020)	NA	Discussion of early Project design and that water use and management will be important to consider in project design and closure planning, along with access to important sites and places and opportunities to backfill to reduce pit voids at closure.
2/10/2020	KNAC/ Nyiyaparli Traditional Owners	USB	Additional biological reports and explanatory memos provided to KNAC	NA	NA	NA

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9/10/2020	NAC/ Ngarlawangga Traditional Owners	USB	Additional biological reports and explanatory memos provided to NAC	NA	NA	NA
9/10/2020	NAC/ Ngarlawangga Traditional Owners	Social Surroundings pre-fieldwork workshop	Whole-day workshop with NAC staff and representatives and Ngarlawangga Traditional Owners to discuss two Projects, including the HD2 Proposal. Discussion of the approvals process and timing and what 'Social Surroundings' is. Discussion of the Project scope and timing, including above water table mining of HD2 and BHT, ore transport infrastructure, proposed Pebble Mouse Creek crossings, water supply options and the potential realignment of part of Great Northern Highway. Discussion of visual impacts from Ngarlawangga country and the biological survey work completed to date. Discussion of the Social Surroundings consultation sought to inform the Project and the approval, and approvals timing.	Water is a main concern for Ngarlawangga, including impacts to waterways and waterholes and the animals that rely on waterholes. Ngarlawangga would like more information about the Pebble Mouse Creek crossings. Dust, access to country and support for Ngarlawangga to access country are also important.	Feedback from Ngarlawangga will be included in the mine design and approval. In field consultation will be undertaken to visit the Project area and better understand important values and potential impacts to help guide work to avoid, reduce or manage impacts. Pebble Mouse Creek crossings will be designed to allow water to flow through. Understanding what areas Ngarlawangga want to access will help us develop options.	Discussion of detailed project design and that surface water flows at Pebble Mouse Creek and access to important areas will be important to consider in project design and closure planning.
22/10/2020	BNTAC/ Banjima Traditional Owners	Banjima LIC meeting	Update on the Project and scope, including that it involves above water table mining at HD2 and BHT, infrastructure for processing and transporting ore (via conveyors or haulage) to HD1, external waste rock landforms and stockpiles, potential realignment of part of Great Northern Highway, water supply (groundwater abstraction and / or existing HD1 dewatering water that is discharged via the gabion). The Project will also include new Pebble Mouse Creek crossings for the haul road/conveyor, and potential new mine access road and realignment of Great Northern Highway, Discussion of approvals process and timing, Social Surroundings consultation and the consultation sought with Banjima.	What impacts will the Project have on Pebble Mouse Creek? What is the cost of water from Weeli Wolli Creek versus Baby Hope?	The Proponent will need to ensure maintenance of Pebble Mouse Creek flows and prevent the banking-up of water upstream of crossings. Water supply will be needed for the Project and several options are being investigated e.g., ground water at Baby Hope or using some of the water from dewatering at HD1 which would otherwise be discharged to Weeli Wolli Creek. The Proponent is keen to receive feedback on the options. In looking at water supply options, the Proponent will take into consideration the impact of using that option and then the costs. The Environmental Protection Authority requires a study on the social surroundings e.g., animals, natural landscape, environment with cultural significance, so we can understand the impacts on the cultural values and look at options to avoid and reduce impacts.	Discussion of detailed project design and that surface water flows at Pebble Mouse Creek and water supply options to reduce impacts to the environment will be important to consider in project design and closure planning.
22/10/2020	KNAC/ Nyiyaparli Traditional Owners	First Social Surroundings in-field consultation	1.5 day in-field consultation with KNAC staff and representatives and Nyiyaparli Traditional Owners to visit areas within the Project and to discuss the Project in more detail. Topics discussed included the importance of water, water use and management and water quality (diversions, discharge, drawdown, dust control), concerns about impacts of dust on country (particularly accumulation in water features/drainage), amenity, impacts to people and animals. Discussed that access to country needs to be easy and not restricted by permit systems, fences, gates etc. More consultation is required to discuss closure planning.	Request that the Proponent investigate moving the proposed waste rock landform south of the HD2 pit further away from Weeli Wolli Creek. Request for additional information and consultation about the size of the proposed pits and waste rock landforms, water use and management, expected dust levels and management, plant and animal studies in the Project area, closure planning, opportunities for Nyiyaparli involvement in on ground monitoring and management work and business development opportunities. Short report from trip received 15 December 2020.	Feedback and recommendations included in planning future in-field consultation. Waste rock landform south of the HD2 pit removed in subsequent mine design updates.	Discussion of detailed project design and key issues to be considered in project design and closure planning.
9/12/2020	NAC/ Ngarlawangga Traditional Owners	Social Surroundings pre-fieldwork workshop	1.5 day workshop with NAC staff and representatives and Ngarlawangga Traditional Owners to discuss what Social Surroundings is, and to scope the first Social Surroundings field trip planned for early 2021 which will be for 2 Projects, including the HD2 Proposal.	Joint planning of the first Social Surroundings field trip planned for early 2021. Key concerns include protecting access to country, protecting animals and animal habitats, protecting water flows and waterways, water use and management, impacts to heritage sites, dust and visual impacts to country, rehabilitation of country after mining.	Feedback included in jointly planning the first in-field consultation with Ngarlawangga which was held in April 2021.	Discussion of detailed project design and key issues to be considered in project design and closure planning.

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27/01/2021	BNTAC/ Banjima Traditional Owners	Meeting with BNTAC staff	Meeting with BNTAC staff to discuss the Project and Social Surroundings consultation sought. Discussion of the Project scope, including that it involves above water table mining at HD2 and BHT, infrastructure for processing and transporting ore (via conveyors or haulage) to HD1, external waste rock landforms and stockpiles, potential realignment of part of Great Northern Highway, water supply (groundwater abstraction and / or existing HD1 dewatering water that is discharged via the gabion). The Project will also include new Pebble Mouse Creek crossings for the haul road/conveyor, and potential new mine access road and realignment of Great Northern Highway. Discussion of biological survey work undertaken to date. Discussion of approvals process and timing, Social Surroundings consultation and the consultation sought with Banjima.	BNTAC has provided the biological survey reports to their consultant to review. BNTAC requested spatial data for the biological surveys.	Project and biological survey spatial data provided on 8/07/2021.	Discussion of detailed project design.
3/03/2021	BNTAC/ Banjima Traditional Owners	Email	Updated biological reports provided to BNTAC and its consultant.	NA	NA	NA
29/03/2021	BNTAC/ Banjima Traditional Owners	Email	Additional environmental reports provided to BNTAC and its consultant.	NA	NA	NA
29/06/2021	BNTAC/ Banjima Traditional Owners	Email	Additional environmental reports provided to BNTAC and its consultant.	NA	NA	NA
11/03/2021	BNTAC/ Banjima Traditional Owners	Banjima LIC/LoMP meeting	Update on the Project scope, including that it involves above water table mining at HD2 and BHT, infrastructure for processing and transporting ore (via conveyors or haulage) to HD1, external waste rock landforms and stockpiles, potential realignment of part of Great Northern Highway, water supply (groundwater abstraction and / or existing HD1 dewatering water that is discharged via the gabion). The Project will also include new Pebble Mouse Creek crossings for the haul road/conveyor, and potential new mine access road and realignment of Great Northern Highway. Discussion of biological survey work undertaken to date. Discussion of approvals process and timing, Social Surroundings consultation and the consultation sought with Banjima.	BNTAC requested more information on how deep and wide the pits will be. Will the Pebble Mouse Creek crossing disrupt the creek? What about dust and other impacts? Can the waste rock landform south of the HD2 pit and near Weeli Wolli Creek be removed? Can the Development Envelope be reduced? Visual impact assessment will be important. Concerns about lack of compensation to Banjima for impacts to country.	The Proponent advised that the Pebble Mouse Creek crossings will be designed to allow water to flow through. We will do more work to understand potential dust creation and how to reduce it. The waste rock landform south of the HD2 pit near Weeli Wolli Creek was removed in subsequent mine designs, and the Development Envelope has been reduced in a number of areas as project planning has refined the footprint. A process to support discussions about compensation to Banjima was agreed around mid 2021.	Discussion of detailed project design and key issues to be considered in project design and closure planning.
18/03/2021	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga LIC meeting	Update on the Project, that at this stage we have a conceptual footprint. The Proponent will consult with NAC and Ngarlawangga further in the next few months before the approvals process commences. The Proponent is seeking Ngarlawangga involvement in Social Surroundings consultation.	NA	NA	High level discussion of Project.
8/04/2021	NAC/ Ngarlawangga Traditional Owners	First Social Surroundings in-field consultation	3 day in-field consultation with NAC staff and representatives and Ngarlawangga Traditional Owners to visit areas within the Project's Development Envelope to discuss the Project in more detail. NB this was an combined trip for 2 projects with only a small amount of time spent discussing the HD2 Proposal. Topics discussed included the importance of water, and maintaining water flows, potential Pebble Mouse Creek crossings, concerns about dust creation, impact to country, impacts to people and animals. Discussed that greater access to country is desired. discussed biological survey work to date.	Key issues raised include impacts to water (including water abstraction, water flows and dust in waterways and waterholes), impacts to cultural heritage, Country, plants and animals and access, changes to the landscape and aesthetic values of Country. Concerns about current and increased traffic on Great Northern Highway, and impacts the potential new bridge may have on water flows and existing water pools along Pebble Mouse Creek. Request for ongoing consultation, including about the proposed Project footprint, cultural values mapping and Traditional Ecological Knowledge surveys, additional visual and sound modelling of the proposed Great Northern Highway realignment. Request for further consultation about closure planning and rehabilitation. Final Report finalised in July 2021.	Key issues raised include impacts to water (including water abstraction, water flows and dust in waterways and waterholes), impacts to cultural heritage, Country, plants and animals and access, changes to the landscape and aesthetic values of Country. Concerns about current and increased traffic on Great Northern Highway, and impacts the potential new bridge may have on water flows and existing water pools along Pebble Mouse Creek. Request for ongoing consultation, including about the proposed Project footprint, as well as closure planning and rehabilitation. Final Report finalised in July 2021.	Discussion of detailed project design and key issues to be considered in project design and closure planning.
23/04/2021	KNAC, BNTAC and NAC	KNAC, BNTAC and NAC	Draft Referrals and draft ESD provided to Traditional Owner groups for review and feedback.	See responses from each Traditional Owner group	See responses from each Traditional Owner group	See responses from each Traditional Owner group
5/07/2021	KNAC/ Nyiyaparli Traditional Owners	Email	Updated biological reports provided to KNAC.	NA	NA	NA

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7/07/2021	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli LIC meeting	Update on Project, discussion of Part IV process and timing, Social Surroundings and consultation to date and ongoing work/changes to project in response. Nyiyaparli feedback sought in relation to ore transport options and Project design.	NA	NA	Discussion of detailed project design.
8/07/2021	BNTAC/ Banjima Traditional Owners	Email	Spatial data files for updated biological surveys provided.	NA	NA	NA
21/07/2021	BNTAC/ Banjima Traditional Owners	Banjima LOMP meeting	Brief discussion that the Project requires Social Surroundings consultation, and that the draft Referral and ESD for the Project has been provided to BNTAC and its consultant for review and feedback. A dedicated Social Surroundings workshop is to be held for the Project to develop the consultation process and plan the consultation.	NA	NA	NA
22/07/2021	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli Social Surroundings workshop	2-day workshop. Update on the Project and changes to the mine design based on feedback to date. Discussion of Part IV process and timing, Social Surroundings consultation to date and planned future consultation. Discussion of approvals process, draft Referral and ESD	Discussion of key Social Surroundings issues including water, dust, restricted access to country, impacts to heritage sites, interfering with caring for country, increased opportunities to take part in on-ground work to monitor and manage country. Need to protect Weeli Wolli Creek, including reducing or removing the waste rock landform near it.	Feedback included in ongoing mine design work. Feedback also included in Short Report for this workshop and the August Social Surrounding in-field consultation which was provided in November 2021	Discussion of detailed project design and key issues to be considered in project design and closure planning.
23/07/2021	BNTAC/ Banjima Traditional Owners	Email	Peer review report prepared on behalf of BNTAC provided to the Proponent.	Feedback provided in respect of biological survey and other studies undertaken to date and additional work required to meet EPA guidance.	Project design is continuing to be refined and additional biological survey and other studies will be undertaken to address any gaps in initial survey coverage and the coverage required for the refined project design. Some changes were made to the draft Referral in response to this report.	NA
29/07/2021	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga Social Surroundings workshop	Workshop to discuss outcomes of Social Surroundings consultation to date (the first Social Surroundings in-field consultation), the approvals process and timing, and provide a Project update.	Social Surroundings consultation to continue. Ngarlawangga requested additional consultation in respect of compensation for impacts to country as well as ongoing consultation about visual and other impacts.	Social Surroundings consultation to continue. Ngarlawangga requested additional consultation in respect of compensation for impacts to country as well as ongoing consultation about visual and other impacts.	High level feedback on project design and additional information regarding visual impacts.
6/08/2021	KNAC/ Nyiyaparli Traditional Owners	KNAC	KNAC provided feedback to the Proponent on the draft Referral and ESD	Feedback provided on draft referral and ESD.	Feedback considered and incorporated into the draft referral and ESD where relevant.	Feedback in respect of referral and ESD.
9/08/2021	KNAC/ Nyiyaparli Traditional Owners	Second Social Surroundings in-field consultation	Second In-field consultation with Nyiyaparli Traditional Owners to visit key, discuss the Project and changes to date in response to Nyiyaparli feedback. Discussion of key feedback to date, key Social Surroundings values and potential impacts including water, water management and water quality (diversions, drawdown, dust control), concerns about dust creation and impacts of dust on country (particularly accumulation in water features/drainage), amenity, animals, people, access to country: including optional access roads to highly significant heritage sites and important plants and animals, including biological surveys to date.	Discussion of key Social Surroundings values including water, dust, access to country, Weeli Wolli Creek and caring for country. Key issues raised include water impacts and water management, mine design, including waste rock landforms and the importance of mine closure and rehabilitation on impacts to country and visual amenity.	Feedback included in ongoing mine design work. Feedback summarised in Short report received in November 2021.	Discussion of detailed project design and key Social Surroundings issues to be considered in project design and closure planning.
16/08/2021	BNTAC/ Banjima Traditional Owners	Meeting with BNTAC staff	Discussion of the information provided by the Proponent to date and the peer review report provided by BNTAC's consultant. Discussion that the Proponent will make some changes to the Referral in response to the feedback received and that it will provide a copy of the updated Referral at the time of submission to the EPA.	BNTAC will prepare a letter providing feedback on the Referral document in respect of three key issues: troglofaunal, inland waters and the link between the HD1 mine and the HD2 Proposal.	The Proponent updated the referral document based on feedback from a number of parties and also considered the feedback from BNTAC. The Proponent provided an updated copy of the referral at the time of lodging with the EPA.	Feedback in respect of the biological and other studies undertaken to date and feedback on the referral document will be considered as part of the approvals documents and process and in mine design, where relevant

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17/08/2021	NAC/ Ngarlawangga Traditional Owners	Email	NAC provided to Rio Tinto feedback on the draft Referral and ESD	Feedback provided on the draft documents. Request for ongoing consultation about the Project footprint, request to reduce the Development Envelope where possible -particularly to remove key heritage and drainage features including Weeli Wolli Creek. Additional information about access, noise, light and litter impacts from the potential diversion of Great Northern Highway. Ngarlawangga desire for greater involvement in environmental survey, monitoring and management work.	The Proponent updated the Referral document based on feedback from a number of parties and also considered the feedback from NAC. The Proponent provided an updated copy of the referral at the time of lodging with the EPA.	Feedback in respect of referral and ESD.
19/08/2021	BNTAC/ Banjima Traditional Owners	Letter from BNTAC	BNTAC provided the Proponent with a letter providing feedback on the draft referral.	Feedback provided in respect of the Inland Waters, Social Surroundings and Subterranean Fauna sections of the referral.	The Proponent updated the referral document based on feedback from a number of parties and also considered the feedback from BNTAC. The Proponent provided an updated copy of the referral at the time of lodging with the EPA.	Feedback in respect of the biological and other studies undertaken to date and feedback on the referral document will be considered as part of the approvals documents and process and in mine design, where relevant.
3/09/2021	KNAC, NAC, BNTAC	Email	Response to feedback from KNAC and NAC on draft Referral, provision of updated Referral to KNAC, NAC and BNTAC	NA	NA	NA
8/09/2021	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga LoMP meeting	Update on project and Social Surroundings consultation to date. Discussion of next steps in the social Surroundings consultation process and that the draft Referral and ESD were provided to NAC for review and feedback.	NAC and its consultants have reviewed the draft Referral and ESD and provided feedback to the Proponent. Ngarlawangga want to progress discussions about compensation Ngarlawangga want more information about water and potential impacts to the the flow of Pebble Mouse Creek.	NAC paused consultation for the project while compensation issues were progressed between the parties. A Social Investment package was developed and presented to the NAC Board in March 2022. This was well received and consultation was scheduled to recommence with a further Social Surroundings in-field consultation in May 2022 but this had to be postponed due to severe weather and flooding in the Pilbara.	Discussion of detailed project design and that flows to Pebble Mouse Creek will need to be considered in project design and closure planning.
4/10/2021	BNTAC/ Banjima Traditional Owners	Meeting with BNTAC staff	Brief update on the approval process and timing, Discussion of the Social Surroundings and consultation sought and proposed timing.	BNTAC requested that the Proponent provide copies of the heritage survey reports for the portion of the Project's Development Envelope in Banjima Country.	Copies of heritage reports were provided on 17/01/2022.	NA
22/11/2021	KNAC/ Nyiyaparli Traditional Owners	Third Nyiyaparli Social Surroundings in-field consultation	Third In-field consultation with Nyiyaparli Traditional Owners to visit key areas, discuss the Project and changes to date in response to Nyiyaparli feedback. Further discussion of key topics including water and water management, dust and impacts of dust on country (particularly accumulation in water features/drainage), amenity, animals, people and closure and rehabilitation.	Discussion of key Social Surroundings values including water, dust, access to country, and closure and rehabilitation. Key issues raised include water impacts and water management, mine design, including waste rock landforms and the importance of mine closure and rehabilitation on impacts to country and visual amenity.	Feedback included in ongoing mine design work. Feedback summarised in Short report received in November 2021.	Discussion of detailed project design and key Social Surroundings issues to be considered in Project design and closure planning.
26/11/2021	BNTAC/ Banjima Traditional Owners	Banjima LIC/LOMP meeting	Update on the project scope. Discussion of Part IV process and timing, Social Surroundings and consultation sought	Discussion of proposed first Social Surroundings field trip and scope of work.	Scope of work developed for first in-field Social Surroundings consultation.	NA
15/12/2021	BNTAC/ Banjima Traditional Owners	Banjima LIC/LOMP meeting	Confirmation of dates for first Social Surroundings in-field consultation, confirmation of scope of work for trip.	Scope of work agreed for Phase 1 of the Social Surroundings Assessment.	NA	NA
17/12/2021	KNAC, NAC and BNTAC	Email	The Proponent provided a copy of updated draft ESD and a summary of what feedback had been incorporated prior to lodgement	NA	NA	NA
17/01/2022	BNTAC/ Banjima Traditional Owners	First Social Surroundings in-field consultation	First in-field Social Surroundings consultation with Banjima Traditional Owners undertaken to identify and record social and cultural values and to identify key issues/concerns to be considered in project design and the approvals documents. Project overview provided and key locations visited. Key topics in respect of which feedback was sought included surface and ground water, dust, noise and vibration, access during and post mining, culturally significant plants and animals, any impacts from increased personnel and traffic, considerations related to mine closure and rehabilitation and visual impacts from the Project. Feedback on ore transport options and water supply options was also sought.	Draft Preliminary Advice provided by BNTAC to the Proponent on 28/03/2022. Key issues/values identified include water, plants, animals, hills/ranges and people. Key themes included protecting country, capacity building and sustainable businesses, and Banjima governance and processes. Protecting water and the flow of water, as well as access to Weeli Wolli Creek were noted as particularly important. Pending an updated Final Report, this information has been incorporated into the draft HD2 Proposal Social Surroundings chapter.	Information from the first in-field consultation and the draft Preliminary Advice will considered in ongoing mine design work as well as the Social Surroundings chapter.	Discussion of detailed project design and key issues to be considered in project design and closure planning, including protection of waterways and water flows and maintaining access to Weeli Wolli Creek.

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8/03/2022	KNAC/ Nyiyaparli Traditional Owners	Email	The proponent provided a copy of the Draft HD2 Proposal ERD and associated appendices. The proponent advised the ERD package will be provided in two tranches (ERD with exception of Fauna chapter and appendices) and remainder on 18 December 2022.	Social Surrounds studies and consultation - HD2 ERD review for Karlka Aboriginal Corporation Nyiyaparli People by Preston Consulting - 05 April 2023. Provided by KNAC to the proponent.	The proponent provided a response to feedback on the KNAC review of the HD2 Proposal ERD and SCHMP on 11 Aug 2023. Refer to table in letter for summary.	TO concern more than just cumulative impacts on surface water Impacts on the waterholes have an impact on sense of place Waste management includes landfills? The MCP largely ignores consultation with Nyiyaparli People So no post mining land use? Despite the ongoing use of the land by TO's?"
14/03/2022	KNAC/ Nyiyaparli Traditional Owners	Fourth Social Surroundings in-field consultation	Fourth in-field consultation to discuss the Project, changes to date in response to Nyiyaparli feedback, discussion of ore transport options, waterholes, closure and rehabilitation and ongoing work to refine the project and avoid, reduce and manage impacts to social surroundings through the SCHMP and ongoing consultation.	Feedback in respect of ore transport options, discussion of the HD2 waterhole and BHT Rockhole, further discussion and feedback in respect of closure and rehabilitation.	Feedback to be included in ongoing mine design work. Summary of feedback to be included in consolidated Social Surroundings report due in June 2022.	Discussion of detailed project design and key issues to be considered in project design and closure planning, including protection of waterways, visual amenity and access to and use of country post-mining.
10/04/2022	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli Ethnobotanical survey	In field consultation to identify and record ethnobotanical and land management information in the vicinity of the HD2 Proposal	Report pending (awaiting the conduct of a second ethnobotanical trip which was postponed from May 2022 to September 2022 due to flooding)	Ethno survey 3 completed 21 Oct 2022	Culturally important elements identified: Ash and Bark, Totem Plants and animals, Burials, Wild Honey, Plant Medicines, Larvae and Eggs, Culturally significant plants. See report for full details.
28/04/2022	KNAC/ Nyiyaparli Traditional Owners	Email	Provision of draft Social Surroundings chapter to KNAC and Nyiyaparli Traditional Owners for review and feedback	Social Surrounds studies and consultation - HD2 ERD review for Karlka Aboriginal Corporation Nyiyaparli People by Preston Consulting - 05 April 2023. Provided by KNAC to the proponent.	The proponent provided a response to feedback on the KNAC review of the HD2 Proposal ERD and SCHMP on 11 Aug 2023. Refer to table in letter for summary.	Weeli Wolli Creek (Wirlawarli) was identified as Nyiyaparli's most important landscape feature in the vicinity of the HD2 Proposal. Though any waterway (Pebble Mouse Creek, for example) and associated yinta (permanent or semi-permanent pool along the creeks and rivers) also hold special importance. There are important sites and places within or adjacent the Development Envelope, too; artefact scatters, cultural scarred trees, rockshelters with cultural assemblages or petroglyphs, and a large cultural site-complex HOPE4-07). These sites and cultural features of the andscape heighten the level of concern around possible impact. And these are elements of culture to be handed on to future generations
4/05/2022	KNAC/ Nyiyaparli Traditional Owners	Social Surroundings consolidation workshop	Three-day Social Surroundings workshop with Nyiyaparli Traditional Owners to discuss the Project, changes to date in response to Nyiyaparli feedback, discussion of residual impacts including to water, country and ongoing work to refine the project and avoid, reduce and manage impacts to Social Surroundings through the SCHMP and ongoing consultation. Discussion of the content and purpose of the Social Surroundings chapter and SCHMP, feedback from Nyiyaparli to inform the SS chapter and joint development of the SCHMP.	Feedback in respect of Project scope and key issues, including initial option to avoid impacts to HD2 waterholes and BHT Rockhole, Consolidated Social Surroundings report pending.	Feedback to be included in ongoing mine design work. Summary of feedback to be included in consolidated Social Surroundings report due in June 2022.	Discussion of detailed project design and key issues to be considered in project design and closure planning, including protection of waterways, visual amenity and access to and use of country post-mining.
17/05/2022	KNAC/ Nyiyaparli Traditional Owners	Nyiyaparli LOMP meeting	Proponent provided an update on HD2 Proposal Provided information about a dust management strategy (included in HD1 S study update), Dust Noise and Vibration monitoring is ongoing. Confirmed access to WWC will be maintained by new access road,	LoMP committee members requested a better timeline that will show how HD2 BHT and HD1 Closure fits together.	Proponent responded it's unlikely that Rio Tinto would go back into HD1 South and HD1 North due to backfill but would need business endorsement for this to be formalised.	NA

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Start date	Stakeholder	Consultation Type / Forum	Information provided by Proponent (summary for ERD and MCP)	Stakeholder Response/ Comments	Proponent Response (summary)	Key feedback for Closure Planning
20/06/2022	BNTAC/ Banjima Traditional Owners	Banjima LIC meeting	Proponent provided a Study update. Proponent advised in response to feedback from previous engagements, the proposed pits and associated activities have been relocated away from Weeli Wolli Creek. Key approvals and timelines discussed, with conversation held regarding requirement for ongoing consultation at Study stage. Proponent presented ore transport options and access to Weeli Wolli Creek during construction. Discussions held regarding progressing social surroundings consultations. First consultation held in January 2021.	Draft minutes to be finalised. Commitment to continue working to progress Social Surroundings consultations.	NA	NA
20/06/2022	KNAC/ Nyiyaparli Traditional Owners	Mine Closure Workshop	Nyiyaparli closure workshop. Discussion of closure planning principles and relationship between HD1 and the HD2 Project.	See below	See below	See below
6/09/2022	KNAC/ Nyiyaparli Traditional Owners	Report: Mine Closure Workshop 20-24 June 2022 [DRAFT] Report prepared for Karlka Nyiyaparli Aboriginal Corporation by Preston Consulting Pty Ltd	Nyiyaparli closure workshop. Discussion of closure planning principles and relationship between HD1 and the HD2 Project.	<u>The report is still in draft</u> - Workshop details - Discussion related to closure of RTIO sites on Nyiyaparli country - Revised Principles for mine closure on Nyiyaparli country - List of Action Items Important considerations regarding this report: - - The report is based on consultation that was pertaining to the HD1 area and therefore some of the recommendations, requests, considerations etc will only be relevant to that area. - This was an early consultation on closure and further consultation will likely lead to additional concerns, ideas and opportunities being raised. - The forum was not a decision-making forum.	Further consultation is required	While this document is still in draft and requires further discussion prior to finalisation, it does provide valuable insight to the areas of alignment with RTIO current plans and processes and those areas where there may be variations or gaps. This information will help to focus attention of future consultations related to closure within the Hope Downs area.
27/06/2022	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga LOMP meeting	Proponent provided an update of HD1 Sustaining (HD2 Proposal) including proposed rock landforms and pits. Life of mine – 7-12 years. Construction – 2024-25. The Study is in Pre-Feasibility (PFS) to move into Feasibility (FS) soon	Ngarlawangga Aboriginal Corporation CEO –raised that officially Ngarlawangga hasn't received any road options - Options preferred to receive prior to field trip	NA	NA
28/06/2022	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga Social Surroundings workshop	Proponent provided and introduction and explanation of the ERD/SS chapter and what it involves. Proponent provided an overview of what an SCHMP is and th SS Champter and SCHMP Process Timeline.	NLW have requested to have 2 day works shops to enable more time to discuss and digest content – This has been agreed	NA	NA
30/06/2022	NAC/ Ngarlawangga Traditional Owners	Email	Template SCHMP provided	NA	NA	Note SCHMP is only being completed for NYI, not required for BAN or NLW.
26/07/2023	NAC/ Ngarlawangga Traditional Owners	Ngarlawangga Closure Principles Workshop	Draft MCP	Feedback on MCP	Reponses to comments	Closure means we are going to get filled in and will go back to looking like Country it is. What we want vs reality of what we will get. We want an asset not a liability. We all have concerns of terminology of mine closure.
10/07/2023	BNTAC/ Banjima Traditional Owners	Email	Draft MCP, Letter to BNTAC_HD2 ERD Response to BNTAC Review	Feedback on MCP	Reponses to comments and changes to MCP	TBC
10/09/2023	KNAC/ Nyiyaparli Traditional Owners	Email	Draft MCP - sent as part of updated August 2023 ERD package	Feedback on MCP	Reponses to comments and changes to MCP	TBC
13/08/2023	EPA	Letter	Draft MCP	Feedback on MCP	Reponses to comments and changes to MCP	TBC
16/08/2023	EPA	Email	Responses to feedback on Part IV assessment, including comments on the MCP and comments specific to closure in the Environmental Review Document.	06.10.2023 EPAS Letter to RTIO - Comments on Hope Downs 2 draft ERD v3 October 2023	Reponses to comments and changes to MCP	TBC

DRAFT

Appendix 3: Closure Knowledge Database

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Rio Tinto Hope Downs 2 closure knowledge database

The closure knowledge database is a summary of the technical reports that directly or indirectly contribute to the development of the closure plan. These documents do not form part of the report and are for indicative purposes only.

The knowledge and understanding of closure issues and management strategies evolve and improve over time, coincident with the development of the mining operation. As a result, some components of some reports and studies may be superseded by new research or studies. While the closure plan addresses the current state of understanding and strategy for closure, the closure knowledge database captures the historical development of closure knowledge, and demonstrates how experience and knowledge developed at other Rio Tinto sites has been considered during the development of the closure plan and across the life of the operation. Accordingly, some information presented in the closure knowledge database may be obsolete.

Technical reports supporting the closure of the operation will be presented as part of the last plan produced prior to the implementation of closure (also known as the Decommissioning Plan).

Geochemical characterisation

Review of Waste Rock Geochemistry a) General Overview of Acid Base Accounting — 2006

Internal reference: RTIO-PDE-0021130

This report contains a general overview of acid base accounting and a summary of the geochemical test work that has been previously completed for various sites and lithologies.

There are large discrepancies in the total sulfur concentration measured using XRF and LECO machines. The XRF machine underestimates the sulfur concentration at values greater than 2%. Materials with total sulfur concentrations less than 0.1% can contain low capacity PAF material, however, it is considered only to be low additional acid and metalliferous risk if the boundary for inert material and potentially acid forming material is shifted from 0.02%S to 0.1%S. A paste pH result of less than 7 should be sent to the black shale dump and a paste pH result of greater than 7 can be sent to an inert material waste dump.

Mineralogical Analysis of Potentially Acid Forming Materials — 2008

Internal reference: RTIO-PDE-0053725

Quantitative mineralogy (QEM-Scan) for samples of rock collected from Tom Price, Channar, West Angelas, Brockman, Paraburdoo (4 East Extension), Western Turner Syncline and Hope Downs 1 North was undertaken. Comparisons were made between two methodologies use to characterise potentially acid forming materials; acid base accounting and mineralogical analysis.

All samples contained elevated total sulfur concentrations and the lithologies were either shale, banded iron formation or dolomite. Pyrite was the dominant mineral contributing to acidity and the dominant sulfate secondary mineralisation consisted of alunite and jarosite.

DRAFT

Determination of ARD potential of Rio Tinto Iron Ore (WA) Waste Rock Samples — 2008

Internal reference: RTIO-PDE-0051613

This report investigates the use of mineralogy to predict acid and metalliferous drainage potential. Analysis of numerous rocks was undertaken using QEM-SCAN.

Areas of waste rock which have underdone oxidation can be identified where sulfur-bearing minerals vary between samples in the form of pyrite, alunite and jarosite. The variability of gangue mineral phases suggest that some areas of composite waste rock pile may provide some neutralising potential while other areas will have no neutralising potential. Variable textural and mineralogical controls on sulfide mineral occurrence result in decreased accessibility of pyrite to oxidising fluids.

Contaminant Leaching from Non-Sulfidic Waste Material — 2011

Internal reference: RTIO-HSE-0145041

The available leach extract data and information pertaining to the distribution of metals and metalloids in non sulfur materials at neutral pH was reviewed. Based on this review conceptual models for controls on their leaching and mobility were developed.

The review found that contaminant leaching from non-sulfidic materials was generally very limited. Usually the pH in leach tests was near-neutral (pH 6 to 8), and dissolved contaminant concentration were at or below detection limits. It is believed that a primary leachable contaminant source is the oxidation of sulfide minerals. Release from oxidising sulfides leads to release of soluble reaction products. Under neutral pH conditions, there is the potential for release of these contaminants when those products dissolve.

Environmental Status of Selenium (Se) in the Pilbara Region of Western Australia – Potential Risk from Iron Ore Mining — 2011

Internal reference: RTIO-PDE-0103857

This report includes information about Selenium geochemistry, distribution in the environment, occurrence in rocks in the Pilbara and potential risks to the environment.

The Selenium (Se) content of shales containing significant pyrite should be recorded as part of the overall risk assessment for acid and metalliferous mine drainage. However, it should also be noted Se solubility is far less constrained by pH than in the case of metals and near neutral drainage may contain significant Se concentrations in solution. It would be most useful to study the Selenium budget of the wetlands in the Pilbara as, apart from the chance poisoning of livestock from the consumption of plants that have taken up high concentrations of Selenium, impacts are most likely to be felt in wetlands receiving mine site drainage.

Contaminant Leaching from Low-Sulphur Waste Minerals (Summary) **2011**

Internal reference: RTIO-PDE-0090689

RTIO's Geochemical Database was reviewed and based upon this data, conceptual models for controls on the leaching and mobility of a range of metals and metalloids were developed. This summary also describes potential controls on the amount of dissolved element that may be released. This is a summary of a comprehensive report RTIO-PDE-0100104.

For most contaminants, dissolved concentrations at circum neutral pH (pH 6 to 8) were very low, typically at or below detection limit. Geochemical modelling indicates that water-rock interactions are controlled by equilibrium, for salt, carbonates and sulphates this equilibrium is often source term limited whilst hydroxyl-sulphates and hydroxides are solubility controlled. Results also indicate that sorption plays an important role in solute concentration; weak (but detectable) sorption occurred for selenium and zinc whilst the strongest sorption was evident for cobalt. The review suggested that storage waste facilities containing low-sulfur materials pose a low level of environmental risk however, there is a small risk of increased in mobility of some contaminants if acidic conditions arise. Acidic conditions can sometimes arise from the interactions between iron and aluminium hydroxyl-sulphates and hydroxides.

Geochemical Assessment of Tailings from Yandi, Paraburdoo, Tom Price, Brockman 4 and Mesa J **2014**

Internal reference: RTIO-PDE-0123030

This report presents the results from geochemical testing and saline solution extraction of tailings samples from Yandi, Paraburdoo, Tom Price, Brockman 4 and Mesa J deposits.

Overall the tailings from these operations are unlikely to generate acid and are not expected to leach significant levels of metals under oxidising or saline conditions.

Oxidation and solute accumulation in dewatered pit wall rocks **2014**

Internal reference: RTIO-PDE-0109045

Dewatering and removing the water table may result in de-saturation of sulphide-bearing lithologies. This study was undertaken to review how oxygen ingress and consequent sulphide oxidation of Mount McRae Shales could impact water quality when the groundwater table rebounds after mining.

Large Scale Column Construction Procedure and Initial Chemistry **2014**

Internal reference: RTIO-PDE-0123894

Large scale column experiments have been constructed to examine the reactivity of hot and cold black shale material in an operational environment. The memo describes the construction of the columns and the first geochemistry data collected after small rainfall events at Rhodes Ridge.

Initial results suggest that effluent water retains the chemistry of the incident rainfall. Constituents to note in the initial chemistry include nitrate and ammonia detected in the hot black shale effluent. This study provides an important comparison between laboratory characterisation studies and field reactivity of waste rock. Data from the large scale column tests can be applied to reactivity of in pit waste/talus as well as waste rock dumps. It can be used as an intermediate to predict long term reactivity of waste rock.

DRAFT

Tom Price – Historical black shale exposures in SEP Pit compared to expected black shale exposures at BS4 and HD4 **2017**

Internal reference: RTIO-PDE-0149285

The purpose of this study was to understand and compare potential surface water and groundwater quality risks from pits with areas of exposed Mount McRae Shale (MCS) at Tom Price, Brockman Syncline 4 and Hope Downs 4 operations.

The annual (approximate wet season) black MCS exposures in South East Prongs (SEP) pit at Tom Price have been modelled as part of this exercise. The maximum black MCS surface area within the SEP pit (from 2000-2010) is modelled to be 200,000 m2 (2010), representing approximately 9% of the SEP pit catchment area. It is noted that acid water was first observed in a SEP groundwater bore in 2001, when total black MCS surface areas were modelled to be 68,500 m2 (3% of total pit shell catchment area). Acidic water within groundwater was observed in 2001, approximately three years after dewatering of the SEP pit commenced in 1998 via a number of in-pit dewatering bores. It is possible that surface water may have been acidic earlier than 2001. The significant accumulation and pooling of water within the SEP pit during large successive rainfall events, particularly Cyclone Monty in 2004 (representing a 12 year ARI (average recurrence interval) at Tom Price), likely caused acidity within the in-pit groundwater bores. In subsequent years, the pH had an increasing trend in many of the bores, however groundwater remained acidic for at least four years following Cyclone Monty.

Geochemical Characterisation of mine waste from Tom Price, Hope Downs 1 and Hope Downs 4 **2018**

Internal reference: RTIO-PDE-0159203

The purpose of this work was to investigate the leaching kinetics of six low-sulfur waste rock samples collected from Tom Price, Hope Downs 1 and Hope Downs 4. Static testing was conducted to provide a 'snapshot' of the geochemical characteristics of each waste rock sample. These tests were completed to screen all samples before commencing more detailed leach column tests. The geochemical test program was designed to assess the degree of risk from the presence of reactive sulfides, acid generation and leaching of soluble metals/metalloids and salts in accordance with relevant mine waste geochemistry and mine closure guidelines.

The results from the geochemical assessment indicate the samples have negligible to low-sulfur content, low but generally sufficient ANC and are generally classified as non-acid forming. The amount of potential acidity that could be generated from the samples is expected to be negligible to low, with all samples having low reactivity; there is a high factor of safety and low risk of any significant acid generation from these materials. Waste rock materials represented by these samples are likely to generate pH neutral surface runoff and seepage with low salinity and generally low concentrations of dissolved metals(loids) (excluding the Tom Price black MCS sample where elevated manganese was measured in the leachate).

Assessment of erosion potential of mineral wastes **2019**

Internal reference: 0

This report summaries the erosion studies undertaken on four mineral wastes from Hope Downs 1 Iron Ore Mine. It includes an assessment of the erodibility of four mineral waste samples (Detrital (Col or Di); Limonite (Li); NEW 1 - Moount Newman Member and NEW 2 - Mount Newman Member.

Bulk samples of four materials were characteristed by experimental methods to derive the key erodibility parameters to calibrate the WEPP model. The Detrital (Col or Di) assessed represents one of the more erosion resistant Detrital wastes assessed since methodical erodibility assessment began in 2012. Results for uniform slopes indicate that for the HD1 climate and moderate risk dumps; the Detrital (Col or Di) can be used on unifrom lifts of up to 15m high with gradients 14 to 20 degrees. Limonite (Li), NEW 1 and 2 materials can used on uniform lifts up to 20m high and gradients 14 to 20 degrees. For high risk dumps; Detrtial material can be used on uniform lifts up to 10m high with gradients of 14 to 20 degrees. Limonite and NEW 1 material can be used on unifrom lifts up to 15m high, with gradients of 14-20 degrees.

Hope Downs (Sustaining Deposits) – Geochemical Characterisation of Waste Rock Samples **2019**

Internal reference: RTIO-PDE-0170053

to provide guidance for waste rock management in particular with respect to managing and limiting acid generation and metalliferous drainage and involved static geochemical characterisation of 96 waste rock samples from 10 stratigraphies at the Hope Downs (Sustaining Deposits) project (Bedded Hilltop and Hope Downs 2 deposits).

Of the 96 samples tested, the 10 lignites had the greatest acid generation potential. The samples were all classed as PAF since they contained significant sulfide sulfur and low ANC. Leachate from the lignites is expected to be generally acidic with high solute concentrations – including high concentrations of major cations (i.e. Ca and Mg), anions (i.e. SO4) and a range of trace elements (e.g. Al, As, Cd, Co, Cr, Cu, Mn, Ni and Zn). The 20 WF samples were all classed as NAF, they contained the greatest ANC and negligible total sulfur. Leachate from the samples was invariably circum neutral to alkaline, with a low solute concentration. The remaining 66 samples were from a range of lithologies. The samples contained low to negligible total sulfur and low to modest ANC with most samples expected to be NAF. The acid generation potential of the samples classed as UC or PAF-LC will be low to negligible. Most samples are expected to generate leachate that is circum neutral and with a low solute concentration.

Physical characterisation

Net solute load response to the installation of infiltration limiting dry cover systems over acid forming waste piles **2014**

Internal reference: RTIO-PDE-0128431

This work was conducted to verify the central design concept of store-and-release covers over sulfidic above water table waste dumps that is, whether limiting net percolation volume through the cover results in a lesser sulfate and acidity load being realised generated and passing through the dump.

The results from this thesis project confirm that the central aim of store-and-release covers to reduce net percolation volume is a valid measure for reducing the net loading of sulfate and acidity. The mechanism through which decreasing net percolation (applied water volume) results in a lesser sulfate and acidity load was identified, however further work in a site context is needed to assess how this relationship between percolation volume and loading persists in the real-world environment.

DRAFT

Growth Media Characterisation **2018**

Internal reference: RTIO-HSE-0324326

This report provides an interpretation of material characterisation data for a total of 53 potential growth media samples made up of 34 samples for which data has been previously collected by Outback Ecology Services on behalf of Rio Tinto, 11 samples for which data has been previously collected by Landloch on behalf of Rio Tinto as part of previous erosion studies and 8 additional samples collected and analysed as part of this project. Based on this characterisation, each material was classified as either suitable or not suitable for use as a growth medium.

Properties tested for included pH1:5 (water), salinity (EC1:5, EC1:2), exchangeable cations (K+, Ca2+, Mg2+, Na+, Al3+), effective cation exchange capacity (ECEC), exchangeable sodium percentage (ESP), particle size distribution (fine fraction<2mm), coarse fraction (> 2mm), particle size distribution (all material), texture, emerson class, dispersion potential rating, rock particle density, rock water absorption and rock cover of rain-armoured surface. A classification scheme for key parameters was then developed to classify a material as suitable or unsuitable. Several materials have properties that were invariably suitable. In some cases, materials have some properties that are suitable and others unsuitable. In others, several of the properties are problematic. Suitable materials represent those that have base properties that are not likely to impede vegetation. Marginal materials are those that are likely to support vegetation but that have some properties that may limit establishment and growth. Unsuitable materials are those that have properties that are likely to significantly impact on vegetation growth either through being saline, prone to dispersion, and having pH values quite different to those typically observed. Of the 53 samples, 21 were recommended as suitable growth media, 25 were assessed as marginal growth media and 8 were not recommended as growth media. Samples which were recommended were sourced from Yandicoogina, Channar, Mesa J, Mesa K, Eastern Range, Paraburdoo and Parker Point. Marginal samples were sourced from Brockman 4, Brockman 2/Nammuldi, Mesa A, Mesa J, Channar, Eastern Range, Paraburdoo, Yandicoogina and Hope Downs 4. Samples which were not recommended were sourced from areas at Greater Paraburdoo (Paraburdoo and Eastern Range), West Angelas, Western Turner Syncline and Parker Point.

Groundwater

Hope Downs 2 Water Supply Abstraction **2019**

Internal reference: RTIO-PDE-0171127

This memorandum provides supporting hydrogeological information for Hope Downs 2.

The HD2 orebody is located within both the Marra Mamba Formation and the overlaying detrtial deposits. The gorundwater table is located in both the Marra Mamba and Wittenoom Formations and is below the base of the detrital deposits. Gorundwater in Marra Mamba Formation is expected to be in hydraulic connection with Wittenoon Formation (forming a single aquifer). Groundwater flow is from southwest to northeast. Depth to groundwater below ground surface ranges between 50 and 100 m. It does become shallower along Weeli Wolli Creek and Pebble Mouse Creek. Abstraction is close to 509,804 kL to supply water for HD1 village. Groundlevels recorded has declined 2 m over 10 yearsperiod, indicating groundwater drawndown is minor and localised. Not aware of any Groundwater Dependent Ecosystems within Wittenoom Aquifer (where abstraction is proposed).

Surface water

Assessment of surface water impacts on sensitive receptors in Weeli Wolli Creek catchment **2019**

Internal reference: RTIO-PDE-0171688

This report presents an assessment of the potential impacts on surface water quantity and quality at Weeli Wolli Spring and Ben's Oasis from mining infrastructure for the Hope Downs 2 proposal, which includes deposits at Bedded Hilltop and Hope Downs 2. A two dimensional hydraulic model was developed to characterise the surface water flow regime of Weeli Wolli Creek and Pebble Mouse Creek.

Results from the regional model indicated that mining operations truncated approx. 3.5% of the total catchment reporting to Weeli Wolli Spring. This results in a loss of 1% of the total run-off volume at the Spring and a reduction of the peak flow by 1.4% (based on 1:100 annual exceedance probability (AEP) 24 hour rainfall event). The catchment reporting to Ben's Oasis was truncated by 0.2% which resulted in a reduction to peak flow of 1.1%. Results from the localised model indicated that during frequent (1:5 AEP) and rare (1:100 AEP) rainfall events, flood depths are increased on the upstream side of the floodway and rail culverts due to the attenuation and backwater impacts of these structures. Sediment transported from the floodway is considered unlikley to impact water quality at Weeli Wolli Spring, due to high flood depths and low velocities on the upstream of the rail crossing.

Water interactions and pit lakes

Geochemical and hydrological processes controlling groundwater salinity of a large inland wetland of northwest Australia **2013**

Internal reference: RTIO-HSE-0198428

Understanding mechanisms of hydrochemical evolution of groundwater under saline and brine wetlands in arid and semiarid regions is necessary to assess how groundwater extraction or injection in large-scale basins may affect the natural interface between saline–fresh aquifers in those systems. This paper investigated the evolution of groundwater of the Fortescue Marsh, a large inland wetland of northwest Australia.

The deep groundwater (>50m depth) of the Fortescue Marsh is highly saline (>100g/L), whilst shallow groundwater (~0–20m depth) and surface water are mainly fresh or brackish. Currently, the marsh is mainly recharged by occasional floodwater. Consequently, salt in the marsh is concentrated by evaporation of rainfall. It was found that groundwater associated with the marsh could be divided into two groups characterised by their stable isotope compositions; i) fresh and brackish groundwater (TDS b10 g L−1; δ18O −8.0 ± 0.9‰) and ii) saline and brine groundwater (TDS N10 g L−1, δ18O varies from +2.5 to −7.2‰). Fresh groundwater was evaporated by<20% compared to rainwater. Brackish water mainly reflects modern recharge whilst saline and brine groundwater reflects mixing between modern rainfall, brackish water and relatively old groundwater.

DRAFT

Testing hay as an in situ remediation option for acidic pit lakes in the Pilbara **2017**

Internal reference:
RTIO-PDE-0159196

A field experiment was conducted at the Tom Price mine in two small temporary pit lakes ('West' and 'East' Lakes). Water-damaged hay produced by Rio Tinto Iron Ore in the Pilbara was used to treat the West Lake, with the East Lake kept untreated. A laboratory-based microcosm experiment was conducted in order to determine if bio-physical processes that occur in microcosms (a classic method in mine water treatment experiments) represent field conditions. A laboratory-based microcosm pilot experiment containing acidic lake water was conducted for 60 days. Results from the pilot demonstrated that (relative to controls) microcosms containing hay become more neutral to pH >6. Review of the pilot experiment resulted in a range of improvements in the design and execution of the microcosm experiment in order to better mimic conditions in the field trial.

The West Lake controls exhibited a slight improvement in pH over the course of the experiment, whereas the East Lake controls did not. The likely contamination of the water and sediment by hay prior to the experiment (due to collection of in situ water after the field experiment commenced) indicates that the carbon that leached from the hay may have been sufficient to increase pH in the microcosms. The main observable effect of lake water source appeared to be that chemical composition of West Lake was such that the hay - while effective at reducing dissolved oxygen concentrations - was not as effective in driving oxidation reduction potential to levels that classically are considered necessary to support sulphate reducing bacteria. A seasonal algal bloom in East Lake indicated that pit lakes are subject to the same processes as natural lakes; the specific cause of the bloom is currently unclear but likely seasonal. The main risk associated with the use of organic matter to treat acidity in pit lakes is the potential for release of problematic quantities of gases such as methane, carbon dioxide or hydrogen sulphide. Due to a lack of within-lake replication the effect of hay on microbial assemblages could not be determined for the field trial. Further research is needed on gas flux and the microbes responsible associated with organic matter treatments in pit lakes to better understand potential risks associated with gas flux on closure.

Flora

Hope Downs 2, Bedded Hilltop and Wonmunna Detailed Flora and Vegetation Survey **2018**

Internal reference:
0

This study summaries the botanical aspects of the Hope Down 2 area.

A total of 379 flora taxa from 50 families and 151 genera were recorded. No threatened flora were recorded within the study area, ten State-listed Priority flora species were recorded; Eremophila sp. Hamersley Range (K. Walker KW 136) P1; Eremophila sp. West Angelas (S. van Leeuwen 4068) P1; Aristida lazaridis P2; Hibiscus sp. Gurinbiddy Range (M.E Trugen MET 15708) P2; Grevillea saxicola P3; Rhagodia sp. Hamersley (M. Trugen 17794) P3; Triodia sp. Mt Ella (M.E Trudgen 12739) P3; Acacia bromilowiana P4; Lepidium catapycnon P4; and Ptilotus mollis P4. Fourteen introduced species were recorded, none listed as Weeds of National Significance or Declared Pests. None of the plant communities were considered threatened ecological community or priority ecological comminunity.

Hope Downs 2 Proposal: Flora and Vegetation Survey May 2019 **2019**

Internal reference:
0

This report presents the finding of a detailed flora and vegetation survey of the Hope Downs 2 (HD2) development envelope, over three separate phases to support and inform the environmental assessment process.

A total of 23 vegetation units were recorded within the study area, none of the units represent a threatened ecological community. One vegetation unit recorded was associated with the Wannamunna land system and held some affinity with the Priority 1 priority ecological community 'West Angelas Cracking Clays', however unlikley to represent the community due to differences in species composition, habitat and scale. There were 411 confirmed vascular flora taxa from 52 families and 161 genera. No threatened flora species were recorded. Eleven state-listed priorty flora were recorded 1 (P1); 2 (P2); 4 (P3); and 4 (P4). Seventeen introduced (weed) species were recorded. None of the weed species are listed as Weed of National Significance or as a Declared Pest.

Fauna

Hope Downs 2 Proposal Fauna Survey - Contextual Analysis **2019**

Internal reference:
0

This letter details the results of statistical comparsion.

The letter concludes the contextual analysis indicates that the Ricky Hills, Stony Plains and Mulga Woodlands habitat types within a local context exhibited a significantly different herpetofauna or bird assemblage from other sampled habitats. Within Rocky Hills its most likley attributed to presence of rock-specialist reptile species or an absence of woodland bird species. The reason for differences in the herpetofauna assemblage of the Mulga Woodland habitat and the bird assemblage of the Stony Plain habitat are unknown and differences appear to be between species that are considered habitat generalists and would be expected to occur across multiple habitat types in the area.

DRAFT

Hope Downs 2 proposal: Fauna Survey March 2019 **2019**

Internal reference: 0

This report presents the finding of a terrestrial Level 2 vertebarte fauna and Short Range Endemic (SRE) assessment of the Hope Downs 2 (HD2) development envelope, over three seperate phases of fauna surveying.

This report concludes there are eight broad fauna habitats types within the survey area, and none are restricted at a local level. The Gorge/Gully and Breakaway habitat were considered important for fauna due to microhabitats they provide (caves and potential for semi-permanent water pools). There were 174 vertebrate fauna species recorded, the fauna species assemblage is considered by Astron typical of the Hamersley subregion. Seven fauna species of conservation sigificance were recorded; Nortehrn Quoll, Pilbara Leaf-nosed Bat, Ghost Bat, Orintal Plover, Lerista macropisthopus remota, Letter-winged Kite and Western Pebble-mound Mouse. Five habitats were considered conductive to relictual SRE; Breakaway, Mulga Woodland, Minor Drainage, Gorge/Gully and Rocky Hill.

Hope Downs 2 Proposal - Matters of National Environmental Sigificance Fauna Assessment **2019**

Internal reference: 0

This reports summaries the matters of national environmental significance (MNES) fauna values associated with Hope Downs 2 study area.

The report concluded eight broad habitat types have been recorded within the study area. The Gorge/Gully and Breakaway habitats were considered important habitat for MNES fauna species, due to microhabitats such as caves and semi-permanent water pools which are improtant for species forgaing and sheltering requirements. Four MNES fauna species; Northern Quoll (Endangered), Ghost Bat (Vulnerable), Pilbrara Leaf-nosed Bat (Vulnerable) and Oriental Plover (Migratory) have been recorded within the study area. The Northern Quoll records are significant due to being on the edge of this species' regional distribution.

Biodiversity improvement studies

Evaluation of mine waste materials as alternative rehabilitation growth medium **2010**

Internal reference: RTIO-HSE-0109961

This study reviewed the physical and chemical properties of soil, tailing and mineral waste from select Pilbara mining operations, to identify waste material and material combinations for use as a topsoil substitute or supplement.

The study showed plant-available nutrients held within the waste materials, although variable, was characteristically low and comparable to natural soils in the region. The majority of the waste materials had macro and micro nutrient concentrations within the range or above the levels measured in benchmark Pilbara topsoil and rehabilitated soils. The pH and phosphorus buffering index of most waste materials were also comparable to that of the benchmark topsoil materials. However, some of the waste types and tailings may need to be mixed with rocky material due to poor physical / erodibility characteristics.

DRAFT

Genetic diversity in Eucalyptus leucophloia across the Pilbara: Provenance zone implications **2011**

Internal reference: RTIO-HSE-0108843

This study was undertaken to define the provenance seed collection zones for a common species of the Pilbara, Eucalyptus leucophloia (Snappy Gum). This report details information on genetic analysis conducted on E. leucophloia. Collections of E. leucophloia were made from 20 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in E. leucophloia was high and was typical of that found in other eucalypt species with wide spread distributions. Across the species the level of population differentiation was low and the majority of the diversity was maintained within populations with only 6% of variation partitioned between populations. Genetic variation in E. leucophloia showed little structure across the Pilbara with no clustering of populations based on any geographical proximity or in association with obvious topographical, physiogeographical or geological features such as the Hamersley or Chichester Ranges. Populations towards the edges of the species distribution within the Pilbara showed greater levels of differentiation from populations within the species main range. The high levels of genetic diversity and low levels of differentiation within E. leucophloia implies that seed resources for rehabilitation can be selected from a wide range within the Pilbara.

Genetic diversity in Acacia ancistrocarpa across the Pilbara: Provenance zone implications **2011**

Internal reference: RTIO-HSE-0119260

This study was undertaken to define the provenance seed collection zones for Acacia ancistrocarpa (Fitzroy Wattle). This report details information on genetic analysis conducted on Acacia ancistrocarpa. Collections were made from 24 populations across the Pilbara bioregion and genetic analysis was conducted on 16 populations using microsatellite markers.

Genetic diversity in A. ancistrocarpa was high but lower than that in E. leucophloia, another widespread species in the Pilbara. Across the species Pilbara range the level of population differentiation was low and the majority of the diversity was maintained within populations with only 3% of variation partitioned between populations. Genetic variation in A. ancistrocarpa showed little structure across the Pilbara with no clustering of populations based on geographical proximity or in association with obvious topographical, physiogeographical or geological features. Populations towards the edges of the species distribution within the Pilbara showed greater levels of differentiation from populations within the species main range. The high levels of genetic diversity and low levels of differentiation within A. ancistrocarpa implies that seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide range within the Pilbara

Root hydraulic conductance and aquaporin abundance respond rapidly to partial root-zone drying events in a riparian Melaleuca species **2011**

Internal reference: RTIO-HSE-0252171

This study examined partial root zone drying (PRD) responses of Melaleuca argentea.

The results demonstrate that PRD can induce rapid changes in root hydraulic conductance and aquaporin expression in roots, which may play a role in short-term water uptake adjustments, particularly in species adapted to heterogeneous water availability.

Baseline Terrestrial Fauna Assessment of Pilbara Rehabilitation Areas **2012**

Internal reference: RTIO-HSE-0134168

In 2011 a fauna survey was conducted within established rehabilitation areas at Brockman 2 and Tom Price mine sites, with the aim of identifying whether fauna is recolonising rehabilitation sites in assemblages comparable to reference sites.

The study found that at least 85 species of native vertebrate fauna, as well as representatives from each of six major groups of invertebrate fauna, are using rehabilitation areas at Brockman 2 and Tom Price, with species compositions that were broadly similar to reference sites. Ant collections were typical of the Pilbara bioregion, with an absence of invasive ant species. The study found greater data correlation between monitoring sites at a particular mine site (Tom Price or Brockman 2) than between rehabilitation and reference sites, indicating the importance of selecting local reference sites. The study concluded that the best candidates for bio-indicators are ants and reptiles.

Hay Project – Native Seed Orchard **2012**

Internal reference: RTIO-HSE-0141263

Commencing in 2011 (and still ongoing), a trial irrigated seed orchard was established at the Hamersley Agriculture Project (Marandoo). The purpose of the trial was to identify an alternate method of addressing seed deficits. If successful, the project may be implemented at other Rio Tinto operations, such as the Nammuldi agriculture project.

Genetic diversity in Aluta quadrata:Implication for management and provenance zone **2012**

Internal reference: RTIO-HSE-0156732

This study was undertaken to define the provenance seed collection zones for Aluta quadrata. This report details information on genetic analysis conducted on Aluta quadrata. Collections were made from 8 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in A. quadrata was moderate and lower than in the other two more widespread Pilbara species, E. leucophloia and A. ancistrocarpa. The findings suggest that its populations may have fluctuated significantly in size over time with genetic drift and possibly inbreeding resulting in a reduction in genetic variability, particularly in rare alleles. Despite the narrow geographic range, the level of population differentiation in A.quadrata was relatively high with 25% of the genetic variation maintained between populations and 19% due to differences between the three different locations. This significant genetic structure indicates that A. quadrata consists of three conservation or management units, Western Ranges, Pirraburdoo and Howie's Hole.

DRAFT

Genetic diversity in Acacia atkinsiana across the Pilbara: Provenance zone implications **2012**

Internal reference: RTIO-HSE-0187256

This study was undertaken to define the provenance seed collection zones for Acacia atkinsiana (Atkins wattle). This report details information on genetic analysis conducted on Aluta quadrata. Collections were made from 16 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in A. atkinsiana was low and lower than that observed in its congener Acacia ancistrocarpa, a widespread species across northern Australia. The level of population differentiation was high and 30% of the diversity was partitioned between populations across the range of A. atkinsiana. Genetic variation in A. atkinsiana showed some structure across the Pilbara with clustering of populations in the western part of the distribution and from the Hamersley Range, along with other populations that were divergent from these groups. The low levels of genetic diversity and high levels of differentiation within A. atkinsiana implies that seed for land rehabilitation and mine-site revegetation programs should be restricted to specific zones. For rehabilitation of sites within the Hamersley Range we recommend seed collections be restricted to that region. Similarly, for rehabilitation in the part of the distribution west of Pannawonica, seed collections should be restricted to that area.

Rehabilitation Quality Metric (RQM) Project **2012**

Internal reference: RTIO-HSE-0164020

Western Australia has no formal process to measure habitat quality and as such RTIO has needed to design its own customised metrics. Vegetation condition scoring has previously been developed by RTIO through a Biodiversity Net Positive Impact Assessment, but a more precise metric was needed. The Rehabilitation Quality Metric (RQM) project was developed to provide a repeatable method to assess rehabilitation quality against pre-determined reference sites, on a site by site basis, to predict rehabilitation ecosystem quality at the time of relinquishment.

The RQM methodology employs seventeen parameters to characterise the landscape, including vegetation, fauna habitat, fauna presence, erosion, and ecosystem function. Parameters are tailored to be an applicable measure for both rehabilitation and native vegetation (reference sites). Parameters are scored, based on measured or observed characteristics, with a value between 0 and 1, with 1 being functional (terrestrial ecosystem is functioning for the maintenance of biodiversity values at a local or property scale) and 0 being dysfunctional (terrestrial ecosystem is failing; indicators of ecosystem function have scored below acceptable levels). Both rehabilitation areas and reference sites are scored. Scores are subsequently determined for the entire mine lease, based on the condition of the land before mining (extrapolated from the reference sites, area weighted) and the likely post-mining conditions (extrapolated from the rehabilitation areas and expected closure domain distribution, area weighted, ie pits with no rehabilitation score 0). The difference between the pre-mining and post-mining scores represents the residual impact of mining.

Propagation of Pilbara spinifex (Triodia sp.) **2012**

Internal reference: RTIO-HSE-0169744

Triodia has often been observed to have very poor establishment from broadcast seed. This project investigated alternatives to growing Triodia (spinifex) from seed, focussing on ways to propagate seedlings from wild harvested material.

The project found the most successful propagating material was stolons. Greatest propagation success was achieved when Triodia were collected when semi to fully dormant (mid Winter-Spring). The 'Moist Root Induction Method' recommended by previous researchers was less successful than the standard propagation techniques employed in this project. Success varied notably between populations. Consequently, any future collections of propagating material should target multiple populations to maximise potential for success.

Pilbara Seed Science Project, Part 2 Final Report Jan 2012 **2013**

Internal reference: RTIO-HSE-0174944

Undertaken between 2009-2012, this seed research investigated germination, biology, dormancy classification and treatments for dormancy alleviation for a range of species from the Pilbara.

The *Acacia atkinsiana, Indigofera monophylla and Sida echinocarpa* seed lots have physical dormancy. Heat treatments and mechanical scarification improved germination on dormant seeds, however, heat treatments killed non-dormant seeds. The treatments used for *Goodenia stobbsiana* seeds failed to overcome dormancy, suggesting deep physiological dormancy. The *Hakea lorea/ chordophylla* seed lots were found to be non-dormant, with very high germination results in the controls. As such, they will not require any pre-treatments prior to direct seeding. The florets surrounding the *Triodia pungens* and *T. wiseana* seeds were found to restrict germination, however, many of the freshly extracted seeds out of the florets were found to be physiologically dormant. Treatments for dormancy include mechanical scarifier to rupture seed coat, hot water (noting potential damage to immature or non-dormant seeds) and increases to germination through wet / dry cycling and / or temperature cycling.

DRAFT

Morphological variation in the western rainbowfish (Melanotaenia australis) among habitats of the Pilbara region of northwest Australia. **2013**

Internal reference: RTIO-HSE-0252169

The aim of this honours thesis was to determine and quantify the extent of morphological variation present in M. australis and relate this to environmental variables, which will provide the first step to understanding how the species copes with environmental change.

This results of this thesis found that there was limited evidence that fish morphology correlated with environmental variables

Patterns of water use by the riparian tree Melaleuca argentea in semi-arid northwest Australia **2013**

Internal reference: RTIO-HSE-0249538

This thesis examines the water use physiology of the riparian tree Melaleuca argentea, and the ways in which this species may respond to anthropogenic disturbances to hydrologic processes.

M. argentea displays highly plastic root-level responses to heterogeneous water availability and to waterlogging, facilitating high rates of water use and growth in the riparian wetland habitats of the Pilbara. Mature M.argentea trees appear to tolerate groundwater drawdown of at least several metres, most likely by employing the same plastic root strategies to access deeper water. M.argentea can also withstand short periods of severe drought, by adopting a 'waiting' strategy of ceasing growth and shedding leaves to avoid moisture loss, a state from which they can then recover. M. argentea populations are unlikely to thrive under large and prolonged reductions in water availability.

Priority Species Seed Quality and Germination Final Report **2013**

Internal reference: RTIO-HSE-0207487

This study investigated the quality and germination biology of a range of priority and keystone (Triodia) plant species from the Pilbara.

Eremophila magnifica subsp. Magnifica has physical & physiological dormancy. Propagation methods other than seed may be more successful. Geijera salicifolia and Olearia mucronata has physiological dormancy. Temperature cycling may be required to stimulate germination. Indigofera ixiocarpa and Indigofera sp. Bungaroo Creek has physical dormancy or is non-dormant. Mechanical scarification may be required. Ptilotus subspinescens is non-dormant and will germinate easily without removal from the perianth sheath. However, seed is likely to lose viability with a few years. Sida echinocarpa and Sida sp. Barlee Range has physical dormancy. Seeds should be removed from the mericarp and then scarified in order to germinate. Triodia pungens has T. wiseana non-deeep or deep physiological dormancy. Germination of de-husked seeds can be improved by applying gibberellic acid or 1% smoke water and wet/dry cycling.

Early physiological flood-tolerance and extensive morphological changes are followed by slow post-flooding root recovery in the dryland tree Eucalyptus camaldulensis subsp. Refulgens **2014**

Internal reference: RTIO-HSE-0252170

This study investigated physiological and morphological response to flooding and recovery in Eucalyptus camaldulensis subsp. Refulgens, a riparian tree species from a dryland region prone to intense episodic flood events.

E. camaldulensis subsp. Refulgens underwent considerable morphological changes during flooding, including extensive adventitious root production, increased root porosity and stem hypertrophy. Physiologically, net photosynthesis and stomatal conductance were maintained for at least 2 weeks of flooding before declining gradually. Despite moderate flood-tolerance during flooding and presumably high environmental selection pressure, recovery of reduced root mass after flooding was poor.

Priority Species Project Progress Report 2013 **2014**

Internal reference: RTIO-HSE-0207486

The Priority Species Project, initiated in 2012, aims to improve knowledge of priority plant species and develop methods to successfully germinate and establish priority species, to enable priority plant species to be integrated into Rio Tinto rehabilitation programmes. This work is being undertaken in conjunction with the Department of Parks and Wildlife.

13 plant species were selected as being potentially suitable for establishment in rehabilitation: Eremophila magnifica subsp. magnifica, Indigofera sp. Bungaroo Creek, Indigofera sp. gilesii, Acacia bromilowiana, Sida sp. Barlee Range, Ptilotus subspinescens, Ptilotus mollis, Acacia subtiliformis, Isotropis parviflora, Grevillea sp. Turee, Hibiscus sp. Canga, Themeda sp. Hamersley Station, and Aluta quadrata. Indigofera sp. Bungaroo Creek and Ptilotus subspinescens were found to readily germinate in laboratory conditions, and a field trial was established at Brockman 4 late in 2013.

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Regional Variation in Metal Concentrations of Pilbara Fish in Relation to Concentrations in Water and Sediments **2014**

Internal reference: RTIO-HSE-0216967

This study aimed to characterise and document natural, background metal concentrations in freshwater fishes from different locations across the Pilbara in order to understand how local geology may affect baseline metal levels in fish tissues and surface waters. Metal concentrations were analysed from water, sediment and muscle and liver tissues from fish collected from up to 13 sites as yet unimpacted by mining across the Pilbara during October (dry season) of 2012.

Levels of dissolved metals from water samples were generally low. However, some elevated concentrations of Boron, Copper and Zinc were recorded. Concentrations of heavy metals in sediments were variable across the Pilbara. Generally, sediment concentrations were well below the Interim Sediment Quality Guidelines (ISQG). However, metal concentrations in excess of ISQG TVs were recorded for Chromium and Copper at some sites. There was no relationship between metal concentrations in sediment and those in water. Metal concentrations in fish tissue (muscle and liver) varied between species with some significantly higher in some particular species. The study concluded that variation in metal concentrations in water, sediment and fish across pools in the Pilbara was likely to be mainly dictated by the local geological setting in which the pool occurs.

Progress Report 2014, Ecological responses of native fishes to dynamic water flows in northwest arid Australia **2014**

Internal reference: RTIO-HSE-0246021

This three year Australian Research Council linkage Project commenced in 2013 and aims to increase understanding of the effects of altered stream flows on the Pilbara freshwater aquatic environment. Project aims: 1. Quantifying fish biodiversity and population structure in relation to hydrological and environmental parameters to identify thresholds of ecological concern for water management; 2. Determine the fundamental physiological, morphological and behavioural adaptations of fishes to variations in water quality using experimental manipulations; and 3. Examine spatial scales of gene flow to determine if increased flows increase genetic connectivity relative to natural-flow sites.

To date work has focuses on characterisation of baseline physicochemical parameters across aquatic habitats within the Fortescue River catchment (Aim 1), analysis of variation in rainbow fish morphometrics and mechanosensory lateral line systems in response to geographic region and water management regime (Aim 2), and extraction of DNA samples from 17 populations across the Fortescue River catchment (Aim 3). The project will culminate in the development of a predictive model for stream restoration relevant to future closure scenarios for above and below-groundwater mines. Results from an honours thesis indicate that rainbow fish body shape varies according to geographic region but fish from a dewatered site (WW Ck) were more streamlined than other populations from the upper Fortescue catchment. This statement of results has been superseded by the results of the actual thesis report RTIO-HSE-0252169.

Progressive rehabilitation

Seeding success in rehabilitation

2019

Internal reference:
RTIO-HSE-0330943

This report aims to outline which species have been successful and unsuccessful in rehabilitation as part of previous seed mixes. This will allow future rehabilitation efforts to focus on key species and realise savings in seed costs by eliminating poor recruiting species. By costing these unsuccessful species in non-recruitment circumstances, it is aimed to demonstrate the importance of considering previous seed success in the future. Highlighting unsuccessful species will also allow focus to shift to these species in regards to trialling new methods of planting and pre-treating seed. It is also aimed to identify opportunity species that may have been underutilised in the past despite their success, due to a lack of collated knowledge on rehabilitation success. Natural recruiting species will also be analysed, to determine which species are dominant natural recruiters.

The top 10 and bottom 20 recruiting species were identified. The bottom 20 were recommended for further research to determine better germination and/or establishment processes. Ten species were also identified as promising but rarely used, so should be tested in upcoming rehabilitation where possible.

Landform design

Results of flume investigations of the stability of rock mulches

1998

Internal reference:
RTIO-HSE-0109221

This study assessed the potential for rock mulches to be stripped from the soil surface by overland flows.

Although 150-300mm diameter BIF was not removed by simulated overland flows, even for 100mm/hr simulated runoff on 55% gradients, considerable scour of the spoil between the rocks was observed, indicating potential for long-term development of rills or gullies if the level of rock cover was less than 100%. Large reductions in sediment concentrations were observed when finer rocks were mixed with BIF. The data indicate that it is crucial for any rock mulch to cover a wide range of particle diameters, including a component of finer rocks. The resulting mixed rock created a framework of large rocks that resist movement by flows, while the smaller rocks reduce erosion being anchored within the larger (framework) rock. For rock mulches with a mixture of rock diameters, 80% cover produced acceptable erosion rates. Sediment loads were slightly higher for 40% cover by rock of mixed diameters, and it was speculated that this may also achieve acceptable erosion rates with the addition of vegetation.

Final Landform Design Criteria for Use During Mine Planning

2012

Internal reference:
RTIO-PDE-0159989

Rio Tinto Iron Ore WA have historically designed closure landforms for waste materials with berms ~10 m, lifts ~20 m and ad hoc alterations to batter gradients where erosion rates have been perceived to be unacceptably high. This report integrates recent advances in characterisation and modelling of materials, climate and erosion processes to provide appropriate final landform batter characteristics for key Pilbara mineral wastes and soils.

Material properties of mineral wastes were assessed and classified for the range of mineral wastes found across Rio Tinto Pilbara sites. Climate sequences were used to model and test potential erosion rates for a range of batter configurations (shapes (linear, concave), heights, gradients, berm capacity) and validated against existing slopes for which material and climate data were available. This information was used to develop a searchable waste dump batter database for all major mineral wastes and soils, intended for use during mine planning design.

DRAFT

Contamination

Impact of Nitrogen from Explosives on Mine Site Water Quality

2008

Internal reference:
RTIO-PDE-0054638

The likely issues associated with the use of nitrogen based explosives on mineral waste and any leachate water are explored in this report. The amounts of explosives used on site are described, along with nitrogen chemistry and toxicity. Nitrogen concentrations for various mine sites and specific lithologies are presented which includes concentration in rock assays and liquid extracts.

It was concluded that the largest risk of nitrogen contamination is likely to arise from the discharge of surface waters that have been in contact with blasted materials and are discharged off site into creeks or waterways. This becomes a more significant issue if the water is also acidic. Algae (ie cyanobacteria) plumes have been identified in acidic water at Tom Price

Control Measures for Potentially Acid Forming Pit Wall Rocks

2010

Internal reference:
RTIO-PDE-0079541

Desktop study of potential strategies to manage exposed sulfidic materials and find viable options for management was conducted with a focus on the Hope Downs 1 and Tom Price sites.

Chemical treatments have the potential to be effective only in the short-term and only for minor water quality issues. Grouting of the pit walls is expected to have limited applicability, although grout curtains behind the wall may have success (untested). Cover technologies have the greatest potential to be effective over the long term, but would need to be resistant to puncture by underlying rocks, resistant to weathering and UV damage ie shotcrete, geomembranes. For long term performance the exposed surface need to be as stable and free of loose material as possible. Treatment effectiveness will also depend on the site conditions, eg chemical less effective at Tom Price.

Workshop Summary and Desktop Review: Dewatering and Sulfate Accumulation **2012**

Internal reference:
RTIO-PDE-0101903

This is a summary of a workshop held to determine the risks of dewatering sulphides within the pit wall. The outcomes from this workshop will be used to develop models to estimate the mass of sulfate produced as a consequence of dewatering activities.

There are many processes that contribute to poor pit water quality. Most of these processes are known and accounted for in existing models. However, the science of fluid flow in fractured rock is not well developed and this lack of knowledge restricts the outcomes of studies on pit water quality. There is a general lack of empirical data for estimating parameters used in models, creating a large degree of uncertainty in predictive models. Sensitivity analysis can be used to overcome some of these challenges.

Development of a conceptual model: Sulfate accumulation as a consequence of pit dewatering activities, memo **2012**

Internal reference:
RTIO-PDE-0101903

Mine dewatering and the consequent lowering of the water table may result in desaturation of sulfide bearing lithologies. The objective of this work was to develop a conceptual model of the associated processes: where sulphide bearing rock intersects the pit walls, and where the sulphide bearing rock is located behind the pit walls but not directly exposed on the pit wall face.

The conceptual model developed estimates the mass of sulfate produced as a consequence of dewatering activities, considering processes during operations and after operations cease, and using sensitivity analysis where parameter inputs are uncertain. The model output provides the basis for an assessment of potential impacts on water quality for general risk assessment applications. Further work was identified to improve parameterisation of the model, including the collection of additional empirical data for pit wall fracturing, saturation of pit wall fractures and sulfide oxidation rates in talus and on pit walls.

Ethnographic or archaeological values

Water and Indigenous People in the Pilbara: A Preliminary Study, CSIRO: Water for a Healthy Country **2011**

Internal reference:
RTIO-HSE-0218222

Water resources are vital to Indigenous identities, beliefs, environmental philosophies and livelihoods. This report provides a broad-scale scoping study of Indigenous relationships to water in the Pilbara and considers the potential impacts of Indigenous water values.

Indigenous belief systems perceive water as an elemental part of the broader cultural landscape, held and managed under customary systems of law. Water sources were derived during the Dreaming and are the most important features in the Pilbara cultural landscape. Interviews raised issues of long term drying, obstruction of water flow, over-extraction, inappropriate discharge from de-watering and access restrictions.

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Appendix 4: Closure Risk Register

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
The safety risk for people entering HD2 after it has been rehabilitated and closed has not been effectively mitigated (696068)	• Post-closure access / land-use requirements, e.g. for stock/pastoralism, people, heritage, environmental monitoring, adjacent mining activities. • Potential for general public to create their own access if appropriate access not provided. • Long term integrity of abandonment bunds. • Decommissioning of infrastructure not implemented effectively. • Some roads will be retained for post-closure access. • Realignment of the Hwy has the potential to complicate access and safety controls.	Health and Safety Community and Social Performance License to operate Legal and Regulatory Compliance	Abandonment bunds to prevent inadvertent access [782553] Above ground infrastructure made safe or removed [782555] Closure studies process (OoM, PFS, FS) 758192 Biannual Local Implementation Committee meetings with TO's 758281 Cultural Heritage Management Plan 703848 RTIO Closure Strategy 758188 Rio Tinto Closure Standard 758190	Single fatality to member of public Loss of access to significant cultural or environmental site causes upset or non compliance with commitments	IV	**IV**
Implementation of the closure strategy does not achieve the required cultural heritage outcomes	• Previously unidentified heritage sites or cultural heritage values, not considered in existing assessment, discussions, agreements or with no authority to disturb. • Changes to landforms at closure have potential to alter conditions at downstream sites, e.g. consider drainage, landform footprint, erosion implications. • Cessation of maintenance of / access to heritage site. • Cultural values not considered in rehabilitation strategies. • The presence of several heritage sites in close proximity to mining areas. • Plans for repatriation of salvaged artefacts not well understood. • Downstream regional area of high value to multiple Traditional Owner groups. • Changes to environmental conditions due to cessation of operational or artificial support / mitigation activities, e.g. dewatering, water supplementation. • Unplanned impact to known heritage site from machinery activity/material movement. • Impacts to PMC heritage values, or WWC downstream environments due to mining activities. • No closure consultation has occurred in regards to final closure landform or other aspects of Hope Downs 2 closure	Licence to Operate Communities and Social Performance Legal Total Cost of Closure	Cultural Heritage Management Plan [703848] Ground disturbance Approval Request system [758266] Heritage GIS database [519558]	Cessation of maintenance of / access to heritage site. Closure implementation results in unapproved impacts to cultural heritage values in the area (i.e. previously unidentified heritage sites or cultural heritage values, not considered in existing assessment, discussions, agreements or with no authority to disturb). Waterways are not returned to prior to mine life and so cultural use cannot return to what was expected (due to water levels, water quality, accessibility etc)	IV	**III**

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
Inadequate management of contaminating activities at HD2 during operations increases closure costs (696032)	• Poor use or uncontrolled use of chemicals and hydrocarbons during operations. • Inadequate housekeeping practice and maintenance of work areas and equipment. • Contaminated sites have not been identified. • Inadequate clean-up of contamination. • Potential contamination source has not been addressed. • The full nature and extent of reportable contaminated sites have not been adequately determined. • Lag contamination events from historical waste disposal practices. • Changes in regulatory expectations and continually developing regulatory understanding of emerging contaminates of concern.	Total cost of closure Environment Lega and Regulatory Compliance	Licensing of Prescribed Premises [783245] RTIO Contaminated Sites Strategy [782520] RTIO Environment Design Standard for Permanent Infrastructure [782521] RTIO Environment Design Standards Temporary Infrastructure [782523] RTIO Landfarm Work Practice [782519] RTIO Landfill Work Practice [782518] RTIO Potentially Contaminated Sites Register [519506] RTIO Spill Response Procedure [779354]	Contamination is identified during closure implementation or post closure and remediation is required	III	III
Waste dumps and or landbridges at HD2 are subject to excessive erosion (974458)	• Material characterisation assumptions are incorrect. • Incorrect assumptions or understanding of technical aspects underpinning the closure strategy. • Climatic conditions or changes impact outcomes.	Environment Licence to Operate Total cost of closure	Physical materials characterisation completed for common waste types [519539] Closure review of landform designs through MDAS system [758263] Landform Design Guidelines [754554] RTIO Rehabilitation handbook [759546] RTIO SCARD management plan [519521] Temporary and permanent surface water structures designed to conform with relevant legal and engineering standards 519543	Waste dumps and / or Landforms require re-work to achieve closure outcomes Downstream environmental receptor impacted and needs remediation	III	III

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
Failure to reach agreement with the State on suitable completion criteria for HD2 (696208).	• Current completion criteria still at conceptual stage. • Final completion criteria not agreed with key stakeholders. • Inadequate consultation with stakeholders to identify expectations. • Regulator standards change with time (required to achieve the "standard of the day"). • Insufficient or unreliable corporate knowledge to define final completion criteria. • Unrealistic expectations for closure outcomes (restoration compared to rehabilitation). • Research not being undertaken and/or outcomes not being analyzed/utilized. • Conceptual models and/or limited technical data to achieve proposed closure strategies.	Total cost of closure Licence to operate	Closure legal obligations register [757139] Mine Closure Plan is updated for approval every three years [757145] Progressive rehabilitation is trialed and completed during operations [758285] Quarterly regulator closure forum [758282] RTIO Stakeholder Engagement Strategy for Closure [754125] Stakeholder Engagement Register [757141] Business Conformance Audit (Closure) 754099 Post Closure Monitoring & Maintenance Plan 759549 Rehabilitation monitoring program 759547 MCP is updated for approval every three years 757145 Quarterly regulator closure forum 758282 RTIO Closure Strategy 758188 Rio Tinto Closure Standard 758190 Closure studies process (OoM, PFS, FS) 758192	Stakeholder engagement with regulators fails to reach agreement on closure strategy leading to increased closure costs and relationship impacts	III	III

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
Implementation of the closure strategy does not achieve the required environmental outcomes.	• Scheduled, listed or declared rare and / or threatened species of flora or fauna present in/adjacent to site. • Downstream regional area of high value. • Regional groundwater impacts not well understood. • Environmental conditions post-closure differ significantly from pre-mining conditions. • Post-mining land use differs from pre-mining land use. • Failure to understand or consider cumulative impacts on off-site areas. • Changes to environmental conditions due to cessation of operational or artificial support / mitigation activities, e.g. dewatering, water supplementation.	Environment Compliance	Baseline flora and fauna surveys [759550] Biological GIS database [782559] Ground disturbance Approval Request system [758266] Rehabilitation trials to increase confidence in rehabilitation outcomes [759222] RTIO Rehabilitation handbook [759546] Seed management and procurement program [759225] Soil resource management work practice [759226] RTIO Closure Strategy 758188 Rio Tinto Closure Standard 758190 Closure studies process (OoM, PFS, FS) 758192 Research and Development program 764041 Rehabilitation monitoring program 759547 Post Closure Monitoring & Maintenance Plan 759549 Progressive Rehabilitation is trialled and completed during operations 758285 Environmental exclusions zones established to protect conservation significant fauna and habitat 832623	Regional impact results in loss of trust, delay to relinquishment and increased closure costs.	III	III

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
Inadequate management of surface water results in increased closure complexity and costs	• Unplanned post-closure impacts occur as a result of migration of a contaminant (e.g. sediment) off-site. • Diversion or catchment of important surface water flows on-site, impacting on downstream areas off-site.	Environment Community and Social Performance Total cost of closure	Water management strategies during operations prioritise minimisation of closure management liability 786840 Water discharge monitoring and management plans 702366 Temporary and permanent surface water structures designed to conform with relevant legal and engineering standards 519543 Environmental and groundwater monitoring regime in place during operations 699589	Impact requires ongoing management or clean up	III	III

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
Rehabilitation outcomes at HD2 do not meet closure objectives.	• Vegetation established, but does not re-seed in same abundance. • Weed competition. • Species selection / insufficient species diversity. • Animal interference i.e. feral animals eating new growth. • Changes to soil water conditions e.g. salinity, water logging. • Vegetation does not provide suitable habitat for local fauna. • Availability of soil/poor stockpile management/failure to collect soils during ground disturbing activities. • Low moisture retention i.e. hydrophobic soils development, very rocky materials. • Chemical properties of materials on waste dump / rehab surface e.g. salt circulation, alkalinity. • Completion criteria are currently indicative only and therefore final requirements/expectations are not yet understood or agreed.	Environment Total cost of closure Legal and Regulatory Compliance	Rehabilitation trials to increase confidence in rehabilitation outcomes [759222] RTIO Rehabilitation handbook [759546] Seed management and procurement program [759225] Soil resource management work practice [759226] Rehabilitation monitoring program 759547 Baseline flora and fauna surveys [759550] Biological GIS database [782559] Environmental Management Plan [759548] Ground disturbance Approval Request system [758266] (Issue/Site specific) Management Plan MSA's with contractors 759823 Skilled and resourced closure planning team within RTIO 759826 Rehabilitation trials to increase confidence in rehabilitation outcomes 759222 Post Closure Monitoring & Maintenance Plan 759549 Research and Development program 764041 Environmental exclusions zones established to protect conservation significant fauna and habitat 832623	Rehabilitation (~50% $50M AUD) rework is required causing increase of costs and delayed relinquishment	III	III
Consultation fails to identify and/or address stakeholder concerns [696247]	• Conflicting stakeholder expectations or areas of authority e.g. different regulators for environment, heritage, health, economic, tourism. • Conflicting legal obligations e.g. State Agreement and EPA. • Interactions between catchment land uses, including mining developments, at different points in time. • Traditional owners are not satisfied with the rehabilitation undertaken. Consultation fails to identify issues prior to them being playing out.	Community and Social Performance Licence to operate Legal and Regulatory Compliance Total cost of closure	Mine Closure Plan is updated for approval every three years [757145] RTIO Closure Strategy [758188] RTIO Stakeholder Engagement Strategy for Closure [754125] Stakeholder Engagement Register [757141]	Consultation is undertaken but fails to idenitfy stakeholder concerns.	III	III

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Risk Title	Potential Causes (trigger/Indicators)	Impacts/Consequences	Existing Controls	Evaluation Rationale	Inherent Risk Classification	Current Risk Management Class
Pit wall stability at HD2 compromises closure outcomes (696059)	• Influence of erosion, subsidence, seismicity, wall slip. • Influence of groundwater recovery and surface water flows on stability. • Creek system neighbouring or within zone of instability, potential stream capture. • Geotechnical assessment incorrectly defines the zone of instability. • Built landforms (waste dumps/land bridges) within potentially unstable pit edge zone. • Run on from surface water catchments onto waste dumps and pits (currently not incorporated into design)	Community and Social Performance License to operate Environment Environment Total Cost of Closure	D3 Standard Management of Slope Geotechnical Hazards 758274 Buttressing design to improve pit wall stability at closure 786838 Geotechnical assessments for wall stability and zone of collapse as part of mine design reviews 519534 Closure review of landform designs through MDAS system 758263 Landform Design Guidelines 754554	Post closure pit wall failure impacts potential MNES habitat	III	II
Acid and / or metalliferous drainage generation creates a contaminated site (969040).	• Interaction of water and mineral waste could generate acid / alkaline levels that leach metals / salts from the mineral waste or local environment.	Environment Legal & Regulatory Compliance Licence to Operate Total cost of closure	Groundwater operating and monitoring plan [702372] Geochemical waste characterisation and column leach tests [702369] RTIO Mineral Waste Management Plan for undeveloped resource and studies [754152] RTIO SCARD management plan [519521]	AMD results in an environmental legacy and ongoing acid water management is required (i.e. acid water treatment plant). Note: No PAF expected to be encountered during operations.	II	II

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Appendix 5: Closure Action Register

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Ref	Task	Indicative timeframe
1	Develop SMART completion criteria for HD2 and BHT deposits; considering stakeholder consultation and access requirements, climatic, geotechnical, mineral waste, hydrogeological, hydrological, flora and fauna knowledge and assessments.	2030
2	Stakeholder engagement strategy and communications plan to be prepared for community, regulators, and internal audience.	Next Closure Plan
3	Undertake specific closure stakeholder engagement to determine social and cultural heritage values to be maintained at the closure of the HD2 and BHT deposits, include salvage and repatriation of sites.	Next Closure Plan
4	Undertake visual impact assessment of HD2 and BHT deposits final landform configuration and visibility from GNH and other key vantage points or points of cultural heritage importance.	Next Closure Plan
5	Develop seed mix(es) HD2 and BHT deposits in line with progressive rehabilitation targets and consultation with stakeholders.	Next Closure Plan
6	Develop consultation tools to assist in communicating closure strategy with stakeholders.	Next Closure Plan
7	Schedule consultation with stakeholders over the life of asset to consult on closure strategy options and opportunities.	Ongoing
8	Complete consultation with TOs on key heritage locations and access requirements post-closure to contribute to the final closure landform or landscape	Ongoing
9	Complete consultation on closure outcomes, completion criteria and measurement tools.	Ongoing
10	Complete consultation on the final closure landform or landscape and opportunities for TOs to get involved.	Ongoing
11	Investigate opportunity to allow safe access for viewing/observation of post-closure landform to deter unauthorised access to site.	Next Closure Plan
12	Potential social and economic impacts to be assessed including amenity, public health associated with closure activities, loss of employment and business opportunities.	Ongoing
13	Consult with stakeholders to address any potential socio-economic impacts post-closure.	Ongoing
14	Complete landform evolution modelling to confirm the optimal final Waste Rock Landform design, including physical waste characterisation.	Next Closure Plan
15	Flood modelling of the closure landform to consider climatic variation and the potential for extreme rainfall events.	Next Closure Plan
16	Develop post-closure monitoring and maintenance plan for HD2 and BHT deposits	2030
17	Evaluate planned post-closure pit wall stability for HD2 and BHT deposits pits to determine if mitigation is required to prevent wall collapse and PMC creek capture.	Ongoing
18	The zone of geotechnical instability or PUPEZ will be revised and updated for HD2 and BHT deposits in each iteration of the MCP to reflect any changes to the mine plan, understanding of the closure landscape and to address any updated flood modelling.	Ongoing
19	The location of the proposed pit abandonment bunds for the HD2 and BHT deposits will be revised and updated in each iteration of the MCP to reflect any changes to the mine plan, understanding of the closure landscape and to address any updated flood modelling.	Ongoing

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20	Develop a rehabilitation materials inventory for HD2 and BHT deposits for low erodibility waste to be utilised for capping and abandonment bunding where required.	Ongoing
21	Undertake landform evolution modelling for HD2 and BHT landforms to further inform and verify final landform design and rehabilitation parameters.	Ongoing
22	Site specific geotechnical assessments will be completed for rehabilitation designs of final closure landforms for HD2 and BHT deposits to confirm closure landform safety and stability.	Ongoing
23	Complete consultation with the State on preferences with regards to final closure landform and public access to the post-closure landscape. This will be determined through ongoing consultation during the life of the operation.	Ongoing
24	Assess opportunities to allow safe access for viewing/observation of the post-closure landform near the highway to deter unauthorised access to site. If this is considered appropriate to key stakeholders, details will be included in further updates to this MCP.	2030
25	Assess the expected post-closure access to the site, and include the installation of additional control measures, where appropriate.	2030
26	Site specific physical waste characterisation will be progressively undertaken when each mineral waste unit becomes available during mining operations.	Ongoing
27	Include HD2 and BHT deposit materials in updates of the BST.	Ongoing
28	Undertake further testing of BHT (detrital) lignite materials when geological units become available during mining operations as per the SCARD management plan.	Ongoing
29		
30	Revise waste rock landform rehabilitation and overall closure landform designs based on physical waste characterisation, BST parameters, hydrological and ecological factors and stakeholder consultation as required.	Ongoing
31	Update the topsoil balance for estimated topsoil recovery annually once mining commences.	Ongoing
32	Complete subsoil characterisation work when vegetation clearing commences as required.	Ongoing
33	Undertake Preliminary Site Investigation 5 years prior to closure.	2030
34	Undertake Detailed Site Investigation 2 years prior to closure.	2032
35	Complete final options assessment for water source for HD2 Proposal and impacts for HD2 and BHT deposits.	Next Closure Plan
36	Update closure hydrogeological model with new conceptualisations for HD2 and BHT deposits water supply options.	Ongoing
37	Complete closure hydrogeological water quality model for HD2 and BHT deposits once water supply options are agreed with stakeholders.	Next Closure Plan
38	Update the conceptual hydrogeological model for HD2 and BHT deposits final closure landform 5 years from closure.	2029
39	Update surface water modelling for PMC creek diversion in line with changes to landform design and closure strategy for HD2 deposit (1:100AEP, 1:1000AEP and 1:10,000AEP).	Ongoing
40	Upgrade of drainage designs for permanent closure drainage structures (PMC) where required, in line with flood risk assessments (1:100AEP, 1:1000AEP and 1:10,000AEP).	2030
41	Undertake hydrological water quality sampling of PMC and WWC prior to commencing mining of the HD2 and BHT deposits.	2025
42	Undertake hydrological modelling (1:100AEP, 1:1000AEP and 1:10,000AEP) of updated landbridge closure strategy and designs.	Ongoing
43	Undertake hydrological modelling of abandonment bund alignment and final closure landform for HD2 and BHT deposits (1:100AEP, 1:1000AEP and 1:10,000AEP).	2030

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44	Determine required engineering flood mitigation structures for HD2 and BHT deposit's closure landforms.	2030
45	Conservation significant areas will be considered in closure planning with reference to post-closure land use, access to the landscape and closure outcomes.	Ongoing
46	Seed mixes have not been developed for the HD2 Proposal, to facilitate progressive rehabilitation. Considering the short mine life for the HD2 Proposal, flora species recorded in baseline surveys will be used to inform rehabilitation seed mix(es). Seed mixes will be developed in consultation with stakeholders.	2025
47	The selection of reference / analogue sites and the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) have not yet been undertaken. Vegetation mapping completed for the HD2 Proposal will be used to inform the selection of reference / analogue sites and inform the development of revegetation completion criteria (species richness, percentage cover and percentage weed cover) and monitor against progressive rehabilitation	Next Closure Plan
48	Select reference / analogue sites for HD2 and BHT deposits to inform revegetation criteria and progressive rehabilitation.	Next Closure Plan
49	Implement progressive closure and rehabilitation of waste rock landforms and disturbed areas as soon as possible to reduce closure liabilities.	Ongoing
50	Revise seed mix(es) in line with progressive rehabilitation targets and consultation with stakeholders.	2030
51	Conduct closure research and rehabilitation trials to demonstrate methodologies.	Ongoing
52	Complete fauna habitat assessment of the final closure landform for HD2 and BHT deposits 5 years from closure.	2029
53	Undertake review of final closure landform and completion criteria to determine the functional habitats likely to be present post-closure.	2029
54	Incorporated social and cultural heritage values regarding Special Places for Nyiyaparli, as documented in the HD2 SCHMP (Rio Tinto 2023), into the MCP.	Next Closure Plan
55	The risk title regarding cultural heritage will be reworded and evaluated to ensure that closure outcomes consider social values.	Next Closure Plan

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Appendix 6: Landform Design Criteria

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HD2 DP_NW (Goanna)

Waste volume	174 Mm^3	
Erodibility ranking		
	Low	12 %
	Medium	31 %
	High	57 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	Y
	Fibrous minerals ☐	Mm^3
	WFSF ☐	-
Overall height (m)	150	
Topsoil required (Mm^3)	**0.6**	

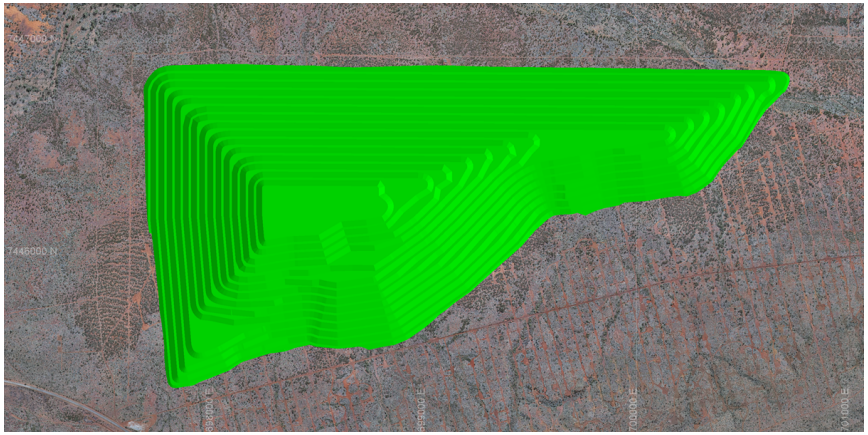
	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	34	20°
Lift height (m)	10	7
Berm width (m)	23.6	11
Berm slope (deg)	°	°
Footprint (ha)	264	269

Comments:

Please note designs are conceptual and features such as ramps and design parameters are subject to change.
Capping requirements will be assessed as more information on material characteristics are gained through further study.

Construction Design

Rehabilitation Design



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HD2 DP_NC (Tortoise)

Waste volume	34Mm^3	
Erodibility ranking		
	Low	56 %
	Medium	31 %
	High	28 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	Y
	Fibrous minerals ☐	Mm^3
	WFSF ☐	-
Overall height (m)	75	
Topsoil required (Mm^3)	**0.2**	

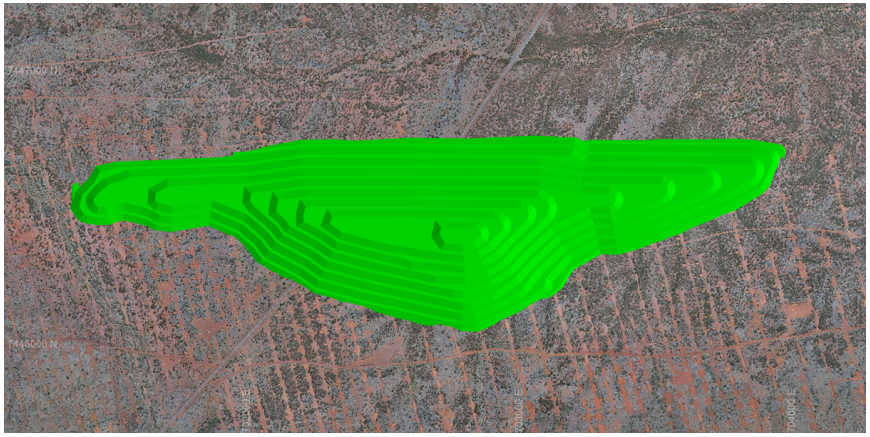
	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	34	20°
Lift height (m)	10	7
Berm width (m)	23.6	11
Berm slope (deg)	°	°
Footprint (ha)	75	77

Comments:

Please note designs are conceptual and features such as ramps and design parameters are subject to change.
Capping requirements will be assessed as more information on material characteristics are gained through further study.

Construction Design

Rehabilitation Design



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BHT DP_NELG

Waste volume	125Mm³	
Erodibility ranking		
	Low	94 %
	Medium	2 %
	High	4 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	N
	Fibrous minerals ☐	Mm³
	WFSF ☐	-
Overall height (m)	175	
Topsoil required (Mm³)	**0.5**	

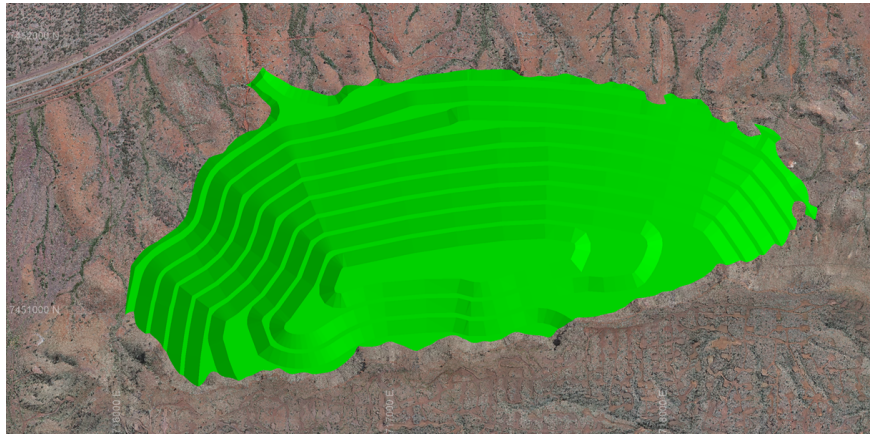
	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	36°	20°
Lift height (m)	10	10
Berm width (m)	24	10
Berm slope (deg)	°	°
Footprint (ha)	207	207

Comments:

Please note designs are conceptual and features such as ramps and design parameters are subject to change.

Construction Design

Rehabilitation Design



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BHT DP_NEWD

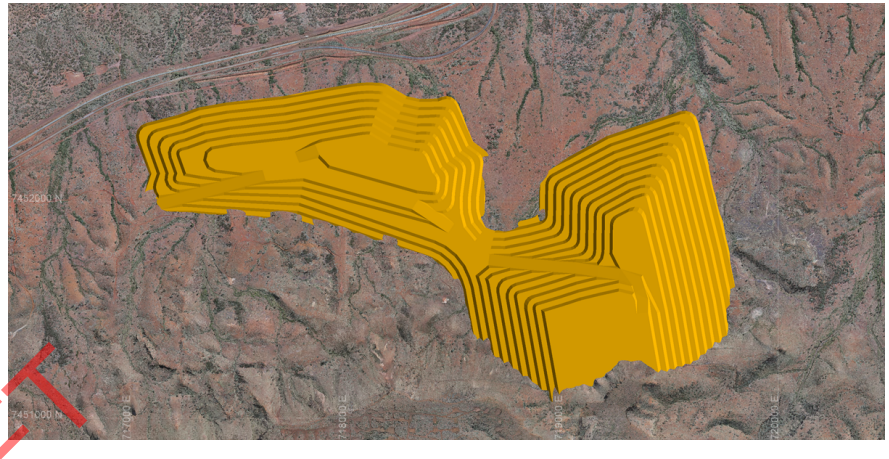
Waste volume	83 Mm^3	
Erodibility ranking		
	Low	82 %
	Medium	3 %
	High	15 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	N
	Fibrous minerals ☐	Mm^3
	WFSF ☐	-
Overall height (m)	120	
Topsoil required (Mm^3)	**0.5**	

	Construction Specifications	Rehabilitation Specifications
Slope angle (deg)	36°	20°
Lift height (m)	10	10
Berm width (m)	24	10
Berm slope (deg)	°	°
Footprint (ha)	204	206

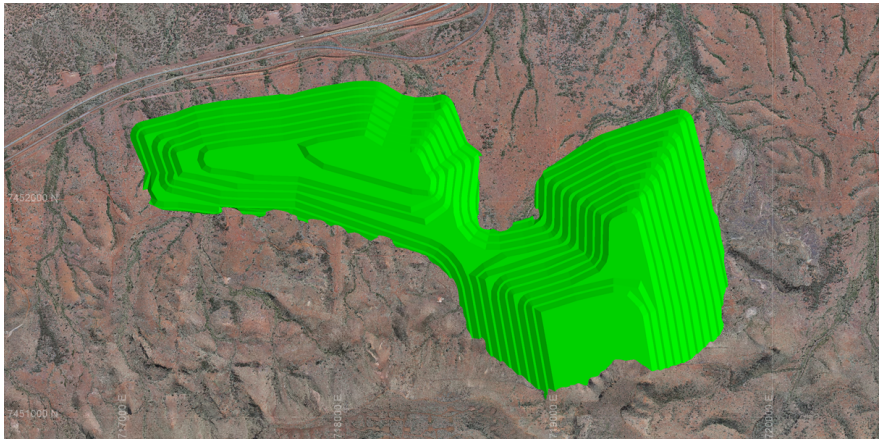
Comments:

Please note designs are conceptual and features such as ramps and design parameters are subject to change.

Construction Design



Rehabilitation Design



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BHT LB_West

Waste volume	During operations - 6.0Mm³, Rehabilitation - 0.188Mm³	
Erodibility ranking		
	Low	82 %
	Medium	3 %
	High	15 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	N
	Fibrous minerals ☐	Mm³
	WFSF ☐	-
Overall height (m)	Max 47m	
Topsoil required (Mm³)	**N/A**	

	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	36°	20 °
Lift height (m)	15m	15m
Berm width (m)	24m	10m
Berm slope (deg)	3°	11°
Footprint (ha)	38.6ha	

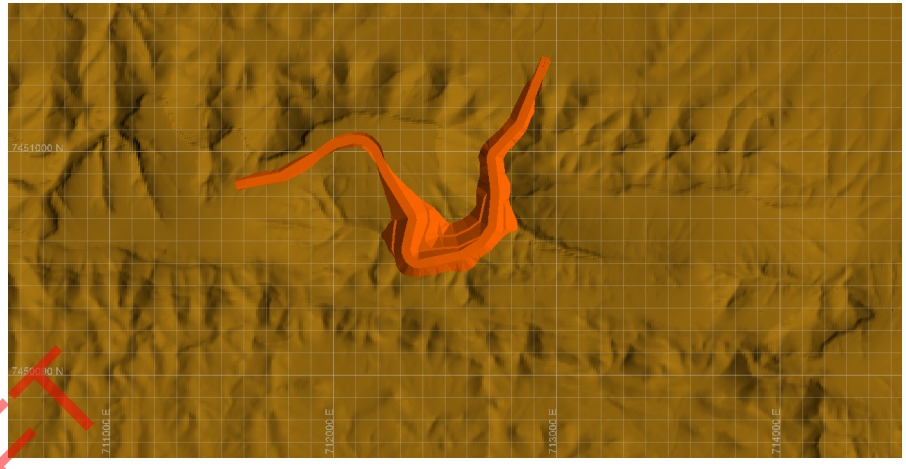
Comments:

Landbridge designs are conceptual and are likely to change with updates to pit designs and schedules.

The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge not located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.

The external portion will have an updated rehabilitation design completed prior to approval of the project, designs and landforms evolution modeling are underway and planned for completion in 2023.

Construction Design



Rehabilitation Design

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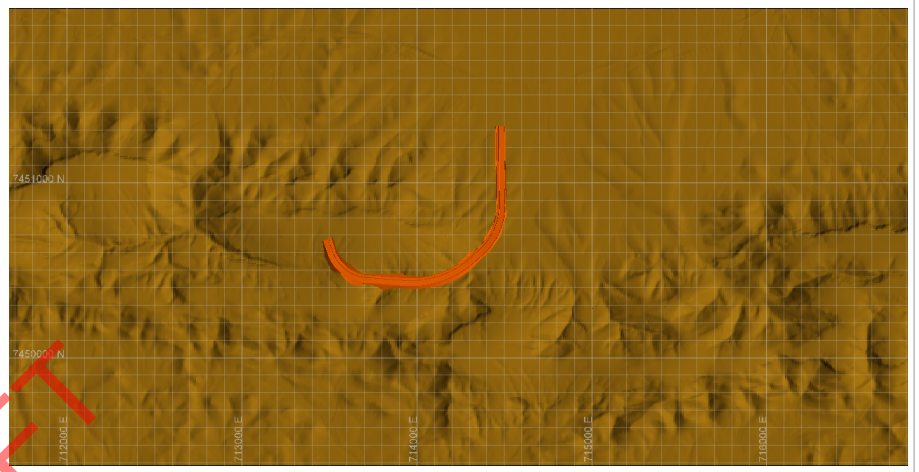
BHT LB_CEN

Waste volume	During operations - 0.7Mm^3. Rehabilitation - Removed at closure.	
Erodibility ranking		
	Low	82 %
	Medium	3 %
	High	15 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	N
	Fibrous minerals ☐	Mm^3
	WFSF ☐	-
Overall height (m)	Max.31m	
Topsoil required (Mm^3)	N/A	

Construction Design



Rehabilitation Design

N/A

	Construction Specifications	Rehabilitation Specifications
Slope angle (deg)	36°	20 °
Lift height (m)	15m	20m
Berm width (m)	24m	10m
Berm slope (deg)	3°	11°
Footprint (ha)	12.5ha	

Comments:

Landbridge designs are conceptual and are likely to change with updates to pit designs and schedules.

The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge not located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.

The external portion is currently planned to be reclaimed at closure, however, updated designs and landforms evolution modeling are underway and planned for completion in 2023.

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BHT LB_Central 3

Waste volume	During operations - 0.9Mm³ , Rehabilitation - 0.066Mm³	
Erodibility ranking		
	Low	82 %
	Medium	3 %
	High	15 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	-
	Fibrous minerals ☐	Mm³
	WFSF ☐	-
Overall height (m)	Max 38	
Topsoil required (Mm³)	N/A	

	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	36°	20 °
Lift height (m)	15m	20m
Berm width (m)	24m	10m
Berm slope (deg)	3°	11°
Footprint (ha)	8.2ha	

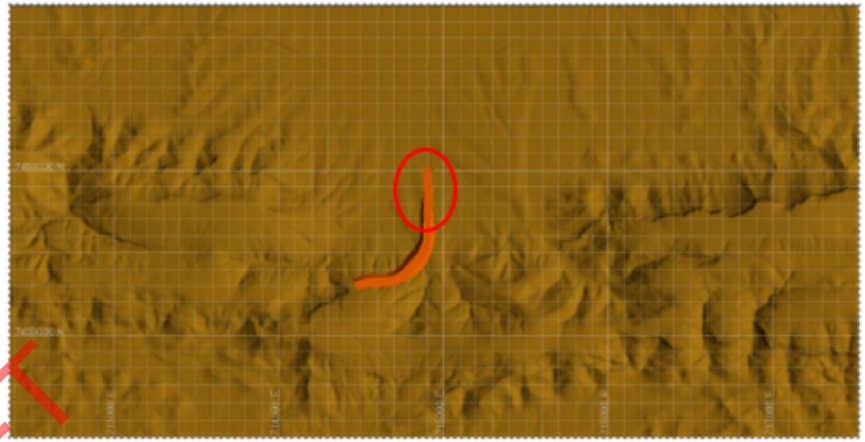
Comments:

Landbridge designs are conceptual and are likely to change with updates to pit designs and schedules.

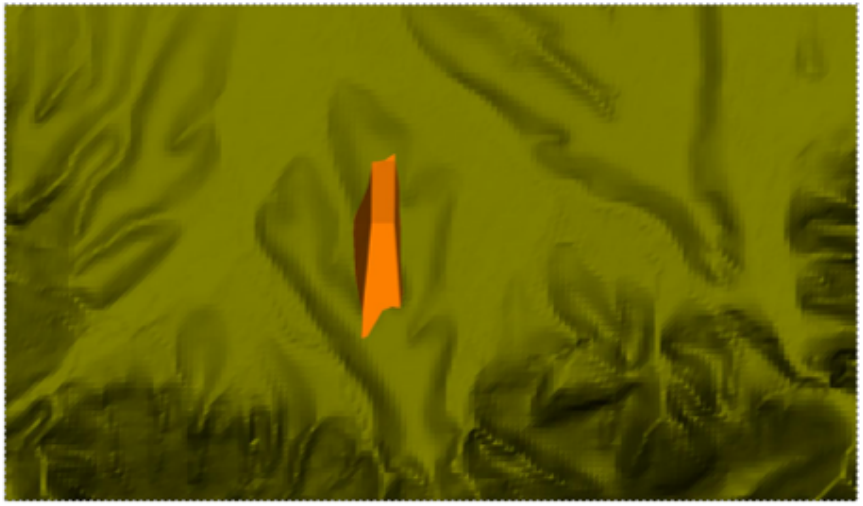
The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge not located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.

The external portion will have an updated rehabilitation design completed prior to approval of the project, designs and landforms evolution modeling are underway and planned for completion in 2023.

Construction Design



Rehabilitation Design



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BHT LB_East 6

Waste volume	During operations - 0.8Mm³ , Rehabilitation - 0.061Mm³	
Erodibility ranking		
	Low	82 %
	Medium	3 %
	High	15 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	N
	Fibrous minerals ☐	Mm³
	WFSF ☐	-
Overall height (m)	Max. 78m	
Topsoil required (Mm³)	**N/A**	

	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	36°	20 °
Lift height (m)	15m	20m
Berm width (m)	24m	10m
Berm slope (deg)	3°	11°
Footprint (ha)	10.1ha	

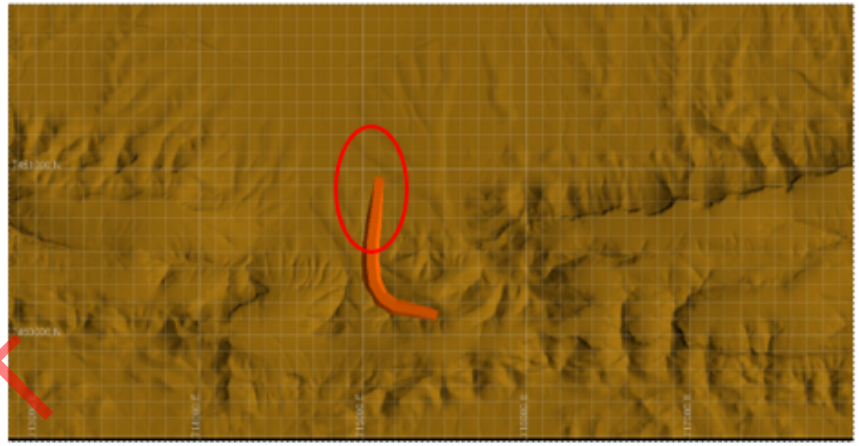
Comments:

Landbridge designs are conceptual and are likely to change with updates to pit designs and schedules.

The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge not located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.

The external portion will have an updated rehabilitation design completed prior to approval of the project, designs and landforms evolution modeling are underway and planned for completion in 2023.

Construction Design



Rehabilitation Design

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BHT LB_East

Waste volume	During operations -1.6Mm^3 , Rehabilitation - 0.20Mm^3 and 0.12Mm^3	
Erodibility ranking		
	Low	82 %
	Medium	3 %
	High	15 %
Classification	Inert ☒	Capping required at closure:
	PAF ☐	N
	Fibrous minerals ☐	Mm^3
	WFSF ☐	-
Overall height (m)	Max. 78m	
Topsoil required (Mm^3)	**N/A**	

	Construction Specifications	**Rehabilitation Specifications**
Slope angle (deg)	36°	20 °
Lift height (m)	15m	20m
Berm width (m)	24m	10m
Berm slope (deg)	3°	11°
Footprint (ha)	38.6ha	

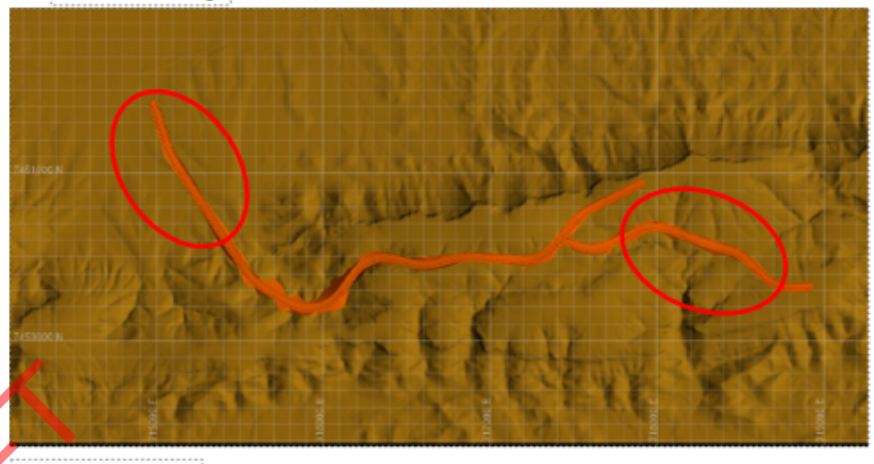
Comments:

Landbridge designs are conceptual and are likely to change with updates to pit designs and schedules.

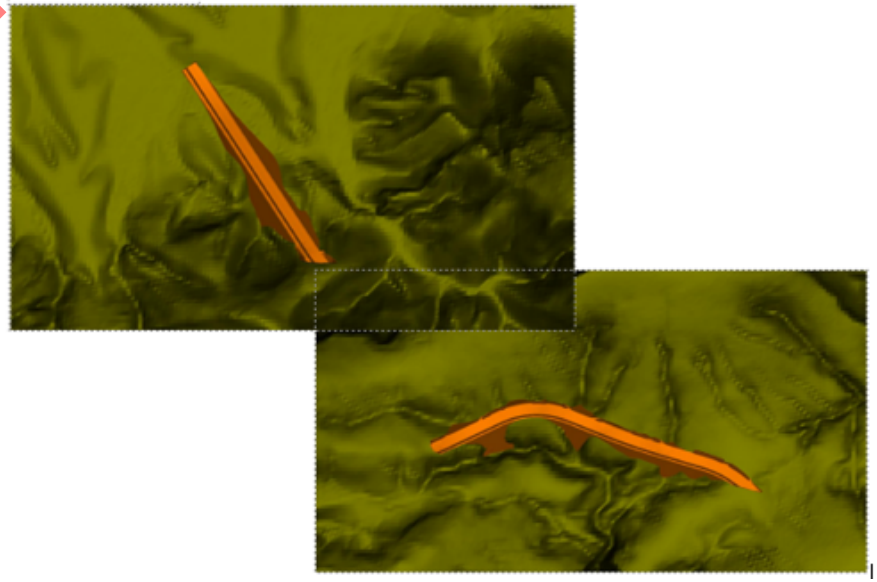
The majority of this landbridge is in pit and does not require a rehabilitation design, portions of the landbridge not located within pit areas will be reclaimed into the adjacent pit areas or shaped to maintain surface water flows where possible.

The external portion will have an updated rehabilitation design completed prior to approval of the project, designs and landforms evolution modeling are underway and planned for completion in 2023.

Construction Design



Rehabilitation Design



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Appendix 7: Memorandum: Characterisation of erosion potential of mineral wastes for use in developing rehabilitated landform designs, Hope Downs 1 & 2

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TOOWOOMBA
PO Box 57 HARLAXTON QLD 4350
Phone 07 4613 1825 | **Fax** 07 4613 1826

PERTH
PO Box 5175 SOUTH LAKE WA 6164
Phone 08 9494 2835 | **Fax** 08 9494 2837

NEWCASTLE
PO Box 7017 REDHEAD NSW 2290
Phone 02 4965 7717 | **Fax** 07 4613 1826

Level 12, Central Park
152-158 St George's Terrace
PERTH WA 6000

20 May 2020

2079.20e (Rev 1)

Attn: Belinda Yaqub – Closure Specialist, Studies and Technology

Memorandum: Characterisation of erosion potential of mineral wastes for use in developing rehabilitated landform designs, Hope Downs 1 & 2

1. Introduction

1.1 Regulatory expectations

Across Australia, mining regulatory bodies provide guidance on the required state of rehabilitated landforms. In Western Australia the Department of Mines, Industry Regulation and Safety (DMIRS) define land rehabilitation as the, "return of disturbed land to a safe, stable, non-polluting/non-contaminating landform in an ecologically sustainable manner that is productive and/or self-sustaining consistent with the agreed post-mining land use"[1]. In their technical guidance note on waste rock dumps, DMIRS also state that the geometry of waste dump batter slopes should be designed such that they are not prone to significant erosion[2].

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Fundamental to creating safe, stable, and non-polluting landforms is the development of land surfaces that do not erode at rates likely to be unstable in the long-term, that are sufficiently stable such that vegetation can establish, and that generate sediment levels consistent with background levels such that the impact on the surrounding landscape is low.

1.2 Rio Tinto's historical involvement in erodibility testing and erosion modelling

Rio Tinto Iron Ore (WA) has been involved in the development of erosion assessment methods for mining waste landforms for a long time, with the first application of material erodibility testing and erosion models to mining landforms occurring in 1998. Since that time, the use of models has improved and been refined to the point where final landform shapes can be informed through models calibrated using site-specific material erodibility and climate data.

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[1] Department of Mines, Industry Regulation and Safety (2020) *Mine Closure Plan Guidance - How to prepare in accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans*, Version 3.0, Government of Western Australia, https://www.dmp.wa.gov.au/Documents/Environment/REC-EC-112D.pdf, accessed 22 July 2020.

[2] Department of Mines and Petroleum (2009) *Waste Rock Dumps, Environmental Notes on Mining*, Government of Western Australia, https://www.dmp.wa.gov.au/Documents/Environment/ENV-MEB-223.pdf, accessed 22 July 2020.

In the period of 1998 to 2006, this included field based studies at Tom Price, Paraburdoo, and Nammuldi, and laboratory-based studies for materials from Tom Price, Channar, and Marandoo. Rio Tinto Iron Ore (WA) undertook an extensive project in 2010-2012 along with several studies since that time to source erodibility data for a range of materials across all the Pilbara iron ore mine sites. These data have been used to establish a means by which a material's erosion characteristics can directly inform mine and rehabilitation planning. An outcome of these projects has been the creation of a database of erodibility parameters for a large number of mineral wastes. This erodibility parameter database has subsequently been used within erosion models[3] to define a collection of erosionally stable landform batter geometries (height, gradient, and profile shape) for the key mineral wastes and soils across Rio Tinto Iron Ore's Pilbara operations. Rio Tinto use these erosionally stable batter geometries to develop 3-D rehabilitation landform designs that will satisfy long-term erosional stability requirements.

Erodibility ranking

The materials for which erodibility data exists have been given a general erodibility ranking (high, medium, low) to assist in describing the different mineral waste types. The ranking system was developed by considering the particle size distribution (PSD) and rain armoured rock cover levels for a range of Rio Tinto's materials. The ranking system is broad in nature and is used to describe the relative erodibilities in different mineral waste types.

The erodibility ranking system was developed by considering the erosion potential of mineral wastes using the Revised Universal Soil Loss Equation (RUSLE). The RUSLE is an empirical equation that calculates erosion using 5 factors. Of these factors, 2 (K, erodibility and C, cover) are specifically related to the material (the remaining 3 describe the climate and slope conditions).

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The K-factor describes the erodibility of the fine fraction (<2mm) excluding the coarse fraction. It is estimated from the equation given in Rosewell and Loch (2002)[4] using material characterisation data. The C-factor describes the rock cover levels of a surface that has been armoured under simulated rainfall. It was calculated using the RUSLE software (version 1.06) supplied by the US Department of Agriculture that allows for the C-factor to be determined based on rock cover.

The results of this testing (on 36 mineral waste samples from across the Pilbara sites) showed that the K-factor (fine fraction only) are consistent with highly and very highly erodible materials[4]. When factoring in the rock cover levels observed for each material in the differences in erodibility became apparent. The major driver of material erodibility was not the erodibility of the fine-fraction, but the amount of rock that was typically within a material. Using the erodibility rankings (high, medium, low) given in Rosewell and Loch (2002), materials that typically had rock cover levels >70% had low erodibility, materials with rock cover levels of 30-70% had medium erodibility, and materials with rock cover levels <30% had high erodibility.

[3] The Water Erosion Prediction Program (WEPP) is the main runoff/erosion model used.
[4] Rosewell, C.J. and Loch, R.J. (2002) *Estimation of the RUSLE soil erodibility factor*, in N. McKenzie, K. Coughlan, and H. Cresswell (eds), Soil Physical Measurement and Interpretation for Land Evaluation, CSIRO Publishing, Collingwood.

It is important to note that the actual erosion that occurs for a given material is dependent on not only the material erodibility, but also on the climate and how the materials are placed. A material that has low erosion risk can be used to produce an erosionally unstable batter if the batter gradients are too steep or the slope length too long. Therefore, the actual erosion potential of a material is not defined by this ranking, but by the results of the erosion modelling that considers all these factors (materials, climate, and batter geometry).

The erodibility database

To create the erodibility database from which erosionally stable batter geometries are defined using erosion modelling, available information on mineral waste types were initially collated from Rio Tinto's waste drilling records. This collated information was used to determine the range of key waste types for sites across the Pilbara. Erodibility parameters for these key waste types were then gathered using simulated rainfall and overland flow techniques.

Long-term erosion modelling

The erodibility parameters are used within erosion models to develop rehabilitated landform design batter geometries for a range of climates and mineral wastes. More detail on the process of testing, validation of the model outputs, and the character of the climate files used are discussed below. At this stage, it is important to note that the climate files used contain numerous rainfall events that represent a wide range of rainfall intensities, durations and frequencies. These range from frequent small events through to rare and large rainfall events. Therefore, the long-term erosion rates modelled are those derived from a wide range of rainfall events.

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Establishing acceptable long-term erosion rates

The suitability of the batter geometries is determined by comparison of the modelled long-term average erosion rates with rates that have been found to be acceptable. Historically, this long-term acceptable erosion rate has been set based on a desire to limit the initiation of rill erosion. More recently, a review of acceptable erosion rates for the Pilbara region considered acceptability using six different concepts: rates of soil renewal, maintenance of soil quality, rates of natural erosion, rates that lead to gully development, water quality, and impacts on vegetation[5]. The results of this review confirmed that the rates of long-term erosion used to classify the acceptability of modelled batter geometries are consistent with those found to be acceptable using the wider range of concepts.

2. Identification and classification of key minerals wastes

The following section seeks to describe the different waste types extracted from Rio Tinto (WA) iron ore mines in the Pilbara, and explain the rationale behind the selection of the key mineral wastes for which detailed testing of erodibility was conducted.

[5] Howard, E.J. and Loch, R.J. (2019) *Acceptable erosion rates for mine waste landform rehabilitation modelling in the Pilbara, Western Australia*, in AB Fourie & M Tibbett (eds), Proceedings of the 13th International Conference on Mine Closure, Australian Centre for Geomechanics, Perth, pp. 1545-1560, https://doi.org/10.36487/ACG_rep/1915_121_Howard

2.1 Waste types

Rio Tinto Iron Ore (WA) initially defines mineral wastes based on deposit geology which is described in detail in *Geology and Mineralogy of the Hamersley Province Ores*[6]. Deposit geologies include the Banded Iron Formation from which come Brockman and Marra Mamba hosted deposits, and Channel Iron Deposits. Other deposits such as Detrital Iron Deposits can occur as overburden to the ore hosted in the more extensive Banded Iron Formation.

Mineral wastes within each deposit geology are subsequently classified by their waste 'geozone'. Geozones are well-defined sequences of rock strata that have consistent characteristics across broad regions of the Pilbara. A total of 18 waste geozones were identified for Brockman deposits, 18 for Marra Mamba deposits and 8 for Channel Iron Deposits. Each waste geozone can then be further classified into individual waste types. Table 1 lists the mineral waste types defined by Rio Tinto. They are found within different waste geozones. The abundance of the different wastes can vary between geozones.

Table 1: Mineral waste types found within various waste geozones.

Banded Iron Formation (BIF)	Pyrolusite*	Aluminous Shale
Magnetic BIF	Pyrite*	Pisolite
Quartz*	Dolerite (fresh)	Calcite
Siliceous Goethite	Manganese*	Clay
Cherty BIF	Dolomite	Water Reactive Clay
Ferruginous Chert	Dolerite	Soil
Secondary Silica*	Hematite*	Powdery BIF
Jasperlitic BIF	Shale	Cavity Fill
Goethitic BIF	Ferruginous Shale	Dolerite (weathered)
Silcrete	Goethitic Shale	Crocidolite*
Goethitic Chert	Carbonaceous Shale	Calcrete
Magnetite	Manganiferous Shale	Ochreous Hematite

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* These minerals may be indicated as present in the waste material, but do not represent an actual waste rock type that is delineated within the geology/mining model.

2.2 Abundance of different waste types

The abundance of each waste type within the various waste geozones was assessed across Rio Tinto's Pilbara drill hole and geological database with specific focus on existing operations at the time of the study: Greater Paraburdoo, Western Turner Syncline, Brockman 2, Brockman 4, Mount Tom Price, Marandoo, Nammuldi, Silvergrass East, Hope Downs 1 (North and South), Mesa A, Mesa J, and Mesa K.

For Brockman and Marra Mamba deposits, the assessment utilised existing drilling records that generally list geozone, material type, and material hardness for each drilling sample length (typically a vertical interval of 1.5m or 2.0m depending on the age of the database). Wastes can be described as hard, medium, or soft, with hard wastes being more competent and slow

[6] Rio Tinto Iron Ore (2010) Geology and Mineralogy of the Hamersley Province Ores, Rio Tinto Iron Ore.

weathering, and likely to present as rocky waste once blasted and transported to a waste stockpile. Soft wastes tend to be more weathered and/or fine-grained or unconsolidated. In terms of erosion, they tend to represent more problematic materials than the hard wastes. Medium wastes are neither hard nor soft (or are a combination of the two), and for the sake of this assessment were considered more erodible than the harder wastes. For each of the sites listed above, the drilling records were first separated into the different waste geozones. Then, within each waste geozone, the abundance of different waste types was determined.

To assist in assessment of the large database of materials, these waste types were grouped into 'hard', 'medium', and 'soft' wastes[7]. In doing so, the abundance of different wastes within each waste geozones could be determined and the major wastes (typically those comprising more than ~90% of the waste) identified. Sections marked as ore were excluded from this assessment.

It is noted that geozones describe a mixture of waste types. Given that individual waste types are not generally segregated during mining, defining wastes more broadly by their geozones and assessing these (rather than individual waste types) provide a realistic basis from which to assess erosion potential. Defining the erodibility of individual waste types could be misleading and difficult to apply to create landform designs. For Channel Iron Deposits, geozones were not defined at the time of sample collection and testing. In these cases individual waste types were assessed. This is suitable because the different wastes can be managed as separate materials.

The assessment of wastes for the Brockman and Marra Mamba deposits and Channel Iron Deposits are described below.

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2.3 Wastes within Brockman and Marra Mamba hosted deposits

Summary data for the wastes from the Brockman and Marra Mamba deposits were sourced from Landloch's report titled *Final Landform Design Criteria for Mine Planning*[8].

A summary of the mineral waste assessment for the Brockman hosted deposits[9] and Marra Mamba hosted deposits[10] are shown in Tables 2 and 3, respectively. Also listed in these tables are the major waste types for each waste geozone. This is based on the assessment of Rio Tinto's drill hole data.

There were several key findings of the assessment:

- The proportions of individual waste types contained within a particular geozone remains relatively consistent irrespective of the ore body in question. This means that a geozone can be used to describe a relatively consistent mixture of different material types.

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[7] Hard waste types include Banded Iron Formation (BIF), Calcrete, Magnetic BIF, Siliceous BIF, Cherty BIF, Ferruginous Chert, Jasperlitic BIF, Goethitic BIF, Silcrete, Goethitic Chert, Magnesite, Fresh Dolerite, Medium wastes include Dolomite. Soft wastes include Shale, Ferruginous Shale, Goethitic Shale, Carbonaceous Shale, Manganiferous Shale, Aluminous Shale, Pisolite, Clay, Water Reactive Clay, Soil, Powdery BIF, Cavity Fill, Dolerite (weathered), and Ochreous Hematite.

[8] Landloch Pty Ltd (2012) Final landform design criteria for mine planning, Report prepared for Rio Tinto Iron Ore (WA)

[9] Deposits included SEC6, SEC7, 4EST, 4WES, 5W, 94E, CHE, 84E, 64E, 47E, 37E, 32E, 23E, 24E, 11W, B1, S17, and S10.

[10] The assessment used a range of Marra Mamba mine site, including Silvergrass, Hope Downs 1 North, Hope Downs 1 South, Marandoo, and Nammuldi.

- The Dales Gorge waste geozones (401, 411, 421, 431), Joffre waste geozones (201-261), Footwall zone geozone (501), and the Marra Mamba geozones (711-781) excluding West Angelas Shale (701) all contain similar proportions of hard wastes and similar dominant waste types. Therefore, these geozones can be considered to be similar from the perspective of erosion.
- The West Angelas Shale (701, 705) geozones are similar to each other but different to other Marra Mamba geozones. Therefore, these two geozones can be considered erosionally similar.
- The Whaleback Shale waste geozones (301,311) contain similar proportions of hard and soft wastes and the same dominant waste types. These can also be considered erosionally similar.
- Detritals are variable in their abundance of hard waste types, though they tend to be dominated by clay and shale wastes. Therefore, it can be expected that there is variability in the erosion potential of materials geologically classed as detritals.

Table 2: Proportion of hard and soft and medium wastes within the Brockman waste geozones.

Waste Geozone	Mean Proportion (%)of:		Major Waste Types	
	Hard Materials	Soft and Medium Materials	Hard	Soft/Medium
201 – Joffre 6	78	22	BIF wastes	Shales
211 – Joffre 5	83	17	BIF wastes	-
221 – Joffre 4	84	16	BIF wastes	-
231 – Joffre 3	80	20	BIF wastes	-
241 – Joffre 2	82	18	BIF wastes	-
251 – Joffre 1	77	23	BIF wastes	Shales
261 – Undifferentiated Joffre	78	22	BIF wastes	Shales
265 – Joffre Hydrated	34	66	BIF wastes	Shales
301 – Whaleback Shale 2	38	62	BIF wastes	Shales, Ferruginous Shale
311 – Whaleback Shale 1	49	51	BIF wastes	Shales, Ferruginous Shale
321 – Undifferentiated Whaleback Shale	48	52	BIF wastes	Shales
325 – Whaleback Shale Hydrated	25	75	BIF wastes	Shales, Ferruginous Shale
401 – Dales Gorge 3	83	17	BIF wastes	Shales
411 – Dales Gorge 2	75	25	BIF wastes	Shales
421 – Dales Gorge 1	83	17	BIF wastes	Shales
431 – Undifferentiated Dales Gorge	70	30	BIF wastes	Powdery BIF, Shales
435 – Dales Gorge Hydrated	31	69	BIF wastes	Shales
501 – Footwall Zone	62	38	BIF wastes	Shales
601 – Mount McRae Shale	5	95	BIF wastes	Shales, Carbonaceous Shale

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Given these findings, and the fact that different waste types within a geozone are not generally segregated during mining, waste geozones were used as the basic waste unit to assess material erodibility and from which landform batter geometries were developed.

Table 3: Proportion of hard and soft and medium wastes within the Marra Mamba waste geozones.

Waste Geozone	Mean Proportion (%)of:		Major Waste	
	Hard Materials	Soft + Medium Materials	Hard	Soft/Medium
701 – West Angelas Shale	16	84	BIF wastes	Shales, Clay
705 – West Angelas Shale Hydrated	12	88	-	Shales, Clay
781 – Undifferentiated Marra Mamba	74	26	BIF wastes	-
711 – Undifferentiated Newman	83	17	BIF wastes	-
741 – Newman	45	55	BIF wastes	Shales
721 – Newman	75	25	BIF wastes	-
731 – Newman	75	25	BIF wastes	-
751 – Newman	83	17	BIF wastes	-
761 – MacLeod	64	36	BIF wastes	Shales
771 – Nammuldi	71	29	BIF wastes	Shales
785 – Marra Mamba Hydrated	15	85	BIF wastes	Shales, Clay
7 – Detritals	6	94	-	Clay, Shales
8 – Calcrete Detritals	9	91	-	Calcrete, Clay
9 – Lignite Detritals	4	96	-	Clay, Shales
11 – Colluvium Detritals	27	73	-	Clay, Shales
12 – Rounded Detritals	25	75	-	Clay, Shales
31 – Cemented Limonitic Detritals	15	85	-	Clay
81 – Siderite Detritals	5	95	-	Clay, Dolomite

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2.4 Material selection

Based on the assessment of materials detailed above, the following key materials were identified:

- Dales Gorge Member, Footwall Zone, and Marra Mamba (considered collectively);
- Joffre Member;
- Whaleback Shale;
- West Angelas Shale;
- Weathered pisolite;
- Alluvials; and
- Detritals.

Hydrated zone materials were also considered separately because it was recognised by Rio Tinto geologists that:

- They are available at the start of mining for all deposits;
- They tend to include stable, coarse, blocky material with minor fine-grained components;
- They are likely to be more similar in appearance to materials from the natural landscape than some wastes and hence are preferred in this sense;
- Being weathered, they are relatively inert (low ARD risk);
- They are generally available in large volumes; and
- There may be more flexibility to stockpile them and use in final waste dumps.

3. Material testing

Erodibility studies have been carried out on 48 waste samples from Rio Tinto's Pilbara iron ore mining operations. The waste types tested include Alluvials, Calcrete, Clay Waste, Coarse Tails, Dales Gorge Member, Detritals, Footwall Zone, Hydrated Zone, Joffre Member, Limonite (a type of detrital), Mount McRae Shale, Mount Newman Member, Powdery BIF, Tertiary Pisolite Clay, Topsoil, Weathered Dolerite, Whaleback Shale, Weathered Pisolite, and West Angelas Shale. Of these 48 bulk samples, 6 were sourced specifically from Hope Downs 1:

- Hydrated Zone;
- Limonite;
- Mount Newman Member dominated by BIF (2 samples); and
- Detritals (3 samples).

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These material types cover 75% of the waste from HD1 North, 79% of the waste at HD1 South, 85% of the waste at BH, 44% of the waste from HD2. An additional 8 samples of Dales Gorge and Joffre wastes, and 5 samples of West Angelas Shale are available from other Rio Tinto iron ore sites. Using these, 84% of the HD2 waste types have also been broadly characterised. These would be broadly applicable to both HD1 and HD2.

3.1 Material characterisation testing

Samples of the fine component (<2 mm) of these materials were sent to a commercial soil laboratory and analysed for soil $pH_{1:5}$, $EC_{1:5}$ as a measure of salinity, Exchangeable Sodium Percentage (ESP), and particle size distribution (coarse sand, fine sand, silt, and clay). These properties were used to define risks to vegetation growth inherent in the wastes (e.g. salinity and poor structure), and to consider risks associated with tunnel erosion. The data was also used to assist in parameterising the runoff and erosion model.

The coarse component (>16 mm) of the rocky wastes were further assessed for properties that indicate their likely durability, tendency to weather, and usefulness as an armour material. Properties assessed include rock particle size, rock particle density, and rock water absorption.

3.2 Material erodibility

Assessment of long-term erosion potential for each of the materials was assessed using the Water Erosion Prediction Program (WEPP) model. WEPP describes erodibility using 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).

These WEPP erodibility parameters were derived for each of the 48 samples from data collected using application of:

- Simulated rain to a soil or waste surface, and measurement of runoff and sediment in runoff to obtain estimates of K_i and K_e; and
- Surface water flows to obtain estimates of K_R and τ_c.

Rainfall simulation and overland flows

Rainfall and overland flow simulation have been widely used to define the erodibility of mine wastes in WA. The process is briefly described below.

For rainfall simulation, flat fan nozzles mounted on an oscillating manifold positioned ~2m above a test surface produce the simulated rain (Figure 1). The kinetic energy generated by the nozzles are ~29.5 J/m2/mm, consistent with the energy of natural rainfall at intensities >40 mm/h. The nozzles uniformly sweep back and forth across the test plots, achieving high spatial distribution (<10% coefficient of variation) of the generated rainfall. For each material triplicate plots are subjected to a rainfall event sufficiently intense (usually 80-100mm/hr) to ensure runoff occurs. This allows measurement of rainfall infiltration and interrill erodibility.

For overland flow simulations, rill erodibility parameters are derived by applying various rates of overland flow to flumes 0.4 m wide and 2.0 m long set at gradients ranging from 10-30% (Figure 2). Rill erodibility and critical shear were derived on the basis of relationships between flow shear stress and sediment detachment rates measured from these flumes.

A summary of the parameter values adopted for each broad waste type (combining like samples) is also listed below in Table 5. The adopted parameter values of Table 5 represent an average value for each parameter for all samples collected within the material type.

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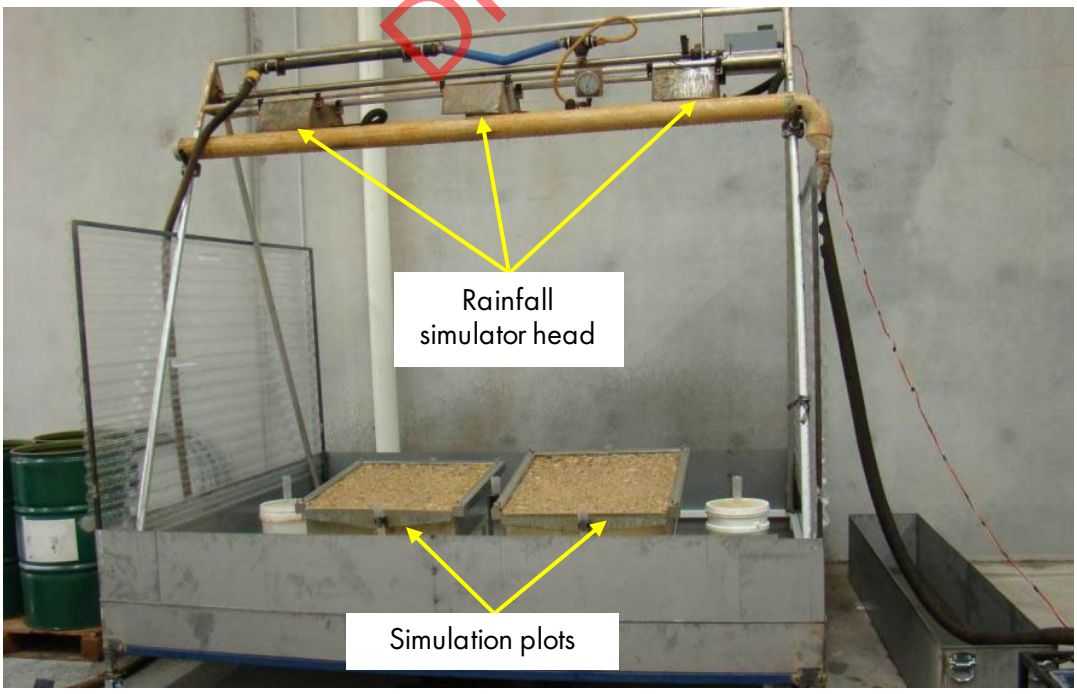

Figure 1: Typical laboratory-based rainfall simulator installation

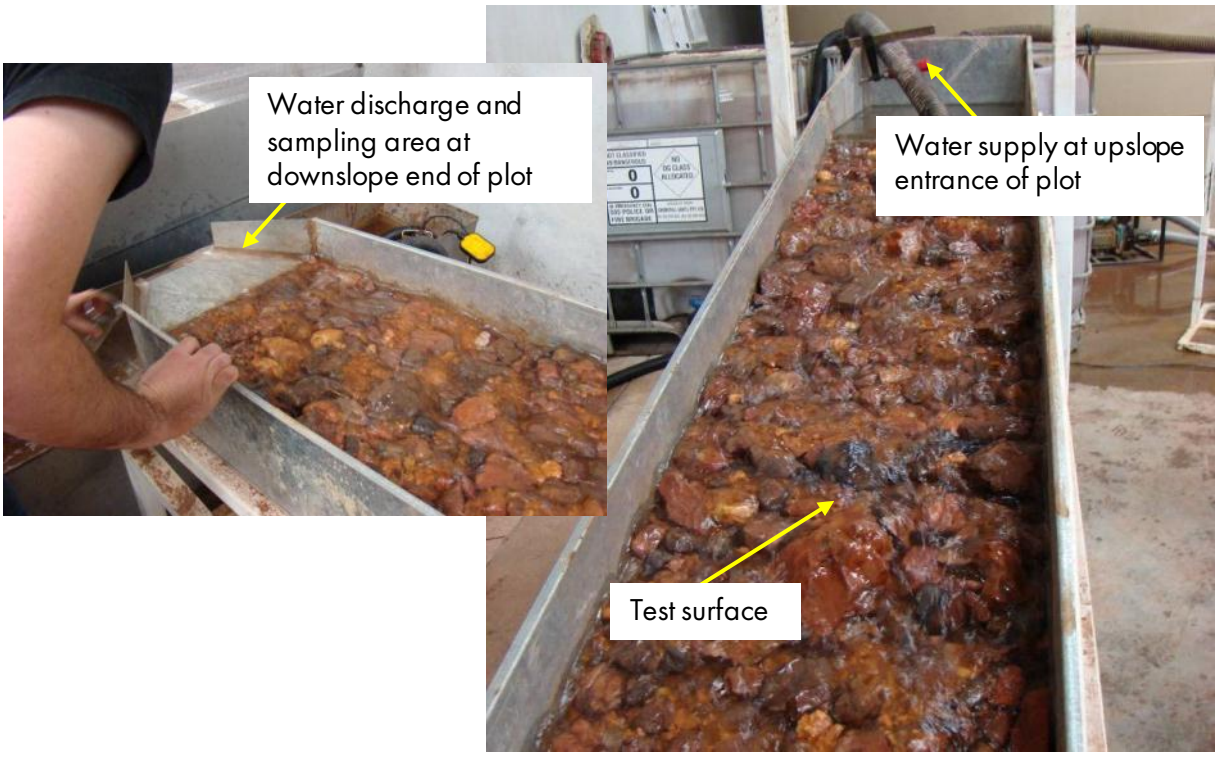

Figure 2: Example of flume plot setup used to apply overland flows.

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Table 5: Parameter values adopted for each waste material.

Material	**K_e (mm/h)**	**K_i (kg.s/m^4)**	**K_R (s/m)**	**τ_c (Pa)**
Alluvials	20	246,568	0.0072	28
West Angelas Shale	28	609,814	0.0030	19
Calcrete	34	349,975	0.0016	46
Clay waste	10	285,844	0.0043	13
Detritals	26	236,317	0.0116	28
Dales Gorge	33	203,540	0.0033	28
Dolerite	20	335,337	0.0027	11
Footwall	33	203,540	0.0033	28
Hydrated Zone	103	63,860	0.0030	28
Joffre	33	203,540	0.0033	28
Limonite	25	448,929	0.0029	40
MacLeod Member	33	203,540	0.0033	28
McRae Shale	25	763,560	0.0010	20
Nammuldi Member	33	203,540	0.0033	28
Mt Newman Member	25	311,045	0.0034	44
Powdery BIF	12	531,064	0.0090	10
Tertiary Pisolite Clay	11	435,600	0.0016	37
Weathered pisolite	15	612,276	0.0097	6
Whaleback Shale	46	100,207	0.0042	26

The erodibility parameters that underpin the adopted batter geometries are:

- Material specific and collected in such a way[11] that they can be used for a range of locations and data geometries;
- A direct measure of erosion potential for a material (not a surrogate measure);
- Repeatable, with the methods having been first developed by the U.S. Department of Agriculture, and used hundreds of times by numerous groups to generate parameters.
- Accurate and precise, with assessments of measured erosion from many rehabilitation landforms being shown to be close to modelled values calculated using these erodibility parameters (see Validation of WEPP Modelling section below).

3.3 Erosion modelling

The WEPP model

The 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 watersheds. 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). Soil characteristics important to erosion processes are updated every day. When rainfall occurs, those soil characteristics are considered in determining the likelihood of any runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the inputted slope profile. The erosion component of the WEPP model uses a steady-state sediment continuity equation as the basis for the 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 flow hydraulic shear stress, and when the sediment load of the flow is below its capacity to transport sediment. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

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Climate data

All WEPP simulations developed by Landloch use a 100-year stochastic climate sequence for Rio Tinto sites derived from observed data from the sites themselves and nearby Bureau of Meteorology weather stations. Nine associated climate sequences were created for 15 mine sites:

- Brockman 2, Brockman 4, and Nammuldi;
- Tom Price and Western Turner Syncline;
- West Angelas;
- Channar, Eastern Range, and Paraburdoo;
- Marandoo;
- Hope Downs 1;
- Hope Downs 4;
- Mesa J and Mesa A; and
- Yandicoogina.

[11] By defining erodibility on a shear stress-basis and not on the basis of a set slope length or gradient.

Each of the 9 sequences contain 36,525 daily climate data sets that describe rainfall total, storm duration and intensities, temperature, solar radiation, and wind. The 100-year sequences contain a wide range of rainfall events, including several extreme events. Each climate sequence was assessed against the Bureau of Meteorology's Design Rainfall Data System to consider the Annual Exceedance Probabilities (AEP) of the larger rainfall events. The findings were summarised in Table 6.

Table 6: AEP and ARI values of the three rarest rainfall events per climate sequence.

Climate Sequence	Rainfall Event Details					
	Rarest		2nd Rarest		3rd Rarest	
	Total & Duration	AEP & ARI	Total & Duration	AEP & ARI	Total & Duration	AEP & ARI
Annual Exceedance Probability (%)						
Brockman 2 & 4, and Nammuldi	268mm 5 hours	<0.05	175mm 5 hours	0.07	171mm 4 hours	0.1
Tom Price & Western Turner Syncline	256mm 4 hours	<0.05	145mm 3 hours	0.05	135mm 7 hours	0.7
West Angelas	145mm 5 hours	0.2	140mm 4 hours	0.2	147mm 11 hours	1
Channar, Eastern Range, & Paraburdoo	317mm 13 hours	0.1	176mm 6 hours	0.2	140mm 4 hours	0.2
Marandoo	289mm 9 hours	<0.05	223mm 6 hours	0.05	165mm 6 hours	0.2
Hope Downs 1/2	195mm 7 hours	0.3	194mm 7 hours	0.3	203mm 10 hours	0.5
Hope Downs 4	254mm 12 hours	0.3	211mm 10 hours	0.5	189mm 9 hours	1
Mesa J and Mesa A	301mm 7 hours	0.05	282mm 11 hours	0.2	181mm 7 hours	1
Yandi	219mm 4 hours	0.07	177mm 5 hours	0.5	143mm 4 hours	0.7
Average Recurrence Interval (Years)						
Brockman 2 & 4, and Nammuldi	268mm 5 hours	>2,000	175mm 5 hours	1,500	171mm 4 hours	1,000
Tom Price & Western Turner Syncline	256mm 4 hours	>2,000	145mm 3 hours	2,000	135mm 7 hours	150
West Angelas	145mm 5 hours	500	140mm 4 hours	500	147mm 11 hours	100
Channar, Eastern Range, & Paraburdoo	317mm 13 hours	1,000	176mm 6 hours	500	140mm 4 hours	500
Marandoo	289mm 9 hours	>2,000	223mm 6 hours	2,000	165mm 6 hours	500
Hope Downs 1/2	195mm 7 hours	333	194mm 7 hours	333	203mm 10 hours	200
Hope Downs 4	254mm 12 hours	333	211mm 10 hours	200	189mm 9 hours	100
Mesa J and Mesa A	301mm 7 hours	2,000	282mm 11 hours	500	181mm 7 hours	100
Yandi	219mm 4 hours	1,500	177mm 5 hours	200	143mm 4 hours	150

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The rarest event within the climate sequences typically has an AEP <0.2%, equivalent to rainfall storms with an average recurrence interval (ARI) of more than 500 years. These storms are defined within the Australian Rainfall and Runoff Guideline (AR&R) as 'very rare' rainfall events. In several cases, the rarest event has an AEP of <0.05% (>2,000 year ARI). These are consistent with 'extreme' rainfall events as defined by AR&R. The rarest event within the Hope Downs' sequence is an AEP of <0.3% (333 year ARI).

It is also noted that there are several extreme to very rare rainfall events in each of the climate sequences. For example, for HD1, the second rarest rainfall event has an AEP of 0.3% (333 year ARI) and the third rarest event has an AEP of 0.5% (200 year ARI). Therefore, it can be concluded that these climate sequences represent climates consistent with long-term averages, including the occurrence of multiple very rare rainfall events. The resultant erosion modelling is therefore also consistent with long-term averages, including the erosion that would occur from very rare events.

Erosion of differing batter geometries

The different waste materials have different erodibilities. This translates into different erosion potentials (hence the generally classification of some wastes as being high erodibility and others being medium and low erodibility). The erosionally stable batter geometries developed for each material account for these differences in erosion potential by adopting different slope geometries. For example, a material that is highly erodible would require to be used on much shorter slope lengths (same as smaller vertical intervals). A less erodible material could be used on longer slope lengths.

The appropriate slope geometry is set by assessing the modelled long-term erosion rate against acceptable erosion rates for the Pilbara. Howard and Loch (2019)[12] produced a summary of acceptable erosion rates for the Pilbara region. It considered a number of approaches by which an acceptable erosion rate could be defined. They include linking erosion rates to:

- Rates of soil renewal (soil formation and deposition by dust);
- Maintenance of surface soil/growth media quality;
- Rates of naturally occurring erosion in the Pilbara;
- Rates that increase the potential for gully development;
- Water quality and off site impacts; and
- Impacts on vegetation.

Based on this assessment, it was found that – regardless of the approach – the acceptable rates of long-term erosion were similar. A value of 6t/ha/y for long term average slope erosion was found to be reasonable, consistent with the rates of soil renewal and naturally occurring erosion, and consistent with a surface with a low tendency for rill and gully erosion. Given that the batter geometries that are typically adopted by Rio Tinto are modelled to erode at rates less than 6t/ha/y, it is considered that the slopes being used are suitable, provided surface water control from the dump top and berms are also suitably managed.

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[12] Howard, EJ & Loch, RJ 2019, 'Acceptable erosion rates for mine waste landform rehabilitation modelling in the Pilbara, Western Australia', in AB Fourie & M Tibbett (eds), Proceedings of the 13th International Conference on Mine Closure, Australian Centre for Geomechanics, Perth, pp. 1545-1560, https://doi.org/10.36487/ACG_rep/1915_121_Howard

Validation of WEPP modelling

WEPP model validation data is provided to demonstrate that it is able to adequately predict erosion in a mining context. The WEPP model has been extensively validated by Landloch for mine site batters (Figure 3). Erosion data for this validation were sourced from 27 locations on 12 waste landforms on mine sites in Western Australia. Several sites were located at Rio Tinto's Pilbara iron ore sites. The observed erosion data were collected using cross-slope transects 30-50 m wide, located on upper and lower sections of waste dump batters. Batter shapes include both linear and concave cross-sectional profiles. Gradients assessed are consistent with the slopes commonly used for mining landforms. Surfaces assessed include loamy soils, clay soils, and rocky sandy loam soils. The ages of the batters range from 3–8 years. Slope conditions range from minimally eroded to heavily eroded.

The measured cumulative erosion rates show good agreement with rates predicted by WEPP. Given that these data include predictions from both the upper and lower section of landform batters, WEPP is shown to be able to suitably predict changes in erosion rates with changing slope lengths and gradients. Model output can adequately represent both runoff accumulation down the slope, and flow concentration across the slope. The accuracy of the predictions shown in Figure 3 also indicates that the methods used to derive the essential model parameters are producing well calibrated model results. This gives confidence that accurate calibration of the WEPP model can be achieved provided suitable laboratory and field-based methodologies are used.

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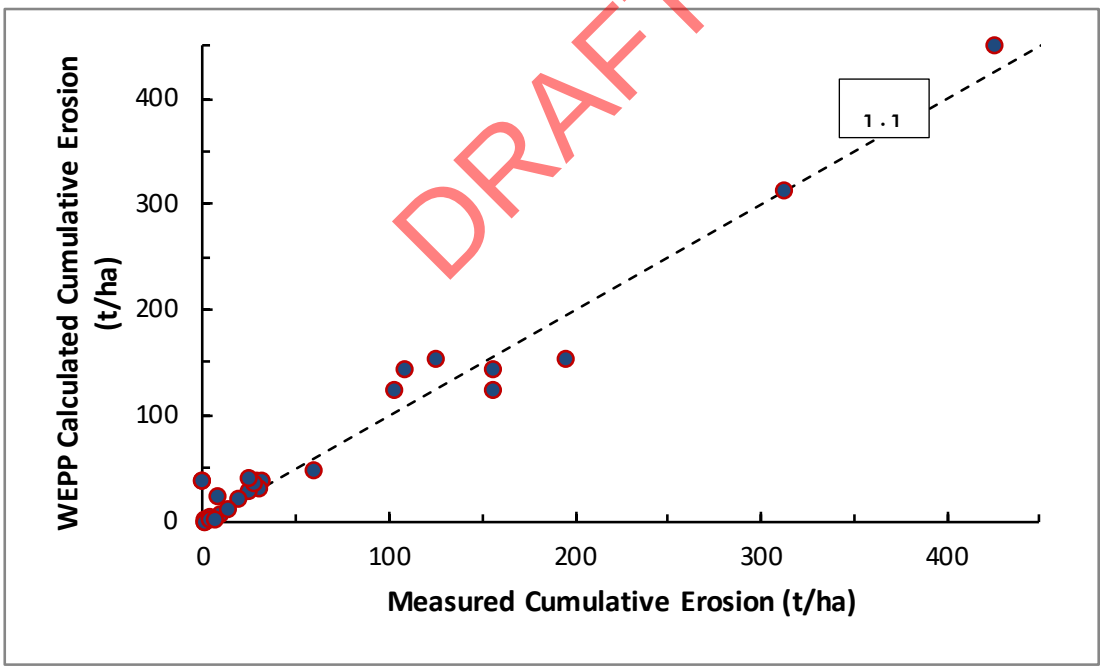

Figure 3: WEPP-predicted cumulative erosion and observed cumulative erosion rates for 27 batter slope locations from Western Australian mine sites.

Summary

Erosion modelling has used data collected from 48 samples of key wastes across Rio Tinto's Pilbara operations. These samples have been subjected to testing to measure their erodibility, with these erodibility parameters used to model long-term erosion using the WEPP model.

The climate sequences used in the modelling contain a wide range of rainfall events including several extreme and rare events. The model results have been compared against acceptable erosion rate values consistent with measured erosion for undisturbed land in the Pilbara, soil renewal rates, and rates at which the risk of rill and gully erosion is low. The model output has been validated at 27 locations on mine sites in Western Australia and shown to agree with observed erosion.

3.4 Landform evolution modelling

A range of erosion models exist that can be usefully deployed as part of landform design at different phases of mining operations. The models include process-based two-dimensional models such as WEPP, from which Rio Tinto's erosionally stable landform batter designs have been developed. The other type of model is a three-dimensional landform evolution model (LEM). The SIBERIA LEM is the most widely adopted model for use in mining, particularly in Australia. The key attributes of these different models are outlined in Table 7. The SIBERIA LEM is a model tailored to the consideration of the impacts of the 3-D shape on the long-term stability of a landform. SIBERIA modifies the 3-D shape of a landform in response to erosion and deposition. It is different to a surface water model in that it doesn't predict runoff or route flow over the surface. Rather it uses relationships between surface hydrology (contributing areas and discharge rates) and erosion to predict changes in 3-D landform shape.

Within the context of mining landforms, SIBERIA has been used to consider the:

- likelihood of the development of rill or gully erosion;
- breaching of surface layers required to encapsulate underlying problematic wastes;
- erosion risk at the interface of a waste landform and undisturbed ground;
- erosional impact of placement of different materials over the land surface.

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SIBERIA is more complex to parametrise than process-based erosion models such as WEPP. SIBERIA requires parameterisation with time series data of runoff and erosion for a specific material and broad landform shape. It does not accept input of daily rainfall values. Because it is fitted to time series data for runoff and erosion, the SIBERIA LEM cannot easily be used to predict erosion for a single rainfall event. For example, it is not able to be used to predict land changes in response to an extreme event. The intent of SIBERIA is to long long-term changes in landform shape (over decades or hundreds of years).

Given that the final 3-D landform shape is not exactly known during the early phases of mining (i.e. feasibility or approvals stage) and that SIBERIA is tailored to modelling 3-D shapes, the use of SIBERIA is limited in these early stages. Process-based models such as WEPP provide sufficient information in order for the broad geometry of a rehabilitation landform to be defined. For example, details such as the erosionally stable slope length, height, and gradient, the profile shape (linear, concave etc.) the required capacity of cross-slope berms and crest bunding can all be derived from WEPP modelling. If the broad shape of the landform is set based on erosion model output, and if the model output indicates that the broad scale will be erosionally stable in the long-term, the resultant 3-D landform is likely stable, assuming it is coupled with an investigation of surface water flows to account for risks such as impeding flood flows (which SIBERIA is not equipped to do). SIBERIA modelling becomes increasingly useful closer to the point of rehabilitation when more detailed engineering designs are completed and address risks such as how the landform ultimately meshes with the surrounding landscape.

Table 7: Key attributes of the WEPP and SIBERIA erosion and landform evolution models.

Attribute	WEPP	SIBERIA
Time step	Daily	Annual
Slope profiles considered	Complex	Very complex
Consideration of vegetation	Poor	Fair
Erodibility parameter	Measurable	Derived from runoff & erosion data
Consideration of sediment transport	Good	Fair
Consideration of different surface erosion processes	Good	Fair
Consideration of tunnel (piping) erosion	Not possible	Not possible
Prediction of deposition	Good	Fair
Modelled timeframes(s)	Single events-years	Years-hundreds of years

4. Materials of Hope Downs 1/2

4.1 Material abundance

Three deposits exist at Hope Downs 1 (HD1): HD1 North, HD1 South, and Baby Hope (BH). Hope Downs 2 (HD2) consists of both HD2 and the associated Bedded Hilltop (BHT) areas. Tables 5 and 6 provide a summary of the percentage of each waste material type at HD1 and HD2 respectively. Proportions for HD1 are those provided by B. Yaqub (Rio Tinto) on 22 July 2020. Proportions for HD2 are those from the 2020 Mine Closure Plan.

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Table 8: Waste material summary for HD1

Waste types	Waste Proportion (%) for:		
	HD1 North	HD1 South	BH
Marra Mamba (Newman, Nammuldi, MacLeod)	41	12	9
Detritals	52	31	61
Hydrated	1	42	15
Wittenoom	0	13	1
Other	5	1	14

Table 9: Waste material summary for HD2 including BHT

Waste types	Waste Proportion (%)
Marra Mamba (Newman, Nammuldi, MacLeod)	8
Detritals	36
Dales Gorge	22
West Angelas Shale	18
Footwall	7
Other	6

Newman Member materials and Detritals are dominant wastes at HD1 North and BH. Detritals and Hydrated Zone wastes are dominant at HD1 South. Dales Gorge and West Angelas Shale are present in appreciable proportions at HD2. Several materials specifically sourced from HD1 were recently tested, including a Detrital, a Limonite (a type of Detrital), and two examples of Newman Member materials. Previous testing for a Hydrated Zone waste and 2 other samples of Detrital also exist for HD1. Three examples of Dales Gorge are available from Tom Price and Western Turner Syncline, and 2 examples of West Angelas Shale and 1 Detrital are available from West Angelas and Marandoo. These materials will be used to discuss plant growth and erosion potential below. They are applicable for both HD1 and HD2.

4.2 Plant growth potential

A summary of these data for the HD1 and HD2 is given in Tables 10 and 11.

Table 10: Characteristics of the soil fraction (<2mm) of the specific Hope Downs 1 and other site wastes tested for erodibility.

Source Location	Geology	Particle Size Distribution (Fine Fraction)				Soil Texture	$pH_{1:5}$ (H_2O)	$EC_{1:5}$	ESP
		Coarse Sand	Fine Sand	Silt	Clay				
		%	%	%	%		-	dS/m	%
Hope Downs 1	Detrital (Col or Di)	61.4	7.4	7.6	23.6		6.1	0.07	5
	Limonite (Li)	56.2	18.9	9.9	14.9		7.6	0.07	2
	Newman Member	50.0	26.3	13.3	10.4		7.5	0.07	6
	Hydrated Zone	80		5	15	SL	-	-	-
	Detrital 1	59	24	0	16	SL	7.4	1.1	9
	Detrital 2	-	-	-	-	-	-	-	-
Tom Price/ Western Turner Syncline	Dales Gorge 1	24	2	38	34	CL	8.5	0.08	2
	Dales Gorge 2	45	22	24	25	CL	-	-	-
	Dales Gorge 3	18	23	20	35	ZL	-	-	-
West Angelas/ Marandoo	West Angelas Shale 1	28	33	8	32	CL	5.6	0.05	7
	West Angelas Shale 2	-	-	-	-	-	-	-	-

Notes: Coarse sand: 2.0-0.2mm; Fine sand: 0.2-0.02mm; Silt: 0.02-0.002mm; Clay <0.002mm. Texture: ZCL: Silty Clay Loam; SL: Sandy Loam; SCL: Sandy Clay Loam; CL: Clay Loam; ZL: Silty Loam. '-' indicates that no data are available for this parameters. Those samples with no baseline data shown here are included for completeness as they are present in the erodibility testing results.

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Table 11: Characteristics of the coarse fraction (>2mm) of the specific Hope Downs 1 and other site wastes tested for erodibility.

Source Location	Geology	Full Particle Size Distribution				Coarse Fraction Content	Rock Partide Density	Rock Water Absorption
		Rock	Pebble	Gravel	Fines			
		%	%	%	%	%	g/cm³	%
Hope Downs 1	Detrital (Col or Di)	12	14	49	23	77	3.2	1.4
	Limonite (Li)	20	11	38	31	69	2.3	12.5
	Newman Member	19	17	44	20	80	3.2	2.3
	Hydrated Zone	60	22	17	1	99	4.6	3.5
	Detrital 1	7	6	42	45	55	2.9	5.3
	Detrital 2	29	15	35	19	81	-	-
Tom Price/ Western Turner Syncline	Dales Gorge 1	32	22	33	13	87	2.3	13.2
	Dales Gorge 2	0	19	38	43	57	-	-
	Dales Gorge 3	0	32	18	50	50	-	-
West Angelas/ Marandoo	West Angelas Shale 1	21	12	39	28	72	-	-
	West Angelas Shale 2	0	8	12	80	20	-	-
	Detrital	8	11	56	26	74	-	-

Notes: Rock: >45mm; Pebble: 15-45mm; Gravel: 2-15mm; Fines: <2mm.

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The materials have the following properties:

- Commonly low salinity (though one sample had elevated salinity), with values unlikely to adversely affect plant germination or growth.
- Acidic to alkaline pH values.
- High coarse fraction content (50-99%, mean 73%) except for West Angelas Shale, which has ~20% coarse fraction.
- The rock fraction of the samples tested (Table 11) tends to be dense (high rock particle density) and the water absorption rates are low to moderate. The materials are likely to be reasonable for use as armouring, particularly materials that contain BIF.
- The fine fraction (< 2 mm diameter) of the samples tested tends to have a sandy loam to clay loam texture.
- Wastes generally have low (<6%) Exchangeable Sodium Percentage (ESP), though ESP values can be moderate (6-10%) on occasion. Low ESP indicates a clay fraction with a low tendency to disperse and a low risk of structural decline. One sample of Detrital has a slightly elevated ESP value (9%). However, this material would still have a low tendency for structural decline for the following reasons. In the case of the Detrital, 55% of the material is non-dispersive gravels, pebbles, and rock (Table 11). Of the remaining 45% of the material, 83% is non-dispersive sands and silts. Therefore, the potentially dispersive clays account for only 7% of the total volume of the Detrital material. One sample of West Angelas Shale also has elevated ESP values. Assessing it in the same way, 89% of the material is non-dispersive pebbles, gravels, sands, and silts, and only 11% of the material is potentially dispersive clay. The overall structure of these 2

moderate ESP materials is controlled by the significant proportion of non-dispersive coarse fragment. The majority of the voids between the non-dispersive coarse fragments are filled with non-dispersive sands. Therefore, if the clay were to disperse, it is not likely to mobilise through the void spaces within the material and will not likely result in tunnel erosion. That said, the dispersion of the clay may cause hardsetting surfaces that will impact runoff and erosion rates. This impact is incorporated in the erodibility testing and the erosionally stable batter geometries adopted for these materials.

4.3 Erodibility

Table 12 shows the site specific erodibility parameters for Hope Downs 1 (Western Turner Syncline data was used for Dales Gorge, and West Angelas was used for West Angelas Shale) compared to the average parameters adopted for erosion modelling and from which Rio Tinto has developed rehabilitation batter geometries.

Table 12: Site specific erodibility parameters and those generally adopted for erosion modelling.

Material	Erosion Class	K_e (mm/h)	K_i (kg.s/m^4)	K_R (s/m)	τ_c (Pa)
Detritals (Col or Di)					
Average Value (Detrital)	High	26	236,317	0.0116	28
HD1 COL/DI Sample	High	7	375,227	0.0022	40
Limonite (Li)					
Average Value (Detrital)	High	26	236,317	0.0116	28
HD1 LI Sample	High	25	448,929	0.0029	40
Detritals					
Average Value	High	26	236,317	0.0116	28
HD 1 DET Samples (average of 2)	High	27	272,445	0.0085	21
Newman Member 1					
Average Value	Low	33	203,540	0.0033	28
HD1 NEW Sample	Low	10	347,648	0.0014	41
Newman Member 2					
Average Value	Low	33	203,540	0.0033	28
HD1 NEW Sample	Low	40	274,442	0.0054	46
Hydrated Zone					
Average Value	Low	103	63,860	0.0030	28
HD1 HYD Sample	Low	200	50,000	0.0001	14
Dales Gorge					
Average Value	Low	33	203,540	0.0033	28
WTS DG Sample	Low	18	128,962	0.0010	45
West Angelas Shale					
Average Value	High	28	609,814	0.0030	19
West Angelas ANG Samples (average of 2)	High	18	594,097	0.0102	17

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The impact of this variation in erodibility parameters was assessed by conducting additional modelling with the WEPP model. Predicted erosion for the Detritals using the average parameters indicates that a stable geometry would be a uniform gradient of 20 degrees and height of 7m. When compared to the 'Col or Di' form of detritals, the Col or Di materials are more erosion resistant, achieving stable heights of 15m at 20 degrees. For the Limonite material, the stable height is predicted to be 20m at 20 degrees. Therefore, these materials are more resistant to erosion than the average Detritals. The Detritals from HD1 are predicted to erode at rates similar to the rates predicted using the average parameter set, and stable heights for the HD1 Detritals are similar to those predicted using the average parameters.

Based on these results, it can be concluded that the HD1 detritals have similar erodibility or are more erosion resistant that the average Detrital from which landform batter geometries have been developed.

Historically, the Newman Member materials have been considered similar to the Dales Gorge material because of a similar composition. Testing of two samples of the Newman Member materials from HD1 has shown that both samples are as or more resistant to erosion than the average Dales Gorge parameters. As such, stable heights of 20m and gradients of 20 degrees are suitable for this material.

The Hydrated Zone waste from HD1 is much more erosion resistant than the average Hydrated parameters that have been used to generate stable batter geometries for this material. Therefore, stable heights of 20m and gradients of 20 degrees are suitable for this material.

For the Dales Gorge waste, there are no samples from HD1 or HD2. Adoption of the average Dales Gorge parameters from Western Turner Syncline predicts that 20m high batters at 20 degrees are stable. Additional modelling suggests that slope heights of 15m and gradients of 20 degrees would have erosion rates higher than adopted in previous modelling but within the rates of acceptable erosion reported for the Pilbara by Howard and Loch (2019)[13]. Therefore, the slope geometries adopted for Dales Gorge using the average parameter set appear reasonable.

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For West Angelas Shale, there are no parameters specific to HD1. These materials are highly erodible, and when the West Angelas Shale from West Angelas were considered (the closest site to HD1), they were found to be more erodible than the average parameter set. This indicates that this material poses a risk in terms of erosion and will require specific management (i.e. burial) if slope heights greater than 5m are adopted at HD1 or HD2.

5. Closing

Erosion modelling has used data collected from 48 samples of key wastes across Rio Tinto's Pilbara operations. These samples have been subjected to testing to measure their erodibility, with these erodibility parameters used to model long-term erosion using the WEPP model. The climate sequences used in the modelling contain a wide range of rainfall events including several extreme and rare events.

[13] Howard, EJ & Loch, RJ 2019, 'Acceptable erosion rates for mine waste landform rehabilitation modelling in the Pilbara, Western Australia', in AB Fourie & M Tibbett (eds), Proceedings of the 13th International Conference on Mine Closure, Australian Centre for Geomechanics, Perth, pp. 1545-1560, https://doi.org/10.36487/ACG_rep/1915_121_Howard

The model results have been compared against acceptable erosion rate values consistent with measured erosion for undisturbed land in the Pilbara, soil renewal rates, and rates at which the risk of rill and gully erosion is low. The model output has been validated at 27 locations on mine sites in Western Australia and shown to agree with observed erosion.

An assessment of the samples specific to Hope Downs 1/2 (and for other sites with similar waste types) show that the batter geometries generated using the averaged adopted erodibility parameters will be suitable for use at Hope Downs 1/2, with the exception of West Angelas Shale. This waste was shown to be erodible, and will require specific management (i.e. burial) if batter heights greater than 5m are adopted at HD1 or HD2.

Regards

Mr EVAN HOWARD
PRINCIPAL CONSULTANT

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All care and diligence have been exercised in testing, interpreting data and the development of recommendations presented in this document. 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 document.

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Appendix 8: Suitability of Topsoil for Plant Growth HD2 & BHT

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SUITABILITY OF TOPSOIL FOR PLANT GROWTH

HOPE DOWNS 2 AND BEDDED HILLTOP

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Rio Tinto Iron Ore

May 2022

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TOOWOOMBA
PO Box 57
HARLAXTON QLD 4350
Phone (07) 4613 1825

PERTH
PO Box 5175
SOUTH LAKE WA 6164
Phone (08) 9494 2835

NEWCASTLE
PO Box 7017
Redhead NSW 2290
Phone (02) 4965 7717

Landloch Pty Ltd
A.C.N. 011 032 803
A.B.N. 29011032803

Web site: www.landloch.com.au
Email: admin@landloch.com.au

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EXECUTIVE SUMMARY

Landloch Pty Ltd (Landloch) was engaged by Rio Tinto Iron Ore (RTIO) to undertake characterisation testing of a range of soils from Hope Downs 2 and Bedded Hilltop. Thirty-eight (38) soil samples were selected by RTIO and tested for a range of parameters. The purpose of the characterisation was to determine the plant growth potential of the soils, with pH, salinity, structural stability, water regime, and fertility all being considered.

Fifty-two percent of the Hope Downs 2 soils have pH values that are lower than would be expected from the available broad scale data; 48% of the soils have suitable pH values. All but 2 of the 15 Bedded Hilltop soils have suitable pH. The low values for some soils are not commonly leading to increased available aluminium concentrations, nor are they leading to a reduction in nutrient availability to levels likely to limit plant growth. However, there could be some negative impact on soil biological activity. It is concluded that the low pH of some soils is not likely to have a significant impact on vegetation growth, and that field or pot trials aimed at establishing this for the low pH soils may be useful. If it is established that vegetation is adversely impacted by the low pH, amendments such as lime could be considered to increase pH values.

The salinity values of all soils are <1dS/m. The soluble chloride values for all soils are also low. Salinity is not likely to limit plant growth.

More of the Bedded Hilltop soils are structurally stable than for Hope Downs 2s. Eleven of the 15 Bedded Hilltop soils (73%) are classed as stable. Eleven of the 23 Hope Downs 2 soils (48%) are classed as stable. In total, 22 of the 38 soils (58%) are structurally stable. The soils that are classed as unstable are spatially well distributed across the Hope Downs 2 and Bedded Hilltop areas. Soils that are classed as structurally unstable are more prone to:

- Reduced permeability;
- Reduced water holding capacity;
- Increased runoff potential;
- Increased erosion potential;
- Reduced root penetrability; and
- Increased tunnel erosion potential.

Given that the *in situ* soils have low salinity and that the observed instability in the sampled soils was often also driven by low salinity, it can be concluded that *in situ* soils may also be structurally unstable and that the sampled soils are therefore similar to the *in situ* soils. The risk posed by structural instability could be addressed through mixing of these soils into rockier, structurally stable wastes as part of rehabilitation. Alternatively, placement of these soils on low gradient areas (<10%) would reduce the risk posed by increased erosion potential. Addition of gypsum could be considered for soils with elevated ESP and low ESI. This includes all structurally unstable soils except for one soil sample (HD2_05). An application rate of 0.2t/ha incorporated into a layer that is 0.1m thick is recommended.

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The Hope Downs 2 soils have higher median total N values than the Bedded Hilltop soils. This could be due to reduced vegetation in the shallower soils from Bedded Hilltop. Soil from Both Hope Downs 2 and Bedded Hilltop have median C:N ratios of 20, indicating that decomposition rates of organic matter will be slightly reduced for many of the soils, and vegetation growth may be improved by addition of some nitrogen. Addition of N as a means of improving vegetation growth should be considered. Options include mixing of low total N soils with higher total N soils, .addition of N-based fertilisers, and inclusion of N-fixing vegetation into the rehabilitation seed mixes.

Total P, available P, available S, trace Cu, trace Mn, and trace Zn values for all soils are within suitable levels. The available K is slightly low for 87% of the Bedded Hilltop soils, but low for only 26% of the Hope Downs 2 soils. Despite being low, these values may not translate into adverse conditions for plant growth. The impact of the addition of potassium could be considered along with the impact of the addition of N within pot or field vegetation trials.

The median plant available water (PAW) value (unadjusted for rock) for both the Hope Downs 2 and Bedded Hilltop soils is 90mm/m. This is classed as suitable. When adjusted for rock, the median PAW for the Hope Downs 2 and Bedded Hilltop soils was 42mm/m and 32mm/m, respectively. Given that rainfall events are often larger than this PAW, the underlying waste materials are likely to function as a water storage zone that plants will need to access. The properties of the material below the soil applied are also important when considering plant growth potential.

Saturated hydraulic conductivity (K_{sat}) values are often higher for the Bedded Hilltop soils (median 74mm/hr) than for the Hope Downs 2 soils (12mm/hr). The higher values for Bedded Hilltop are associated with the higher rock content for these soils. The K_{sat} of the soils from both locations is considered suitable.

The results have been summarised in the table below

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Property	Hope Downs 2	Bedded Hilltop
pH_w, pH_{Ca}	Suitable (pH_w 6-8), though a significant amount of low pH soils exists that may reduce nutrient availability and biological activity.	Suitable (pH_w 6-8).
Salinity, chloride	Suitable ($EC_{1:5}$<1dS/m)	Suitable ($EC_{1:5}$<1dS/m)
Structural stability	Often unstable (52% of soils)	Infrequently unstable (27% of soils)
Fertility	Often low total N (<500mg/kg) Often low available K (<80mg/kg)	Often low total N (<500mg/kg) Sometimes low available K (<80mg/kg)
Plant available water	Suitable (median 90mm/m)	Suitable (median 90mm/m)
Saturated hydraulic conductivity	Suitable (median >10mm/hr)	Suitable (median >10mm/hr)

1 INTRODUCTION

Landloch Pty Ltd (Landloch) was engaged by Rio Tinto Iron Ore (RTIO) to undertake characterisation testing of a range of soils from Hope Downs 2 and Bedded Hilltop. The purpose of the characterisation was to determine the plant growth potential of the soils, with soil pH, salinity, structural stability, water regime, and fertility all considered.

1.1 Scope of work

The following scope of work was undertaken:

- Receive 38 topsoil samples and undertake plant growth potential testing.
- Report the findings of the soil characterisation, including:
  - Methods used for testing,
  - Tabulation and interpretation of the results,
  - Definition of risks associated with the use of these soils, and
  - Management recommendations for their use as soils for rehabilitation.

2 BACKGROUND DETAIL

Hope Downs 2 and Bedded Hilltop are adjacent to each other and both are located ~80km west-north-west of Newman and ~300km south-south-east of Port Hedland, in the Pilbara region of Western Australia (Figure 1).

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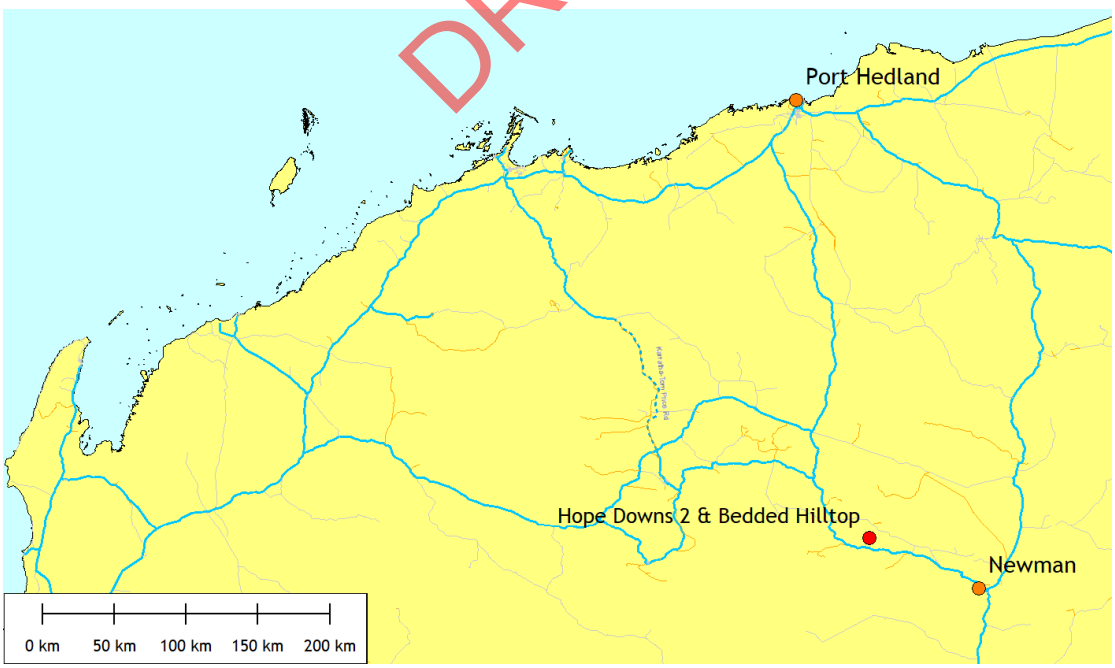

Figure 1: Location of Hope Downs 2 and Bedded Hilltop.

2.1 Climate

Hope Downs 2 and Bedded Hilltop are located in a hot, semi-arid to desert climate. Mean annual rainfall is 277mm[1] and mean annual pan evaporation is 3,350mm[2]. This suggests that surface soil profiles for Hope Downs are very often dry, and that vegetation is adapted to commonly dry soil conditions.

The largest daily rainfall event between 1920 and 2021 was 214mm, which occurred in December 1999. A storm with a daily total of ~150mm has a return period of 50 years. A storm with a daily total of ~100mm has a return period of 10 years. A storm with a daily total of ~40 mm has a return period of 1 year. An assessment of sub-daily rainfall data for the nearest pluviograph station[3] shows an average of 31 storm events per year with events having a mean average rainfall intensity of 4.3 mm/h. The largest average storm intensity was 52.3 mm/hr, and 90% of all storms have an average storm intensity of <9 mm/hr. When peak storm intensities are considered, the mean peak storm intensity was 15 mm/hr. The largest peak storm intensity was 156 mm/hr, and 90% of all storms have a peak storm intensity of <41 mm/hr.

2.2 Soils and landscape

2.2.1 Bedded Hilltop

The Bedded Hilltop mining area is located primarily within the Newman land system which is characterised by rugged plateaux and strike ridges with vertical escarpments, steep scree slopes, and more gently inclined lower slopes. The Newman land system supports hard spinifex grasslands. Soils within the Newman land system are predominantly classified as stony soils, with smaller proportions of red shallow loams and red shallow sands. Stony soils tend to be shallow with physical rooting depths no more than 0.5m. They have circum-neutral pH_w, low salinity, loam to clay loam textures, and very high coarse fragment abundance. The red shallow loams have similar properties except for low coarse fragment abundance. The red shallow sands are similar except for low coarse fragment abundance and a loamy sand to clayey sand texture.

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2.2.2 Hope Downs 2

Hope Downs 2 is located within the Newman, Platform, and Boolgeeda land systems. The relative position of these three land systems is shown in Figure 2 (van Vreeswyk *et al.* 2004). Newman has been described in the previous section. Platform is characterised by dissected slopes and raised plains supporting shrubby hard spinifex. Boolgeeda is characterised by stony lower slopes and plains below systems supporting hard and soft spinifex or mulga shrublands.

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[1] Based on patched point rainfall data for Newman between 1920 and 2021 (Bureau of Meteorology station 7176).
[2] Based on gridded pan evaporation data sourced from the Bureau of Meteorology, http://www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp
[3] Based on data from Capricorn Roadhouse between July 1984 and Nov 2006 (Bureau of Meteorology station 7191).

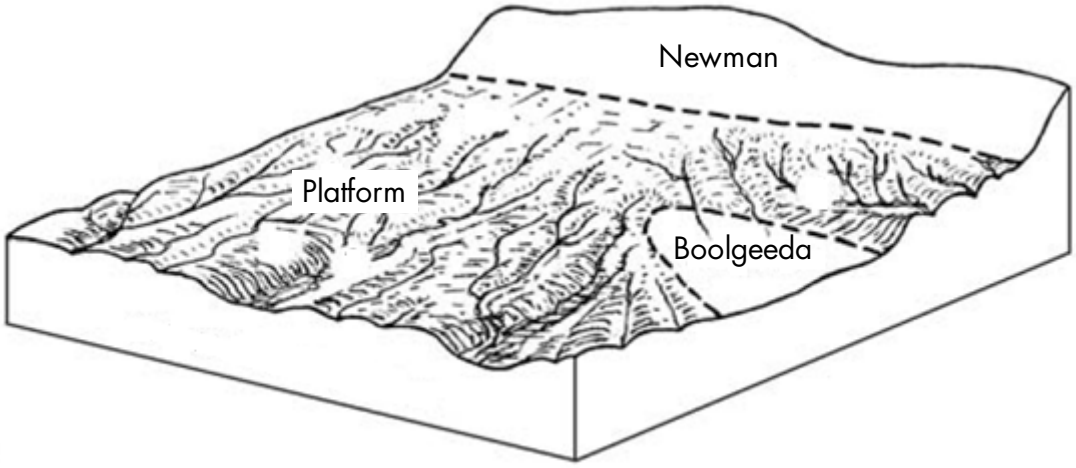

Figure 2: Diagram of the relative position of the Newman, Platform, and Boolgeeda land systems (Source: van Vreeswyk *et al.* 2004).

Soils of the Newman system have been previously described, and their stony and shallow character is a function of their position within the landscape. Soils within the Platform system are predominantly stony soils (similar to those of the Newman system) and red loamy earths. The red loamy earths are similar to the stony soils except they tend to be deeper and have low coarse fragment abundance. Soils within the Boolgeeda system are commonly red shallow loams or red/brown non-cracking clays. Red shallow loams tend to be shallow with physical rooting depths no more than 0.5m. They have circum-neutral pH_w, low salinity, sandy loam to clay loam textures, and low to moderate coarse fragment abundance. The red/brown cracking clays also have a shallow rooting depth due to increased clay content and chemical limitations in soils deeper than ~0.3m. They have neutral to alkaline pH_w, low salinity, and low coarse fragment abundance. Surface soils have a sandy clay texture, with subsoils becoming light to medium clays. Sodicity increases with depth in the non-cracking clays and becomes high in soils deeper than ~0.3m.

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2.2.3 Summary of soils

The soils present at Hope Downs 2 and Bedded Hilltop can be summarised as follows:

- Circum-neutral to alkaline pH_w.
- Low salinity.
- Loam to clay loam textures, with loamy sand and clay textured soils also present but less common.
- Variable coarse fragment abundance, with stony soils having >90% coarse fragments and the loam and clay textured soils within the Boolgeeda land system having <10% coarse fragments.
- Clay subsoils within the Boolgeeda land system may be sodic and prone to dispersion. This is a potential issue for Hope Downs 2 only as the Boolgeeda system is not present at Bedded Hilltop.

3 CHARACTERISATION METHODOLOGY

3.1 Selection of topsoil samples

Thirty-eight (38) soil samples were selected by RTIO. Coordinates and a description of the samples are given in Table 1. Their locations are shown in Figure 3.

Table 1: Sample coordinates and descriptions (GDA94, Zone 50).

Sample ID	Easting (m)	Northing (m)	Description
BHT_01	714,466	7,450,557	Lower elevation, rock, minimal fine material
BHT_02	715,270	7,450,683	In lower elevation, rocky, minimal fine material
BHT_03	710,814	7,450,689	Higher elevation, very rocky
BHT_04	711,254	7,450,890	Higher elevation, very rocky
BHT_05	712,104	7,450,886	Higher elevation, very rocky
BHT_06	712,865	7,450,351	Higher elevation, very rocky, close to gully
BHT_07	714,007	7,450,511	Still high elevation
BHT_08	714,263	7,451,086	Fine material with rocks
BHT_09	714,961	7,450,481	Very rocky area, on side of hill
BHT_10	714,958	7,449,848	Very dry area, rocky material in higher elevation
BHT_11	716,447	7,450,084	Higher elevation, very rocky
BHT_12	716,471	7,450,589	Finer material with rocks
BHT_13	717,914	7,450,148	Dirt like with roots
BHT_14	718,158	7,450,995	Higher elevation, very rocky
BHT_15	718,719	7,450,694	Higher elevation, very rocky, closer to a gully
HD2_01	697,594	7,444,602	Hill side, recent bushfire, rocky material, little soil
HD2_02	698,176	7,444,546	Hill side, recent bushfire, rocky material, little soil
HD2_03	697,905	7,445,198	Finer material with rocks, on lower elevation
HD2_04	699,435	7,444,870	Finer material with rocks, on lower elevation
HD2_05	699,319	7,445,924	Finer soil, on lower elevation
HD2_06	700,553	7,446,345	Finer material with rocks, on lower elevation
HD2_07	700,857	7,445,958	Finer material with rocks, on lower elevation
HD2_08	701,507	7,445,840	Finer material with rocks, on lower elevation
HD2_09	701,037	7,446,470	Finer material with rocks, on lower elevation
HD2_10	701,256	7,446,423	Finer material with rocks, on lower elevation
HD2_11	702,941	7,446,495	Finer material with rocks, on lower elevation
HD2_12	703,310	7,445,661	Finer material with rocks, on lower elevation
HD2_13	703,307	7,446,073	Finer material with rocks, on lower elevation
HD2_14	704,869	7,446,424	Finer material with rocks, on lower elevation
HD2_15	704,110	7,445,763	Finer material with rocks, on lower elevation
HD2_16	704,470	7,446,372	Finer material with rocks, on lower elevation
HD2_17	704,788	7,445,938	Finer material with rocks, on lower elevation
HD2_18	705,706	7,446,381	Finer material with rocks, on lower elevation
HD2_19	705,806	7,445,994	Finer material with rocks, on lower elevation
HD2_20	706,556	7,446,290	Finer material with rocks, on lower elevation
HD2_21	706,885	7,446,013	Finer material with rocks, on lower elevation
HD2_22	707,162	7,446,343	Finer material with rocks, on lower elevation
HD2_23	707,537	7,446,491	Finer material with rocks, on lower elevation

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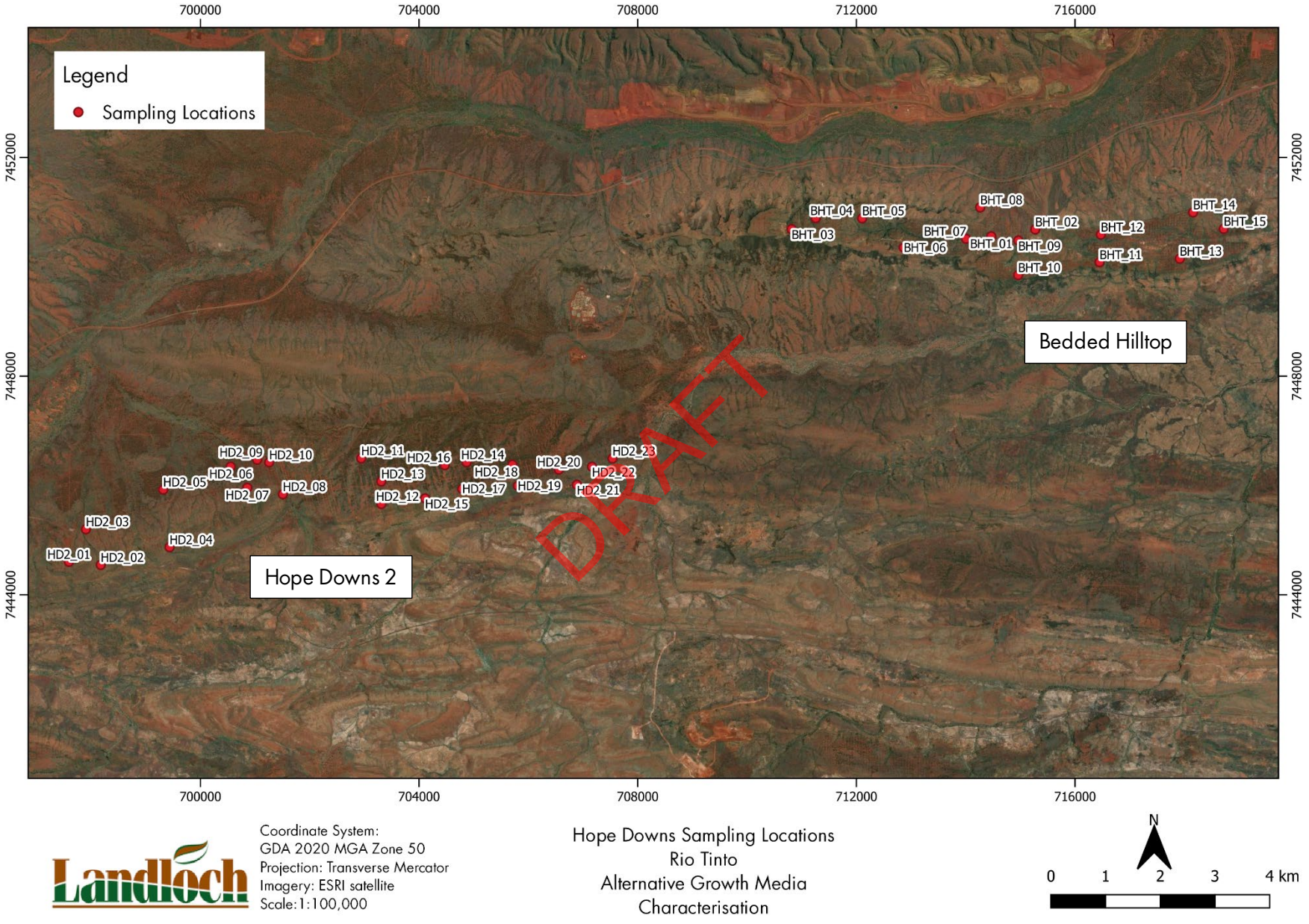

Figure 3: Sampling locations of topsoil samples from Hope Downs 2 and Bedded Hilltop.

3.2 Soil characteristics assessed

Each soil sample was sieved through a 2mm sieve and the coarse fraction percent was recorded[4]. Unless otherwise stated, sub-samples of the fine fraction[4] were sent to an ASPAC and NATA[5] accredited laboratory and tested for the following properties:

- Soil pH_w, measured in a 1:5 solid:water solution;
- Soil pH_{Ca}, calculated based on pH_w;
- Electrical Conductivity ($EC_{1:5}$), measured in a 1:5 solid:water solution;
- Total soluble chloride (Cl);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Al^{3+});
- Effective Cation Exchange Capacity (ECEC), calculated as the sum of exchangeable cations;
- Exchangeable Sodium Percentage (ESP), calculated as the ratio of exchangeable sodium to ECEC and expressed as a percentage;
- Exchangeable Magnesium Percentage (EMP), calculated as the ratio of exchangeable magnesium to ECEC and expressed as a percentage;
- Ca:Mg ratio, calculated as the ratio between exchangeable Ca and exchangeable Mg, using the units of meq/100g;
- Electrochemical Stability Index (ESI), calculated as the ratio of $EC_{1:5}$ (dS/m) to ESP (%);
- Emerson Dispersion Index[6];
- Total N, ammonium (NH_4^+), nitrate (NO_3^-);
- Organic C;
- Total P;
- Plant available P (Colwell), K (Colwell), and S (KCl);
- Trace elements (Cu, Zn, Mn) (DTPA extractable);
- Plant Available Water (PAW), calculated as the difference in volumetric moisture contents measured at soil suctions of 33kPa and 1,500kPa[6];
- Saturated hydraulic conductivity (K_{sat})[6]; and
- Particle size distribution (PSD) (coarse sand, fine sand, silt, clay)[7].

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3.3 Interpretation of results

3.3.1 Soil pH_w and pH_{Ca}

The pH_w of the soils was assessed using a 1:5 soil:water solution. The pH_{Ca} was estimated as the pH_w value minus 0.8 using the conversion equation given in Moore (2001). The impact of the pH on plant growth was assessed by comparing the measured pH_w values with the pH_w values of *in situ* soils that currently support vegetation. Sampled soils that have similar pH_w to that of the *in situ* soils can be considered suitable for plant growth – at least with respect to soil pH.

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[4] The coarse fraction includes particles with diameters >2mm. The fine fraction includes all particles with diameters <2mm.
[5] Australian Soil and Plant Analysis Council; National Association of Testing Authorities
[6] Performed in a laboratory not accredited with NATA or ASPAC.
[7] Coarse sand: 2.0-0.2mm; fine sand: 0.2-0.02mm; silt: 0.02-0.002mm; clay: <0.002mm

The range of pH_w for *in situ* soils was sourced from the soils information that accompanies the soil landscape mapping supplied by Western Australia's Department of Primary Industries and Regional Development[8]. This soils information represents a modelled mean value for a particular soil-landscape zone and actual pH_w values can vary significantly. It does, however, offer a reasonable estimate of the pH_w of soils for the Hope Downs 2 and Bedded Hilltop areas. Using this data source, soil pH_w values range from 7.0 to 7.5. This pH_w range lies within the pH rating of 'slightly alkaline' (Hazelton and Murphy 2016) (7.0-8.0). Nutrient availability for slightly alkaline soils is generally very similar to soils that are slightly acidic (6.0-7.0).

For this study, soils with pH_w values ranging from 6.0-8.0 (slightly acid to slightly alkaline) are classified as having pH that would not adversely affect vegetation growth. For pH_{Ca}, the range used to define suitable soil was 5.2-7.2. pH values outside of this range may have an impact on plant growth. The severity of the impact would need to be quantified through further studies. Vegetation may still grow in soils with pH_w values that fall outside this range, though it may not grow optimally.

3.3.2 Soil salinity ($EC_{1:5}$) and total soluble chloride

3.3.2.1 Soil salinity

Salinity was assessed by measuring the electrical conductivity of a 1:5 soil:water solution. Most salinity suitability ranking systems assume agricultural vegetation, and direct application of these systems to plant species used in rangeland rehabilitation is not appropriate. Western Australia's Department of Primary Industries and Regional Development provides a summary of published salinity tolerance values for a range of common species used in revegetation of disturbed rangelands in Western Australia. These data were reported by Tanji and Kielen (2003). Salt tolerant species (e.g. *Atriplex*, *Tecticornia*) are likely to exhibit some adverse impacts on vegetation growth at $EC_{1:5}$ values of >1.2dS/m[9]. van Vreeswyk *et al.* (2004) used $EC_{1:5}$ values of greater than 0.8dS/m and 1.2dS/m to define highly saline topsoils and subsoils, respectively.

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The range of $EC_{1:5}$ for *in situ* soils was also determined using the soils information that accompanies the soil landscape mapping supplied by Western Australia's Department of Primary Industries and Regional Development. $EC_{1:5}$ values were found to be <0.1dS/m at Hope Downs 2 and Bedded Hilltop, suggesting that salt tolerant species are not likely to be commonly endemic.

For this study, an $EC_{1:5}$ value >1dS/m was used to indicate soils sufficiently saline to adversely impact vegetation establishment and growth. $EC_{1:5}$ values of 1-2dS/m may limit the establishment and growth of more salt sensitive species, but vegetation growth is still likely to occur. $EC_{1:5}$ values <1dS/m are not likely to significantly impact vegetation establishment and growth.

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[8] Accessed via the Natural Resources Information (WA) system managed by the Government of Western Australia, http://maps.agric.wa.gov.au/nrm-info/

[9] Tolerance values were given as EC values measured using the saturation extract method (EC_e). Conversion between $EC_{1:5}$ and EC_e is not exact and is dependent on texture. Hazelton and Murphy (2016) suggest that for sandy loam soils, EC_e should be divided by 14 to estimate $EC_{1:5}$.

3.3.2.2 Total chloride

Chloride is measured along with $EC_{1:5}$ as an indicator of the dominance of Cl salts. Chloride, as opposed to sulphate salts, tends to be more toxic to plants at the same level of salinity. The proportion of the $EC_{1:5}$ that is supplied by chloride salts (EC_{Cl}) can be estimated by dividing the chloride concentration expressed in mg/kg by 66,400 (DNR 1997). Both $EC_{1:5}$ and EC_{Cl} are expressed as dS/m.

3.3.3 Structural stability

A soil's structural stability was assessed by considering the interrelated properties of exchangeable cations, salinity, and particle size distribution. The Emerson test was also conducted, though its value was used as only a guide when considering structural instability. Preference was given to the chemical and physical indicators when assessing issues of soil structure.

From a chemical perspective, the proportion of exchangeable sodium (Na) held on the soil's exchange complex in relation to other exchangeable cations is important. This is referred to as the Exchangeable Sodium Percentage (ESP). McKenzie *et al.* (2004) considers the measurement of ESP as suitable for assessing the potential for clay dispersion and tunnel erosion risk when a soil's Effective Cation Exchange Capacity (ECEC) is ≥3meq/100g and where exchangeable Na ≥0.3meq/100g. Further, the risk of clay dispersion is greatest in soils with loam or clay textures (clay fraction ≥10%); sand dominated soils are not prone to structural instability via clay dispersion. Where these conditions are met, ESP ≥6% are considered to indicate a soil at increased risk of structural instability.

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Additionally, the dispersion potential for a soil is influenced by interactions between clay content, ESP, and $EC_{1:5}$. The Electrochemical Stability Index (ESI) is a means of considering the relationship between ESP and $EC_{1:5}$ for loam and clay textured soils. A tentative critical ESI value is 0.05 (McKenzie 1998), with ESI <0.05 (and clay content ≥10%) indicating a soil that is prone to structural instability.

Magnesic soils can also be prone to structural instability. This is assessed using a combination of the Exchangeable Magnesium Percentage (EMP), Ca:Mg ratio, and ESP. Fenton and Conyers (2002) indicated that Mg by itself has little effect on spontaneous clay dispersion. However, it can enhance the effect of exchangeable Na in causing clay dispersion. Where EMP ≥30%, dispersion may occur when the Ca:Mg ratio is <1, ESP ≥4%, and/or ESP + (EMP ÷ 10) is ≥6% (assuming clay content is also >10%).

From a physical perspective, soils with a high combined fine sand, silt, and clay fraction (particles ≤0.2mm) are prone to structural instability, even if their clay fractions are not chemically dispersive. This is because these smaller particles can mobilise within the voids of the coarser sand matrix. For this reason, soils with a combined fine sand, silt, and clay fraction ≥70% are considered to be at increased risk of structural instability (Vacher *et al.* 2004).

Finally, a soil can have a fine fraction that is prone to structural instability for any of the reasons described above, but if the proportion of unstable fines is small, the soil as a whole may remain stable and not be prone to structural instability. Typically, a binary mixture with >30-40% fine particles and <60-70% coarse particles could be considered

a fine material that contains a coarse fraction; a binary mixture with <30-40% fine particles and >60-70% coarse particles could be considered a coarse material that contains a fine fraction. Based on this, a fines cut-off of ≥40% seems reasonable, with soils that contain ≥40% fines being at risk of structural instability if it meets one or more of other criteria described above.

To capture interactions between physical and chemical properties and their effect on structural stability, the soils were assessed against four criteria. If any of these criteria are met, the soil was classified as being prone to structural instability.

ESP-based criteria: • Clay content ≥10% of fines, and • Fines ≥40%, and • ECEC ≥3meq/100g, and • Exchangeable Na ≥0.3meq/100g, and • ESP ≥6%.	EMP-based criteria: • Clay content ≥10% of fines, and • Fines ≥40%, and • ECEC ≥3meq/100g, and • EMP ≥30%, Ca:Mg <1, & ESP ≥4%, or • EMP ≥30%, Ca:Mg <1, & (ESP + (EMP ÷ 10) ≥6%
ESI-based criteria: • Clay content ≥10% of fines, • Fines ≥40%, and • ESI <0.05.	PSD-based criteria: • Fines ≥40%, and • Fine sand + silt + clay ≥70% of fine fraction.

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The Emerson class was used as a general guide of aggregate stability and the possible impacts of dispersive clay fractions. It can be used only as a general guide because of the large number of factors that determine whether clay dispersion occurs, such as sodicity, salinity, clay type, history of working of the soil and the speed of aggregate wetting (Hazelton and Murphy 2016). Soils with an Emerson class of 1, 2, or 3 can be considered to have an unstable structure due to the presence of a dispersive clay fraction. Class 4 soils may be structurally unstable, and classes 5 and 6 are likely to have a stable clay fraction provided salinity values are not high.

3.3.4 Fertility

The impact of the fertility of the soils on rehabilitation success was assessed by comparing their fertility values with those of *in situ* soils that currently support vegetation. Soils that have similar or heightened fertility to that of the *in situ* soils can be considered unlikely to limit plant growth.

Fertility values for Hope Downs 2 and Bedded Hilltop were sourced from values in the Soil and Landscape Grid of Australia (SLGA)[10]. These values are predicted based on spatial modelling and represent the best estimate of soil attributes using the currently available soil information. Information is available for total N, total P, and organic C. Values for plant available P, K, and S, and trace elements were based on available published tolerance values and Landloch's experience with soils across the Pilbara.

[10] https://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html

Total N is used to indicate the amount of nitrogen in a soil. Values from the SLGA indicated that total N values <500mg/kg are common for surface soils in the region of Hope Downs 2 and Bedded Hilltop. Mineralised forms of N (NH_4^+ and NO_3^-) indicate the amount of N held in forms that are more readily available to plants. These numbers tend to be highly variable and dependent on factors such as the time of sampling, the amount of rainfall prior to sampling, and sample handling protocols. The mineralised forms of N were not used to consider the suitability of the N store, but were used to consider the proportion of N that may be readily available to plants.

Organic C is used with total N to consider the relative rate of decomposition of organic matter where present. C:N ratios <25 indicate sufficiently high organic matter to allow for unimpeded decomposition of organic matter. C:N ratios >25 indicate that C levels are high relative to the available N, and that decomposition will slow unless N is added. For these soils, addition of N may be beneficial, but its availability for plant growth may be limited as the N is utilised for the decomposition of organic material. It is possible for the addition of N to lead to a decrease in plant growth in the short term as a result. Therefore, if fertiliser addition is considered, it must first be trialled to quantify the impacts of these interactions.

Total P is used to indicate the amount of phosphorus in a soil. Information from the SLGA indicated that total P values can be <200mg/kg, but commonly range from 200-500mg/kg. Plant available P values tend to be much lower than the total P value, with values <2mg/kg indicating a soil with very low available P. Suitable available P values tend to be >8-10mg/kg.

Suitable available K, S, and trace element values were based on measured values for soils on other iron ore mine sites in the Pilbara. Adopted values are:

- Plant available K (Colwell), >80mg/kg;
- Plant available S (KCl), >2mg/kg;
- Plant available Cu (DTPA), >0.2mg/kg;
- Plant available Mn (DTPA), >4mg/kg; and
- Plant available Zn (DTPA), >0.5mg/kg.

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3.3.5 Water regime

3.3.5.1 Plant available water

For sandy loam to clay loam soils without rock, PAW of 90-150mm of water per metre depth of soil are common (Hazelton and Murphy 2016). Values less than this indicate a soil for which water holding capacity may be limited, likely through poor soil structure. In this report, these PAW values without adjustment for the presence of rock are used to consider limitations in water holding capacity of the fine fraction,

The PAW adjusted for rock is also reported as a means of demonstrating a more realistic PAW value for the actual soils being examined. This allows for the PAW to be compared against the typical size of storm events that occur at Hope Downs 2 and Bedded Hilltop.

In all cases, the values reported are based on volumetric moisture contents, and assume a bulk density of 1.5g/cm^3.

3.3.5.2 Saturated hydraulic conductivity

For sandy loam to clay loam soils, saturated hydraulic conductivity values can range from 10-60mm/hr, assuming weak pedality (Hazelton and Murphy 2016). Values lower than this would indicate a soil that could be considered less permeable than is commonly measured for similar textured soils. The presence of an appreciable coarse fraction will likely act to increase this rate. Properties such as structural instability may act to reduce this rate.

4 DATA INTERPRETATION

Results of the characterisation of soils from Hope Downs 2 and Bedded Hilltop are provided in Appendix A. The data are summarised in this section. An interpretation of values is also given, based on the scheme outlined in Section 3.

4.1 Soil pH_w

The pH_w for the Hope Downs 2 and Bedded Hilltop soils are given in Figure 4.

The pH_w of the Hope Downs 2 soils range from 4.6-8.0 and average 6.0. Of the 23 Hope Downs 2 soils supplied, 12 had a low pH_w (4.6-5.9, average 5.5). The remaining 11 soils had pH_w values within the range that is likely to not limit plant growth. The pH_w of the Bedded Hilltop soils range from 5.6-8.2 and average 6.5. Of the 15 Bedded Hilltop soils supplied, one soil had a low pH_w (5.6) and one had a high pH_w (8.2). The remaining 10 soils had pH_w values within the suitable range.

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A large proportion of the Hope Downs 2 soils (12 samples, 52%) have pH_w values that are classed as slightly-strongly acidic. These low pH soils are spatially well distributed across the Hope Downs 2 area. Of those 12 soils, 7 were within 0.5 pH units of the suitable range, and 11 were within 1.0 pH unit of the suitable range. Soils with low pH_w (<5.5) are associated with increased solubility of aluminium, decreased availability of several nutrients including nitrogen, phosphorus, potassium, and sulphur, and decreased soil biological activity. The measured exchangeable aluminium values do show some trend towards greater mobility at lower pH values. However, similar exchangeable aluminium values are observed for soils with higher pH_w. A comparison of the nutrient data for those Hope Downs 2 soils with acidic pH against those with alkaline pH show a relative decrease in total nitrogen and available potassium, but the actual values for the acidic pH soils are commonly still within levels that are not likely to limit plant growth.

In summary, 52% of the Hope Downs 2 soils have pH values that are lower than would be expected from the available broad scale data; 48% of the soils have suitable pH values. All but 2 of the Bedded Hilltop soils have suitable pH. Although low pH_w is present, the low values for those soils are not commonly leading to available aluminium concentrations significantly greater than that measured in soils with higher pH_w. Nor are they leading to a reduction in nutrient availability to levels likely to limit plant growth. However, there could be some negative impact on soil biological activity. It is concluded that the low pH is not likely to have a significant impact on vegetation growth, and that field or pot trials aimed at establishing this for the low pH soils may be useful. If it is established that vegetation is adversely impacted by the low pH, amendments such as lime could be considered to increase pH values.

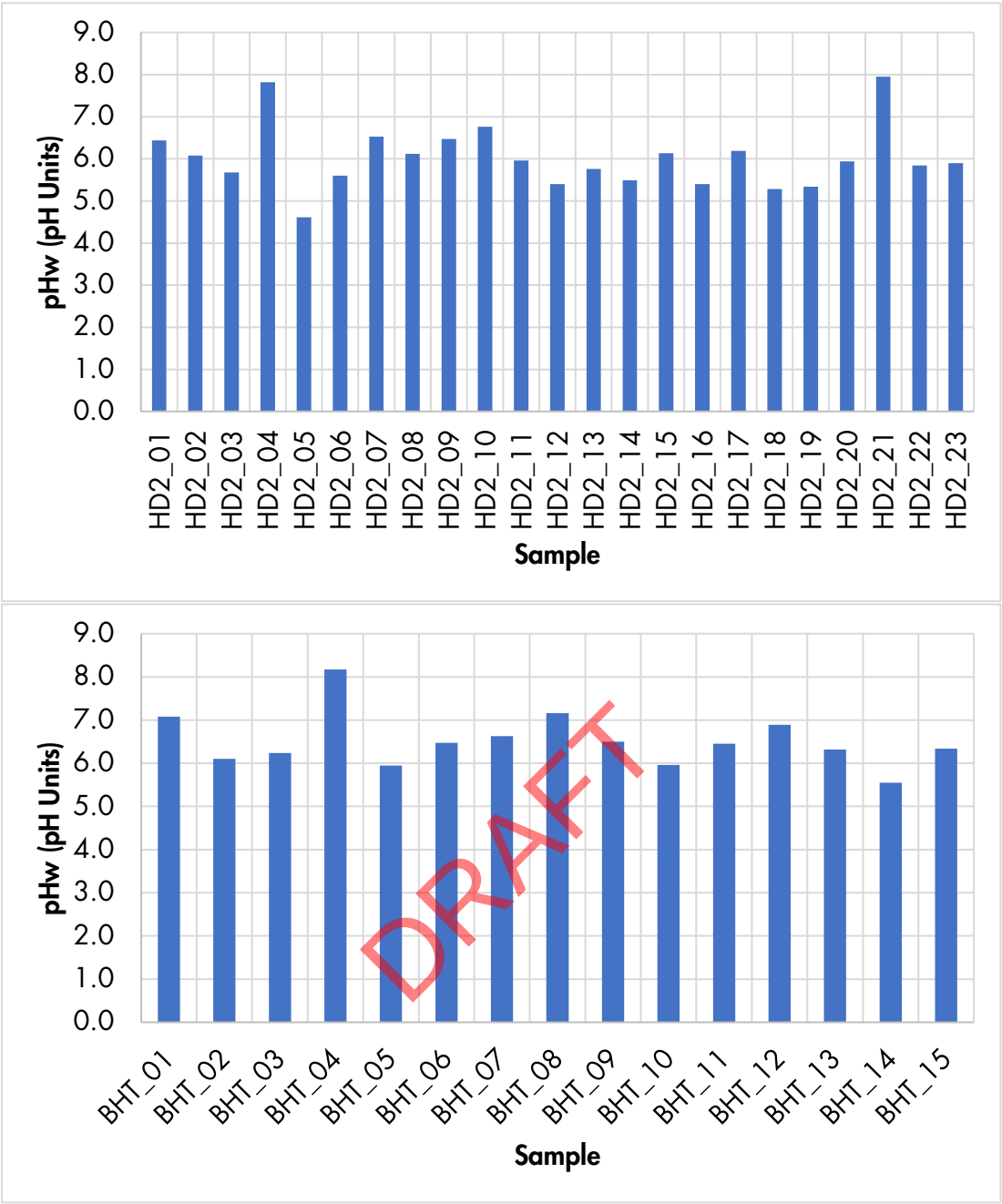

Figure 4: pH_w values for the Hope Downs 2 soils (top) and Bedded Hilltop soils (bottom)

4.2 Salinity ($EC_{1:5}$) and chloride

The salinity ($EC_{1:5}$) values of all soils are <1dS/m. The highest value recorded is 0.41dS/m (HD2_05). Therefore, salinity is not likely to adversely impact vegetation establishment and growth in these soils.

The soluble chloride values for all soils are also low. The proportion of $EC_{1:5}$ that is supplied by chloride salts (EC_{Cl}) was estimated to be <1%. This suggests that the small amount of salts that are present are likely to be sulphate based salts that originate from the soil's parent material.

4.3 Structural stability

Results of the assessment of structural stability are given in Table 2.

The Bedded Hilltop soils are more structurally stable than the Hope Downs 2 soils. Eleven of the 15 Bedded Hilltop soils (73%) are classed as stable. Of the 4 that are classed as unstable, all are classed as unstable due to their low salinity, while one is also unstable due to its high combined fine sand, silt, and clay fraction. Eleven of the 23 Hope Downs 2 soils (48%) are classed as stable. Of the 12 that are classed as unstable, 11 are classed as unstable due to their low salinity. Four are also classed as unstable because of their elevated ESP and 10 because of their high combined fine sand, silt, and clay fraction. Several soils are classed as unstable due to more than one criteria.

In total, 22 of the 38 soils (58%) are structurally stable. The soils that are classed as unstable are spatially well distributed across the Hope Downs 2 and Bedded Hilltop areas. Soils that are classed as structurally unstable are more prone to:

- Reduced permeability;
- Reduced water holding capacity;
- Increased runoff potential;
- Increased erosion potential;
- Reduced root penetrability; and
- Increased tunnel erosion potential.

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Given that the *in situ* soils have low salinity (section 3.3.3) and that the observed instability in the soils was often also driven by low salinity, it can be concluded that *in situ* soils may also be structurally unstable and that the soils are therefore similar to the *in situ* soils.

The risk posed by structural instability could be addressed through mixing of these soils into rockier, structurally stable wastes as part of rehabilitation. This would increase the coarse fraction content that will assist with the maintenance of structure. Alternatively, placement of these soils on low gradient areas (<10%) would reduce the risk posed by increased erosion potential.

Addition of gypsum could be considered for soils with elevated ESP and low ESI. This includes all structurally unstable soils except for HD2_05. An application rate of 0.2t/ha incorporated into a layer that is 0.1m thick is recommended. Amendment of the instability of HD2_05 is best addressed through its incorporation into another structurally stable material.

Table 2: Assessment of the risk of structural stability.

Sample ID	ESP	EMP	ESI	PSD	Structurally Stable?
BHT_01					Yes
BHT_02					Yes
BHT_03					Yes
BHT_04					Yes
BHT_05					Yes
BHT_06					Yes
BHT_07					Yes
BHT_08					Yes
BHT_09					Yes
BHT_10			✓		No
BHT_11					Yes
BHT_12			✓		No
BHT_13			✓	✓	No
BHT_14					Yes
BHT_15			✓		No
HD2_01					Yes
HD2_02					Yes
HD2_03					Yes
HD2_04			✓		No
HD2_05				✓	No
HD2_06			✓	✓	No
HD2_07					Yes
HD2_08					Yes
HD2_09			✓	✓	No
HD2_10			✓	✓	No
HD2_11	✓		✓	✓	No
HD2_12	✓		✓	✓	No
HD2_13			✓	✓	No
HD2_14			✓	✓	No
HD2_15					Yes
HD2_16	✓		✓	✓	No
HD2_17			✓	✓	No
HD2_18	✓		✓		No
HD2_19					Yes
HD2_20					Yes
HD2_21					Yes
HD2_22					Yes
HD2_23					Yes

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4.4 Fertility

The Hope Downs 2 soils have total N values ranging from 114-1252mg/kg with a median value of 426mg/kg. The Bedded Hilltop soils have total N values ranging from 197-1004mg/kg with a median value of 284mg/kg. The lower nitrogen levels in the Bedded Hilltop soils could be due to reduced vegetation in these shallower soils. The range in total nitrogen values is given in Figure 5.

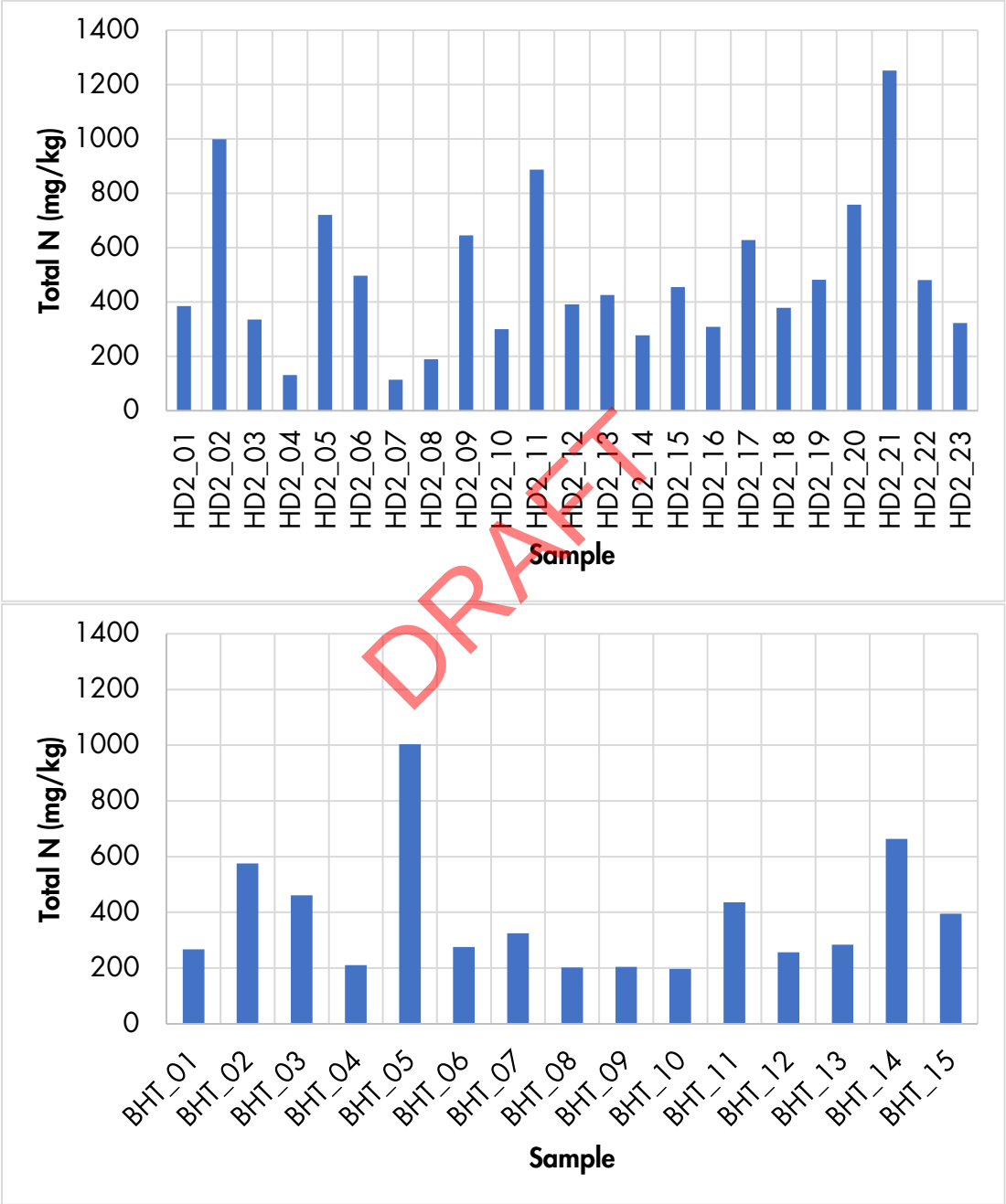

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Figure 5: Total nitrogen values for the Hope Downs 2 soils (top) and Bedded Hilltop soils (bottom)

Both the Hope Downs 2 and Bedded Hilltop soils generally have relatively low ammonium-N and nitrate-N, indicating that a small proportion of the nitrogen is in readily-available forms and that a large proportion is contained within organic matter present in the soils.

Organic C values range from 0.4-1.5% (median 0.7%) for the Hope Downs 2 soils, and 0.4-1.7% (median 0.8%) for the Bedded Hilltop soils. The C:N ratios range from 4-79 (median 20) for Hope Downs 2 soils, and 8-61 (median 20) for the Bedded Hilltop soils.

Median values of 20 indicate that decomposition rates of organic matter will be slightly reduced for many of the soils, and vegetation growth may be improved by addition of some nitrogen. Addition of N as a means of improving vegetation growth should be considered and could be done through any or all of these options:

- Mixing of soils with higher total N levels to those with lower total N values prior to spreading during rehabilitation.
- Addition of N-based fertiliser. The rates, types, and modes of application would need to be determined through pot or field based trials.
- Inclusion of N-fixing vegetation into the seed mixes used as part of rehabilitation.

Total P, available P, available S, trace Cu, trace Mn, and trace Zn values for all soils are within suitable levels. The available K is slightly low for 87% of the Bedded Hilltop soils, but low for only 26% of the Hope Downs 2 soils. Despite being low, these values may not translate into adverse conditions for plant growth. The impact of the addition of potassium could be considered along with the impact of the addition of N within pot or field vegetation trials.

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4.5 Water regime

4.5.1 Plant available water

Plant available water content (without adjustment for the coarse fraction) for the Hope Downs 2 soils ranged from 60-180mm water per metre of soil (median 90mm/m). The PAW for the Bedded Hilltop ranged from 75-120mm/m (median 90mm/m). These values are consistent with common PAW values for sandy loam soils, though it is within the lower bounds of the range. This could be due to the loss (partial to complete) in structure caused by disturbance of the soil. This disturbance is akin to the disturbance that would occur during stripping and rehandling of the soils as part of rehabilitation. Given that the structure of soils used in rehabilitation would improve through time, the measured values are likely to increase through time. Therefore, the PAW of the soils is considered suitable.

When the PAW values are adjusted to include the rock fraction, the PAW for the Hope Downs 2 soils range from 16-148mm/m (median 42mm/m), and the PAW for the Bedded Hilltop soils range from 16-60mm/m (median 32mm/m). The adjusted PAW is strongly correlated to the coarse fragment content (Figure 6).

Soils with a higher abundance of coarse fragments hold less water. Storms with a return period of 1 year (40mm, see section 2.1) are likely to wet these soils through to a depth of ~1m. Rarer storm events are likely to wet to depths greater than 1m. Given that soils are often placed in thin layers during rehabilitation (much thinner than 1m), the underlying waste materials are likely to function as a water storage zone that plants will be able to access. This highlights that the properties of the underlying material (below the soil applied) are also important when considering plant growth potential.

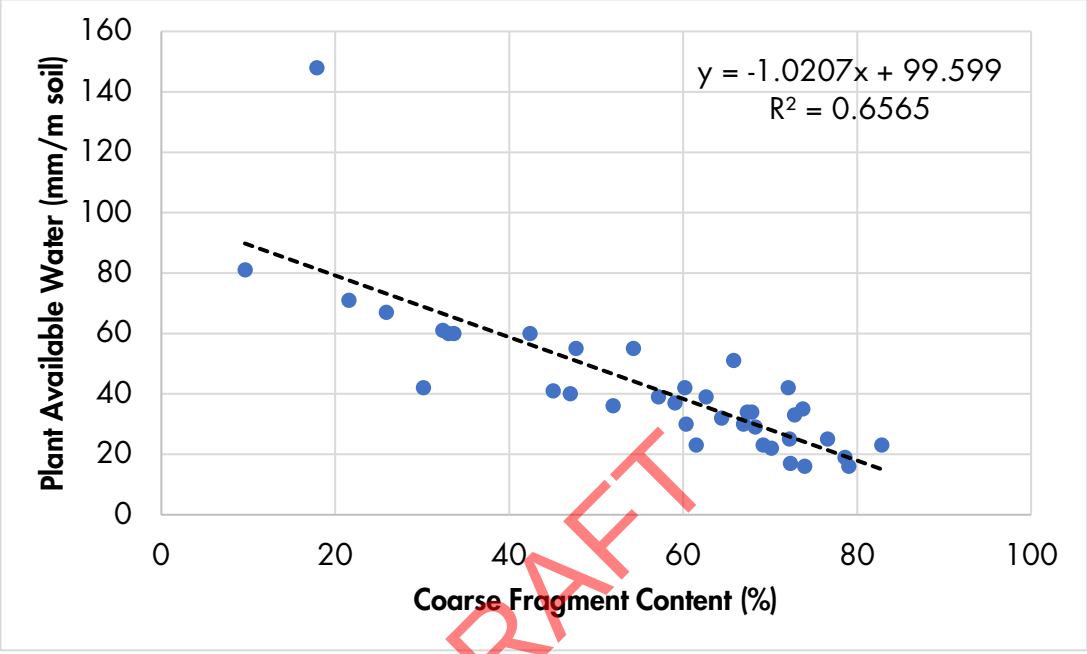

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Figure 6: Plant available water compared to coarse fragment content.

4.5.2 Saturated hydraulic conductivity

Saturated hydraulic conductivity (K_{sat}) values are often higher for the Bedded Hilltop soils than for the Hope Downs 2 soils. K_{sat} values for the Hope Downs 2 soils range from 4-29mm/hr and have a median value of 12mm/hr. K_{sat} values for the Bedded Hilltop soils range from 7-1564mm/hr and have a median value of 74mm/hr. Figure 7 shows the measured values compared to the coarse fragment content. In general, those soils with larger coarse fragment contents, (particularly >70%), have higher saturated hydraulic conductivity.

Excluding the K_{sat} values for the soils with larger coarse fractions (>70%), the mean K_{sat} value for all soils is 13mm/h. This is consistent with common values, though it is within the lower bounds of the range. Similar to PAW, this could be due to the loss in structure caused by disturbance of the soil, and it will likely increase through time after they are used as part of rehabilitation. Therefore, the K_{sat} of the soils is considered suitable.

It is instructive to compare the K_{sat} values to the typical rainfall intensity values. Steady infiltration rates are approximately twice the measured K_{sat} values, and a K_{sat} value of 13mm/h would likely translate to a steady infiltration rate of ~20-30mm/hr. This infiltration rate is larger than the average rainfall intensities for storms in the Hope Downs area (90% of all storms have an average intensity of <9mm/hr), but lower than the peak

intensity values that can occur in a few events. It can be concluded from this that the majority of rainfall events that occur will readily infiltrate into these soils, but that there will be some events that will cause runoff and possibly erosion. The amount of erosion will depend on a range of factors including the duration of runoff, the intensity of the rainfall, and the erodibility of the soil.

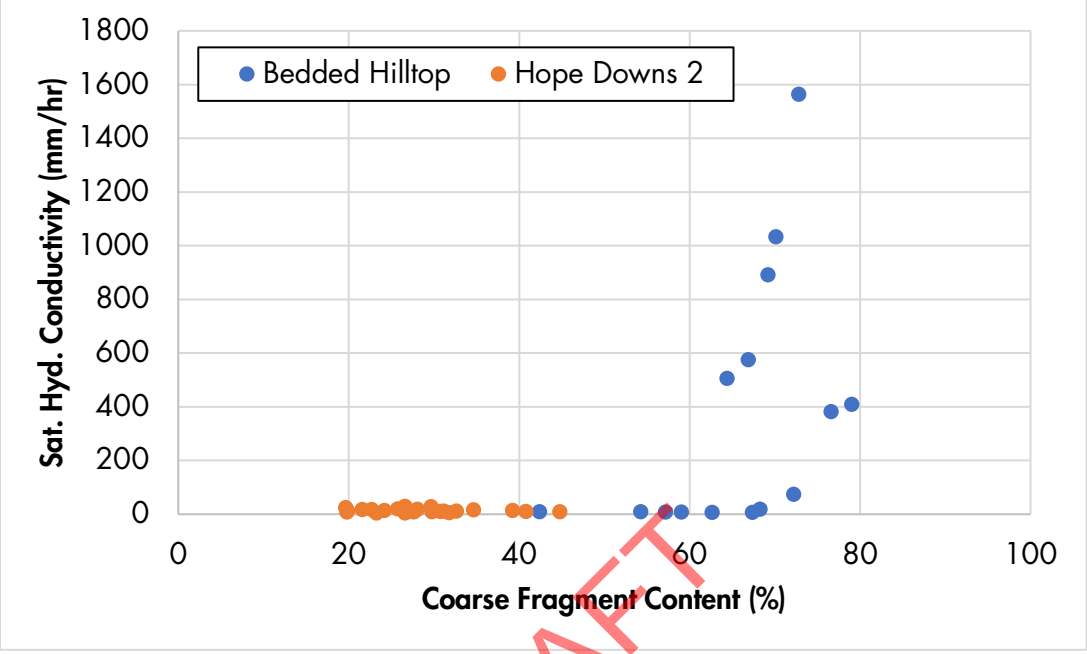

Figure 7: Saturated hydraulic conductivity compared to coarse fragment content.

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5 SUMMARY

A summary of the suitability of the soils is given in Table 3. Soils from Hope Downs 2 and Bedded Hilltop are considered separately. The summary uses the mean or median values for the samples provided.

The topsoil samples could be considered to have similar properties to soils in the region of Hope Downs 2 and Bedded Hilltop, with the following caveats.

The pH of the soils at Hope Downs 2 is often lower than likely present (based on the available broadscale data) and the impact of the low pH could be considered using field/pot trials. Lime could be used to address the low pH if the trials show it to be necessary.

The structural instability of the soils may be similar to that present in the *in situ* soils and may be mitigated by mixing these soils with structurally stable materials as part of rehabilitation activities. The ability to RTIO to achieve this mixing is yet to be determined. The availability of stable materials and machinery to do the mixing would need to be ascertained.

The Bedded Hilltop often has low nitrogen levels and can also sometimes have low available potassium. The Hope Downs 2 soil can also have low nitrogen and often has low available potassium. The impact of these low nutrient levels should be investigated further. Field or pot trials could be used to consider the impact on plant growth to

changes in the levels of these nutrients via fertiliser. As part of any field/pot trials of fertiliser, the type, rate and mode of delivery of the nutrient should also be considered as they can have a significant bearing on the efficacy of the fertiliser. Nitrogen levels could also be altered through mixing low N and high N soils together as part of rehabilitation. To achieve this, RTIO would need to demonstrate the ability to achieve this mixing as part of any rehabilitation action. Alternatively, N levels could be altered through inclusion of N-fixing vegetation into the seed mix. The availability of N-fixing rehabilitation species and the degree to which these plant can cause an increase in available N would need to be investigated.

Table 3: Summary of suitability.

Property	Hope Downs 2	Bedded Hilltop
pH_w, pH_{Ca}	Suitable (pH_w 6-8), though there are a significant amount of low pH soils that may reduce nutrient availability and biological activity. This reduction did not reduce fertility to unsuitable levels. Field/pot trials to confirm this is recommended. Lime could be used to increase pH if shown by trials to be needed	Suitable (pH_w 6-8). Only 1 of 15 soils had slightly low pH and 1 of 15 soils had slightly high pH.
Salinity, chloride	Suitable ($EC_{1:5}$<1dS/m)	Suitable ($EC_{1:5}$<1dS/m)
Structural stability	Often unstable (52% of soils)	Infrequently unstable (27% of soils)
Fertility	Often low total N (<500mg/kg) Often low available K (<80mg/kg)	Often low total N (<500mg/kg) Sometimes low available K (<80mg/kg)
Plant available water	Suitable (median 90mm/m)	Suitable (median 90mm/m)
Saturated hydraulic conductivity	Suitable (median >10mm/hr)	Suitable (median >10mm/hr)

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APPENDIX A: TABULATED RESULTS

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Analyses	Unit	HD2_01	HD2_02	HD2_03	HD2_04	HD2_05	HD2_06
pH_w	pH units	6.44	6.08	5.68	7.82	4.61	5.60
pH_{Ca}	pH units	5.64	5.28	4.88	7.02	3.81	4.80
$EC_{1:5}$	dS/m	0.03	0.04	0.01	0.03	0.41	0.06
Chloride	mg/kg	18.7	28.7	21.9	22.1	65.6	20.2
Ca^{2+}	meq/100g	2.6	4.7	1.8	1.8	3.1	3.6
Mg^{2+}	meq/100g	1.0	1.3	0.8	1.0	0.7	0.8
K^{+}	meq/100g	0.3	0.5	0.2	0.1	0.4	0.4
Na^{+}	meq/100g	0.3	0.2	0.1	0.2	0.2	0.3
Al^{3+}	meq/100g	0.1	0.0	0.1	0.0	0.2	0.2
ECEC	meq/100g	4.2	6.6	3.0	3.0	4.5	5.3
ESP	%	6.0	2.7	4.8	5.0	4.0	5.5
EMP	%	23	20	26	32	15	16
Ca:Mg	-	2.7	3.6	2.2	1.8	4.5	4.3
ESI	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Emerson Class	-	3	3	5	3	5	5
Total N	mg/kg	385	999	335	131	720	497
Ammonium, NH_4	mg/kg	3.15	3.95	6.23	<2.0	10.4	4.04
Nitrate, NO_3	mg/kg	2.93	7.04	2.17	1.5	232	15.1
Organic C	%	0.9	0.4	0.5	0.7	0.7	0.6
Total P	mg/kg	489	474	468	225	601	483
Av. P	mg/kg	14.9	8.5	20.8	23.0	20.0	17.1
Av. K	mg/kg	159	188	91.1	80.7	209	144
Av. S	mg/kg	7.4	9.3	11	7.2	23	16
Trace Cu	mg/kg	0.9	1.0	0.8	1.0	2.2	2.9
Trace Mn	mg/kg	26	48	37	12	59	46
Trace Zn	mg/kg	0.6	0.8	0.6	1.0	1.3	1.2
Coarse fraction*	%	74	74	79	48	26	32
Coarse sand*^	%	39.2	29.8	19.8	44.8	26.6	29.7
Fine Sand*^	%	44.6	52.5	62.1	33.8	37.0	37.7
Silt*^	%	3.0	4.8	4.8	8.3	11.6	9.8
Clay*^	%	13.1	12.9	13.3	13.1	24.9	22.8
PAW	mm/m	60	135	90	105	90	90
PAW (adjusted)#	mm/m	16	35	19	55	67	61
K_{sat}#	mm/hr	14	9	8	10	29	28

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Analyses	Unit	HD2_07	HD2_08	HD2_09	HD2_10	HD2_11	HD2_12
pH_w	pH units	6.53	6.12	6.47	6.76	5.96	5.40
pH_{Ca}	pH units	5.73	5.32	5.67	5.96	5.16	4.60
$EC_{1:5}$	dS/m	0.02	0.02	0.02	0.01	0.09	0.02
Chloride	mg/kg	19.1	12.6	18.8	14.6	29.8	20.6
Ca^{2+}	meq/100g	2.1	2.4	5.2	6.3	4.0	2.5
Mg^{2+}	meq/100g	1.3	0.9	1.7	2.7	1.1	1.3
K^{+}	meq/100g	0.1	0.1	1.2	0.6	0.4	0.1
Na^{+}	meq/100g	0.4	0.4	0.3	0.4	0.4	0.4
Al^{3+}	meq/100g	0.2	0.1	0.1	0.0	0.1	0.1
ECEC	meq/100g	4.1	3.9	8.4	10.0	6.0	4.3
ESP	%	10	9.5	3.1	3.6	7.1	8.5
EMP	%	31	24	20	27	18	30
Ca:Mg	-	1.7	2.6	3.2	2.3	3.7	1.9
ESI	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Emerson Class	-	3	3	3	3	3	3
Total N	mg/kg	114	189	645	300	887	391
Ammonium, NH_4	mg/kg	3.95	3.15	2.07	3.24	<2.0	2.16
Nitrate, NO_3	mg/kg	3.63	5.22	3.06	1.42	31.3	2.71
Organic C	%	0.9	0.6	1.0	0.6	0.9	0.5
Total P	mg/kg	394	326	568	373	482	351
Av. P	mg/kg	19.7	27.4	32.5	42.2	12.1	20.4
Av. K	mg/kg	90.6	68.2	431	228	140	67.2
Av. S	mg/kg	8.4	6.7	6.5	6.9	14	10
Trace Cu	mg/kg	0.8	1.0	2.9	3.5	3.5	1.9
Trace Mn	mg/kg	26	43	35	18	23	28
Trace Zn	mg/kg	0.5	0.6	4.0	3.9	2.2	0.7
Coarse fraction*	%	72	61	18	10	34	52
Coarse sand*^	%	32.6	40.8	23.3	26.6	22.7	19.9
Fine Sand*^	%	46.5	43.2	36.2	47.0	39.1	48.8
Silt*^	%	4.7	4.7	14.1	11.6	8.5	6.8
Clay*^	%	16.2	11.3	26.4	14.7	29.6	24.5
PAW	mm/m	60	60	180	90	90	75
PAW (adjusted)#	mm/m	17	23	148	81	60	36
K_{sat}#	mm/hr	12	11	4	4	18	12

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Analyses	Unit	HD2_13	HD2_14	HD2_15	HD2_16	HD2_17	HD2_18
pH_w	pH units	5.76	5.49	6.13	5.40	6.19	5.28
pH_{Ca}	pH units	4.96	4.69	5.33	4.60	5.39	4.48
$EC_{1:5}$	dS/m	0.02	0.03	0.02	0.03	0.03	0.02
Chloride	mg/kg	16.6	20.3	17.6	16.7	14.5	14.3
Ca^{2+}	meq/100g	2.6	2.4	3.0	2.8	4.3	2.6
Mg^{2+}	meq/100g	0.9	1.2	1.1	0.9	1.3	0.7
K^{+}	meq/100g	0.3	0.2	0.1	0.2	0.5	0.3
Na^{+}	meq/100g	0.2	0.1	0.3	0.3	0.2	0.3
Al^{3+}	meq/100g	0.1	0.1	0.0	0.3	0.2	0.2
ECEC	meq/100g	4.1	4.0	4.5	4.4	6.4	4.1
ESP	%	4.4	3.3	6.6	7.3	3.3	8.0
EMP	%	23	31	24	20	20	16
Ca:Mg	-	2.8	1.9	2.7	3.1	3.4	4.0
ESI	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Emerson Class	-	3	5	3	5	3	3
Total N	mg/kg	426	277	455	309	628	379
Ammonium, NH_4	mg/kg	<2.0	2.25	5.45	2.79	2.34	2.34
Nitrate, NO_3	mg/kg	7.35	7.58	4.33	4.63	2.94	3.73
Organic C	%	0.8	0.7	0.9	0.7	1.1	0.9
Total P	mg/kg	348	426	432	382	292	442
Av. P	mg/kg	22.6	13.2	26.7	26.2	10.1	16.4
Av. K	mg/kg	97.0	70.0	67.5	70.3	200	126
Av. S	mg/kg	7.8	8.8	9.0	13	8.5	9.7
Trace Cu	mg/kg	2.7	2.1	1.4	3.1	3.7	2.6
Trace Mn	mg/kg	14	27	41	23	39	37
Trace Zn	mg/kg	0.9	1.2	0.6	1.8	4.1	1.3
Coarse fraction*	%	30	33	60	45	47	22
Coarse sand*^	%	19.7	27.7	31.8	25.8	28.1	31.2
Fine Sand*^	%	44.2	37.5	45.2	41.3	42.6	39.7
Silt*^	%	8.5	6.5	6.5	8.6	4.9	8.0
Clay*^	%	27.6	28.3	16.5	24.4	24.4	21.2
PAW	mm/m	60	90	105	75	75	90
PAW (adjusted)#	mm/m	42	60	42	41	40	71
K_{sat}#	mm/hr	24	10	6	19	19	11

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Analyses	Unit	HD2_19	HD2_20	HD2_21	HD2_22	HD2_23
pH_w	pH units	5.34	5.94	7.95	5.84	5.90
pH_{Ca}	pH units	4.54	5.14	7.15	5.04	5.10
$EC_{1:5}$	dS/m	0.08	0.04	0.11	0.04	0.01
Chloride	mg/kg	38.7	19.3	23.9	22.1	17.0
Ca^{2+}	meq/100g	3.9	4.0	7.4	3.8	2.2
Mg^{2+}	meq/100g	1.4	1.0	1.3	1.2	1.1
K^{+}	meq/100g	0.1	0.3	0.7	0.3	0.2
Na^{+}	meq/100g	0.2	0.3	0.2	0.1	0.1
Al^{3+}	meq/100g	0.1	0.0	0.0	0.0	0.1
ECEC	meq/100g	5.8	5.6	9.7	5.2	3.8
ESP	%	4.1	4.8	2.1	1.0	2.6
EMP	%	25	18	14	22	29
Ca:Mg	-	2.7	3.9	5.6	3.3	2.1
ESI	-	<0.05	<0.05	0.05	<0.05	<0.05
Emerson Class	-	5	3	3	3	5
Total N	mg/kg	482	758	1252	481	323
Ammonium, NH_4	mg/kg	10.2	4.61	<2.0	3.06	<2.0
Nitrate, NO_3	mg/kg	12.1	10.3	4.12	11.8	1.06
Organic C	%	1.0	1.5	1.4	1.0	0.5
Total P	mg/kg	279	374	603	442	283
Av. P	mg/kg	35.6	8.7	21.4	12.8	20.7
Av. K	mg/kg	75.4	105	302	99.7	90.5
Av. S	mg/kg	18	9.5	8.7	8.6	8.8
Trace Cu	mg/kg	2.2	1.2	1.7	1.2	0.8
Trace Mn	mg/kg	20	34	18	49	31
Trace Zn	mg/kg	0.9	0.8	0.8	0.8	0.6
Coarse fraction*	%	60	68	66	72	83
Coarse sand*^	%	24.2	34.6	30.7	27.5	21.6
Fine Sand*^	%	47.8	45.8	43.3	49.3	57.9
Silt*^	%	6.4	4.8	6.8	4.9	5.0
Clay*^	%	21.6	14.7	19.1	18.3	15.5
PAW	mm/m	75	105	150	150	135
PAW (adjusted)#	mm/m	30	34	51	42	23
K_{sat}#	mm/hr	14	16	11	9	18

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Analyses	Unit	BHT_01	BHT_02	BHT_03	BHT_04	BHT_05	BHT_06
pH_w	pH units	7.08	6.10	6.24	8.17	5.95	6.47
pH_{Ca}	pH units	6.28	5.30	5.44	7.37	5.15	5.67
$EC_{1:5}$	dS/m	0.02	0.02	0.02	0.04	0.01	0.02
Chloride	mg/kg	21.1	21.4	23.0	21.8	16.3	18.7
Ca^{2+}	meq/100g	2.7	2.8	2.4	3.4	3.0	1.7
Mg^{2+}	meq/100g	0.8	1.0	1.0	0.8	1.1	0.7
K^+	meq/100g	0.1	0.2	0.1	0.2	0.2	0.1
Na^+	meq/100g	0.4	0.3	0.1	0.1	0.2	0.2
Al^{3+}	meq/100g	0.0	0.1	0.1	0.0	0.1	0.1
ECEC	meq/100g	4.1	4.3	3.6	4.5	4.6	2.7
ESP	%	8.9	5.9	3.4	1.8	5.1	5.6
EMP	%	21	24	26	17	24	24
Ca:Mg	-	3.2	2.7	2.5	4.5	2.7	2.6
ESI	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Emerson Class	-	3	3	3	5	3	5
Total N	mg/kg	267	576	461	210	1004	275
Ammonium, NH_4	mg/kg	<2.0	4.83	7.62	<2.0	7.71	2.43
Nitrate, NO_3	mg/kg	1.97	5.08	3.57	2.05	1.62	2.58
Organic C	%	0.5	1.1	0.8	0.5	1.4	0.7
Total P	mg/kg	561	492	558	349	559	495
Av. P	mg/kg	24.6	14.1	19.1	16.9	13.3	24.6
Av. K	mg/kg	70.6	75.0	74.3	76.5	72.9	66.8
Av. S	mg/kg	4.6	3.7	7.0	9.4	7.7	20
Trace Cu	mg/kg	1.1	0.7	0.7	0.7	0.9	0.6
Trace Mn	mg/kg	15	34	34	11	36	23
Trace Zn	mg/kg	0.9	0.7	0.6	0.6	0.7	0.6
Coarse fraction*	%	70	72	69	73	77	67
Coarse sand*^	%	42.3	30.4	41.8	32.0	28.1	51.1
Fine Sand*^	%	44.6	49.4	43.5	49.8	53.6	34.0
Silt*^	%	3.1	5.0	3.1	1.5	5.0	4.9
Clay*^	%	10.0	15.2	11.6	16.7	13.3	10.0
PAW	mm/m	75	90	75	120	105	90
PAW (adjusted)#	mm/m	22	25	23	33	25	30
K_{sat}#	mm/hr	1033	74	892	1564	382	576

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Analyses	Unit	BHT_07	BHT_08	BHT_09	BHT_10	BHT_11	BHT_12
pH_w	pH units	6.63	7.16	6.50	5.96	6.45	6.89
pH_{Ca}	pH units	5.83	6.36	5.70	5.16	5.65	6.09
$EC_{1:5}$	dS/m	0.03	0.04	0.04	0.02	0.01	0.03
Chloride	mg/kg	16.6	20.2	30.4	35.4	16.9	16.8
Ca^{2+}	meq/100g	2.6	3.9	2.1	1.2	2.5	3.2
Mg^{2+}	meq/100g	0.9	1.3	1.1	1.0	1.1	0.9
K^{+}	meq/100g	0.1	0.1	0.1	0.1	0.2	0.1
Na^{+}	meq/100g	0.2	0.2	0.2	0.1	0.2	0.1
Al^{3+}	meq/100g	0.1	0.1	0.2	0.1	0.1	0.0
ECEC	meq/100g	3.9	5.7	3.7	2.4	4.1	4.3
ESP	%	5.8	3.4	6.0	4.5	4.4	2.5
EMP	%	22	23	29	41	27	20
Ca:Mg	-	3.0	3.0	2.0	1.2	2.3	3.6
ESI	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Emerson Class	-	3	3	5	5	3	3
Total N	mg/kg	325	202	204	197	436	257
Ammonium, NH_4	mg/kg	3.33	2.43	6.84	7.88	3.33	2.25
Nitrate, NO_3	mg/kg	2.43	7.13	5.31	2.89	1.46	6.25
Organic C	%	0.7	0.4	0.4	0.5	0.7	0.8
Total P	mg/kg	524	332	407	654	424	482
Av. P	mg/kg	25.9	21.1	21.0	30.2	22.7	20.6
Av. K	mg/kg	66.2	71.1	65.7	63.3	76.9	66.3
Av. S	mg/kg	21	12	7.9	41	8.1	9.3
Trace Cu	mg/kg	0.8	0.8	0.6	0.4	0.6	0.8
Trace Mn	mg/kg	15	19	23	8.5	24	24
Trace Zn	mg/kg	0.5	0.5	0.7	0.5	0.6	0.5
Coarse fraction*	%	64	63	67	54	79	59
Coarse sand*^	%	40.3	34.9	27.8	38.4	33.1	39.3
Fine Sand*^	%	33.3	42.8	52.6	34.7	53.7	42.5
Silt*^	%	6.5	5.0	3.1	6.6	3.2	6.7
Clay*^	%	19.9	17.2	16.5	20.3	10.0	11.6
PAW	mm/m	90	105	105	120	75	90
PAW (adjusted)#	mm/m	32	39	34	55	16	37
K_{sat}#	mm/hr	506	7	7	9	409	8

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Analyses	Unit	BHT_13	BHT_14	BHT_15
pH_w	pH units	6.32	5.55	6.34
pH_{Ca}	pH units	5.52	4.75	5.54
$EC_{1:5}$	dS/m	0.02	0.33	0.02
Chloride	mg/kg	17.2	126	21.4
Ca^{2+}	meq/100g	3.9	4.6	2.0
Mg^{2+}	meq/100g	1.5	1.7	1.1
K^+	meq/100g	0.3	0.2	0.1
Na^+	meq/100g	0.3	0.7	0.3
Al^{3+}	meq/100g	0.1	0.1	0.1
ECEC	meq/100g	6.0	7.3	3.7
ESP	%	4.5	9.9	7.8
EMP	%	24	23	30
Ca:Mg	-	2.7	2.8	1.9
ESI	-	<0.05	<0.05	<0.05
Emerson Class	-	3	5	3
Total N	mg/kg	284	664	395
Ammonium, NH_4	mg/kg	<2.0	13.2	8.31
Nitrate, NO_3	mg/kg	4.53	203	4.32
Organic C	%	1.7	0.5	0.6
Total P	mg/kg	329	488	414
Av. P	mg/kg	15.0	19.7	17.3
Av. K	mg/kg	105	90.1	70.2
Av. S	mg/kg	7.3	15	7.8
Trace Cu	mg/kg	1.3	0.9	0.8
Trace Mn	mg/kg	22	49	31
Trace Zn	mg/kg	0.5	0.5	0.5
Coarse fraction*	%	42	68	57
Coarse sand*^	%	23.6	30.8	40.3
Fine Sand*^	%	48.3	48.7	41.4
Silt*^	%	6.9	5.0	3.2
Clay*^	%	21.2	15.4	15.1
PAW	mm/m	105	90	90
PAW (adjusted)#	mm/m	60	29	39
K_{sat}#	mm/hr	10	19	8

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Table notes:

* Coarse fraction: >2mm; coarse sand: 2.0-0.2mm; fine sand: 0.2-0.02mm; silt: 0.02-0.002mm; clay: <0.002mm.

^ Expressed as a percentage of the fine fraction only. The sum of coarse sand, fine sand, silt, and clay will equal 100%, with allowance to be made for rounding error.

Data were adjusted to account for the coarse fraction, assuming that only the fine fraction (<2mm diameter) is able to store moisture. Water retention values measured for the fine fraction were multiplied by the fine fraction percent to estimate the water retention of the fine and coarse fraction combined. Values given are volumetric water contents, assuming a bulk density of 1.5g/cm^3.

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APPENDIX B: LABORATORY DATA SHEETS

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eastwest
geo ag enviro

82 Plain Street Tamworth NSW 2340
e admin@eastwestonline.com.au
t 02 6762 1733
f 02 6765 9109
abn 82 125 442 382

eastwestonline.com.au

ANALYSIS REPORT SOIL

PROJECT NO: EW211809		**Date of Issue:**	**20/01/2022**
Customer:	LANDLOCH PTY. LTD. (W.A.)	Report No:	1
Address:	PO BOX 5175 SOUTH LAKE WA 6164	Date Received:	31/12/2021
		Matrix:	Soil
Attention:	Anna Reed	Location:	2079.21eRTIO HD1
Phone:	08 9494 2835	Sampler ID:	Client Supplied
Fax:	08 9417 3744	Date of Sampling:	23/12/2021
Email:	reed@landloch.com.au	Sample Condition:	Acceptable

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Results apply to the samples as submitted. All pages of this report have been checked and approved for release.

Signed:

Stephanie Cameron
Laboratory Operations Manager

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PROFICIENT LAB
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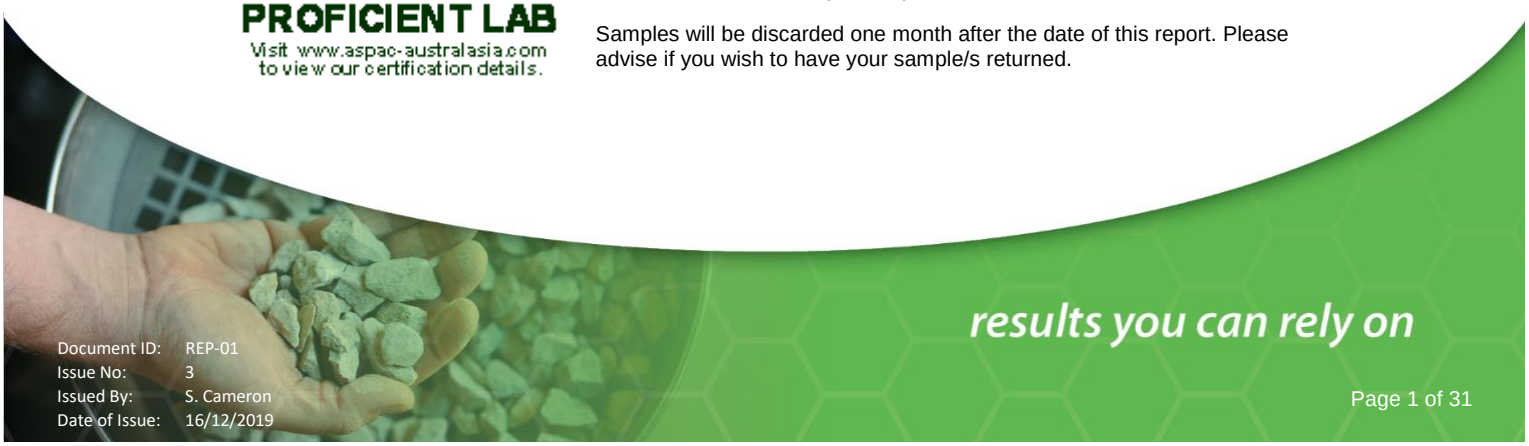
This analysis relates to the sample submitted and it is the client's responsibility to make certain the sample is representative of the matrix to be tested.

Samples will be discarded one month after the date of this report. Please advise if you wish to have your sample/s returned.



ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					BHT_01	BHT_02	BHT_03	BHT_04
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-1**	**211809-2**	**211809-3**	**211809-4**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.20	1.13	1.24	1.47
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	7.08	6.10	6.24	8.17
Chloride Soluble	DA	DAP-06	mg/kg	2	21.1	21.4	23.0	21.8
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.02	0.02	0.02	0.04
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	267	576	461	210
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	1.97	5.08	3.57	2.05
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	<2.0	4.83	7.62	<2.0
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	561	492	558	349
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.48	1.13	0.84	0.46
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	24.6	14.1	19.1	16.9
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	70.6	75.0	74.3	76.5
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	4.63	3.69	6.97	9.42
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.12	0.72	0.70	0.66
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.89	0.65	0.55	0.59
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	14.9	33.8	34.4	10.8
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	8.80	16.6	12.7	6.02
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.37	0.28	0.36	1.36
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	54.9	84.9	44.1	75.4
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	540	555	477	1551
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	101	125	114	101
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	82.8	59.3	28.8	33.3
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	<1.00	4.95	6.45	<1.00
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.14	0.22	0.11	0.19
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	2.70	2.78	2.39	7.76
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	0.84	1.04	0.95	0.84
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.36	0.26	0.13	0.14

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	BHT_01	BHT_02	BHT_03	BHT_04
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-1**	**211809-2**	**211809-3**	**211809-4**
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.01	0.06	0.07	0.01
ECEC	Calculation	PMS-15A1	cmol/kg	na	4.05	4.35	3.64	8.95
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	3.21	2.66	2.51	9.21
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.17	0.21	0.12	0.23
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	3.47	5.01	3.10	2.16
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	66.6	63.8	65.4	86.7
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	20.8	24.0	26.1	9.41
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	8.88	5.93	3.44	1.62
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	0.27	1.27	1.97	0.12
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	94.4

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

					BHT_01	BHT_02	BHT_03	BHT_04
				CLIENT SAMPLE ID				
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-1**	**211809-2**	**211809-3**	**211809-4**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	689
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	91.0
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	19.0
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	0.24
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	3.45
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	0.76
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	0.08
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	4.54
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	4.54
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	0.32
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	5.33
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	75.9
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	16.7
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	1.82
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	NA	NA	NA	0.24
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	48.9	31.8	45.7	58.8
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	21.6	20.7	22.7	13.2
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	22.8	33.7	23.6	20.5
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	1.6	3.4	1.7	0.6
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	5.1	10.4	6.3	6.9

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					BHT_05	BHT_06	BHT_07	BHT_08
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-5**	**211809-6**	**211809-7**	**211809-8**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.14	1.08	1.34	1.07
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	5.95	6.47	6.63	7.16
Chloride Soluble	DA	DAP-06	mg/kg	2	16.3	18.7	16.6	20.2
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.01	0.02	0.03	0.04
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	1004	275	325	202
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	1.62	2.58	2.43	7.12
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	7.71	2.43	3.33	2.43
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	559	495	524	332
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	1.35	0.65	0.70	0.42
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	13.3	24.6	25.9	21.1
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	72.9	66.8	66.2	71.1
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	7.71	19.7	21.4	11.8
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.86	0.63	0.78	0.82
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.69	0.60	0.47	0.51
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	36.3	22.7	15.3	19.1
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	20.5	10.3	9.92	6.48
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.28	0.32	0.40	0.68
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	80.8	36.3	41.6	57.4
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	596	342	517	783
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	131	79.1	104	158
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	53.8	34.8	51.2	43.6
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	4.50	7.05	7.80	7.80
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.21	0.09	0.11	0.15
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	2.98	1.71	2.59	3.92
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	1.09	0.66	0.87	1.32
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.23	0.15	0.22	0.19

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	BHT_05	BHT_06	BHT_07	BHT_08
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-5	211809-6	211809-7	211809-8
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.05	0.08	0.09	0.09
ECEC	Calculation	PMS-15A1	cmol/kg	na	4.56	2.69	3.87	5.66
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	2.73	2.59	2.98	2.97
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.19	0.14	0.12	0.11
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	4.54	3.46	2.76	2.60
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	65.3	63.5	66.8	69.2
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	23.9	24.5	22.4	23.3
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	5.13	5.62	5.76	3.35
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	1.10	2.91	2.24	1.53
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					BHT_05	BHT_06	BHT_07	BHT_08
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	Method Description	Method Reference	Units	LOR	211809-5	211809-6	211809-7	211809-8
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	1.10	1.73	1.91	1.91
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	43.8	34.8	27.2	30.4
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	15.8	33.3	29.3	24.3
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	30.1	22.2	24.2	29.8
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	2.8	3.2	4.7	3.5
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	7.5	6.5	14.5	12.0

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	BHT_09	BHT_10	BHT_11	BHT_12
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-9**	**211809-10**	**211809-11**	**211809-12**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	0.70	1.51	0.97	0.82
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	6.50	5.96	6.45	6.89
Chloride Soluble	DA	DAP-06	mg/kg	2	30.4	35.4	16.9	16.8
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.04	0.02	0.01	0.03
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	204	197	436	257
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	5.31	2.89	1.46	6.25
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	6.84	7.88	3.33	2.25
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	407	654	424	482
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.41	0.53	0.72	0.77
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	21.0	30.2	22.7	20.6
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	65.7	63.3	76.9	66.3
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	7.85	40.8	8.06	9.30
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.60	0.38	0.64	0.76
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.73	0.45	0.57	0.53
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	23.3	8.52	23.9	23.6
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	8.06	7.66	9.90	9.06
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.40	0.54	0.34	0.42
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	37.8	33.7	83.1	38.1
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	424	232	504	639
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	126	117	131	106
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	50.4	24.7	41.4	24.9
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	16.9	6.00	5.55	4.35
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.10	0.09	0.21	0.10
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	2.12	1.16	2.52	3.20
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	1.05	0.98	1.09	0.88
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.22	0.11	0.18	0.11

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					BHT_09	BHT_10	BHT_11	BHT_12
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-9**	**211809-10**	**211809-11**	**211809-12**
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.19	0.07	0.06	0.05
ECEC	Calculation	PMS-15A1	cmol/kg	na	3.67	2.40	4.07	4.33
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	2.02	1.19	2.31	3.62
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.09	0.09	0.20	0.11
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	2.64	3.61	5.24	2.25
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	57.7	48.4	62.0	73.7
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	28.6	40.7	26.8	20.4
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	5.96	4.48	4.43	2.50
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	5.11	2.78	1.52	1.12
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

					BHT_09	BHT_10	BHT_11	BHT_12
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-9**	**211809-10**	**211809-11**	**211809-12**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	4.14	1.47	1.36	1.06
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	38.8	24.1	53.8	25.1
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	17.0	29.1	15.3	29.4
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	32.2	26.3	24.8	31.8
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	1.9	5.0	1.5	5.0
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	10.1	15.4	4.6	8.7

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					BHT_13	BHT_14	BHT_15	HD2_01
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-13**	**211809-14**	**211809-15**	**211809-16**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.38	1.15	1.28	1.00
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	6.32	5.55	6.34	6.44
Chloride Soluble	DA	DAP-06	mg/kg	2	17.2	126	21.4	18.7
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.02	0.33	0.02	0.03
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	284	664	395	385
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	4.53	203	4.32	2.93
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	<2.0	13.2	8.31	3.15
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	329	488	414	489
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	1.73	0.51	0.64	0.89
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	15.0	19.7	17.3	14.9
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	105	90.1	70.2	159
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	7.28	15.1	7.81	7.41
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.30	0.88	0.84	0.90
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.47	0.53	0.53	0.60
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	21.5	48.8	30.6	25.6
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	13.2	12.6	10.1	11.7
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.48	0.54	0.34	0.38
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	118	89.0	50.6	117
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	782	928	407	516
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	174	200	131	116
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	62.5	167	65.5	57.8
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	6.45	6.90	11.4	7.95
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.30	0.23	0.13	0.30
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	3.91	4.64	2.04	2.58
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	1.45	1.67	1.09	0.97
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.27	0.73	0.28	0.25

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					BHT_13	BHT_14	BHT_15	HD2_01
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-13**	**211809-14**	**211809-15**	**211809-16**
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.07	0.08	0.13	0.09
ECEC	Calculation	PMS-15A1	cmol/kg	na	6.01	7.34	3.67	4.19
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	2.70	2.78	1.86	2.67
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.21	0.14	0.12	0.31
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	5.04	3.11	3.54	7.17
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	65.1	63.2	55.5	61.6
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	24.1	22.7	29.8	23.1
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	4.52	9.90	7.76	6.00
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	1.19	1.04	3.45	2.11
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

					BHT_13	BHT_14	BHT_15	HD2_01
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-13**	**211809-14**	**211809-15**	**211809-16**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	1.58	1.69	2.79	1.95
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	26.3	32.5	40.5	30.7
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	17.4	20.8	24.0	27.2
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	35.6	32.9	24.7	30.9
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	5.1	3.4	1.9	2.1
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	15.6	10.4	9.0	9.1

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_02	HD2_03	HD2_04	HD2_05
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-17**	**211809-18**	**211809-19**	**211809-20**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.29	0.81	1.00	1.22
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	6.08	5.68	7.82	4.61
Chloride Soluble	DA	DAP-06	mg/kg	2	28.7	21.9	22.1	65.6
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.04	0.01	0.03	0.41
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	999	335	131	720
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	7.04	2.17	1.50	232
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	3.95	6.23	<2.0	10.4
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	474	468	225	601
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.42	0.46	0.73	0.72
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	8.51	20.8	23.0	20.0
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	188	91.1	80.7	209
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	9.30	10.9	7.19	23.2
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.00	0.78	1.00	2.20
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.81	0.59	0.95	1.29
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	47.7	37.2	12.3	59.4
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	24.4	11.1	8.58	12.6
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.50	0.32	0.38	0.72
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	177	96.3	36.3	183
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	935	351	730	877
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	156	95.3	123	98.2
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	41.6	33.3	52.4	53.7
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	3.15	9.45	<1.00	17.7
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.45	0.25	0.09	0.47
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	4.68	1.76	3.65	4.39
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	1.30	0.79	1.03	0.82
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.18	0.14	0.23	0.23

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_02	HD2_03	HD2_04	HD2_05
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-17	211809-18	211809-19	211809-20
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.04	0.11	0.01	0.20
ECEC	Calculation	PMS-15A1	cmol/kg	na	6.64	3.05	5.01	6.10
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	3.60	2.21	3.56	5.36
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.35	0.31	0.09	0.57
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	6.83	8.11	1.86	7.69
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	70.4	57.6	72.9	71.9
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	19.6	26.1	20.5	13.4
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	2.72	4.75	4.55	3.83
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	0.53	3.45	0.22	3.22
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	163
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	611
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	80.9
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	42.1
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	0.42
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	3.06
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	0.67
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	0.18
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	4.53
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	4.53
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	0.62
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	9.23
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	67.5
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	14.9
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	4.04
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	NA	NA	NA	4.34
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	43.1	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					HD2_02	HD2_03	HD2_04	HD2_05
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	Method Description	Method Reference	Units	LOR	211809-17	211809-18	211809-19	211809-20
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	355	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	117	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	34.6	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	0.11	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	1.78	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	0.98	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	0.15	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	3.02	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	1.82	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	0.11	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	3.66	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	58.7	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	32.3	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	4.98	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	0.77	2.31	0.37	6.51
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	33.2	52.0	29.3	9.0
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	19.9	9.5	31.7	24.2
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	35.1	29.8	23.9	33.6
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	3.2	2.3	5.9	10.5
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	8.6	6.4	9.3	22.6

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_06	HD2_07	HD2_08	HD2_09
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-21**	**211809-22**	**211809-23**	**211809-24**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.10	1.09	0.85	1.44
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	5.60	6.53	6.12	6.47
Chloride Soluble	DA	DAP-06	mg/kg	2	20.2	19.1	12.6	18.8
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.06	0.02	0.02	0.02
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	497	114	189	645
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	15.1	3.63	5.22	3.06
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	4.04	3.95	3.15	2.07
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	483	394	326	568
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.61	0.90	0.58	1.02
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	17.1	19.7	27.4	32.5
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	144	90.6	68.2	431
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	15.6	8.41	6.71	6.46
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	2.94	0.82	1.00	2.92
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.21	0.53	0.59	3.99
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	45.8	26.3	42.8	34.8
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	12.5	7.68	11.6	12.0
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.50	0.46	0.28	0.46
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	156	50.7	50.3	460
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	726	418	473	1047
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	101	152	111	198
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	66.8	93.8	85.8	60.6
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	14.4	16.5	12.8	7.20
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.40	0.13	0.13	1.18
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	3.63	2.09	2.37	5.24
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	0.84	1.27	0.93	1.65
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.29	0.41	0.37	0.26

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_06	HD2_07	HD2_08	HD2_09
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-21	211809-22	211809-23	211809-24
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.16	0.18	0.14	0.08
ECEC	Calculation	PMS-15A1	cmol/kg	na	5.32	4.08	3.93	8.41
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	4.31	1.65	2.56	3.17
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.48	0.10	0.14	0.71
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	7.52	3.19	3.28	14.0
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	68.2	51.3	60.1	62.3
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	15.8	31.1	23.5	19.6
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	5.46	10.0	9.48	3.13
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	3.01	4.50	3.61	0.95
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	3.53	4.05	3.14	1.77
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

					HD2_06	HD2_07	HD2_08	HD2_09
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-21**	**211809-22**	**211809-23**	**211809-24**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	5.29	6.07	4.71	2.65
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	22.0	42.0	29.8	7.2
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	23.1	18.9	28.6	21.6
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	29.4	26.9	30.3	33.6
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	7.6	2.7	3.3	13.1
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	17.8	9.4	7.9	24.5

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_10	HD2_11	HD2_12	HD2_13
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-25**	**211809-26**	**211809-27**	**211809-28**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.40	0.90	0.94	1.02
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	6.76	5.96	5.40	5.76
Chloride Soluble	DA	DAP-06	mg/kg	2	14.6	29.8	20.6	16.6
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.01	0.09	0.02	0.02
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	300	887	391	426
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	1.42	31.3	2.71	7.35
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	3.24	<2.0	2.16	<2.0
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	373	482	351	348
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.64	0.92	0.54	0.79
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	42.2	12.1	20.4	22.6
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	228	140	67.2	97.0
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	6.94	13.6	10.3	7.84
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	3.46	3.49	1.90	2.70
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	3.91	2.17	0.65	0.89
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	18.2	22.8	28.1	13.7
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	9.24	8.80	13.7	9.10
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.30	0.70	0.34	0.46
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	253	144	42.2	102
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	1253	809	495	521
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	322	130	156	110
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	82.8	97.5	84.6	41.1
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	2.25	5.85	7.20	8.40
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.65	0.37	0.11	0.26
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	6.27	4.05	2.48	2.61
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	2.68	1.08	1.30	0.92
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.36	0.42	0.37	0.18

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_10	HD2_11	HD2_12	HD2_13
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-25	211809-26	211809-27	211809-28
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.03	0.07	0.08	0.09
ECEC	Calculation	PMS-15A1	cmol/kg	na	9.98	5.99	4.33	4.06
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	2.33	3.73	1.90	2.84
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.24	0.34	0.08	0.29
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	6.50	6.17	2.50	6.45
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	62.8	67.6	57.1	64.2
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	26.9	18.1	30.0	22.6
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	3.61	7.08	8.49	4.41
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	0.25	1.09	1.85	2.30
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	0.55	1.44	1.77	2.06
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

					HD2_10	HD2_11	HD2_12	HD2_13
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-25**	**211809-26**	**211809-27**	**211809-28**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	0.83	2.15	2.65	3.09
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	13.3	11.0	24.6	16.5
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	23.1	20.2	15.0	16.4
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	40.8	34.8	36.8	36.9
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	10.1	7.6	5.1	7.1
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	12.8	26.3	18.5	23.0

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_14	HD2_15	HD2_16	HD2_17
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-29**	**211809-30**	**211809-31**	**211809-32**
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.30	1.08	1.11	1.35
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	5.49	6.13	5.40	6.19
Chloride Soluble	DA	DAP-06	mg/kg	2	20.3	17.6	16.7	14.5
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.03	0.02	0.03	0.03
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	277	455	309	628
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	7.58	4.33	4.63	2.94
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	2.25	5.45	2.79	2.34
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	426	432	382	292
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.68	0.94	0.68	1.07
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	13.2	26.7	26.2	10.1
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	70.0	67.5	70.3	200
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	8.83	9.00	13.1	8.50
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	2.14	1.42	3.08	3.70
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.19	0.57	1.83	4.14
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	26.9	41.3	23.2	38.9
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	10.7	11.3	8.28	12.6
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.30	0.42	0.37	0.54
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	76.3	58.3	62.5	202
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	474	593	554	851
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	146	131	107	152
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	30.3	69.3	74.7	48.3
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	4.80	2.35	26.1	14.5
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.20	0.15	0.16	0.52
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	2.37	2.97	2.77	4.26
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	1.22	1.09	0.89	1.27
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.13	0.30	0.32	0.21

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_14	HD2_15	HD2_16	HD2_17
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-29	211809-30	211809-31	211809-32
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.05	0.03	0.29	0.16
ECEC	Calculation	PMS-15A1	cmol/kg	na	3.97	4.53	4.44	6.41
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	1.95	2.72	3.11	3.36
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.16	0.14	0.18	0.41
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	4.93	3.30	3.61	8.08
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	59.7	65.4	62.4	66.4
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	30.7	24.1	20.1	19.8
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	3.32	6.65	7.32	3.28
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	1.34	0.58	6.54	2.51
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	1.18	0.58	6.41	3.56
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

					HD2_14	HD2_15	HD2_16	HD2_17
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-29**	**211809-30**	**211809-31**	**211809-32**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	1.76	0.86	9.60	5.33
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	15.5	37.1	20.0	23.0
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	23.4	20.0	20.6	21.6
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	31.7	28.4	33.0	32.8
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	5.5	4.1	6.9	3.8
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	23.9	10.4	19.5	18.8

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_18	HD2_19	HD2_20	HD2_21
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-33	211809-34	211809-35	211809-36
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	1.01	1.20	1.09	1.53
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	5.28	5.34	5.94	7.95
Chloride Soluble	DA	DAP-06	mg/kg	2	14.3	38.7	19.3	23.9
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.02	0.08	0.04	0.11
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	379	482	758	1252
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	3.73	12.1	10.3	4.12
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	2.34	10.2	4.61	<2.0
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	442	279	374	603
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.93	1.02	1.51	1.43
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	16.4	35.6	8.72	21.4
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	126	75.4	105	302
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	9.72	18.2	9.53	8.70
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	2.60	2.18	1.18	1.66
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.29	0.89	0.81	0.83
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	36.5	19.5	34.1	18.4
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	10.6	17.2	14.7	8.28
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.56	0.64	0.36	0.94
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	135	55.3	113	305
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	527	785	805	3026
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	78.9	173	124	208
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	76.0	55.3	61.7	82.9
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	13.6	7.20	2.70	<1.00
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.35	0.14	0.29	0.78
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	2.64	3.93	4.03	15.1
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	0.66	1.44	1.03	1.73
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.33	0.24	0.27	0.36

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_18	HD2_19	HD2_20	HD2_21
				DEPTH				
Test Parameter	Method Description	Method Reference	Units	LOR	211809-33	211809-34	211809-35	211809-36
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.15	0.08	0.03	0.01
ECEC	Calculation	PMS-15A1	cmol/kg	na	4.12	5.83	5.65	18.0
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	4.01	2.72	3.90	8.73
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.53	0.10	0.28	0.45
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	8.40	2.43	5.13	4.34
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	64.0	67.3	71.3	84.0
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	16.0	24.7	18.3	9.62
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	8.02	4.12	4.75	2.00
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	3.67	1.37	0.53	0.06
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA	NA	NA
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA	NA	NA
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA	NA	NA
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA	NA	NA
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA	NA	NA
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	3.34	1.77	0.66	0.25
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	292

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

					HD2_18	HD2_19	HD2_20	HD2_21
			CLIENT SAMPLE ID					
			DEPTH					
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-33**	**211809-34**	**211809-35**	**211809-36**
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA	NA	1475
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	158
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA	NA	46.4
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	0.75
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	7.38
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA	NA	1.32
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA	NA	0.20
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	9.65
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	5.60
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA	NA	0.57
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA	NA	7.76
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA	NA	76.4
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA	NA	13.6
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA	NA	2.09
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	5.00	2.65	0.99	0.12
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	13.9	23.9	33.9	26.8
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	26.8	18.4	22.9	22.5
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	34.1	36.4	30.3	31.7
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	6.9	4.9	3.2	5.0
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	18.2	16.4	9.7	14.0

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_22	HD2_23		
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-37**	**211809-38**		
Moisture Content (Oven Dry)	Oven-Dry	PMS-17	%	na	0.87	1.08		
pH (1:5 in H20)	Electrode	R&L 4A2	pH units	na	5.84	5.90		
Chloride Soluble	DA	DAP-06	mg/kg	2	22.1	17.0		
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.04	0.01		
Total N (LECO)	LECO	R&L 7A5	mg/kg	50	481	323		
Extractable Nitrate-N	DA	DAP-03	mg/kg	0.5	11.8	1.06		
Ammonium - N (Ex)	ExKCl/UV-Vis	PMS-22	mg/kg	2	3.06	<2.0		
Phosphorus (Total)	HNO3/HCLO4 ICP	ICP-03	mg/kg	40	442	283		
Organic Carbon (LECO)	LECO	R&L 6B3	%	0.05	0.95	0.54		
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	1	12.8	20.7		
Potassium (Available)	Bicarb/ICP	R&L 18A1	mg/kg	10	99.7	90.5		
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	8.62	8.83		
Extractable Copper	DTPA/ICP	R&L 12A1	mg/kg	0.2	1.22	0.76		
Extractable Zinc	DTPA/ICP	R&L 12A1	mg/kg	0.2	0.75	0.55		
Extractable Manganese	DTPA/ICP	R&L 12A1	mg/kg	0.5	48.6	30.9		
Extractable Iron	DTPA/ICP	R&L 12A1	mg/kg	0.5	15.8	8.20		
Extractable Boron	Hot CaCl2/ICP	R&L 12C2	mg/kg	0.2	0.36	0.22		
Exchangeable Potassium	NH4Cl/ICP	R&L 15A1	mg/kg	10	97.7	94.3		
Exchangeable Calcium	NH4Cl/ICP	R&L 15A1	mg/kg	20	755	449		
Exchangeable Magnesium	NH4Cl/ICP	R&L 15A1	mg/kg	10	138	131		
Exchangeable Sodium	NH4Cl/ICP	R&L 15A1	mg/kg	10	11.5	22.2		
Exchangeable Aluminium	KCl/ICP	R&L 15G1	mg/kg	1	1.65	9.15		
Exchangeable Potassium	R&L 15A1	R&L 15A1	cmol/kg	na	0.25	0.24		
Exchangeable Calcium	R&L 15A1	R&L 15A1	cmol/kg	na	3.78	2.25		
Exchangeable Magnesium	R&L 15A1	R&L 15A1	cmol/kg	na	1.15	1.09		
Exchangeable Sodium	R&L 15A1	R&L 15A1	cmol/kg	na	0.05	0.10		

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ANALYSIS REPORT

PROJECT NO: EW211809 Location: 2079.21eRTIO HD1

				CLIENT SAMPLE ID	HD2_22	HD2_23		
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-37**	**211809-38**		
Exchangeable Aluminium	Calculation	R&L 15J1	cmol/kg	na	0.02	0.10		
ECEC	Calculation	PMS-15A1	cmol/kg	na	5.24	3.78		
Ca/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	3.28	2.06		
K/Mg Ratio	Calculation	PMS-15A1	cmol/kg	na	0.22	0.22		
Exchangeable Potassium %	Calculation	PMS-15A1	%	na	4.78	6.40		
Exchangeable Calcium %	Calculation	PMS-15A1	%	na	72.0	59.4		
Exchangeable Magnesium %	Calculation	PMS-15A1	%	na	21.9	28.9		
Exchangeable Sodium %	Calculation	PMS-15A1	%	na	0.95	2.56		
Exchangeable Aluminium %	Calculation	PMS-15A1	%	na	0.35	2.69		
Exchangeable Potassium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA		
Exchangeable Calcium	ICP-OES	R&L 15A2	mg/kg	20	NA	NA		
Exchangeable Magnesium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA		
Exchangeable Sodium	ICP-OES	R&L 15A2	mg/kg	10	NA	NA		
Exchangeable Potassium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA		
Exchangeable Calcium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA		
Exchangeable Magnesium	PMS-15A2	PMS-15A2	cmol/kg	na	NA	NA		
Exchangeable Sodium	R&L 15A2	R&L 15A2	cmol/kg	na	NA	NA		
ECEC	Calculation	PMS-15A2	cmol/kg	na	NA	NA		
Ca/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA		
K/Mg Ratio	Calculation	PMS-15A2	cmol/kg	na	NA	NA		
Exchangeable Potassium %	Calculation	PMS-15A2	%	na	NA	NA		
Exchangeable Calcium %	Calculation	PMS-15A2	%	na	NA	NA		
Exchangeable Magnesium %	Calculation	PMS-15A2	%	na	NA	NA		
Exchangeable Sodium %	Calculation	PMS-15A2	%	na	NA	NA		
Exchangeable Aluminium %	Calculation	PMS-15A2	%	na	0.40	2.25		
Exchangeable Potassium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA		

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ANALYSIS REPORT

PROJECT NO: EW211809 **Location: 2079.21eRTIO HD1**

				CLIENT SAMPLE ID	HD2_22	HD2_23		
				DEPTH				
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**211809-37**	**211809-38**		
Exchangeable Calcium	ICP-OES	R&L 15C1	mg/kg	20	NA	NA		
Exchangeable Magnesium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA		
Exchangeable Sodium	ICP-OES	R&L 15C1	mg/kg	10	NA	NA		
Exchangeable Potassium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA		
Exchangeable Calcium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA		
Exchangeable Magnesium	PMS-15C1	PMS-15C1	cmol/kg	na	NA	NA		
Exchangeable Sodium	R&L 15C1	R&L 15C1	cmol/kg	na	NA	NA		
ECEC	Calculation	PMS-15C1	cmol/kg	na	NA	NA		
Ca/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA		
K/Mg Ratio	Calculation	PMS-15C1	cmol/kg	na	NA	NA		
Exchangeable Potassium %	Calculation	PMS-15C1	%	na	NA	NA		
Exchangeable Calcium %	Calculation	PMS-15C1	%	na	NA	NA		
Exchangeable Magnesium %	Calculation	PMS-15C1	%	na	NA	NA		
Exchangeable Sodium %	Calculation	PMS-15C1	%	na	NA	NA		
Exchangeable Aluminium %	Calculation	PMS-15C1	%	na	0.19	1.05		
Gravel >2.0mm	Sieve	ASTMD422-63	%	na	34.3	52.3		
Coarse Sand 0.2-2.0mm	Sieve	ASTMD422-63	%	na	18.1	10.3		
Fine Sand 0.02-0.2mm	Sieve	ASTMD422-63	%	na	32.4	27.6		
Silt 0.002-0.02mm	Hydrometer	ASTMD422-63	%	na	3.2	2.4		
Clay <0.002mm	Hydrometer	ASTMD422-63	%	na	12.0	7.4		

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This Analysis Report shall not be reproduced except in full without the written approval of the laboratory.

Soils are air dried at 40^{o}C and ground <2mm.

NB: LOR is the Lowest Obtainable Reading.

DOCUMENT END

Agricultural Chemistry Pty Ltd

5 Mittani Court
Raceview Qld 4305

Phone: 0409 494 288
Fax:
email: ian@agriculturalchemistry.com.au

Date Received: 29/12/2021
Date Completed: 8/2/2022

FINAL REPORT

DRAFT

Project:

2079.21e RTIO HD1

All results in this report relate only to the items tested. Results are expressed on an "as received basis".

Client Name: Landloch Pty Ltd

Contact: Anna Reed

Sample Type: soil

Number of samples: 38

Agricultural Chemistry Pty Ltd

Soil Analysis Report
Batch Number: 22/01

Date Received: 29/12/2021
Date Completed: 8/2/2022

Client: Landloch Pty Ltd

Lab No	Sample ID	Depth	K-Sat	Vol Drained	Time	1/3 bar	15 bar
		cm	cm/hr	mls	min	%	%
1	BHT_01		103.3	1800	9	13	8
2	BHT_02		7.4	860	60	14	8
3	BHT_03		89.2	1900	11	14	9
4	BHT_04		156.4	1600	10	18	10
5	BHT_05		38.2	1480	20	16	9
6	BHT_06		57.6	1450	13	15	9
7	BHT_07		50.6	1470	15	18	12
8	BHT_08		0.65	150	120	16	9
9	BHT_09		0.65	150	120	14	7
10	BHT_10		0.90	210	120	21	13
11	BHT_11		40.9	1900	24	14	9
12	BHT_12		0.75	175	120	12	6
13	BHT_13		0.95	220	120	16	9
14	BHT_14		1.85	430	120	14	8
15	BHT_15		0.77	180	120	15	9
16	HD2_01		1.38	320	120	13	9
17	HD2_02		0.90	210	120	19	10
18	HD2_03		0.84	196	120	15	9
19	HD2_04		0.95	220	120	17	10
20	HD2_05		2.9	675	120	17	11
21	HD2_06		2.8	650	120	17	11
22	HD2_07		1.18	275	120	14	10
23	HD2_08		1.08	250	120	12	8
24	HD2_09		0.41	95	120	24	12
25	HD2_10		0.44	102	120	16	10
26	HD2_11		1.79	415	120	18	12
27	HD2_12		1.23	285	120	16	11
28	HD2_13		2.43	565	120	15	11
29	HD2_14		0.95	220	120	17	11
30	HD2_15		0.56	130	120	17	10
31	HD2_16		1.94	450	120	16	11
32	HD2_17		1.91	445	120	17	12
33	HD2_18		1.12	260	120	16	10
34	HD2_19		1.42	330	120	16	11
35	HD2_20		1.59	370	120	17	10
36	HD2_21		1.05	245	120	23	13
37	HD2_22		0.89	206	120	20	10
38	HD2_23		1.76	410	120	18	9

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METHOD DESCRIPTIONS

Soil

Methods used to Analyse Samples

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
pH	4A1	1.1	0.1	pH	pH	1:5 water extr, pH meter
EC	3A1	5.4	0.01	dS/m	Electrical conductivity	1:5 water extr, EC meter
Cl	5A2	10.0	10.0	mg/kg	Chloride	1:5 water extr, (AA) colorimetric
NO3-N	7C2	6.7	1.0	mg/kg	Nitrate-nitrogen	1:5 water extr, (AA) colorimetric
NH4-N	7C2	7.8	0.6	mg/kg	Ammonium-nitrogen	1M KCl extr, (AA) colorimetric
Bicarb.P	9B2	16.8	1.0	mg/kg	Bicarb.ext.phosphorus	0.5M NaHCO3 @ pH 8.5, (AA) colorimetric
TN	7A2	12.9	0.01	%	Total Kjeldahl Nitrogen	Sulphuric acid digest, (AA) colorimetric
OC	8B1	9.7	0.02	%	Organic Carbon	Walkley & Black, (H2SO4/K2Cr2O7), titr.
Ca (Neut)	15A1	10.3	0.10	meq/100g	Exchangeable calcium	1M NH4Cl @ pH 7.0 shake, AAS
Mg (Neut)	15A1	6.6	0.10	meq/100g	Exchangeable magnesium	1M NH4Cl @ pH 7.0 shake, AAS
Na (Neut)	15A1	7.3	0.03	meq/100g	Exchangeable sodium	1M NH4Cl @ pH 7.0 shake, AAS
K (Neut)	15A1	3.9	0.02	meq/100g	Exchangeable potassium	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	no ref	22.1	1.0	%	Particle size, sand	Hydrometer, gravimetric
Silt	no ref	16.6	1.0	%	Particle size, silt	Hydrometer, gravimetric
Clay	no ref	12.7	1.0	%	Particle size, clay	Hydrometer, gravimetric

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*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

For Manager
Analytical Services: _____

Agricultural Chemistry Pty Ltd

METHOD DESCRIPTIONS

Soil

Methods used to Analyse Samples

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
Ca (Alc)	15C1	7.2	0.18	meq/100g	Exchangeable calcium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
Mg (Alc)	15C1	4.7	0.31	meq/100g	Exchangeable magnesium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
Na (Alc)	15C1	9.6	0.09	meq/100g	Exchangeable sodium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
K (Alc)	15C1	4.8	0.02	meq/100g	Exchangeable potassium	1M NH4Cl (alcoholic) @ pH 8.5 leach, AAS
CEC	15I3	5.7	1.0	meq/100g	Cation Exchange Capacity	KNO3 + Ca(NO3)2 extr, (AA) colorimetric
DTPA-Cu	12A1	17.1	0.26	mg/kg	DTPA ext. copper	DTPA extraction, AAS
DTPA-Zn	12A1	16.4	0.10	mg/kg	DTPA ext. zinc	DTPA extraction, AAS
DTPA-Mn	12A1	9.0	0.32	mg/kg	DTPA ext. manganese	DTPA extraction, AAS
DTPA-Fe	12A1	13.0	0.23	mg/kg	DTPA ext. iron	DTPA extraction, AAS
ADMC	2A1	11.9	0.4	%	Air Dried Moisture Content	Gravimetric oven dry @ 105C
R1	NA	20.2	NA		Dispersion Ratio	Ratio [Aqueous dispersible (Silt + Clay):Total (Silt + Clay)]
SO4-S	10B3	11.5	0.6	mg/kg	Sulfate sulfur	Ca(H2PO4)2 @ pH 4.0 extractable sulfate-sulfur, ICPOES
Al	15G1	NA	NA	meq/100g	Exchangeable Aluminium	Exch. Hydrogen and Aluminium by 1M KCl
H+	15G1	NA	NA	meq/100g	Exchangeable Acidity	Exch. Hydrogen and Aluminium by 1M KCl
15 Bar		NA	NA		15 Bar Analysis	Pressure Plate/Gravimetric oven dry @ 105C
1/3 Bar		NA	NA		1/3 Bar Analysis	Pressure Plate/Gravimetric oven dry @ 105C
Permeability	AS 4419			cm/hr	Permeability	

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*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

For Manager
Analytical Services: _____

Agricultural Chemistry Pty Ltd

QUALITY CONTROL DATA

Soil

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

Test Method	Units		Actual Value	Acceptance Criteria [Range]
pH	pH	MB		7.5 - 8.1
EC	dS/m	MB		.120 - .145
Cl	mg/kg	MB		30 - 40
NO3-N	mg/kg	MB		1.5 - 4.1
NH4-N	mg/kg			
Bicarb.P	mg/kg	MB		58 - 75
Total N	%	114-08		.414 - .600
Total P	%	114-08		.189 - .230
Organic Carbon	%	MB		2.3 - 2.8
Ca (Exch. cations)pH7	meq/100g	KAL		17.2 - 20.9
Mg (Exch. cations)pH7	meq/100g	KAL		9.9 - 11.5
Na (Exch. cations)pH7	meq/100g	KAL		1.01 - 1.33
K (Exch. cations)pH7	meq/100g	KAL		.455 - .721
Exch. Acidity	meq/100g			
CEC	meq/100g	S12		58 - 73
Coarse sand	%	RD		29 -33
Fine Sand	%	RD		27 - 33
Silt	%	RD		11 - 16
Clay	%	RD		21 - 30
R1		RD		.40 - .57

Test Method	Units	Test Soil	Actual Value	Acceptance Criteria [Range]
DTPA-Cu	mg/kg	kal		1.55 - 2.10
DTPA-Zn	mg/kg	kal		.15 - .35
DTPA-Mn	mg/kg	kal		31.5 - 61.2
DTPA-Fe	mg/kg	kal		29.1 - 46.3
Suflate-sulfur	mg/kg	PM		60 - 75
15 Bar	%	G	28, 28, 30, 30	23 - 32
0.33 Bar	%	G	45, 47, 48, 50	38 - 52
1 Bar	%	G		36 - 45
3 Bar	%	G		30 - 38
0.1 Bar	%	G		53 - 65
Saturation	%	G		64 - 78
Ca (Exch. cations)pH8.5	meq/100g	S12		27.7 - 37.4
Mg (Exch. cations)pH8.5	meq/100g	S12		22.88 - 26.5
Na (Exch. cations)pH8.5	meq/100g	S12		2.0 - 2.28
K (Exch. cations)pH8.5	meq/100g	S12		1.64 - 2.09

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EMERSON DISPERSION TEST

CLIENT: RTIO Hope Downs 1
PROJECT: Hope Downs 2 Topsoil Suitability
PROJECT CODE: 2079.21e
MATERIAL: Growth media
DATE: 16/12/2021

SAMPLE ID	Description	SLAKING @ 2 HOURS Y/N	DISPERSION @ 2HOURS Y/N	DISPERSON @ 20 HOURS Y/N	REMOULD DISPERSION @ 2 HOURS Y/N	SHAKE TEST D/F	EMERSON CLASS -
BHT_01	Lower elevation, rock, minimal fine material	No aggregates	No aggregates	No aggregates	Y - SLIGHT	D	3
BHT_02	In lower elevation, rocky, minimal fine material	N	N	N	Y	D	3
BHT_03	Higher elevation, very rocky	No aggregates	No aggregates	No aggregates	Y - SLIGHT	D	3
BHT_04	Higher elevation, very rocky	No aggregates	No aggregates	No aggregates	N	D	5
BHT_05	Higher elevation, very rocky	No aggregates	No aggregates	No aggregates	Y	D	3
BHT_06	Higher elevation, very rocky, close to gully	No aggregates	No aggregates	No aggregates	N	D	5
BHT_07	Still high elevation, closer to	Y	N	N	Y - SLIGHT	D	3
BHT_08	Finer material with rocks	No aggregates	No aggregates	No aggregates	Y	D	3
BHT_09	Very rocky area, on side of hill	No aggregates	No aggregates	No aggregates	N	D	5
BHT_10	Very dry area, rocky material in higher elevation	No aggregates	No aggregates	No aggregates	N	D	5
BHT_11	Higher elevation, very rocky	No aggregates	No aggregates	No aggregates	Y	D	3
BHT_12	Finer material with rocks	Y	N	N	Y	D	3
BHT_13	Dirt like with roots	Y	N	N	Y	D	3
BHT_14	Higher elevation, very rocky	No aggregates	No aggregates	No aggregates	N	D	5
BHT_15	Higher elevation, very rocky, closer to a gully	No aggregates	No aggregates	No aggregates	Y	D	3

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SAMPLE ID	Description	SLAKING @ 2 HOURS Y/N	DISPERSION @ 2HOURS Y/N	DISPERSON @ 20 HOURS Y/N	REMOULD DISPERSION @ 2 HOURS Y/N	SHAKE TEST D/F	EMERSON CLASS -
HD2_01	On side of hill, recent bushfire through area, rocky material, little soil	No aggregates	No aggregates	No aggregates	Y	D	3
HD2_02	On side of hill, recent bushfire through area, rocky material, little soil	No aggregates	No aggregates	No aggregates	Y	D	3
HD2_03	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	N	D	5
HD2_04	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y	D	3
HD2_05	Finer soil, on lower elevation	Y	N	N	N	D	5
HD2_06	Finer material with rocks, on lower elevation	Y	N	N	N	D	5
HD2_07	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y - SLIGHT	D	3
HD2_08	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y - SLIGHT	D	3
HD2_09	Finer material with rocks, on lower elevation	Y	N	N	Y	D	3
HD2_10	Finer material with rocks, on lower elevation	Y	N	N	Y	D	3
HD2_11	Finer material with rocks, on lower elevation	N	N	N	Y - SLIGHT	D	3
HD2_12	Finer material with rocks, on lower elevation	Y	N	N	Y	D	3
HD2_13	Finer material with rocks, on lower elevation	Y	N	N	Y	D	3
HD2_14	Finer material with rocks, on lower elevation	Y	N	N	N	D	5
HD2_15	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y - SLIGHT	D	3
HD2_16	Finer material with rocks, on lower elevation	Y	N	N	N	D	5
HD2_17	Finer material with rocks, on lower elevation	Y	N	N	Y	D	3
HD2_18	Finer material with rocks, on lower elevation	Y	N	N	Y	D	3
HD2_19	Finer material with rocks, on lower elevation	N	N	N	N	D	5
HD2_20	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y	D	3
HD2_21	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y	D	3
HD2_22	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	Y	D	3
HD2_23	Finer material with rocks, on lower elevation	No aggregates	No aggregates	No aggregates	N	D	5

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BASE PROPERTIES DATA

CLIENT NAME: RTIO Hope Downs 2
PROJECT NAME: Hope Downs 2 Topsoil Suitability
PROJECT CODE: 2079.21e
DATE: 16/12/2021

Sample ID	Description	Coarse Fragments >2mm
BHT_01	Lower elevation, rock, minimal fine material	70
BHT_02	In lower elevation, rocky, minimal fine material	72
BHT_03	Higher elevation, very rocky	69
BHT_04	Higher elevation, very rocky	73
BHT_05	Higher elevation, very rocky	77
BHT_06	Higher elevation, very rocky, close to gully	67
BHT_07	Still high elevation, closer to	64
BHT_08	Finer material with rocks	63
BHT_09	Very rocky area, on side of hill	67
BHT_10	Very dry area, rocky material in higher elevation	54
BHT_11	Higher elevation, very rocky	79
BHT_12	Finer material with rocks	59
BHT_13	Dirt like with roots	42
BHT_14	Higher elevation, very rocky	68
BHT_15	Higher elevation, very rocky, closer to a gully	57
HD2_01	On side of hill, recent bushfire through area, rocky material, little soil	74
HD2_02	On side of hill, recent bushfire through area, rocky material, little soil	74
HD2_03	Finer material with rocks, on lower elevation	79
HD2_04	Finer material with rocks, on lower elevation	48
HD2_05	Finer soil, on lower elevation	26
HD2_06	Finer material with rocks, on lower elevation	32
HD2_07	Finer material with rocks, on lower elevation	72
HD2_08	Finer material with rocks, on lower elevation	61
HD2_09	Finer material with rocks, on lower elevation	18
HD2_10	Finer material with rocks, on lower elevation	10
HD2_11	Finer material with rocks, on lower elevation	34
HD2_12	Finer material with rocks, on lower elevation	52
HD2_13	Finer material with rocks, on lower elevation	30
HD2_14	Finer material with rocks, on lower elevation	33
HD2_15	Finer material with rocks, on lower elevation	60
HD2_16	Finer material with rocks, on lower elevation	45
HD2_17	Finer material with rocks, on lower elevation	47
HD2_18	Finer material with rocks, on lower elevation	22
HD2_19	Finer material with rocks, on lower elevation	60
HD2_20	Finer material with rocks, on lower elevation	68
HD2_21	Finer material with rocks, on lower elevation	66
HD2_22	Finer material with rocks, on lower elevation	72
HD2_23	Finer material with rocks, on lower elevation	83

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Appendix 9: Proposal AMD Risk Assessment

DRAFT

Pilbara Iron Company (Services) Pty Ltd
Level 18
Central Park
152-158 St Georges Terrace
Perth WA 6000
Australia
T +61 (8) 9327 2000

Technical memo

From	Steven Lee, Sarah Fyfe
Department	Mineral Waste - Water Resource Evaluation
To	Michelle Doak, Kylie McKay, Belinda Yaqub, Chantelle Dodge
Copies	Shane Trott
Reference	RTIO-PDE-0178960
Date	November 2020

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Hope Downs 2 and Bedded Hilltop AMD risk assessment

Context

A review of the acid and metalliferous drainage (AMD) risk associated with the Hope Downs 2 and Bedded Hilltop iron ore deposits has been completed to support the Hope Downs 2 Mine Closure Plan. This review considers drillhole and mine planning data, supplemented by geochemical test data, to assess the AMD risks relating to waste rock remaining upon closure.

The overall AMD risk for the Hope Downs 2 and Bedded Hilltop deposits is low.

Background Information

The risk assessment process followed is outlined in *Geochemical Risk Assessment Process for Rio Tinto's Pilbara Iron Ore Mines* (Green and Borden, 2011). A risk-based process is used to identify those rock types which require specific management to mitigate the impacts associated with AMD.

It is recognised that AMD includes *acidic drainage* (elevated concentrations of metals at low-pH), *neutral metalliferous drainage* (elevated concentrations of metals at near-neutral to alkaline pH) and *saline drainage* (generally low concentrations of metals, but moderate concentrations of sulfate, magnesium and calcium, at neutral to alkaline pH) (INAP, 2009; DIIS, 2016). With the presence of potentially acid forming (PAF) rock types associated with sulfide or some sulfate minerals, it is understood that neutral metalliferous drainage requires, at a minimum, low-pH conditions on a microscopic scale as a mechanism to initially solubilise contaminants. If the PAF rock also has sufficient acid neutralising capacity (ANC), the acid generated is *neutralised*. However, as a result of this reaction, concentrations of some contaminants (e.g., As, Cd, Mn, Ni, Sb, Se and Zn) do not precipitate at near-neutral pH, and remain in solution, resulting in poor-quality drainage (DIIS, 2016). An analysis of total sulfur in mineral waste will help infer the likelihood for the rock type to generate acidity which may lead to poor quality drainage characterised by either low-pH or near-neutral pH.

Rio Tinto has undertaken an extensive program of geochemical testing over several years to understand the potential for AMD to occur as a result of exposing various waste rock types common to Pilbara mining operations. The geochemical characterisation process considers sulfur content and elemental abundance as an indicator of acidic and neutral metalliferous drainage potential, and is supported by static (acid base accounting) and, if appropriate, kinetic testing of target materials. It is understood that poor quality drainage may also result from low-sulfur waste rock containing compounds that do not require acidic conditions to maintain elevated concentrations of parameters of concern. For instance, the dissolution of readily soluble salts may mobilise minor and trace elements into pore water that may then be transported into the surrounding environment via surficial or internal drainage. This risk is assessed by considering elemental data collected during routine and extra analysis of drillhole samples, and the results derived from a phased and risk-based approach involving the selection of fit-for-purpose leach extract tests (e.g., Green et al. (2019)). General methodologies used by laboratories to undertake geochemical test work are attached in Appendix A.

The results of geochemical test work and interpretation are applied to the geological and mining models to ensure materials posing potential geochemical risks are identified prior to mining and managed appropriately. This work is in accordance with internal standards and processes.

The most significant geochemical risk posed by mining iron ore deposits in the Pilbara is associated with the sulfide mineral pyrite, which can form sulfuric acid when exposed to oxygen and water. The unoxidised (black) Mount McRae Shale and Lignite a part of the detrital sequence, are most commonly associated with pyrite and AMD, are known to occur in the Hope Downs 2 and Bedded Hilltop deposits. Other sulfate minerals, such as alunite and jarosite, may also pose a geochemical risk, albeit the risk is usually lower due to self-limiting chemical processes.

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Acid Base Accounting and Geochemical Characterisation

Acid Base Accounting and Geochemical Characterisation has been undertaken on 96 reverse-circulation (RC) drillhole samples collected from the Hope Downs 2 (43 samples) and Bedded Hilltop (53 samples) deposits (SRK, 2019). The purpose of these tests was to determine:

- The net acid generating potential;
- The acid neutralising capacity (ANC); and
- The presence and quantities of leachable contaminants.

The test work results are available in a report detailing the geochemical characterisation of samples from Hope Downs 2 and Bedded Hilltop (SRK, 2019). A summary of the sample information, sulfur assay values, acid neutralising capacity and the final classification are available in and the collar locations for the drillholes selected are shown in Appendix B. In summary of the 96 Samples analysed, the lignite material tested had the greatest potential for acid generation and metal release, all were classed as Potentially Acid forming (PAF). The total sulfur content of the lignite material ranged from 1.27% to as high as 33.3%, with the sulfur either present as pyrite or marcasite. Leachate from the lignite was generally acidic with high solute concentrations.

Two samples, one from the Dales Gorge Member and one from the Footwall Zone were classed as PAF in a low capacity (<5kg H_2SO_4/t) to generate acidity. The 20 Wittenoom Formation samples were all classed as Non-acid forming (NAF) and had considerable ANC. The remaining 64 samples were classified as Non-acid forming or Uncertain (NAF). These samples are expected to generate circum neutral leachates with low solute concentrations.

RioTinto

Table 1 - Summary of ABA and NAG data

Strat	Statistic	No. of Samples	Paste pH	Paste EC	NAG pH	NAG pH 4.5	NAG pH 7	ANC	Total S	MPA	NAPP	AMIRA Classification			
			pH units	µS/cm	kg H_2SO_4/t				%	kg H_2SO_4/t		NAF	UC (NAF)	PAF-LC	PAF
DET	Min.	14	5.7	69	6.2	<0.1	<0.1	<0.5	<0.01	0.3	-32	13	1		
	Median		7.5	191	7.3	<0.1	<0.1	2.65	0.02	0.6	-				
	Max.		8.6	735	9.2	<0.1	0.4	32.9	0.03	0.9	0.4				
DET LIG	Min.	10	1.9	1,930	1.8	19.4	42.3	<0.5	1.27	39	38				10
	Median		3.8	3,925	2.2	150	221	<0.5	6.63	203	-				
	Max.		5.6	21,100	2.6	626	699	6.9	33	1019	1013				
DG	Min.	15	4.6	40	3.9	<0.1	<0.1	<0.5	<0.01	0.3	-0.2	2	12	1	
	Median		6.4	72	6.2	<0.1	0.7	<0.5	0.02	0.6	-				
	Max.		8.8	461	7	0.8	2.4	0.9	0.07	2.1	4.1				
FWZ	Min.	9	3.9	43	4.1	<0.1	<0.1	<0.5	<0.01	0.3	-0.2	3	5	1	
	Median		6	140	6.2	<0.1	0.4	<0.5	0.02	0.6	-				
	Max.		6.8	1,540	6.8	0.8	4.7	0.5	0.15	4.6	0.7				
MCS	Min.	7	4.5	115	5.6	<0.1	<0.1	<0.5	0.02	0.6	-0.5	3	4		
	Median		6.7	214	6.1	<0.1	0.5	0.7	0.02	0.6	-				
	Max.		7.1	575	7.2	<0.1	2	1	0.04	1.2	0.1				
MTS	Min.	2	6.2	96	6.4	<0.1	<0.1	<0.5	<0.01	0.3	-0.5	1			
	Median		6.4	133	6.6	<0.1	0.25	0.65	0.015	0.5	-				
	Max.		6.6	169	7	<0.1	0.4	0.8	0.02	0.6	0.1				
WF	Min.	20	3.8	40	5.6	<0.1	<0.1	<0.5	<0.01	0.3	-968	20			
	Median		7.6	294	8.1	<0.1	<0.1	6.15	<0.01	0.3	-				
	Max.		9.8	1,310	10.2	<0.1	1.5	968	0.14	4.3	-0.2				
NEW	Min.	9	5.4	19	6.6	<0.1	<0.1	<0.5	<0.01	0.3	-8.7	9			
	Median		7.5	78	7.2	<0.1	<0.1	<0.5	<0.01	0.3	-				
	Max.		8.9	276	8.5	<0.1	0.7	9	<0.01	0.3	-0.2				
MAC	Min.	7	4	26	4.6	<0.1	<0.1	<0.5	<0.01	0.3	-0.2	4	3		
	Median		7.2	102	6.6	<0.1	0.5	<0.5	<0.01	0.3	-				
	Max.		8.4	911	7.4	<0.1	2.1	0.7	0.1	3.1	2.6				

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Table 1 - continued

Strat	Statistic	No. of Samples	Paste pH	Paste EC	NAG pH	NAG pH 4.5	NAG pH 7	ANC	Total S	MPA	NAPP	AMIRA Classification			
			pH units	µS/cm	kg H_2SO_4/t				%	kg H_2SO_4/t		NAF	UC (NAF)	PAF-LC	PAF
NAM	Min.	3	6	30	6	<0.1	0.5	<0.5	<0.01	0.3	-0.2	2	1		
	Median		6.7	117	6.4	<0.1	0.6	<0.5	<0.01	0.3	-				
	Max.		7.6	239	6.6	<0.1	2	<0.5	0.03	0.9	0.4				
All Samples	Min.	96	1.9	19	1.8	<0.1	<0.1	<0.5	<0.01	0.3	-968	57	27	2	10
	Median		7	167	6.7	<0.1	0.3	<0.5	0.02	0.6	-				
	Max.		9.8	21,100	10.2	626	699	968	33	1,019	1013				

Note: EC – Electrical Conductivity; NAG – Net Acid Generation; ANC – Acid Neutralising Capacity; S – Sulfur; MPA – Maximum Potential Acidity; NAPP – Net Acid Producing Potential; NAF – Non Acid Forming; UC – Uncertain; PAF – Potentially Acid Forming; LC – Low Capacity.

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Total Sulfur Analysis of Drillhole Samples

An analysis of sulfur values in drillhole data for the three deposits (to the July of 2020) was undertaken to identify those rock types requiring further investigation related to acid-forming potential (and any related metalliferous drainage). An outcome of this analysis includes determining the likelihood that a rock type will pose an acid drainage risk. For the purpose of this assessment, the rock types comprise like-material separated into their sub-divided stratigraphy and further differentiated on dominant material type (ore, waste or hydrated – "Tag"). It should be noted that the following factors may also influence the interpretations in this report:

- Negative assay results represent concentrations below the detection limit. The assay value for the element was taken to the absolute value (i.e. the detection limit). This approach is conservative, as the true values for these assays sit somewhere between zero and the detection limit value;
- Assay values of "-99" or "zero" (0) indicate that the element was not assayed and were deleted and not considered in this assessment;
- The logging code for pyrite (PYT) can be used where it is readily identifiable. However, logging codes either do not exist or are not readily used for the sulfate minerals gypsum or alunite as these minerals are less identifiable. In lieu of direct logging information for these two minerals, concentrations of potassium and calcium within elevated-sulfur samples can be used to infer the presence of these sulfate minerals, though is it also possible that the two elements may be present in various other minerals in the sample. Sulfate may also be present in other minerals other than pyrite, alunite or gypsum.
- Total sulfur was measured using the XRF method rather than using combustion infrared detection techniques. The XRF method may underestimate the total sulfur concentrations when the sulfur values are high.
- The drillhole data for the ore body is extensive with less data collected for waste rock types. Information on all waste material that has or will be mined in the future may be missing due to the focus on characterising the ore body rather than the waste material;
- Some intervals had incomplete stratigraphy, strand or tag information. These samples were grouped into an UNKNOWN rock type category;

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The following analyses have been conducted on the dataset divided spatially using a filter in the acquire database on the "PROJECTCODE" field. Drillhole samples represent lithologies associated with the Bedded Hilltop and Hope Downs 2 deposits and that not all rock types drilled and listed in the tables are expected to be mined.

A total of 655 intervals from Bedded Hilltop and Hope Downs 2 deposits had pyrite visually identified in the logging. For Bedded Hilltop, pyrite was visually identified in 644 intervals with the majority of the samples associated with Lignite, Mount McRae Shale and Wittenoom Formation, representing 86% of all the intervals with pyrite logged. A smaller number of intervals from the Mount Sylvia Member, Dolerite, Limonite, Dales Gorge Member, Whaleback Shale and detritals had pyrite visually identified. Only 11 intervals from the Hope Downs 2 deposit had pyrite visually identified, associated with the Marra Mamba hydrated, West Angela Member and detritals. These intervals are associated with oxidised stratigraphies and/or low sulfur samples, so it is unlikely that pyrite or sulfides are present.

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Sulfur Assay Analysis of Bedded Hilltop samples

A summary of the total sulfur analysis performed using the drillhole sample assays extracted from the acQuire database up until the end of July 2020 is given in Table 2. The average sulfur value for those samples with elevated-sulfur is considered for the analysis. Drillhole samples represent rock types associated with the Bedded Hilltop deposit, and that not all rock types drilled and listed in the table are expected to be mined and were further filtered by the proposed pit shell as seen by the in-pit sulfur analysis (Table 3).

The highest sulfur value associated with the Bedded Hilltop deposit is 27.4% associated with lignite. Along with other high sulfur lignite sample they are located below the water table, black in colour, with lignite (LIG), pyrite (PTY) and PYR (which is pyrolusite; however, it is more likely that this was meant to be logged as PYT) logged.

Approximately 2.7% of the 62,252 samples have sulfur values greater than 0.3%, with approximately 6.9% of waste samples with sulfur values greater than 0.3%. Those rock types where more than 3% of samples have sulfur values greater than 0.3% include: Lignite, Limonite Waste, Dolerite, Whaleback Shale Waste, Mount McRae Shale, Mount Sylvia Formation and Wittenoom Formation. When the proposed pit shells are used to filter the drillhole intervals, of the 21,786 samples located within the pit shell there are only 15 samples with sulfur greater than 0.3%, indicating that the majority of elevated sulfur samples sit outside of the proposed pit shell.

Based on the outcome of the analysis it is unlikely that any stratigraphic units will require management during operations and should be confirmed by reviewing the mining models for PAF quantities.

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Table 2 – Total Sulfur analysis for the Bedded Hilltop deposit

Strand-tag Group	Total Samples Assayed for S	Number of Samples with S>0.1%	Percentage of total samples with S>0.1%	Number of samples with S>0.3%	Percentage of total samples with S>0.3%	Average S for samples with S>0.1%	Average S for samples with S>0.3%
Clay	857	12	1.40%	1	0.12%	0.18	0.42
Calcrete	227	1	0.44%	0	0.00%	0.13	-
Lignite	**868**	**866**	**99.77%**	**839**	**96.66%**	4.66	4.8
Detrital Waste	**1292**	**44**	**3.41%**	15	1.16%	0.69	1.75
Detrital Ore	**1020**	**44**	**4.31%**	8	0.78%	0.26	0.83
Canga Waste	**57**	**4**	**7.02%**	0	0.00%	0.15	-
Canga Ore	**627**	**23**	**3.67%**	2	0.32%	0.17	0.48
Limonite Waste	**758**	**88**	**11.61%**	**30**	**3.96%**	0.76	1.92
Limonite Ore	**1522**	**119**	**7.82%**	33	2.17%	0.32	0.79
Pisolite Waste	642	4	0.62%	1	0.16%	0.19	0.37
Pisolite Ore	1606	41	2.55%	8	0.50%	0.23	0.45
Red Ochre Detrtial Waste	27	0	0.00%	0	0.00%	-	-
Red Ochre Detrtial Ore	75	1	1.33%	0	0.00%	0.1	-
Dolerite	**47**	**38**	**80.85%**	**22**	**46.81%**	0.48	0.68
Whaleback Shale Waste	**362**	**50**	**13.81%**	**19**	**5.25%**	0.37	0.73
Whaleback Shale Ore	43	0	0.00%	0	0.00%	-	-
Whaleback Shale Hydrated	**121**	**8**	**6.61%**	0	0.00%	0.15	-
Dales Gorge Waste	**5270**	**121**	**2.30%**	5	0.09%	0.15	0.6
Dales Gorge Ore	14439	192	1.33%	6	0.04%	0.15	0.82
Dales Gorge Hydrated	**7249**	**381**	**5.26%**	15	0.21%	0.16	0.68
Footwall Zone Waste	4926	151	3.07%	13	0.26%	0.19	0.86
Footwall Zone Ore	**4483**	**229**	**5.11%**	1	0.02%	0.13	0.4
Mt McRae Shale	**5054**	**622**	**12.31%**	**464**	**9.18%**	1.84	2.41
Mount Sylvia Formation	**417**	**68**	**16.31%**	**38**	**9.11%**	0.66	1.04
Wittenoom Formation	**516**	**69**	**13.37%**	**48**	**9.30%**	1.2	1.63
UNKNOWN	**9747**	**499**	**5.12%**	90	0.92%		

Total number of samples assayed for S	**62252**	**62252**
Total number of samples with S>0.1%/0.3%	**3675**	**1658**
Percentage of total with S>0.1%/0.3%	**5.90%**	**2.66%**
Total number of waste samples assayed for S**	**21320**	**21320**
Total number of waste samples with S>0.1%/0.3%	**2138**	**1473**
Percentage of total waste samples with S>0.1%/0.3%	**10.03%**	**6.91%**

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Table 3 – Total in-pit sulfur analysis for the Bedded Hilltop deposit

Strand-tag Group	Total Samples Assayed for S	Number of Samples with	Percentage of total samples	Number of samples with	Percentage of total samples
CLAY	22	0	0.00%	0	0.00%
DET WASTE	174	5	2.87%	0	0.00%
DET ORE	**387**	**18**	**4.65%**	2	0.52%
CA WASTE	15	0	0.00%	0	0.00%
CA ORE	**287**	**14**	**4.88%**	0	0.00%
LI WASTE	**59**	**10**	**16.95%**	0	0.00%
LI ORE	**73**	**18**	**24.66%**	0	0.00%
PI WASTE	**19**	**2**	**10.53%**	0	0.00%
PI ORE	378	6	1.59%	0	0.00%
ROD WASTE	4	0	0.00%	0	0.00%
WS WASTE	**166**	**24**	**14.46%**	**7**	**4.22%**
WS ORE	30	0	0.00%	0	0.00%
WS HYD	**67**	**6**	**8.96%**	0	0.00%
DG WASTE	**1441**	**54**	**3.75%**	0	0.00%
DG ORE	8546	131	1.53%	1	0.01%
DG HYD	**4889**	**186**	**3.80%**	3	0.06%
FWZ WASTE	345	5	1.45%	0	0.00%
FWZ ORE	**971**	**53**	**5.46%**	0	0.00%
MCS	107	0	0.00%	0	0.00%
UNKNOWN	**3806**	**196**	**5.15%**	2	0.05%
Total number of samples assayed		21786		21786	
Total number of samples with S>0.1%/0.3%		728		15	
Percentage of total with S>0.1%/0.3%		**3.34%**		0.07%	
Total number of waste samples		2186		2186	
Total number of waste samples with S>0.1%/0.3%		100		7	
Percentage of total waste samples with S>0.1%/0.3%		**4.57%**		0.32%	

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Sulfur Assay Analysis of Hope Downs 2

A summary of the total sulfur analysis performed using the drillhole sample assays extracted from the acQuire database up until the end of July 2020 is given in Table 4. The average sulfur value for those samples with elevated-sulfur is considered for the analysis. Drillhole samples represent rock types associated with the Hope Downs 2 deposit, and that not all rock types drilled and listed in the table are expected to be mined and were further filtered by the proposed pit shell as seen by the in-pit sulfur analysis (Table 5). The highest sulfur value associated with the Hope Downs 2 deposit is 4.13% and is associated with hydrated MacLeod Member located within 14 m of the surface and has coincidently high potassium. It is likely that this sample is alunite, an aluminium hydroxysulfate

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mineral.

Approximately 0.5% of the 89,006 samples have sulfur values greater than 0.3%, with approximately 0.6% of waste samples with sulfur values greater than 0.3%. Only the Fortescue Group stratigraphic unit has 3.9% of samples with sulfur values greater than 0.3%. When the proposed pit shells are used to filter the drillhole intervals, of the 29,978 samples located within the pit shell there are only 231 samples with sulfur greater than 0.3%, spread across all the rock types. NAM WASTE and NAM ORE have greater than 3% of samples with S >0.3%, however all are in proximity of the surface and are above water table so unlikely to be sulfide minerals.

Based on the outcome of the analysis it is unlikely that any stratigraphic units will require management during operations and should be confirmed by reviewing the mining models for PAF quantities.

Table 4 - Total Sulfur analysis for the Hope Downs 2 deposit

Strand-Tag group	Total Samples assayed for S	Number of Samples with S>0.1	Percentage of Samples with S>0.1%	Number of samples with S>0.3	Percentage of Samples with S>0.3%	Average S for samples with S>0.1%	Average S for samples with S>0.3%
CLAY	7382	209	2.83%	41	0.56%	0.25	0.58
CALCRETE	57	4	7.02%	1	1.75%	0.24	0.51
DET WASTE	9159	321	3.50%	75	0.82%	0.26	0.56
DET ORE	783	19	2.43%	0	0.00%	0.14	-
CA WASTE	27	10	37.04%	0	0.00%	0.16	-
CA ORE	61	2	3.28%	0	0.00%	0.12	-
LI WASTE	184	13	7.07%	3	1.63%	0.2	0.38
LI ORE	205	6	2.93%	1	0.49%	0.15	0.36
PI WASTE	145	2	1.38%	0	0.00%	0.13	-
ROD WASTE	7408	542	7.32%	71	0.96%	0.2	0.49
ROD ORE	8812	442	5.02%	43	0.49%	0.18	0.5
WF	2176	5	0.23%	1	0.05%	0.23	0.46
ANG WASTE	13311	796	5.98%	65	0.49%	0.2	0.83
ANG ORE	3182	332	10.43%	4	0.13%	0.14	0.62
ANG HYD	864	16	1.85%	2	0.23%	0.18	0.36
NEW WASTE	8265	23	0.28%	3	0.04%	0.22	0.42
NEW ORE	9685	82	0.85%	2	0.02%	0.13	0.55
MAC WASTE	3373	275	8.15%	23	0.68%	0.22	1.16
MAC ORE	2202	568	25.79%	19	0.86%	0.16	0.63
NAM WASTE	1729	52	3.01%	12	0.69%	0.32	0.89
NAM ORE	540	129	23.89%	12	2.22%	0.22	0.87
MM HYD	6251	402	6.43%	44	0.70%	0.22	0.86
FOR	332	39	11.75%	13	3.92%	0.62	1.52
(blank)	2873	74	2.58%	2	0.07%		
Total number of samples assayed for S		89006		89006			
Total number of samples with S>0.1%/0.3%		4363		437			
Percentage of total with S>0.1%/0.3%		4.90%		0.49%			
Total number of waste samples assayed for S		53548		53548			
Total number of waste samples with S>0.1%/0.3%		2291		308			
Percentage of total waste samples with S>0.1%/0.3%		4.28%		0.58%			

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Table 5 - Total in-pit sulfur analysis for the Hope Downs 2 deposit

Strand-Tag group	Total Samples assayed for S	Number of S>0.1	Percentage of Samples with S>0.1%	Number of samples with S>0.3	Percentage of Samples with S>0.3%
CLAY	905	33	3.65%	21	2.32%
DET WASTE	4608	173	3.75%	40	0.87%
CA WASTE	491	10	2.04%	0	0.00%
CA ORE	23	2	8.70%	0	0.00%
LI WASTE	52	1	1.92%	0	0.00%
LI ORE	111	2	1.80%	0	0.00%
PI WASTE	75	0	0.00%	0	0.00%
ROD WASTE	1005	169	16.82%	13	1.29%
ROD ORE	2151	247	11.48%	31	1.44%
WF	36	0	0.00%	0	0.00%
ANG WASTE	3686	660	17.91%	64	1.74%
ANG ORE	1971	298	15.12%	4	0.20%
ANG HYD	706	16	2.27%	2	0.28%
NEW WASTE	661	11	1.66%	2	0.30%
NEW ORE	6810	69	1.01%	2	0.03%
MAC WASTE	285	9	3.16%	2	0.70%
MAC ORE	690	141	20.43%	8	1.16%
NAM WASTE	87	7	8.05%	6	6.90%
NAM ORE	179	58	32.40%	11	6.15%
MM HYD	4174	182	4.36%	24	0.57%
FOR WASTE	15	1	6.67%	0	0.00%
UNKNOWN	1257	29	2.31%	1	0.08%

Total number of samples assayed	**29978**	**29978**
Total number of samples with S>0.1%/0.3%	**2118**	**231**
Percentage of total samples with S>0.1%/0.3%	**7.07%**	**0.77%**
Total number of waste samples	**11906**	**11906**
Total number of waste samples with S>0.1%/0.3%	**1074**	**148**
Percentage of total waste samples with S>0.1%/0.3%	**9.02%**	**1.24%**

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PAF Risk flagging in the mining models
Based on the review of the mining models hdipr_hd1bht_20200817_007 and hdipr_hd2_20200902_028 no PAF material is flagged as occurring within the mine plan and is consistent with the findings of the sulfur assay analysis.

Analysis of Geochemical Enrichment in the Bedded Hilltop and Hope Downs 2 deposits
The multi-element analysis of all drillhole assay data (derived from the full chemical suite) for Bedded Hilltop and the corresponding GAI values are given in Appendix C.

The extent of enrichment of a drillhole sample can be reported as the Global Abundance Index (GAI), which relates the actual concentration with average crustal abundance on an adjusted log 2 scale (Bowen, 1979). The GAI is typically expressed in integer increments where a GAI of zero indicates the element is present at a concentration similar to, or less than, the average crustal abundance, and a GAI of 6 indicates approximately a 100-fold enrichment above the average crustal abundance. The main purpose of the GAI is to provide an indication of elemental enrichment that may be of environmental importance. Generally, a GAI of 3 or greater signifies enrichment that warrants further examination, while a GAI of 1 or 2 indicates the element may be elevated. The same factors as for analysing drillholes may also influence the interpretations within this section. Most rock types are either enriched or elevated in Fe, as correlated with the iron mineralisation associated with the ore body. Arsenic (As) is enriched in most rock types while tin (Sn) is generally elevated.

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In general, whilst concentrations of some trace elements of potential environmental concern (e.g. As, Pb) were enriched or elevated in some of the sampled ore and waste materials, these elements will not necessarily mobilise into groundwater. Arsenic in particular is commonly enriched in ore and waste for many Hamersley Group deposits. Iron oxy-hydroxides such as hematite and magnetite have high sorption capacities for As (e.g., Zhang et. Al., 2004), and consequently, these materials have been used around the world for treating water enriched in arsenic.

In summary, the following elements have been identified as being enriched in the Bedded Hilltop deposit and should be considered in any monitoring related to potential AMD impacts: **Fe, As, Mn, Sn, S and Zn.**

AMD Risk Assessment and Conclusion
A review of the acid and metalliferous drainage (AMD) risk associated with the Hope Downs 2 and Bedded Hilltop iron ore deposits has been completed to support the Hope Downs 2 Mine Closure Plan. This review considers drillhole and mine planning data, supplemented by geochemical test data, to assess the AMD risks relating to waste rock remaining upon closure. Furthermore, information in this assessment can be used to support the development of a source-path-receptor model or AMD-related ecological risk assessment to describe the mechanisms by which acid and metals/metalloids may mobilise from specific mining areas (including specific pit voids and waste dumps) and interact with environmental receptors.

Mining of the assessed designs for Hope Downs 2 and Bedded Hilltop deposits pose a low AMD risk.

The AMD Hazard Scorecard, as described in Geochemical Risk Assessment Process for Rio Tinto's

Pilbara Iron Ore Mines (Green and Borden, 2011) has also been completed and presented in Appendix D.

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Appendix A – Summary of Geochemical Test Work Methodologies

RTIO-PDE-0174239 - Methodologies used for geochemical test work:
http://iodms/iodms/drl/objectId/090188a380bd490e

(memo attached)

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Iron Ore
93-95 William Street
Perth 6000
Western Australia
T + 61 (8) 9327 2000

From	Kate Glasson
Department	Water Resource Evaluation & Services - Mineral Waste Management
To	Steven Lee and Lisa Terrusi
Date	20/02/2020
Number of pages	5
Reference	RTIO-PDE-0174239

Methodology Memo

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Context

This memorandum aims to provide an outline for all methodologies used for geochemical test work coordinated by the Mineral Waste Management team. Test work programmes undertaken for various rock types are designed to characterise and assess the geochemical risks related to acid and metalliferous drainage (AMD) including acidic, neutral and saline drainage.

1.0 Acid base accounting (ABA)

The acid-base account involves static laboratory procedures which evaluate the acid generation and neutralising potential of minerals. The list below contains the recommended basic screening tests used to categorise the relative acid forming potential of a sample.

1.1 Total sulfur

Total sulfur is commonly determined using LECO analysis. The analysis does not distinguish between acid and non-forming acid forming sulfur species. Analysis using X-ray Fluorescence (XRF) typically underestimates sulfur concentrations compared to that determined using LECO (Eaglan & White, 1998). For samples with high sulfur content it is important that LECO tests are undertaken rather than using XRF.

1.2 Sulfate sulfur

The sample is dissolved in dilute hydrochloric acid (HCl) and the solution is bulked to volume. An aliquot of this solution is then analysed by ICP-AES to determine the (soluble) sulfate sulfur content. In some cases, routine sulfate sulfur calculated does not account for sulfate associated with alunite (or jarosite). Therefore, sulfur attributed to sulfate vs sulfide can be determined using the chromium reducible (CRS) method which is not subjected to interference from organic matter (SRK,2010; Linklater et al., 2012)

1.3 Chromium reducible sulfur (CRS) method

A direct measure of the sulphide sulfur can be made using the CRS method. By conversion of reducible sulfur species to H_2S the amount of sulfur generated is quantified. The analysis yields an estimate of pyrite and other disulphides, elemental sulfur and acid volatile sulfides (SRK, 2010).

1.4 Total carbon
The sample is combusted in oxygen at a high temperature. Carbon present in the sample is evolved as carbon dioxide and swept to a measurement cell for quantification by infrared detection (LECO).

1.5 Total inorganic carbon (TIC) and total organic carbon (TOC)
Inorganic carbon is removed by reaction with dilute hydrochloric acid. After drying, the remaining sample is combusted in oxygen. Any organic carbon in the sample present as organic matter or graphite is evolved as carbon dioxide and swept to a cell for quantification by infrared detection (LECO).

1.6 Leach test
Simple leach extraction involves dissolution of elements from the solid matrix using de-ionised water. The water and solids are mixed at a ratio of 1:2 (solids: water) and agitated for a period of 12 hours. The leachates are filtered (e.g., using 0.45 µm or 0.2 µm filters) prior to analysis. Analytical techniques are selected depending on the elements under investigation and include ICP-AES and ICP-MS.

1.7 Modified leach tests
A variety of leach tests are available to ensure the selected test method closely simulates the site-specific ambient environment and conditions. These tests are outlined in *Rio Tinto's framework for evaluating risks from low sulfur waste rock* report (Green et al., 2019) and include mild acid leach, alkaline leach, saline leach, high temperature leaching, multi-step leach and low contact ratio leach

1.8 Paste pH (1:2)
Paste pH measurements are performed on a 1:2 solid:water extract.

1.9 Paste EC (2:1)
Electrical conductivity (EC) measurements are performed on a 1:2 solid:water extract.

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1.10 Acid neutralising capacity (ANC)
Determined by adding HCl to the sample, heating it, and then back-titrating the mixture with NaOH in order to determine the amount of HCl that remains on completion of the reaction. The amount of acid consumed in the initial reaction is calculated and expressed as the ANC. Details of the procedure are outlined in the AMIRA International *ARD Test Handbook* (AMIRA , 2002).

1.11 Net acid generation (NAG) testing via single addition NAG
The single addition NAG test is explained briefly below. However, there are other methods via kinetic and sequential NAG and more information can be found in the AMIRA Handbook (AMIRA , 2002).
The single addition NAG test involves addition of hydrogen peroxide to prepared samples. The NAG pH is the pH of the final solution. The resultant acidity is then titrated (using NaOH) to pH 4.5 to pH 7. Details of the procedure are outlined in the AMIRA International *ARD Test Handbook* (AMIRA, 2002)

2.0 Detailed Static and kinetic tests
In order to better understand, provide definition and resolve issues identified in the initial screening of samples, follow up testing can be conducted. Detailed geochemical test commonly used are as follows and are outlined in AMIRA (2002).

2.1 Sequential NAG test
For samples with high sulfide content it is possible for oxidation to be incomplete in the single addition NAG test. To overcome this limitation, a multi-stage sequential NAG test is often carried out.

2.2 Kinetic NAG test
The kinetic NAG test is similar to the single addition NAG test except that the temperature, pH and EC liquor are recorded. Variability in these parameters are an indication of the kinetics of sulfide oxidation and acid generation during the test (AMIRA , 2002).

2.3 Acid buffering characteristic curves (ABCC) test
This test involves the constant monitoring of pH whilst conducting a slow titration (AMIRA, 2002). Data collected from this test provides insight into the portion of ANC within a sample readily available for acid neutralisation.

2.4 Mineralogy
Mineralogy of a sample can be determined using various techniques including optical mineralogy, scanning electron microscopy (SEM, QEM SEM), micro-probe, x-ray diffraction (XRD) and bulk elemental/oxide determinations (such as ICP or XRF) (Price, 2009)

2.5 Fizz rating
The fizz test is used to evaluate if carbonates are present by adding a few drops of concentrated HCl to a sample and observing if there is a slight, moderate or strong fizz (AMIRA, 2002).

2.5 Leach column test
Leach column tests are used to compliment the other geochemical investigations described above. Generally, columns are loaded with crushed waste rock or tailings and subjected to wetting and drying cycles to encourage oxidation and flushing of oxidation products (AMIRA , 2002). Water flushed through the column is tested and analysed for a variety of parameters. More details on the free draining leach column or saturated columns which are typically used can be found in AMIRA (2002) and Green et al., (2019). Another widely used long term prediction test, humidity cells, subjects samples to cycles of dry and moist air and leaching (Price, 2009).

3.0 Intrinsic oxidation rate (IOR)
The IOR is the rate of oxidation of material at a point in a system under the particular conditions which pertain to that point. When dealing with sulfidic materials, IOR is key to understanding timescales over which pollutants will be generated (ANSTO, 2006).

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4.0 Calculated data

4.1 Maximum potential acidity (MPA)
Calculated by multiplying the total sulfur content (wt%) by 30.6. Approach assumes that all sulfur is present as pyrite (AMIRA , 2002).

4.2 Acid potential (AP)
Calculated by multiplying the sulfide-sulfur content (wt%) by 30.6 (AMIRA , 2002).

4.3 Sulfide-sulfur
Total sulfur minus sulfate sulfur.

4.4 Carbonate neutralising potential (CarbNP)
Calculated by multiplying inorganic carbon content (wt%) by 81.6.

4.5 Net acid producing potential (NAPP)
NAPP is the difference between AP and ANC of the sample:
NAPP= AP-ANC
*If AP is not available, then MPA can be used.

4.6 Net potential ratio (NPR)
NPR is the ratio of MPA and ANC:
NPR = ANC/MPA
This ratio is commonly used as a way of assessing the risk of acid generation from waste rock materials. It is an alternative way of looking at the acid base account and provides an indication of the relative margin of safety (for prevention of acid material) within a material (AMIRA , 2002). Various ANC/MPA values are reported in literature and typically range from 1 to 3, a ratio of 2 or more signifies a high probability that the material will remain circum-neutral in pH (AMIRA , 2002).
*If AP is not available, then MPA can be used.

5.0 Analysis

The ABA analysis should provide information on the sample such that the sample can be classified as NAF, PAF or UC. For more detailed information on sample classification refer to AMIRA (2002).

5.1 Non-acid forming (NAF)

Samples classified as NAF are unlikely to be acid generating and either there is a low acid potential or there is sufficient neutralising potential within the material to counteract any acidity produced.

5.2 Potentially acid forming (PAF)

A sample that has been classified as PAF has a positive NAPP and a final NAGpH<4.5. There is a high chance that a sample classified as PAF will be acid producing.

5.3 Uncertain (UC)

A sample is classified as uncertain if the NAPP result is positive and NAGpH>4.5, or when the NAPP is negative and NAGpH <4.5. Samples with a high organic content are also classified as uncertain.

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SRK. (2010). *Brockman Syncline 2 Project Stage 2 Geochemical Characterisation.*

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Appendix B – Geochemical Sample Locations

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Bedded Hilltop Geochemical Characterisation Locations

Date: 11/11/2020

710,000 712,500 715,000 717,500 720,000

7,452,500 7,450,000 7,447,500

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Legend

- ABA_Samples
- BHT Proposed Pits/Dumps

N

0 0.5 1 2 Km

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Hope Downs 2
Geochemical
Characterisation Locations

Date: 11/11/2020

700,000 702,500 705,000 707,500

7,447,500 7,445,000 7,442,500

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Legend

- ABA Samples
- HD2 Proposed Pits/Dumps

N

0 0.5 1 2 Km

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Appendix C – Global Abundance Indices for Bedded Hilltop and Hope Downs 2

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Bedded Hilltop GAI

	Crustal abundance	UNKNOWN				CLAY				CALCRETE				LIGNITE				DET WASTE				DET ORE				CA WASTE				CA ORE				LI WASTE			
	mg/kg	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min
FE_XRF_pct	41000	2	4	3		2	2	3		1	1	2		1	1	3		2	3	3		3	3	3	1	2	2	3	1	3	3	3	2	2	2	3	
AI2O3_pct_BEST	309885.8414																																				
P_XRF_pct	1000			1				1								1																				1	
TIO2_XRF_pct	9343.471903			1				1												1																1	
CAO_XRF_pct	57367.26547			1				1				1								1																	
MN_COMBINED_D	950			6				5				3				4			2	3				2				5				3				5	
MGO_XRF_pct	37539.70763			1				1				2																									
S_XRF_pct	260	1	1	9				3				1		6	6	9		2		9				6				2				3		1		9	
MNO_XRF_pct	1226.665453							2				2		1	1	4																				4	
K2O_XRF_pct	50593.35038																																				
NA2O_XRF_pct	62007																																				
ARS_XRF_ppm	1.5	4	5	10	1	4	4	8	1	3	3	6	1	6	4	10	1	4	4	9	1	4	4	8	1	4	4	6	1	4	4	6	1	6	5	9	1
BA_XRF_ppm	500			3				2				1																1								2	
CL_XRF_ppm	130			4				2								1				2				1								1				4	
CO_XRF_ppm	20			4				5				5		1		7			4	5				2				4				1				5	
CR_XRF_ppm	100			4				3								1								2												1	
CU_XRF_ppm	50			2				1				1				2				1																	
NA_PPM_COMBINED_D	23000																																				
NI_XRF_ppm	80			5				3				2				3				2				1												2	
PB_XRF_ppm	14			3				3				2				3				2				1												2	
SN_XRF_ppm	2.2	2	2	4		2	1	3		1		4		1		5		1	3	4		2	1	4		1		2		2	2	4		1		4	
SR_XRF_ppm	370																																				
V_XRF_ppm	160			1																																2	
ZN_XRF_ppm	75			8				3				4		3	1	8			2	6				3				2				2		1		7	
ZR_XRF_ppm	190			1				1												1																1	

	Crustal abundance	LI ORE				PI WASTE				PI ORE				ROD WASTE				ROD ORE				DOLERITE				WS WASTE				WS ORE				WS HYD			
	mg/kg	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min
FE_XRF_pct	41000	3	3	3	2	2	2	3	1	3	3	3	2	3	3	3	2	3	3	3	2			2		2	3	3		3	4	3	2	3	3	3	
AI2O3_pct_BEST	309885.8414																																				
P_XRF_pct	1000			1								1								1																	
TIO2_XRF_pct	9343.471903			1																								1									
CAO_XRF_pct	57367.26547																																				
MN_COMBINED_D	950			6				3				2								1				2				5				1				2	
MGO_XRF_pct	37539.70763																						1	1													
S_XRF_pct	260			6				3				4								1		3	2	5		1	1	5				1				2	
MNO_XRF_pct	1226.665453			2																																	
K2O_XRF_pct	50593.35038																																				
NA2O_XRF_pct	62007																																				
ARS_XRF_ppm	1.5	5	4	9	1	4	4	7	1	4	4	7	1	4	4	5	3	5	5	7	3	3	3	4	1	5	5	9	1	5	4	7	2	4	4	5	1
BA_XRF_ppm	500			3																								1									
CL_XRF_ppm	130			4				2				2																3								2	
CO_XRF_ppm	20	1		3				2				1										1	1	2				4								3	
CR_XRF_ppm	100																					2	2	3				1									
CU_XRF_ppm	50			1								2																1								2	
NA_PPM_COMBINED_D	23000																																				
NI_XRF_ppm	80			2								1										1	1	2				1								2	
PB_XRF_ppm	14			2								2				1				1				2		1	1	3								2	
SN_XRF_ppm	2.2	1		4		2	1	3		2	2	4		2	2	4		2	2	3		2		3		1	1	4		2	3	3		1		3	
SR_XRF_ppm	370																																				
V_XRF_ppm	160																																				
ZN_XRF_ppm	75	2	1	4				2				2												1				2				2				1	
ZR_XRF_ppm	190			1				1																				1									

	Crustal abundance	DG WASTE				DG ORE				DG HYD				FWZ WASTE				FWZ ORE				MCS				MTS				WF			
	mg/kg	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min
FE_XRF_pct	41000	2	3	3		3	4	3		3	3	3		2	2	3		3	4	3	1	1	3	3		1	3	3		1	1	3	
AI2O3_pct_BEST	309885.8414																																
P_XRF_pct	1000			1				1				1				1				2				1									
TIO2_XRF_pct	9343.471903							1				1				1				1				1									
CAO_XRF_pct	57367.26547																															1	
MN_COMBINED_D	950			3				4				4				6				5				6				5		2		6	
MGO_XRF_pct	37539.70763																											1				1	
S_XRF_pct	260		1	4				6				5				5			1	3		2		8		1		6		2		7	
MNO_XRF_pct	1226.665453							1												3				3				1		2		6	
K2O_XRF_pct	50593.35038																																
NA2O_XRF_pct	62007																																
ARS_XRF_ppm	1.5	3	4	8	1	4	4	9	1	4	3	9	1	5	4	10	1	5	5	9	1	6	7	10	1	5	6	9	1	4	4	7	1
BA_XRF_ppm	500			1				1				3				3				2				3								1	
CL_XRF_ppm	130			4				3				3				5				2				3				2				1	
CO_XRF_ppm	20			2				3				4				4				3				5				2				4	
CR_XRF_ppm	100							2																2				3				3	
CU_XRF_ppm	50							1				1				3				3				4				2				1	
NA_PPM_COMBINED_D	23000																																
NI_XRF_ppm	80							1				2				1				2				2				2				2	
PB_XRF_ppm	14		1	3				3				5				4				2		1	2	4		1	1	3		1	1	4	
SN_XRF_ppm	2.2	1	1	4		2	3	4		1		4		1		4		1	2	4		2	3	4		2	3	4		2	2	4	
SR_XRF_ppm	370																																
V_XRF_ppm	160																							1									
ZN_XRF_ppm	75			5				3				3				4				4		1	1	5			1	3				3	
ZR_XRF_ppm	190			1				1				1				1				1				1									

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Hope Downs 2 GAI

	Crustal abundance	CLAY				CALCRETE				DET WASTE				DET ORE				CA WASTE				CA ORE				LI WASTE				LI ORE			
	mg/kg	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min
FE_XRF_pct	41000	2	2	3		1	1	3		2	2	3		3	3	3	1	2	2	3	2	3	3	3		2	2	3		3	3	3	2
Al2O3_pct_BEST	309885.8414																																
P_XRF_pct	1000																																
TIO2_XRF_pct	9343.471903			3				1				2				1								1				1					
CAO_XRF_pct	57367.26547			1				1																									
MN_XRF_pct	950			6		1		5				7				5				3				4		1		6			2		
MGO_XRF_pct	37539.70763			1				1																									
S_XRF_pct	260			5				3				5				2				2				1				3			3		
MNO_XRF_pct	1226.665453																																
K2O_XRF_pct	50593.35038																																
NA2O_XRF_pct	62007																																
ARS_XRF_ppm	1.5	3	3	6	1	3	3	4	1	3	3	6	1	3	3	5	1	2	3	3	1	3	2	4	1	3	4	5	1	3	3	4	1
BA_XRF_ppm	500			1								2																					
CL_XRF_ppm	130			3				5				5				2				1								1			2		
CO_XRF_ppm	20			5				3				3				3				2				3				1			2		
CR_XRF_ppm	100	1	1	3				1				3				1								2				2					
CU_XRF_ppm	50			2				1				2												1									
NA_XRF_ppm	23000																																
NI_XRF_ppm	80			3				1				2																					
PB_XRF_ppm	14	1	1	3				2				5				2																	
SN_XRF_ppm	2.2	1		4		1		3		1		4		1		4				2		1											
SR_XRF_ppm	370																																
V_XRF_ppm	160			2				1				2				1																	
ZN_XRF_ppm	75	1		4		2	1	5				4				3		2	2	4		1	1	3		1		3		1		4	
ZR_XRF_ppm	190			2								1																					

	Crustal abundance	PI WASTE				ROD WASTE				ROD ORE				WF				ANG WASTE				ANG ORE				ANG HYD				NEW WASTE			
	mg/kg	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min
FE_XRF_pct	41000	2	2	3	1	2	2	3		3	4	3		1	1	3		2	2	3		3	4	3	2	3	3	3	1	2	4	3	
Al2O3_pct_BEST	309885.8414																																
P_XRF_pct	1000																																
TIO2_XRF_pct	9343.471903			1				2				1				1				1												1	
CAO_XRF_pct	57367.26547															2				1													
MN_XRF_pct	950			1		1		7			5	7		4	2	8		3	1	8		1		7		1		6				4	
MGO_XRF_pct	37539.70763							1								2				1													
S_XRF_pct	260			1				5				5				3				6				4				3				3	
MNO_XRF_pct	1226.665453																																
K2O_XRF_pct	50593.35038																																
NA2O_XRF_pct	62007																																
ARS_XRF_ppm	1.5	4	3	5	1	4	4	6	1	3	4	6	1	4	4	6	1	4	4	7	1	3	4	6	1	3	3	5	1	1	3	4	1
BA_XRF_ppm	500							3				1				2				2				1				2				2	
CL_XRF_ppm	130			1				2				2				4				4				2				3				2	
CO_XRF_ppm	20			3				3				4				5				6				2				2				2	
CR_XRF_ppm	100			2				2				3				2				2				1				1				2	
CU_XRF_ppm	50			1				2				2				2				2				1				1				1	
NA_XRF_ppm	23000																																
NI_XRF_ppm	80			1				2				2				3				4				1									
PB_XRF_ppm	14	1	1	2				3			1	2				2				3				2				2			1	2	
SN_XRF_ppm	2.2	2	2	4		1		4		1	2	4		1		4		1		4		1	2	4		1		3		1	2	4	
SR_XRF_ppm	370																			1													
V_XRF_ppm	160			1				1				1				1				1												1	
ZN_XRF_ppm	75			3				5			3	4		1		7				7				4				3			1	3	
ZR_XRF_ppm	190																																

	Crustal abundance	NEW ORE				MAC WASTE				MAC ORE				NAM WASTE				NAM ORE				MM HYD				FOR			
	mg/kg	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min
FE_XRF_pct	41000	3	5	3	1	2	2	3		3	3	3	2	2	2	3		3	3	3	2	3	3	3		1	1	3	
Al2O3_pct_BEST	309885.8414																												
P_XRF_pct	1000		1									1												1					
TIO2_XRF_pct	9343.471903							1																1					
CAO_XRF_pct	57367.26547																											1	
MN_XRF_pct	950			6				5				1				3				1				7				3	
MGO_XRF_pct	37539.70763																												
S_XRF_pct	260			4				6				4				5		1		5				5		1		6	
MNO_XRF_pct	1226.665453																												
K2O_XRF_pct	50593.35038																												
NA2O_XRF_pct	62007																												
ARS_XRF_ppm	1.5	2	4	4	1	2	2	4	1	2	2	4	1	2	2	4	1	2	2	5	1	2	2	4	1	1	1	4	1
BA_XRF_ppm	500			2				1																1					
CL_XRF_ppm	130			2				4				3				2				1				5				2	
CO_XRF_ppm	20			4				3				3				4				3				2		1		5	
CR_XRF_ppm	100							2				1				2				2				2				2	
CU_XRF_ppm	50			3				2				3				3				2				3				3	
NA_XRF_ppm	23000																												
NI_XRF_ppm	80			1				1				1				2								1				3	
PB_XRF_ppm	14		1	2				2				2				2				2				2				2	
SN_XRF_ppm	2.2	1	3	4		1		4		1		4		1		4		1		4		1		4		1		3	
SR_XRF_ppm	370																												
V_XRF_ppm	160							1								1								1				1	
ZN_XRF_ppm	75			4				4				5				5		1		4				4			3	2	6
ZR_XRF_ppm	190																												

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Appendix D – AMD Hazard Scorecards

Project Name	Bedded Hilltop
Assessment Date	1/11/2020
Compiled by	Steven Lee
Final ARD Hazard Assessment	**LOW**

Version Date: 13/02/12
Version Number: 2

RTIO ARD Hazard Score

1. Preliminary Assessment (Order of Magnitude/Exploration)

A. Preliminary Geology Hazard

	Select Relevant Option Below	Score	Option Details
Ore Deposit Type	D) Enriched Dales Gorge Member mined below the water table (un-oxidised Mt McRae shale likely present)	19	Moderate/High
Host & Country Rock Neutralising Potential	Minor (5-25%)	7	
Brownfield's / Greenfields	Greenfield		
Known ARD Issues on Site	No	0	
	Geology Hazard Score		**29**

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Complete following sections

B. Incipient ARD Risk

	Select Relevant Option Below	Score
Operation Age	< 5 years	5

**By default, all new projects should receive a <5 years value*

C. Scale of Disturbance

	Select Relevant Option Below	Score
Total Waste Stored	50 - 250 million tonnes	5
Footprint	100 - 250 hectares	3

D. Transport Pathways

	Select Relevant Option Below	Score
Project / Exploration?	Yes	
Precipitation / Areal Potential Evapo-transpiration Ratio	1/10 to 1/3 ratio_mining below the water table in an aquitard or an isolated local aquifer	3

**All new projects should respond Yes to Project / Exploration*

E. Sensitivity of Receiving Environment

	Select Relevant Option Below	Score
Distance to Perennial/Ephemeral Water Bodies	500 - 2000 metres	1
Alkalinity	>35 mg/L	1
Distance to closest protected / permanently inhabited area	>10000 metres	0

Preliminary Hazard Assessment

Preliminary Hazard Score	47
Preliminary Risk Assessment	**MODERATE**

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2. Detailed Assessment (Pre Feasibility/ Feasibility/Mining)

This assessment should be completed by an ARD expert

Pit	Bedded Hilltop

F. Geochemical Hazard (Interrogate the drill hole database)

	Select Relevant Option Below	Score	Option Details
Waste sulfur risk	Total number of waste samples with S>0.1% is between 3% and 10%, less than 0.5% of samples have S>0.3%	2	4.57%/0.32% (AWT pit)
Ore grade sulfur risk	Total number of ore grade samples with S>0.1% is less than 3%	0	
Spatial distribution of sulfur	Sulfur scattered throughout the pit and through numerous lithologies	3	only 15 inpit intervals with S>0.3%
Chemical enrichment	Enrichments of contaminants that are unlikely to mobilise into groundwater	1	

G. Mine Planning Hazard

	Select Relevant Option Below	Score	Option Details
PAF material management	No special waste management needed	0	NO PAF Material mined
Bulk NPR (Mass of neutralising material x mean ANC) / (Percent of lithology greater than 0.1% x tonnes of lithology x mean sulfur concentration for all data greater than 0.1 x 30.6 + repeat for each PAF lithologies)	>3	0	No PAF Material Mined
PAF rock mass disturbed or exposed (waste tonnes with S>0.1%)/(total tonnes of waste)*100	< 3% of the total disturbed mass	0	NO PAF Material mined
Pit backfilling	Pit will not be backfilled	5	Conservative assumption

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H. Water Management Hazard

	Select Relevant Option Below	Score	Option Details
Dewatering volume	No releases of water	0	No dewatering of orebody required
Surface water	Isolated pit	0	
Water treatment during Operation	No water treatment or special management for ARD needed	0	No PAF
Final void management	No PAF rock exposures likely on final pit shell	0	No PAF (AWT Deposit)

Combined Hazard Assessment

Preliminary Assessment Score	47
Detailed Assessment Score	11
Combined Hazard Score	23
Risk Ranking	LOW

This risk ranking score card is relevant for Pilbara based iron ore operations and the ranking system can be used to assess the relative risk of each operation. The ranking system is likely to overestimate the risk if compared to porphry copper or some coal deposits.

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Project Name	Hope Downs 2
Assessment Date	1/11/2020
Compiled by	Steven Lee
Final ARD Hazard Assessment	**LOW**

Version Date: 13/02/12
Version Number: 2

RTIO ARD Hazard Score

1. Preliminary Assessment (Order of Magnitude/Exploration)

A. Preliminary Geology Hazard

	Select Relevant Option Below	Score	Option Details
Ore Deposit Type	C) Enriched Marra Mamba Formation and Joffre Member, and/or channel and detrital ore bodies mined below the water table (un-oxidised lignite and black shales other than Mt McRae may be present). Enriched Dales Gorge Member mined above the water table only	14	Moderate / moderate
Host & Country Rock Neutralising Potential	Minor (5-25%)	7	
Brownfield's / Greenfields	Greenfield		
Known ARD Issues on Site	No	0	
		Geology Hazard Score	**23**

Complete following sections

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B. Incipient ARD Risk

	Select Relevant Option Below	Score
Operation Age	< 5 years	5

**By default, all new projects should receive a <5 years value*

C. Scale of Disturbance

	Select Relevant Option Below	Score
Total Waste Stored	50 - 250 million tonnes	5
Footprint	100 - 250 hectares	3

D. Transport Pathways

	Select Relevant Option Below	Score
Project / Exploration?	Yes	
Precipitation / Areal Potential Evapo-transpiration Ratio	1/10 to 1/3 ratio_mining below the water table in an aquitard or an isolated local aquifer	3

**All new projects should respond Yes to Project / Exploration*

E. Sensitivity of Receiving Environment

	Select Relevant Option Below	Score
Distance to Perennial/Ephemeral Water Bodies	500 - 2000 metres	1
Alkalinity	>35 mg/L	1
Distance to closest protected / permanently inhabited area	>10000 metres	0

Preliminary Hazard Assessment

Preliminary Hazard Score	41
Preliminary Risk Assessment	**MODERATE**

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2. Detailed Assessment (Pre Feasibility/ Feasibility/Mining)

This assessment should be completed by an ARD expert

Pit	Hope Downs 2

F. Geochemical Hazard (Interrogate the drill hole database)

	Select Relevant Option Below	Score	Option Details
Waste sulfur risk	Total number of waste samples with S>0.1% is between 3% and 10%	7	9%/1.24% (AWT pit designs)
Ore grade sulfur risk	Total number of ore grade samples with S>0.1% is between 3% and 10% but less than 0.5% of the samples have S>0.3%	2	
Spatial distribution of sulfur	Sulfur scattered throughout the pit and through numerous lithologies	3	Limited S intervals >0.3%
Chemical enrichment	Enrichments of contaminants that are unlikely to mobilise into groundwater	1	

G. Mine Planning Hazard

	Select Relevant Option Below	Score	Option Details
PAF material management	No special waste management needed	0	No PAF Exposed
Bulk NPR (Mass of neutralising material x mean ANC) / (Percent of lithology greater than 0.1% x tonnes of lithology x mean sulfur concentration for all data greater than 0.1 x 30.6 + repeat for each PAF lithologies)	>3	0	No PAF exposed
PAF rock mass disturbed or exposed (waste tonnes with S>0.1%)/(total tonnes of waste)*100	< 3% of the total disturbed mass	0	No PAF exposed
Pit backfilling	Pit will not be backfilled	5	Worst case

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H. Water Management Hazard

	Select Relevant Option Below	Score	Option Details
Dewatering volume	No releases of water	0	No dewatering of orebody required
Surface water	Isolated pit	0	
Water treatment during Operation	No water treatment or special management for ARD needed	0	No PAF
Final void management	No PAF rock exposures likely on final pit shell	0	No PAF (AWT Deposit)

Combined Hazard Assessment

Preliminary Assessment Score	41
Detailed Assessment Score	18
Combined Hazard Score	28
Risk Ranking	LOW

This risk ranking score card is relevant for Pilbara based iron ore operations and the ranking system can be used to assess the relative risk of each operation. The ranking system is likely to overestimate the risk if compared to porphry copper or some coal deposits.

For RTIO internal distribution only. The manager of Technical Projects and Development will need to review and approve this prior to external release. This risk assessment should be read in conjunction with the detailed ARD Risk Assessment

Appendix 10: Geochemical Characterisation of Waste Rock Samples

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Hope Downs (Sustaining Deposits) – Geochemical Characterisation of Waste Rock Samples

Report Prepared for

Rio Tinto Iron Ore

DRAFT

Report Prepared by

SRK Consulting (Australasia) Pty Ltd

RTS158

July 2019

Hope Downs (Sustaining Deposits) – Geochemical Characterisation of Waste Rock Samples

Rio Tinto Iron Ore

152–158 St Georges TCE
Perth WA 6000

SRK Consulting (Australasia) Pty Ltd

Level 17, 44 Market Street
Sydney NSW 2000

e-mail: sydney@srk.com.au
website: www.asia-pacific.srk.com

Tel: +61 2 8079 1200
Fax: +61 2 8079 1222

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SRK Project Number RTS158

July 2019

Compiled by

Alex Watson
Principal Consultant

Email: awatson@srk.com.au

Peer Reviewed by

Claire Linklater
Principal Consultant

Author:

Alex Watson

Executive Summary

This work forms part of ongoing geochemical characterisation of samples from various Rio Tinto Iron Ore (RTIO) mining operations. The overall purpose of the geochemical characterisation program is to provide guidance for waste rock management in particular with respect to managing and limiting acid generation and metalliferous drainage.

The current program involved static geochemical characterisation of 96 waste rock samples from 10 stratigraphies at the Hope Downs (Sustaining Deposits) project (Bedded Hilltop and Hope Downs 2 deposits).

Of the 96 samples tested, the 10 lignites had the greatest acid generation potential and were all classed as potentially acid forming (PAF). The total sulfur content of the samples ranged between 1.27% and 33.3% (mostly as pyrite or marcasite) and the acid neutralising capacity (ANC) was low (<0.5 kgH_2SO_4/t to 7 kgH_2SO_4/t). Leachate from the lignites was generally acidic with high solute concentrations – including high concentrations of major cations (i.e. Ca and Mg), anions (i.e. SO_4) and a range of trace elements (e.g. Al, As, Cd, Co, Cr, Cu, Mn, Ni and Zn).

Two additional samples from the Dales Gorge and Footwall Zone lithologies were also classified as PAF, with a low capacity (<5 kgH_2SO_4/t) to generate acidity. These samples contained some sulfur (up to 0.15%) and negligible ANC (<0.5 kgH_2SO_4/t).

The 20 Wittenoom Formation (WF) samples were all classed as non acid forming (NAF); they contained significant ANC (up to 968 kgH_2SO_4/t) and negligible total sulfur (typically <0.01%). Leachate from the samples was invariably circum neutral to alkaline, with a low solute concentration.

The remaining 64 samples were from a range of lithologies, contained low to negligible total sulfur (up to 0.1%) and low to modest ANC (up to 33 kgH_2SO_4/t) – most samples (37 out of 64) were classified as NAF. The classification of 27 samples was uncertain (UC) and while most are not expected to be acid generating, eight contain a small store of readily soluble acidic weathering products. Most samples are expected to generate leachate that is circum neutral and with a low solute concentration.

SRK makes the following recommendations:

- A subset of the lignite samples should be submitted for kinetic column leach tests and measurement of the oxygen consumption rate. Special focus should be given to the behaviour of nitrogen in the leach tests (to follow up on an observation from previous studies that nitrogen release may be coincident with oxidation of carbonaceous materials).
- Supplemental leach testwork should be carried out on a subset of detrital and WF samples.

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (Australasia) Pty Ltd (SRK) by Rio Tinto Iron Ore (RTIO) and the ALS laboratory in Brisbane and the Genalysis/ Intertek laboratory in Perth. The opinions in this Report are provided in response to a specific request from RTIO to do so. SRK has exercised all due care in reviewing the supplied information. While SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this Report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

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1 Introduction

This work forms part of ongoing geochemical characterisation of samples from various Rio Tinto Iron Ore (RTIO) mining operations. The overall purpose of the geochemical characterisation program is to provide guidance for waste rock management in particular with respect to managing and limiting acid generation and metalliferous drainage.

The current program involved characterisation of waste rock samples from the Hope Downs (Sustaining Deposits) project (Bedded Hilltop and Hope Downs 2 deposits).

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2 Work Program

RTIO staff selected and collected 96 reverse circulation (RC) drill chip samples from 10 lithological units at the project site. The samples were selected to represent waste rock. A complete list of the samples is provided in Appendix A, and a summary is shown in Table 2-1 (in stratigraphical order, from youngest to oldest).

Table 2-1: Sample details

Stratigraphy	Strat Code	Bedded Hilltop (HD1)	HD2	Total	Comments
Detritals	DET	15	9	14	10 of the Bedded Hilltop samples are lignites (LIG)
Dales Gorge Member	DG	15	-	15	
Footwall Zone	FWZ	9	-	9	
Mount McRae Shale	MCS	7	-	7	
Mount Sylvia Formation	MTS	2	-	2	
Wittenoom Formation	WF	5	15	20	
Newman Member	NEW	-	9	9	
MacLeod Member	MAC	-	7	7	
Nammuldi Member	NAM	-	3	3	
Total		**53**	**43**	**96**	

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The samples were submitted to the ALS laboratories (ALS) in Brisbane for preparation and analytical testwork. An initial phase of screening test work (Phase 1) comprised the following tests on all samples:

- Paste pH and electrical conductivity (EC) (at a 2:1 liquid to solid (L:S) ratio)
- Total sulfur
- Acid neutralisation capacity (ANC)
- Single addition net acid generation (NAG) tests
- Multi-element chemical analysis.

Based on the Phase 1 test results, a subset of samples was selected for Phase 2 testing, comprising:

- Sulfur speciation (chromium reducible sulfur and sulfate-sulfur)
- Carbon speciation (total inorganic carbon (TIC) and total organic carbon (TOC))
- Acid buffering characteristic curves (ABCC)
- Mineralogical assessment (quantitative X-ray diffraction (XRD))
- Static de-ionised (DI) water leach tests (2:1 L:S, 12 hour tumble).

Most testing was undertaken by ALS. The XRD analysis was completed at the Intertek/ Genalysis laboratory in Perth.

The Phase 1 and Phase 2 static test methods are summarised in Appendix B and are consistent with the *ARD Test Handbook* (AMIRA, 2002).

3 Results and Discussion

3.1 Mineralogy

The mineralogical assessment used powder XRD to identify the primary mineral phases. The procedure included the addition of an internal standard (e.g. corundum) to allow quantification of the phases identified. A total of 16 samples were assessed, and the results are shown in Appendix C and summarised in Table 3-1.

The sulfide minerals pyrite and marcasite were identified in eight samples at concentrations ranging between <1% and 38%. The samples were from the DET stratigraphy (four lignite samples), together with one sample each from the DG, FWZ, WF and NEW stratigraphies. The highest concentrations were present in lignite sample IDL538. A low concentration of sphalerite was also identified in one of the WF samples.

Other sulfur minerals present in the lignite samples included sulfates and hydroxysulfates. These minerals were present at concentrations between <1% and 7% (sulfates) and <1% and 4% (hydroxysulfates).

Carbonate minerals were identified in nine of the samples at concentrations between <1% and 82%. Most of the samples were from the WF lithology (four samples), lignites (two samples) and one sample each from the NEW, MAC and NAM lithologies. Dolomite was the most common carbonate identified and was present at high concentrations in two samples: 82% (IEZ052, WF) and 49% (ICL231, WF). A high concentration (25%) of rhodochrosite was also identified in one sample (HST214, WF). Low concentrations of aragonite (IDL538, lignite), calcite (ICY663, MAC) and siderite (ICV737, lignite and IEZ199, WF) were also recorded, typically around 1% or less.

Other minerals identified in the samples were silicates and aluminosilicates (at concentrations up to 86%) and oxides and oxyhydroxides (at concentrations up to 75%).

The amorphous content of the samples ranged between 10% and 71%. The sample with most amorphous material was IDL399 (71%, lignite), followed by IEX186 (67%, lignite).

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Table 3-1: Results of the mineralogical assessment

Mineral	Approx Formula	Mineral Group	Mineral Abundance (wt%) for Sample ID and Stratigraphy															
			IEX071	IDL399	IEX186	ICV737	IDL538	IET896	IEW143	HWL551	IEZ052	IEZ199	ICL231	HST214	HST257	ICV072	ICY563	ICI423
			DET	DET-Lig				DG	FWZ	MCS	WF					NEW	MAC	NAM
Pyrite	FeS_2	Sulfides		3	13	1	38	1						4		1		
Marcasite	FeS_2				1		11	1	<1					1				
Sphalerite	(Zn,Fe)S														<1			
Melanterite	$FeSO_4(H_2O)_7$	Sulfates					1											
Gypsum	$CaSO_4.2H_2O$			<1														
Bassanite	$CaSO_4.0.5H_2O$			1	2													
Pickeringite	$MgAl_2(SO_4)_4.22(H_2O)$						7											
Rozenite	$FeSO_4.4(H_2O)$						4											
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Hydroxy-sulfates			1	2	4											
Alunite	$KAl_3(SO_4)_2(OH)_6$						<1											
Aragonite	$CaCO_3$	Carbonates					1											
Calcite	$CaCO_3$																<1	
Dolomite	$CaMg(CO_3)_2$										82	<1	49	<1			4	1
Rhodocrosite	$MnCO_3$													25		2		
Siderite	$FeCO_3$					1						<1						
Quartz	SiO_2	Silicates and alumino-silicates	8	<1	1	47	1	<1	5	37	4	1	5	2	27	1	1	1
Chlorite	$(Fe,Al,Mg)_6(Si,Al)_4O_{10}(OH)_8$												3					
Illite/Muscovite	$(K,Ca,Na)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH)_2$			1		14				5		1		1	15			
Kaolin	$Al_2Si_2O_5(OH)_4$		20	19	14	25		20	6	4		29	3	8	21		9	16
Serpentine	$Mg_3Si_2O_5(OH)_4$			1														
Na, Ca Plagioclase	$(Na,Ca)(Al,Si)_2Si_2O_8$			2														
Magnetite	Fe_3O_4	Oxides and oxy-hydroxides	<1	<1		<1	<1		1	<1		<1		1		<1	<1	<1
Gibbsite	$Al(OH)_3$			1	<1													
Goethite	FeO(OH)		16				1	52	56	18	2	12	7	24	10	62	59	61
Hematite	Fe_2O_3		25	1	1			1	1	17	1	15	<1	7	1	12	4	10
Anatase	TiO_2		1	1	<1							<1						
Rutile	TiO_2		1	<1		1				<1		1		<1	1			
Lithiophorite	$(Al,Li)MnO_2(OH)_2$														<1			
Amorphous Content		-	30	71	67	10	31	25	31	19	11	41	33	28	24	22	23	11

Notes: Amorphous content calculated by difference (100% - sum of absolute estimates).

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3.2 Paste pH and electrical conductivity

Paste pH and EC results are tabulated in Appendix D. The paste tests give an indication of availability of readily soluble oxidation products and salts. An acidic pH (pH <5) may indicate the presence of acidic reaction products generated by sulfide oxidation. An alkaline pH (pH >7) suggests the presence of reactive neutralising minerals, or, if categorised as potentially acid generating, that the sample has, as yet, not oxidised sufficiently to become acidic.

Paste EC provides an indication of the state of oxidation/ weathering, where higher EC values usually suggest a more advanced state of oxidation/ weathering. Where the sample originates from a naturally saline environment, an elevated paste EC may simply indicate the presence of residual salts in the sample. Plots of the paste pH and EC as a function of total sulfur content are shown in Figure 3-1 and Figure 3-2 respectively. The samples are differentiated by stratigraphic unit.

Figure 3-1 shows the paste pH of the samples ranges between 1.9 and 9.8. The paste pH of most samples (77 out of 96) is greater than 5, with 13 samples giving paste pH values that were alkaline (pH >8). Acidic paste pH values (pH less than 5) were recorded for 19 of the samples (9 of the 10 lignite samples, five FWZ, two MAC, two DG and one WF sample).

Figure 3-2 shows that the paste EC of most samples (83 out of 96) was low, less than 1,000 µS/cm. Three of the samples (two WF and one FWZ) gave rise to marginally higher paste EC, up to 1,540 µS/cm. The highest values were measured for lignite samples (between 1,930 µS/cm and 21,100 µS/cm).

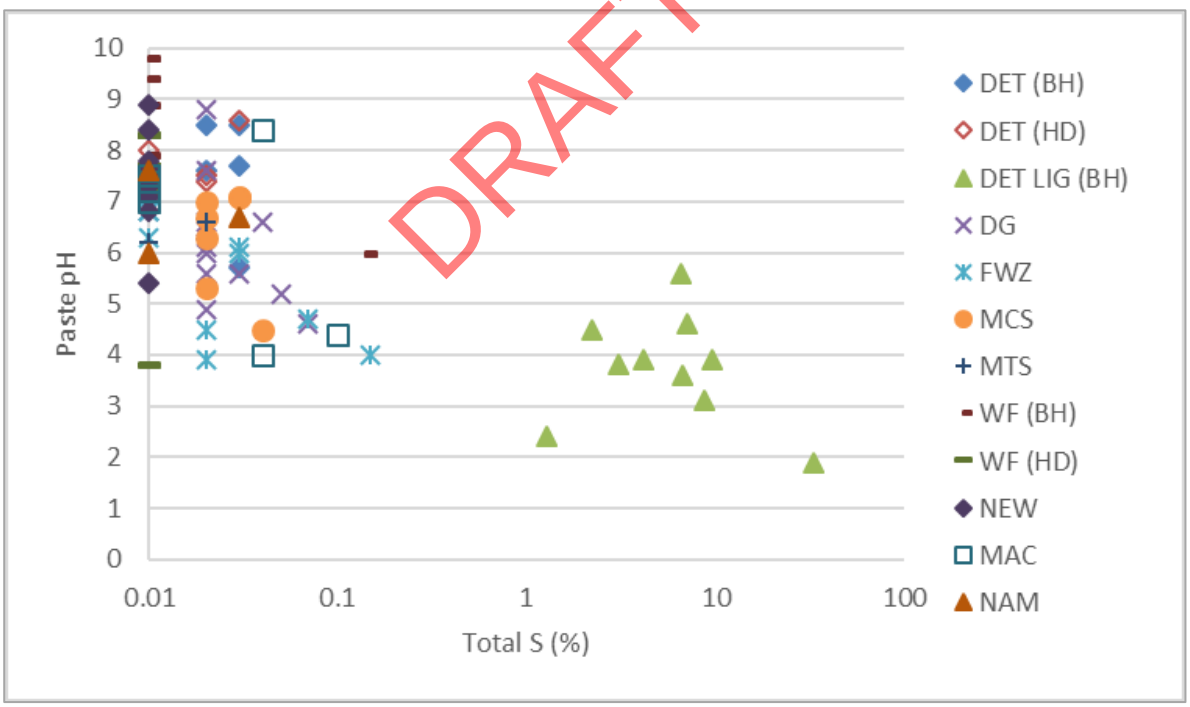

Figure 3-1: Paste pH plotted as a function of total sulfur content

Notes: BH – Bedded Hilltop; HD – Hope Downs 2.

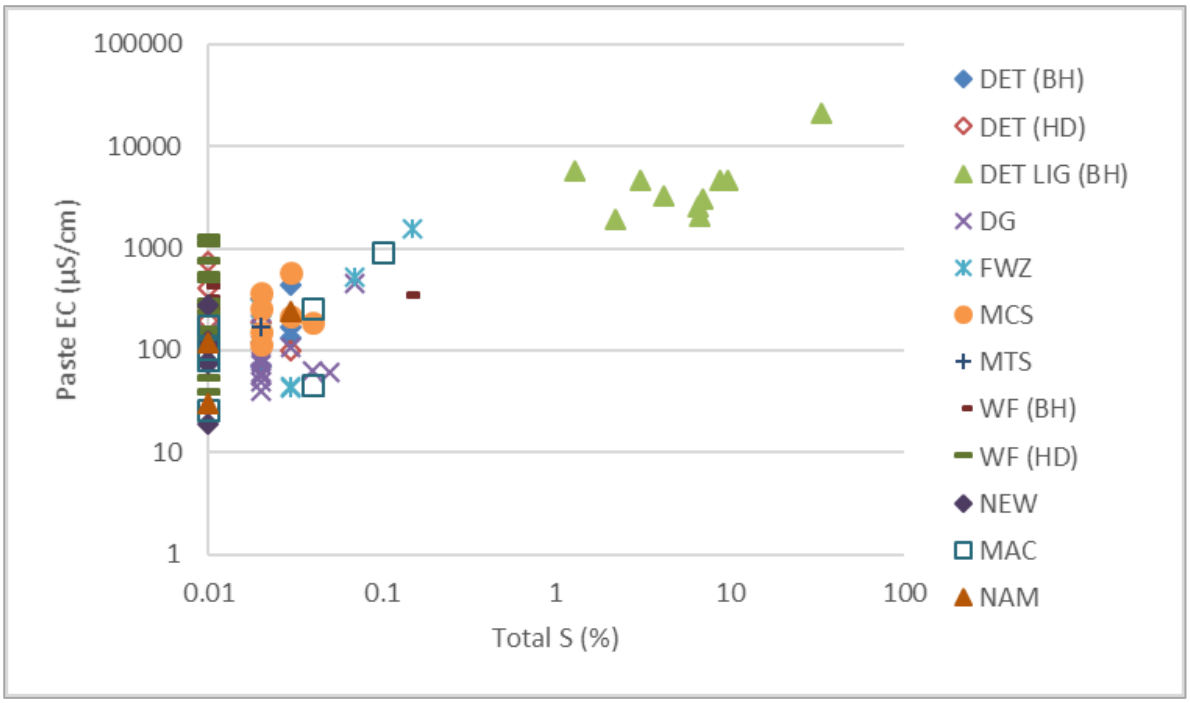

Figure 3-2: Paste EC plotted as a function of total sulfur content

Notes:
Log scale on the x and y axis; BH – Bedded Hilltop; HD – Hope Downs 2.

3.3 Acid base accounting

A summary of the results from acid base accounting (ABA) testwork is presented in Table 3-2. A complete set of results is given in Appendix D.

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3.3.1 Acid generation potential

The maximum potential acidity (MPA) is calculated based on the total sulfur content assuming all the sulfur will transform to sulfuric acid. The acid potential (AP) is calculated using estimates of oxidisable sulfide sulfur (usually calculated as the difference between the total sulfur content and the acid soluble sulfur content).

The total sulfur content of the samples ranged from <0.01% to 33.3%. The sulfur content of most samples was low – with sulfur present below the limit of detection (0.01%) in 45 samples and between 0.01% and 0.15% in a further 41 samples (a total of 86 samples). The highest sulfur contents, between 1.27% and 33.3% were present in the 10 lignite samples.

The results of sulfur speciation testwork carried out on a subset of 19 samples is shown in Table 3-3. The table shows that sulfide sulfur generally dominates in the 10 lignite samples and the WF sample. In all other samples (DG, FWZ and MAC), sulfate sulfur dominates.

Comparison of the measured total sulfur with that calculated from the sum of the CRS (chromium reducible sulfur) and SO_4-S showed good agreement for all samples from the DG, FWZ and MAC lithologies. While there was also good agreement for two of the lignite samples, in most cases the calculated values either overestimated (two samples) or underestimated (six samples) the total sulfur content. Possible explanations may be sample variability, or the presence of hydroxysulfate minerals. Hydroxysulfates such as jarosite may not be fully soluble under the conditions of the HCl (hydrochloric acid) digest analytical procedure for sulfate sulfur – which would result in a portion of the sulfate sulfur remaining undetected. The lack of agreement was particularly significant for IDL538. For this sample,

inaccurate measurement of the sulfide sulfur content by the CRS test may have contributed; the reliability in the CRS measurement decreases at sulfide sulfur contents greater than 10%.

Table 3-3 includes results of sulfur speciation by mineralogical assessment, where available. There is generally good agreement in the sulfur values determined by LECO analyser and by XRD for the lignite samples and the MAC sample.

There was poor agreement in the LECO and XRD total sulfur values for five samples – HST214 (WF), HST257 (WF), IET896 (DG), IEW143 (FWZ) and ICV072 (NEW). For all five samples, the mineralogical assessment overestimates the sulfide mineral content (significantly in the case of HST214). As the mineralogical results conflict with the results of total sulfur (both LECO and XRF) and sulfur speciation testwork, they are considered unreliable.

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Table 3-2: Summary of ABA and NAG data

Strat	Statistic	No. of samples	Paste pH	Paste EC	NAGpH	NAG pH 4.5	NAG pH 7	ANC	Total S	MPA	NAPP	AMIRA Classification			
			pH units	µS/cm	pH units	kgH_2SO_4/t			%	kgH_2SO_4/t		NAF[1]	UC (NAF)	PAF-LC	PAF
DET	Min.	14	5.7	69	6.2	<0.1	<0.1	<0.5	<0.01	0.3	-32	4(9)	1		
	Median		7.5	191	7.3	<0.1	<0.1	2.65	0.02	0.6	-				
	Max.		8.6	735	9.2	<0.1	0.4	32.9	0.03	0.9	0.4				
DET LIG	Min.	10	1.9	1,930	1.8	19.4	42.3	<0.5	1.27	39	38				10
	Median		3.8	3,925	2.2	150	221	<0.5	6.63	203	-				
	Max.		5.6	21,100	2.6	626	699	6.9	33	1019	1013				
DG	Min.	15	4.6	40	3.9	<0.1	<0.1	<0.5	<0.01	0.3	-0.3	(2)	12	1	
	Median		6.4	72	6.2	<0.1	0.7	<0.5	0.02	0.6	-				
	Max.		8.8	461	7	0.8	2.4	0.9	0.07	2.1	1.6				
FWZ	Min.	9	3.9	43	4.1	<0.1	<0.1	<0.5	<0.01	0.3	-0.2	(3)	5	1	
	Median		6	140	6.2	<0.1	0.4	<0.5	0.02	0.6	-				
	Max.		6.8	1,540	6.8	0.8	4.7	0.5	0.15	4.6	4.1				
MCS	Min.	7	4.5	115	5.6	<0.1	<0.1	<0.5	0.02	0.6	-0.2	(3)	4		
	Median		6.7	214	6.1	<0.1	0.5	0.7	0.02	0.6	-				
	Max.		7.1	575	7.2	<0.1	2	1	0.04	1.2	0.7				
MTS	Min.	2	6.2	96	6.4	<0.1	<0.1	<0.5	<0.01	0.3	-0.5	(1)	1		
	Median		6.4	133	6.6	<0.1	0.25	0.65	0.015	0.5	-				
	Max.		6.6	169	7	<0.1	0.4	0.8	0.02	0.6	0.1				
WF	Min.	20	3.8	40	5.6	<0.1	<0.1	<0.5	<0.01	0.3	-968	12(8)			
	Median		7.6	294	8.1	<0.1	<0.1	6.15	<0.01	0.3	-				
	Max.		9.8	1,310	10.2	<0.1	1.5	968	0.14	4.3	-0.2				
NEW	Min.	9	5.4	19	6.6	<0.1	<0.1	<0.5	<0.01	0.3	-8.7	1(8)			
	Median		7.5	78	7.2	<0.1	<0.1	<0.5	<0.01	0.3	-				
	Max.		8.9	276	8.5	<0.1	0.7	9	<0.01	0.3	-0.2				
MAC	Min.	7	4	26	4.6	<0.1	<0.1	<0.5	<0.01	0.3	-0.2	(4)	3		
	Median		7.2	102	6.6	<0.1	0.5	<0.5	<0.01	0.3	-				
	Max.		8.4	911	7.4	<0.1	2.1	0.7	0.1	3.1	2.6				

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Strat	Statistic	No. of samples	Paste pH	Paste EC	NAGpH	NAG pH 4.5	NAG pH 7	ANC	Total S	MPA	NAPP	AMIRA Classification			
			pH units	µS/cm	pH units	kgH_2SO_4/t			%	kgH_2SO_4/t		NAF[1]	UC (NAF)	PAF-LC	PAF
NAM	Min.	3	6	30	6	<0.1	0.5	<0.5	<0.01	0.3	-0.2	(2)	1		
	Median		6.7	117	6.4	<0.1	0.6	<0.5	<0.01	0.3	-				
	Max.		7.6	239	6.6	<0.1	2	<0.5	0.03	0.9	0.4				
All Samples	Min.	96	1.9	19	1.8	<0.1	<0.1	<0.5	<0.01	0.3	-968	17(40)	27	2	10
	Median		7	167	6.7	<0.1	0.3	<0.5	0.02	0.6	-				
	Max.		9.8	21,100	10.2	626	699	968	33	1,019	1013				

Notes:
[1] Number of samples classified as NAF-Barren shown in parenthesis;
EC – Electrical Conductivity; NAG – Net Acid Generation; ANC – Acid Neutralising Capacity; S – Sulfur; MPA – Maximum Potential Acidity; NAPP – Net Acid Producing Potential; NAF – Non Acid Forming; Bar – Barren; UC – Uncertain; PAF – Potentially Acid Forming; LC – Low Capacity.

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Table 3-3: Results of sulfur speciation tests

Sample ID	Lithology	Total S	Sulfide S	Sulfate S	Sulfide S	Sulfate S	Comment
		LECO	CRS	HCl Digest	XRD	XRD	
		%	%	%	%	%	
ICV737	DET LIG	1.3	0.65	0.62	0.53	0.26	Pyrite (1%) and jarosite (2%)
IDL399	DET LIG	2.2	3.2	0.42	1.6	0.41	Pyrite (3%), gypsum (<1%) and bassanite (1%)
IDL538	DET LIG	33	22	2.15	26	2.4	Pyrite (38%), marcasite (11%) and sulfates and hydroxysulfates
IEX186	DET LIG	7.0	7.1	0.95	7.4	0.6	Pyrite (13%), marcasite (1%), bassanite (2%) and jarosite (1%)
ICV974	DET LIG	3.0	1.3	1.24	-	-	-
ICW891	DET LIG	6.7	4.2	0.51	-	-	-
ICW899	DET LIG	8.7	5	1	-	-	-
IDL765	DET LIG	9.6	6.3	0.39	-	-	-
IER771	DET LIG	6.6	4.8	0.58	-	-	-
IEX193	DET LIG	4.2	2.0	0.83	-	-	-
IET896	DG	0.07	<0.005	0.03	1.1	ND	Pyrite (1%) and marcasite (1%)
HSS954	DG	0.05	0.015	0.005	-	-	-
HSS955	DG	0.02	0.007	0.01	-	-	-
IEW143	FWZ	0.15	<0.005	0.11	0.53	ND	Marcasite (<1%)
IER142	FWZ	0.02	<0.005	0.02	-	-	-
IEZ446	FWZ	0.07	0.006	0.05	-	-	-
ICV792	WF	0.14	0.15	0.03	-	-	-
HST214	WF	<0.01	-	-	2.7	ND	Pyrite (4%) and marcasite (1%)
HST257	WF	<0.01	-	-	0.33	ND	Sphalerite (<1%)
ICV072	NEW	<0.01	-	-	0.53	ND	Pyrite (1%)
ICY563	MAC	0.1	<0.005	0.08	ND	ND	No sulfur minerals detected
ICH905	MAC	0.04	<0.005	0.03	-	-	-

Notes:
S – Sulfur; CRS – chromium reducible sulfur; HCl – Hydrochloric acid; " – " not tested; ND – Not detected.

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3.3.2 Acid neutralising capacity

The ANC ranged between <0.5 kgH_2SO_4/t and 968 kgH_2SO_4/t. For most samples the ANC was low – below the limit of detection (0.5 kgH_2SO_4/t) for 57 samples and between 0.5 kgH_2SO_4/t and 32.9 kgH_2SO_4/t for a further 34 samples (a total of 91 samples). The highest ANC (292–968 kgH_2SO_4/t) was measured in five samples – all from the WF lithology.

Carbonate neutralising potential

The total inorganic carbon (TIC) content may be used to infer the carbonate mineral content and estimate the carbonate neutralisation potential (CarbNP). Carbon speciation testing was carried out on 25 samples (see Appendix D). The CarbNP values ranged from 2 kgH_2SO_4/t to 873 kgH_2SO_4/t. A plot of the calculated CarbNP as a function of the measured ANC is shown in Figure 3-3. The black dotted line on the plot is a line of equivalence (where the CarbNP equals the ANC).

There was good agreement between the CarbNP and ANC for the WF and NEW samples – with most samples plotting close to the line of equivalence. Lignite and DET samples, on the other hand, show poor agreement.

The CarbNP exceeded the ANC for all lignite samples. Very high CarbNP values were calculated for most of the samples, which contained low to negligible measurable ANC. The carbonate in these samples is most likely in the form of iron bearing carbonate minerals that do not contribute effectively to the ANC under oxidising conditions. This includes minerals such as siderite ($FeCO_3$) which was identified in samples tested (Table 3-1). While dissolution of siderite consumes acidity, ferrous iron released has the potential to oxidise to ferric iron and precipitate as $Fe(OH)_3$, generating acidity. Combined, the reactions may not result in net consumption of acidity.

There was considerable scatter in the results for the DET samples, with samples plotting both above and below the line of equivalence. The two samples plotting below the line contain modest ANC (greater than 10 kgH_2SO_4/t) and low CarbNP (up to 3 kgH_2SO_4/t), suggesting most of the ANC measured in the test is associated with neutralisation by silicate minerals.

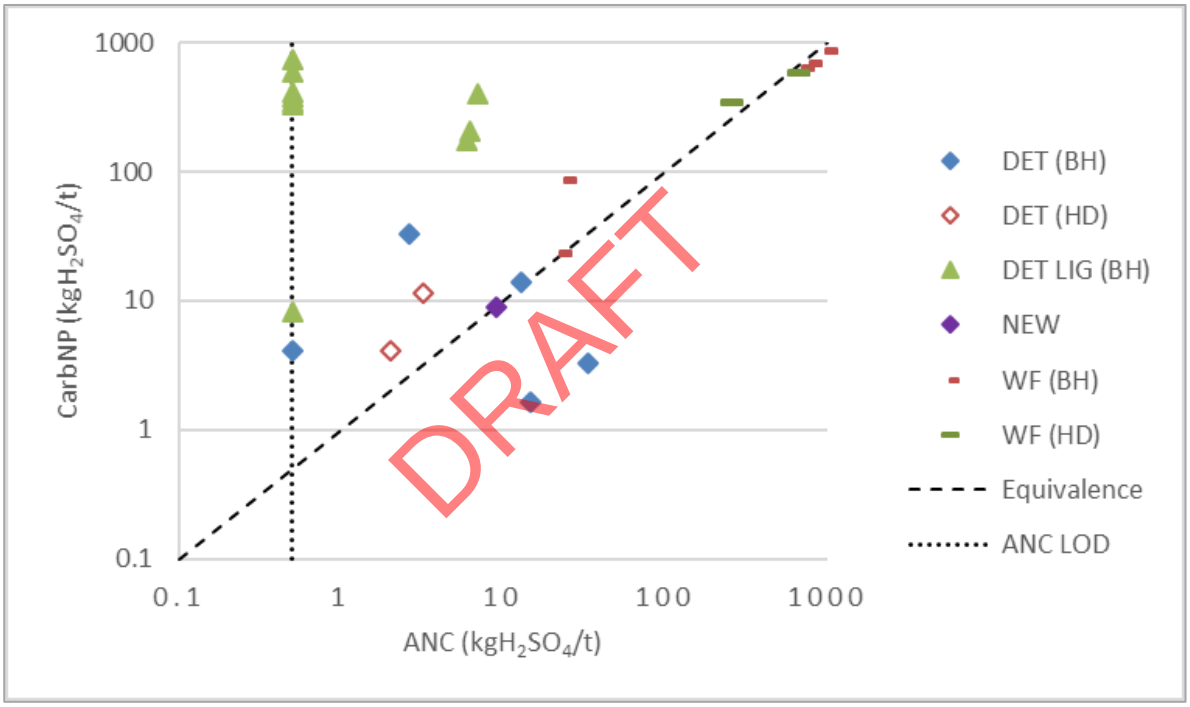

Figure 3-3: CarbNP plotted as a function of ANC

Acid buffering characteristic curves

To assess the availability of neutralising capacity, nine samples (from the DET, WF and NEW stratigraphies), exhibiting a range of ANC values, were submitted for ABCC testing. The results are illustrated in Figure 3-4 (samples with ANC greater than 200 kgH_2SO_4/t) and Figure 3-5 (samples with ANC less than 50 kgH_2SO_4/t) – a full set of results is provided in Appendix E.

Typically, buffering within certain pH ranges can be attributed to neutralisation by specific minerals. For example, buffering at around pH 7 and above is indicative of neutralisation by carbonate minerals such as calcite, while dolomite buffers the pH between pH 6 and 7. Buffering by aluminium and iron hydroxide minerals may occur below pH 4.5.

Figure 3-4 and Figure 3-5 both show strong evidence of buffering by carbonate minerals in most of the samples tested – consistent with the results of the mineralogical assessment, where calcite and dolomite were identified in the samples.

Samples from the WF lithology (Figure 3-4) contained the highest ANC and generally gave rise to well-defined plateaus.

Whilst IEX071 (DET) contained modest ANC (33 kgH_2SO_4/t), the plot shows no evidence of buffering capacity. For this sample, measured ANC may reflect the presence of silicates that were reactive under the conditions of the ANC test.

HST214 contained 25% rhodochrosite. The plot shows that the sample buffered acidity between pH 4 and 5 and Table 3-4 shows that it contained significant available ANC (175 kgH_2SO_4/t to pH 4.5).

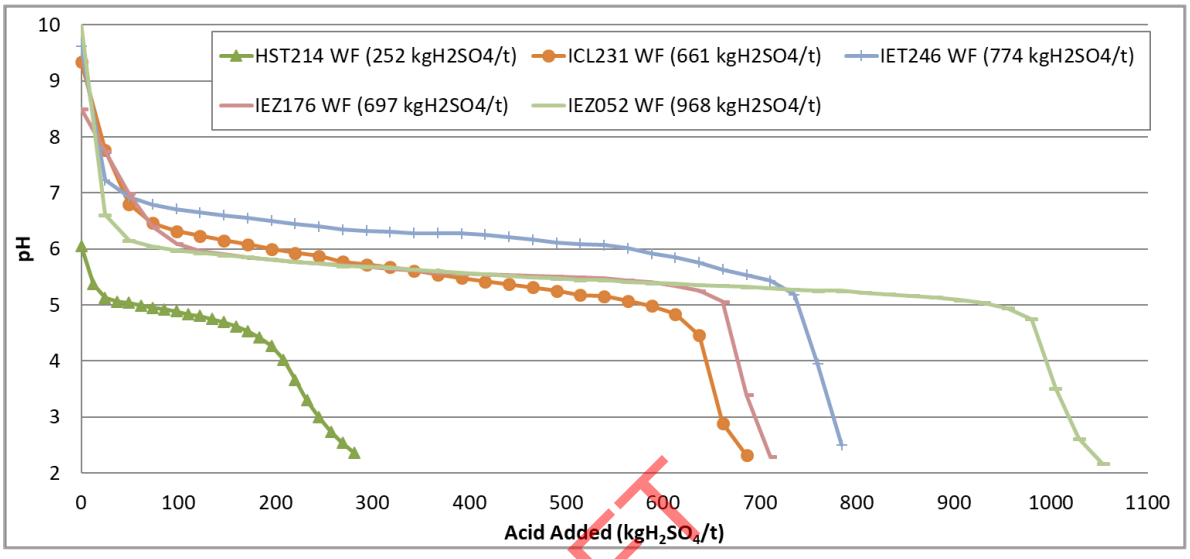

Figure 3-4: Acid buffering characteristic curves – samples with ANC >200 kgH_2SO_4/t

Note: Static ANC values are shown in brackets after the sample ID and stratigraphy.

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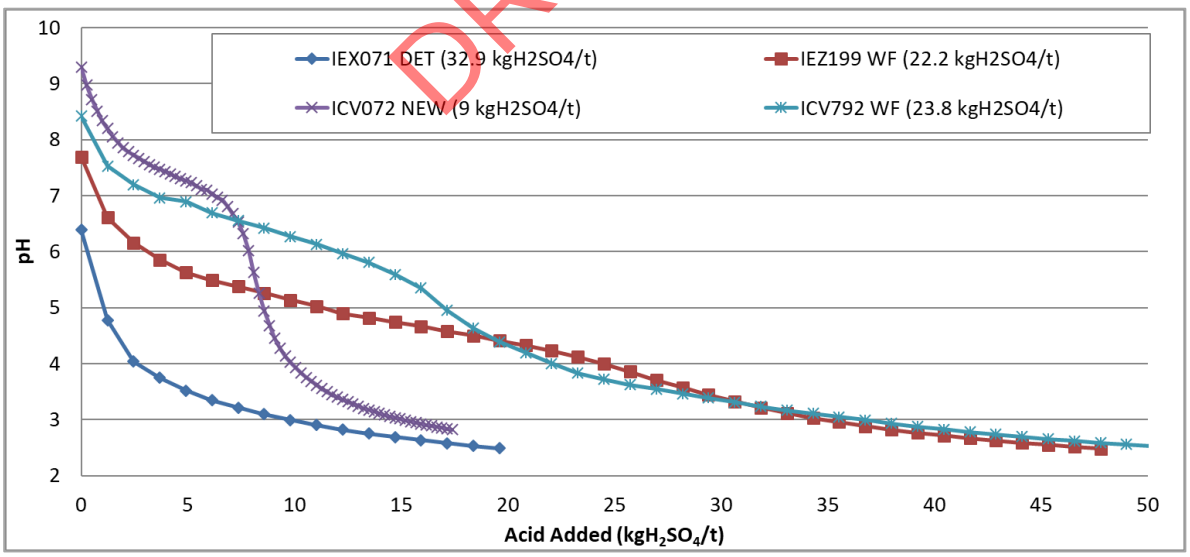

Figure 3-5: Acid buffering characteristic curves – samples with ANC < 50 kgH_2SO_4/t

Note: Static ANC values are shown in brackets after the sample ID and stratigraphy.

The measured ANC and the available ANC (ABCC measured to pH 6 and 4.5) are summarised in Table 3-4. The table also includes the carbonate-based neutralisation potential (CarbNP) calculated from the TIC results.

The ANC consumed to pH 6 ranged between 0.4% and 87% of the total ANC in the samples. For most samples, 69% or more of the ANC was consumed to pH 4.5. These results suggest that most samples contain a high proportion of readily available ANC to buffer pH above 4.5.

However, IEX071 (DET) is an exception; only 5% was consumed. As already mentioned, in this sample, it is possible that alumino-silicates significantly contributed towards the measured ANC.

Table 3-4: Summary of ANC results

Sample ID	Strat	ANC	ANC to pH 6		ANC to pH 4.5		CarbNP
		kgH_2SO_4/t	kgH_2SO_4/t	Consumed (%)	kgH_2SO_4/t	Consumed (%)	kgH_2SO_4/t
IEX071	DET	33	0.3	1	1.7	5	3
IEZ199	WF	22	3.1	14	18	83	24
HST214	WF	252	1.0	0.4	175	69	349
ICV792	WF	23.8	12	50	19	80	87
ICL231	WF	661	196	30	634	96	597
IET246	WF	774	566	73	748	97	702
IEZ176	WF	697	116	17	670	96	647
IEZ052	WF	968	89	9	985	102	873
ICV072	NEW	9	7.8	87	9.0	100	9

3.3.3 Net acid producing potential

The net acid producing potential (NAPP) of the samples is a balance of MPA and ANC (i.e. NAPP = MPA – ANC). A negative NAPP indicates an overall excess of neutralising capacity, while a positive NAPP indicates an excess of acidity.

The calculated NAPP values ranged from -968 kgH_2SO_4/t to 1,013 kgH_2SO_4/t, with most samples (57) giving negative NAPP values. Of the 39 samples that gave rise to positive NAPP values, most were low (NAPP of 29 samples was between 0.02 kgH_2SO_4/t and 4.1 kgH_2SO_4/t).

High NAPP values (between 38 kgH_2SO_4/t and 1013 kgH_2SO_4/t) were calculated for the 10 lignite samples. These samples contained between 1.27% and 33.3% sulfur and low ANC (up to 6.9 kgH_2SO_4/t).

Net acid generation and sample classification is discussed further in following sections.

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3.4 Net acid generation tests

During the NAG test, the samples are contacted with the strong oxidant, hydrogen peroxide, to oxidise sulfide minerals contained in the sample. Concurrently, neutralising minerals present in the sample consumes the acidity generated until either the ANC or sulfide is depleted. Should the ANC be depleted first, excess acidity is generated and the sample pH decreases. Following a predetermined contact time, the solution pH (NAG pH) is recorded and the acidity of the sample is quantified by titration with a base (sodium hydroxide). The acidity generated at pH 4.5 and below is generally attributed to free sulfuric acid and ferric iron resulting from the oxidation of sulfide minerals after consumption of any neutralising mineral phases. The acidity generated between pH 4.5 and pH 7 includes a contribution from metals such as copper that are soluble at pH 4.5 but insoluble at pH 7.

Single addition NAG tests were conducted on all samples to assess the net amount of acid generated by the samples. In general, the results supported the findings of the ABA testwork, with good agreement between the NAG and the NAPP.

While most samples did not generate acidity (NAG pH values were above pH 6, and NAG acidities were generally close to or below detection limits), the 10 lignite samples generated significant acidity and gave rise to strongly acidic pH values.

3.4.1 Sample classification

The NAPP and NAG pH values are commonly used to classify the acid generating potential of samples as shown in Figure 3-6 and Appendix D. The classification scheme is summarised in Table 3-5.

Table 3-5: Summary of classification scheme

Class	Sub-class	Description
NAF	NAF	Samples with a negative NAPP value and a NAG pH ≥4.5
	NAF-Barren	As above, and also a low ANC (≤ 5 kg H_2SO_4/t); such samples have little value with respect to mitigating the effects of acid production in other mine waste materials
PAF	PAF	Samples with a positive NAPP value and a NAG pH <4.5
	PAF-LC	PAF materials associated with low NAG acidities ($NAG_{pH4.5}$ <5 kg H_2SO_4/t)
Uncertain	UC(PAF)	Samples with negative NAPP but giving NAG pH values <4.5
	UC(NAF)	Samples with positive NAPP but giving NAG pH values ≥4.5. Possibly in these samples some of the sulfur present is in non-pyritic forms

Notes: NAF – Non Acid Forming; PAF – Potentially Acid Forming; LC – Low Capacity (to produce acid); UC – Uncertain acid potential.

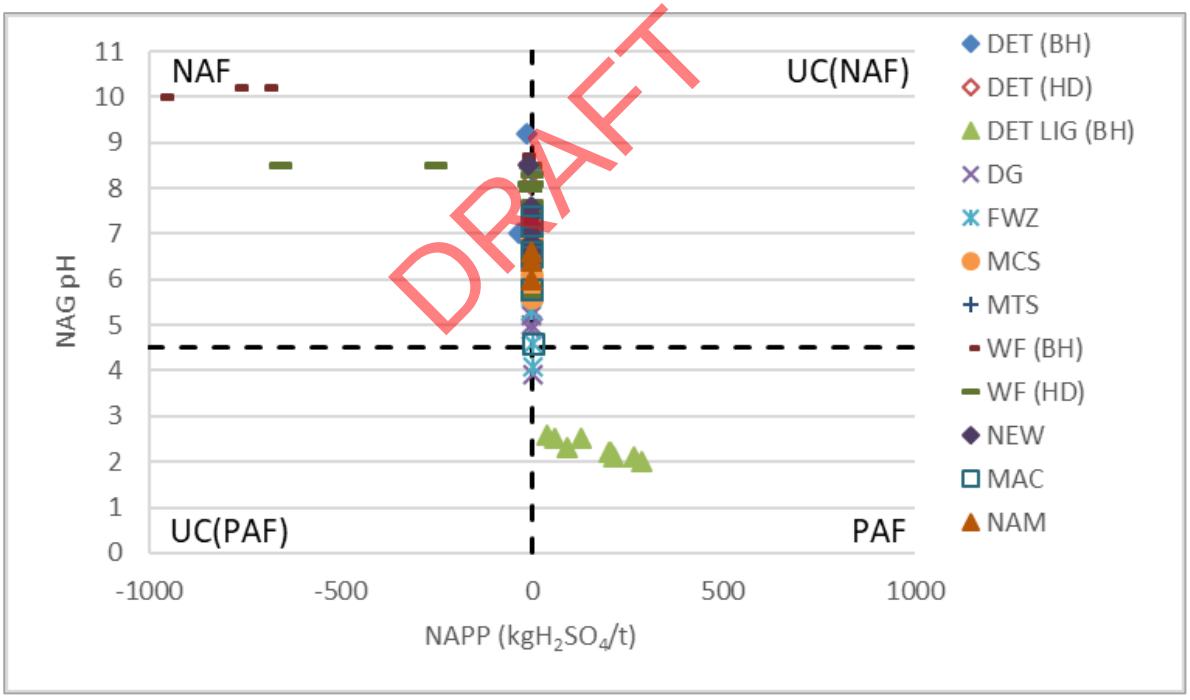

Figure 3-6: Geochemical classification plot

Notes: BH – Bedded Hilltop; HD – Hope Downs 2.

Most of the samples (57 out of 96) were classed as NAF, of which 40 were classed within the 'barren' subclass (where barren indicates material with no value in terms of ANC that could mitigate the effects of acid generation in other mine materials).

Figure 3-6 shows that all 10 of the lignite samples plotted within the PAF quadrant. Two other samples (one DG and one FWZ) were also classed as PAF, but with a low capacity to generate acidity (i.e. less than 5 kgH_2SO_4/t).

The classification of 27 samples was uncertain. These samples generally contained low sulfur (0.1% or less) and negligible ANC (<0.5 kgH_2SO_4/t). While most samples are not expected to be acid generating, eight samples gave rise to paste pH values that were less than 5, suggesting that they contain a store of readily soluble acidic weathering products. These samples were from the DG, FWZ, MAC and MCS lithologies.

For each stratigraphic group, Table 3-2 summarises the distribution of samples between the classes.

3.5 Multi-element chemical assays

The results of multi-element chemical analyses, including the calculated global abundance indicator (GAI) values are provided in Appendix F. The results show that the most abundant elements are Fe and Si as would be expected since iron and silicate minerals were found to be the dominant minerals in most samples.

GAIs provide an indication of how the measured elemental abundances compare to average crustal abundances. Elements with a GAI greater than 3 are considered to be enriched.

A summary of the number of samples that were enriched for each stratigraphy is shown in Table 3-6. Elements enriched in one or more samples were Ag, As, B, Bi, Cd, Hg, Mn, Re, S, Sb, Se, Te, Tl and Zn.

The greatest range of elemental enrichment occurs in DET LIG samples (12 elements) followed by the WF samples (9 elements). Samples from the Newman stratigraphy showed the least enrichment (only one sample that was enriched with Se).

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Table 3-6: Summary of number of samples that were enriched (GAI values ≥3)

Rock type	No. of samples	Ag	As	B	Bi	Cd	Hg	Mn
Detritals	14		13		4		1	
Lignite	10		10	9	3	8	9	
Dales Gorge	15		2		1			
FWZ	9		6					
MCS	7	1	7		6			
MTS	2		2		1	1		
WF	20		13	4	8	3		7
Newman	9							
MacLeod	7							
Nammuldi	3							

Rock Type	No. of samples	Re	S	Sb	Se	Te	Tl	Zn
Detritals	14			11	11	14		
Lignite	10	8	10	3	10	10	2	1
Dales Gorge	15			1	2	4		
FWZ	9			1	3	3		
MCS	7			6	6	7		
MTS	2			1	1	2		
WF	20			11	5	14		2
Newman	9				1			
MacLeod	7				2	3		
Nammuldi	3				1	1		

Note: Cells have been left blank where no samples were enriched.

3.6 Element leachability

Static DI water leach tests were carried out on 25 samples to assess the leachability of contaminants from the materials. The leach tests involved pulverised samples and a 12-hour contact time (during which the sample was tumbled). The leachates were filtered using a 0.2 µm filter.

The results from the individual leach tests are shown in Appendix G. Table 3-7 lists the average dissolved concentrations observed in each stratigraphic unit in the leach tests for selected elements.

Since the physical and chemical conditions of the laboratory leach test will not be the same as those expected in the field – for example, the liquid to solid ratios and contact duration, the laboratory results cannot be used directly to represent leachate quality expected to seep from a stockpile of the material. Depending on field conditions, seepage water quality might be better or worse than indicated by these leach tests.

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The pH of the leachate from the samples ranges from 1.9 to 7.8. For most samples, the leachate was in the near-neutral range (between pH 6 and 8). Two of the lignite samples (IDL538 and ICV737) gave rise to acidic leachates (pH <2.5).

The highest leach EC values were measured for the four lignite samples tested (EC was between 2,610 µs/cm and 24,900 µs/cm). The leach EC ranged between 78 µs/cm and 1,860 µs/cm for all other samples.

Higher levels of dissolved elements suggest the presence of readily soluble salts, such as carbonates, sulfates and chlorides, in the sample. The salts may represent pre-existing weathering products present in the samples, or may have formed following evaporation of sample pore water. Drilling fluids may also contribute to the salt content of samples. Some elements may be sourced from mineral surfaces, e.g. desorbed from ion exchange sites.

The major cations (Ca, Mg, Na and K) and anions (SO_4, Cl and F) were generally present at readily detectable concentrations in the leachate from all samples. The highest concentrations of SO_4, Ca and Mg were present in the leachate from the lignite samples. Concentrations of Na and K were similar for all samples. High concentrations of Ca and SO_4 are likely associated with dissolution of sulfur minerals such as gypsum (which was identified in the mineralogical assessment).

The total N concentration in the leachate from the samples was low – being close to, or below, the limit of detection (0.1 mg/L) for most samples. Readily detectable concentrations were present in the leachate from the lignites, as well as samples ICY563 (MAC) and IEX071 (DET). In most cases, organic N was the dominant species present.

The majority of trace elements (i.e. Ag, Be, Bi, Ce, Cr, Cs, Ga, Hf, Hg, La, Nb, Sb, Sn, Ta, Te, Th, Ti, Tl, U, V, W, Y and Zr) leached at concentrations that were low – close to the limit of detection or below it.

Of the trace elements that were readily detectable in most leachates (i.e. Al, As, B, Ba, Cd, Co, Cu, Fe, Li, Mn, Mo, Ni, Pb, Rb, Se, Sr and Zn), concentrations were highest in the acidic leachate from the lignite samples (IDL538, followed by ICV737).

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Table 3-7: Static leach data summary – average dissolved concentrations

Parameter	Units	Stratigraphy										Min.	Average	Max.
		DET	DET LIG	DG	FWZ	MAC	MCS	MTS	NAM	NEW	WF			
		n=3	n=4	n=2	n=2	n=2	n=3	n=2	n=1	n=1	n=5	n=25		
pH	-	6.7	2.4	6.4	5.6	6.2	6.5	6.6	6.5	7.8	6.4	1.9	3.2	7.8
Ca	mg/L	5.7	8.8	8.5	17	7	6.3	11	19	67	236	<1	57	464
Mg	mg/L	5	24	26	33	8.5	6	8.5	21	61	167	<1	48	394
Na	mg/L	17	68	66	69	27	22	35	21	135	34	5	44	216
K	mg/L	3	8	9	13	4	1	6	2	10	6.2	<1	6	23
SO_4	mg/L	25	10,765	88	218	89	93	30	83	9	116	5	1,797	28,600
Cl	mg/L	13	45	26	187	140	105	22	28	9	91	3	71	366
F	mg/L	0.87	0.25	0.20	0.50	0.30	1.93	0.75	0.90	0.80	0.64	<0.1	0.71	3.60
Al	mg/L	0.10	172	0.03	0.41	0.12	0.08	0.03	0.02	0.013	0.03	<0.01	28	596
As	mg/L	0.001	8.2	0.0006	0.0005	0.0007	0.002	0.0006	0.0003	0.003	0.001	<0.0002	1.31	26
B	mg/L	0.26	1.8	0.27	0.46	0.38	0.41	0.19	0.30	0.16	0.41	0.06	0.57	3.1
Cd	mg/L	0.0002	0.46	0.0003	0.0005	0.0003	0.0005	0.0006	0.0003	0.00005	0.0006	<0.0001	0.07	1.08
Co	mg/L	0.0005	10	0.004	0.005	0.0004	0.005	0.007	0.0002	0.0001	0.003	<0.0001	1.63	33
Cr	mg/L	0.0007	0.35	<0.0002	<0.0002	0.0003	0.0003	<0.0002	<0.0002	<0.0002	0.0007	<0.0002	0.06	0.87
Cu	mg/L	0.0011	2.8	0.001	0.001	0.009	0.004	0.0009	0.0005	0.001	0.002	<0.001	0.45	11
Fe	mg/L	0.50	3,880	0.13	0.07	0.87	0.03	0.008	0.03	0.10	1.10	<0.002	621	12,200
Mn	mg/L	0.01	20	0.30	0.91	0.10	0.10	0.17	0.009	0.004	0.19	0.001	3.31	54
Mo	mg/L	0.001	0.01	<0.0001	0.0001	0.0007	0.0002	0.0006	<0.0001	0.003	0.0007	<0.0001	0.002	0.03
Ni	mg/L	0.002	26	0.02	0.02	0.002	0.01	0.01	0.001	0.002	0.04	<0.001	4.19	85
Pb	mg/L	0.0001	0.08	0.0001	0.0003	0.001	0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.01	0.26
Se	mg/L	0.006	0.08	0.003	0.0005	0.0006	0.003	0.001	0.001	0.001	0.001	0.0003	0.01	0.15
U	mg/L	0.0001	0.21	<0.0001	0.0004	<0.0001	0.0003	<0.00005	<0.0001	0.0001	0.0003	<0.0001	0.03	0.54
Zn	mg/L	0.07	205	0.22	0.60	0.34	0.33	0.06	0.08	0.006	0.39	0.006	33	703

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Parameter	Units	Stratigraphy										Min.	Average	Max.
		DET	DET LIG	DG	FWZ	MAC	MCS	MTS	NAM	NEW	WF			
		n=3	n=4	n=2	n=2	n=2	n=3	n=2	n=1	n=1	n=5	n=25		
NO_2+NO_3	mg/L	0.06	0.53	0.02	<0.01	0.14	0.02	0.01	<0.01	<0.01	0.03	<0.01	0.11	1.28
TKN	mg/L	0.13	0.83	<0.1	<0.1	0.15	0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.22	2.1
Total N	mg/L	0.17	1.4	<0.1	<0.1	0.3	0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.33	3.4

Notes:
NO_2 + NO_3 as N, TKN – total Kjeldahl nitrogen; Average values calculated assuming results below the limit of detection are equal to it; n – number of samples.

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4 Conclusions

The outcomes of the testwork program are summarised below:

- Total sulfur ranged from <0.01% to 33.3%, but was low (less than 0.15%) for 86 of the 96 samples. The 10 lignite samples contained between 1.27% and 33.3%, with a large proportion present as sulfide sulfur (likely pyrite and marcasite).
- The ANC ranged between <0.5 kgH_2SO_4/t and 968 kgH_2SO_4/t and for most samples it was low. The highest ANC (292 kgH_2SO_4/t to 968 kgH_2SO_4/t) was measured in five WF samples – a large proportion was present in the form of dolomite.
- Sample classification indicated that 57 samples were NAF, 27 were UC and 12 were PAF. Of the UC samples, eight generated acidic paste pH values (<5 – they contained a small store of readily soluble acidic weathering products and negligible ANC).
- Leachate pH values were near neutral (between 6 and 8) for most samples but ranged down to acidic values in some tests. The major cations and anions were generally present at readily detectable concentrations in the leachate from all samples.
- While most trace elements leached at concentrations that were low (close to the limit of detection or below it), Al, As, B, Ba, Cd, Co, Cu, Fe, Li, Mn, Mo, Ni, Pb, Rb, Se, Sr and Zn were readily detectable in most leachates.

The main conclusions of the testwork program are as follows:

- Of the 96 samples tested, the 10 lignites had the greatest acid generation potential. The samples were all classed as PAF since they contained significant sulfide sulfur and low ANC. Leachate from the lignites is expected to be generally acidic with high solute concentrations – including high concentrations of major cations (i.e. Ca and Mg), anions (i.e. SO_4) and a range of trace elements (e.g. Al, As, Cd, Co, Cr, Cu, Mn, Ni and Zn).
- The 20 WF samples were all classed as NAF, they contained the greatest ANC and negligible total sulfur. Leachate from the samples was invariably circum neutral to alkaline, with a low solute concentration.
- The remaining 66 samples were from a range of lithologies. The samples contained low to negligible total sulfur and low to modest ANC with most samples expected to be NAF. The acid generation potential of the samples classed as UC or PAF-LC will be low to negligible. Most samples are expected to generate leachate that is circum neutral and with a low solute concentration.

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5 Recommendations

A review of the RTIO geochemical database indicates that eight lignite samples (five from Hope Downs) have been submitted for kinetic column tests in the past. A further 10 lignite samples have been tested as part of this project and provide an opportunity for RTIO to carry out further geochemical testwork to provide greater insight to lignite behaviour.

It is recommended that a subset of the samples be submitted for kinetic column leach tests and measurement of the oxygen consumption rate. The results of kinetic tests will provide an understanding of solute release from the samples and can also be used to calculate the sulfide oxidation rate based on sulfate release rates from the column. Measurement of the oxygen consumption rate will provide an indication of the oxygen consumed due to sulfide oxidation as well as organic carbon present in the samples. The results of the testwork may be used to assess oxygen consumption mechanisms and provide insight into lignite weathering processes.

It is also recommended that a laboratory program be developed to further investigate the leaching characteristics of lignite samples. This was one of the recommendations of a recent review carried out by SRK into N leachability (RTS154 – SRK, 2018). The review concluded that carbonaceous material was the most likely source of N in leachate and that further investigation should be carried out to assess the potential mechanisms for N release.

In addition, it is recommended that supplemental leach testwork be carried out on other DET (strands other than lignites) and WF samples. This could include:

- Low contact ratio leach testing – to assess the influence of contact ratio on leachability
- Mild acid leach testing – to assess the leaching potential of waste material that may come into contact with acidity generated by other materials at the site, for example, as a result of use as a possible management option to mitigate AMD risk from PAF materials.

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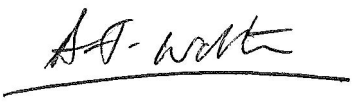
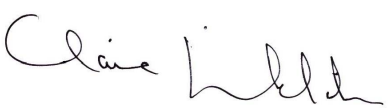


Alex Watson

Principal Consultant

Peer Reviewed by



Claire Linklater

Principal Consultant

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Appendices

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Appendix A: Sample Logs

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Sample Log

Number	Location	Lithology	Project	Hole ID	Site ID	Sample ID	Depth (m)	
							From	To
1	Bedded Hilltop	Detritals	HD1	RC18BHT0134	246209	HWL255	28	30
2	Bedded Hilltop	Detritals	HD1	RC18BHT0174	255149	IEZ059	8	10
3	Bedded Hilltop	Detritals	HD1	RC18BHT0272	242966	IEX071	64	66
4	Bedded Hilltop	Detritals	HD1	RC18BHT0273	242968	IEX144	24	26
5	Bedded Hilltop	Detritals	HD1	RC18BHT0368	241355	IDS997	26	28
6	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0164	242428	IDL399	98	100
7	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0165	242430	IDL538	84	86
8	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0169	243512	IDL765	84	86
9	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0211	244053	IER771	90	92
10	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0273	242968	IEX186	102	104
11	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0273	242968	IEX193	114	116
12	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0274	242970	ICW891	102	104
13	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0274	242970	ICW899	118	120
14	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0275	242972	ICV737	88	90
15	Bedded Hilltop	Detrital Lignite	HD1	RC18BHT0277	243508	ICV974	104	106
16	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0049	254302	HWK433	56	58
17	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0081	254568	HSS954	48	50
18	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0081	254568	HSS955	50	52
19	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0084	253758	IDQ084	78	80
20	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0184	244576	IER035	50	52
21	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0184	244576	IER036	52	54
22	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0187	244572	IER123	8	10
23	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0232	236481	IET896	28	30
24	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0241	240258	IEW193	26	28
25	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0241	240258	IEW194	28	30
26	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0312	218663	IEW862	4	6
27	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0313	219203	IEW882	10	12
28	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0336	224067	IEX556	8	10
29	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0336	224067	IEX557	10	12
30	Bedded Hilltop	Dales Gorge	HD1	RC18BHT0379	241335	IGV835	8	10
31	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0060	251064	HWK820	52	54
32	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0165	242430	IDL631	256	258
33	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0185	244578	IER083	80	82
34	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0188	245112	IER142	14	16
35	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0240	239716	IEW143	6	8
36	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0262	242420	IEZ446	40	42
37	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0274	242970	ICW973	252	254
38	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0334	224063	IEX525	16	18
39	Bedded Hilltop	Footwall Zone	HD1	RC18BHT0377	240523	IGV812	20	22
40	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0061	250525	HWK845	40	42
41	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0076	255911	HSS744	76	78
42	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0105	251592	IDP446	68	70
43	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0135	246204	HWL294	38	40
44	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0143	245934	HWL551	36	38
45	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0190	243490	IER194	26	28
46	Bedded Hilltop	Mount McRae Shale	HD1	RC18BHT0264	240805	IEZ598	32	34
47	Bedded Hilltop	Mount Sylvia Formation	HD1	RC18BHT0142	245662	HWL528	46	48
48	Bedded Hilltop	Mount Sylvia Formation	HD1	RC18BHT0282	247824	IDS102	26	28
49	Bedded Hilltop	Wittenoom Formation	HD1	RC18BHT0173	249737	IEZ052	46	48
50	Bedded Hilltop	Wittenoom Formation	HD1	RC18BHT0221	271343	IET246	64	66
51	Bedded Hilltop	Wittenoom Formation	HD1	RC18BHT0252	265956	IEZ176	36	38
52	Bedded Hilltop	Wittenoom Formation	HD1	RC18BHT0253	265948	IEZ199	34	36
53	Bedded Hilltop	Wittenoom Formation	HD1	RC18BHT0275	242972	ICV792	190	192
54	Hope Downs 2	Detritals	HD2	RC18HD20040	14029	ICX396	10	12
55	Hope Downs 2	Detritals	HD2	RC18HD20060	14344	ICI037	6	8
56	Hope Downs 2	Detritals	HD2	RC18HD20109	27288	ICY932	106	108
57	Hope Downs 2	Detritals	HD2	RC18HD20116	27290	IDR366	102	104
58	Hope Downs 2	Detritals	HD2	RC18HD20176	26652	HST198	116	118
59	Hope Downs 2	Detritals	HD2	RC18HD20241	34321	ICW055	46	48
60	Hope Downs 2	Detritals	HD2	RC18HD20264	34968	IEU297	22	24

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Number	Location	Lithology	Project	Hole ID	Site ID	Sample ID	Depth (m)	
							From	To
61	Hope Downs 2	Detritals	HD2	RC18HD20273	23776	ICW617	18	20
62	Hope Downs 2	Detritals	HD2	RC18HD20319	25373	IET519	146	148
63	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20019	13390	ICY501	38	40
64	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20036	14025	ICX217	14	16
65	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20099	26646	HST001	26	28
66	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20108	27287	ICY868	78	80
67	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20108	27287	ICY871	82	84
68	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20135	29535	ICL231	36	38
69	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20164	27928	IDR802	94	96
70	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20176	26652	HST214	146	148
71	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20177	26653	HST257	72	74
72	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20228	31764	ICV188	50	52
73	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20233	32087	ICV374	66	68
74	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20242	34322	ICW087	38	40
75	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20278	8900	IEU427	16	18
76	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20298	14189	IEV694	68	70
77	Hope Downs 2	Wittenoom Formation	HD2	RC18HD20319	25373	IET547	196	198
78	Hope Downs 2	Newman Member	HD2	RC18HD20059	14343	ICI031	46	48
79	Hope Downs 2	Newman Member	HD2	RC18HD20091	13709	ICP834	72	74
80	Hope Downs 2	Newman Member	HD2	RC18HD20104	26965	ICY761	32	34
81	Hope Downs 2	Newman Member	HD2	RC18HD20140	29843	ICL327	40	42
82	Hope Downs 2	Newman Member	HD2	RC18HD20144	29847	ICL518	96	98
83	Hope Downs 2	Newman Member	HD2	RC18HD20189	31122	ICL787	34	36
84	Hope Downs 2	Newman Member	HD2	RC18HD20200	31760	ICV072	4	6
85	Hope Downs 2	Newman Member	HD2	RC18HD20227	31763	ICV158	58	60
86	Hope Downs 2	Newman Member	HD2	RC18HD20277	8899	IEU414	56	58
87	Hope Downs 2	MacLeod Member	HD2	RC18HD20021	14657	ICY563	30	32
88	Hope Downs 2	MacLeod Member	HD2	RC18HD20053	14337	ICH905	34	36
89	Hope Downs 2	MacLeod Member	HD2	RC18HD20138	29841	ICL281	12	14
90	Hope Downs 2	MacLeod Member	HD2	RC18HD20188	31121	ICL766	36	38
91	Hope Downs 2	MacLeod Member	HD2	RC18HD20199	31759	ICV067	30	32
92	Hope Downs 2	MacLeod Member	HD2	RC18HD20203	33038	IDV159	6	8
93	Hope Downs 2	MacLeod Member	HD2	RC18HD20269	27921	ICW468	16	18
94	Hope Downs 2	Nammuldi member	HD2	RC18HD20073	19603	ICI423	12	14
95	Hope Downs 2	Nammuldi member	HD2	RC18HD20122	27924	IDR622	14	16
96	Hope Downs 2	Nammuldi member	HD2	RC18HD20263	33035	IEU280	60	62

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Appendix B: Laboratory Methods and Calculations

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The tests carried out as part of the geochemical characterisation programme and calculations used to assist in evaluating the acid base accounting parameters of the samples are shown in Table B-1 and B-2 respectively.

Table B-1: Parameters measured and description of method

Parameter	Description
Paste pH (1:2)	pH measurements are performed on a 1:2 solid/water extract.
Paste EC (1:2)	Electrical conductivity measurements are performed on a 1:2 solid/water extract.
Acid neutralising capacity (ANC)	Determined by adding hydrochloric acid (HCl) to the sample, heating it, and then back-titrating the mixture with sodium hydroxide (NaOH) in order to determine the amount of HCl that remains on completion of the reaction. The amount of acid consumed in the initial reaction is calculated and expressed as the ANC. Details of the procedure are outlined in the AMIRA International ARD Test Handbook (AMIRA, 2002).
Total carbon/sulfur	The sample is combusted in oxygen in a Leco furnace at 1350°C. Carbon/sulfur present in the sample is evolved as carbon dioxide/sulfur dioxide and swept to a measurement cell for quantification by infrared detection.
Total organic carbon	Inorganic carbon (carbonates, bicarbonates) is removed by reaction with dilute HCl. After drying, the remaining sample is combusted in oxygen in a Leco furnace at 1350°C. Any organic carbon in the sample present as organic matter or graphite is evolved as carbon dioxide and swept to a cell for quantification by infrared detection. See table B-2 for calculation of total inorganic carbon (TIC).
Acid extractable sulfur (SO_4-S)	Determined by adding HCl to the sample. Soluble sulfates dissolved in the HCl and are detected/quantified by ICP.
Chromium reducible sulfur (CRS)	Dried pulped sample is mixed with acid and chromium metal in a rapid distillation unit to produce hydrogen sulfide which is collected and titrated with iodine to measure CRS.
Single addition net acid generation (NAG) test	The NAG test involves addition of hydrogen peroxide (H_2O_2) to prepared samples (to oxidise any reactive sulfides). The NAG pH is the pH of the final solution. The resultant acidity is then titrated (using NaOH) to pH 4.5 and then to pH 7. Details of the procedure are outlined in the AMIRA International ARD Test Handbook (AMIRA, 2002).
Multi element chemical assay	Involves the near total dissolution of most elements using a variety of digestion techniques (e.g. aqua regia, four acid digest and lithium borate fusion). Analytical techniques are selected depending on the elements under investigation and include XRF, ICP-AES, ICP-MS, AAS, ISE and TGA.
Acid buffering characterisation curve	Involves a slow titration of the sample with HCl, whilst monitoring the pH. Details of the procedure are outlined in the AMIRA International ARD Test Handbook (AMIRA, 2002).
Leach test	Simple leach extraction involves dissolution of elements from the solid matrix using de-ionised water. The water and solids are mixed at a ratio of 2:1 (water:solids) and agitated for a period of 12 hours. Analytical techniques are selected depending on the elements under investigation and include ICP-AES and ICP-MS.
Mineralogical Assessment	Quantitative XRD carried out on a powdered sample containing an internal standard.

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Table B-2: Calculated data

Parameter	Description
Maximum potential acidity (MPA)	Calculated by multiplying the total sulfur content (wt%) by 30.6. Approach assumes that all sulfur is present as pyrite.
Sulfide-sulfur	Difference between Total sulfur and sulfate sulfur
Net acid producing potential (NAPP)	NAPP is the difference between the MPA of the sample and the ANC: NAPP = MPA – ANC
Total inorganic carbon	Total inorganic carbon content was calculated as the difference between the total carbon content and total organic carbon content of the sample.
Carbonate-based neutralisation potential (CarbNP)	Calculated by multiplying the total inorganic carbon content (wt%) by 81.63.

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Appendix C: Mineralogical Assessment

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Phase	Amorphous Content	Alunite	Anatase	Aragonite	Bassanite	Calcite	Chlorite	Dolomite	Gibbsite	Goethite	Gypsum	Hematite	Illite/ Muscovite	Jarosite	Kaolin	Lithiophorite
Sample ID	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
IEX071	30		1							16		25			20	
IDL339	71		1		1				1		<1	1	1		19	
IDL538	31	<1		1						1				4		
IEX186	67		<1		2				<1			1		1	14	
ICV737	10												14	2	25	
IEL199	41		<1					<1		12		15	1		29	
HST214	28							<1		24		7	1		8	
ICV072	22									62		12				
IET896	25									52		1			20	
IEW143	31									56		1			6	
IEZ052	11							82		2		1				
ICL231	33						3	49		7		<1			3	
ICY563	23					<1		4		59		4			9	
HWL551	19									18		17	5		4	
HST257	24									10		1	15		21	<1
ICI423	11							1		61		10			16	
IDL339 DUP	71		1		<1				1		<1	1	1		18	

Phase	Magnetite	Marcasite	Melanterite	Opaline Silica	Pickeringite	Pyrite	Quartz	Quartz (high)	Rhodocrosite	Rozenite	Rutile	Serpentine	Siderite	n Calcium Plag	Sphalerite	Total
Sample ID	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
IEX071	<1						8				1					101
IDL339	<1					3	<1				<1	1		2		101
IDL538	<1	11	1	1	7	38	1			4						100
IEX186		1				13	1									100
ICV737	<1					1	47				1		1			101
IEL199	<1						1				1		<1			100
HST214	1	1				4	1	1	25		<1					101
ICV072	<1					1	1		2							100
IET896		1				1	<1									100
IEW143	1	<1					5									100
IEZ052							4									100
ICL231							5									100
ICY563	<1						1									100
HWL551	<1						37				<1					100
HST257	ND						27				1				<1	99
ICI423	<1						1									100
IDL339 DUP	<1					4	<1				1	1		2		101

Mineral Phase	Approximate Formula
Alunite	KAl3(SO4)2(OH)6
Anatase	TiO2
Aragonite	CaCO3
Bassanite	CaSO4.0.5H2O
Calcite	CaCO3
Chlorite	(Fe,Al,Mg)6(Si,Al)4O10(OH)8
Dolomite	CaMg(CO3)2
Gibbsite	Al(OH)3
Goethite	FeO(OH)
Gypsum	CaSO4.2H2O
Hematite	Fe2O3
Illite/Muscovite	(K,Ca,Na)(Al,Mg,Fe)2(Si,Al)4O10(OH)2
Jarosite	KFe3(SO4)2(OH)6
Kaolin	Al2Si2O5(OH)4
Lithiophorite	(Al,Li)MnO2(OH)2

Mineral Phase	Approximate Formula
Magnetite	Fe3O4
Marcasite	FeS2
Melanterite	FeSO4(H2O)7
Opaline Silica	SiO2
Pickeringite	MgAl2(SO4)4.22(H2O)
Pyrite	FeS2
Quartz	SiO2
Quartz (high)	SiO2
Rhodocrosite	MnCO3
Rozenite	FeSO4.4(H2O)
Rutile	TiO2
Serpentine	Mg3Si2O5(OH)4
Siderite	FeCO3
Sodium Calcium	(Na,Ca)(Al,Si)2Si2O8
Sphalerite	(Zn,Fe)S

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Uncertainty in the analysis should reflect errors (absolute) of no greater than: +/- 10% for phases 50-95%, +/- 5% for phases 10-50% and +/- 2% for phases 3-10%. Phases of < 3% are approaching detection limit and normally no refinements are made on these.

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9251 8100
Facsimile: +61 8 9251 8110
intertek.com
ABN: 32 008 787 237

QUANTITATIVE X-RAY DIFFRACTION ANALYSIS

REPORT PREPARED FOR	SRK CONSULTING (AUSTRALASIA) PTY LTD ALEX WATSON
CLIENT CODE	735.02
JOB CODE	1902747
No. of SAMPLES	16
CLIENT O/N	RTS158
SAMPLE SUBMISSION No.	RTS158
PROJECT	N/A
STATE	PULP
DATE RECEIVED	7/03/2019
DATE COMPLETED	12/04/2019
DATE WRITTEN	12/04/2019
WRITTEN BY	Dr Cat Kealley Dr Sharon Ness
ANALYSING LABORATORY	Perth

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15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9251 8100
Facsimile: +61 8 9251 8110
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SAMPLE DETAILS

DISCLAIMER

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported results(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report is prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or laibility suffered by a third party as a result of any reliance upon or use of this report.

The results provided are not intended for commercial settlement purposes.

SIGNIFICANT FIGURES

The method detection limit is approximately 1 wt% for most phases.

Uncertainty in the analysis should reflect errors (absolute) of no greater than: +/- 10% for phases 50-95%, +/- 5% for phases 10-50% and +/- 2% for phases 3-10%. Phases of < 3% are approaching detection limit and normally no refinements are made on these.

Please note that results are rounded off to integer values

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LEGEND

ND	Not Detected
EMPTY CELL	Phase not included in refinement

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JOB INFORMATION

PREPARATION

XRD16 (dry 50C, mill < 60um, micronised)

ANALYTICAL METHOD

XRDQUANT01 - Quantitative analysis, crystalline and amorphous content

SAMPLING

Sample(s) coned and quartered, then grab(s) taken

AMORPHOUS CONTENT DETERMINATION

Internal standard single scan

ADDITIONS

Internal standard CaF2 (fluorite)
IEX071
IEL199
HST214
IET896
IEW143
IEZ052
ICL231
ICY563
HWL551
HST257

Internal standard TiO2 (rutile)
IDL538
IEX186
ICV072
ICI423

Internal standard ZnO (zincite)
IDL339
ICV737
IDL339 DUPLICATE

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SAMPLE PRESENTATION

Sample(s) packed and presented as unoriented powder mount(s) of the total sample

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JOB INFORMATION

INSTRUMENTATION AND PARAMETERS

INSTRUMENT:

PANalytical Cubix^3 XRD
Copper radiation (operating at 45 kV and 40 mA)
Graphite monochromator (diffracted beam)

PARAMETERS:

Parameter	Setting
Start angle (deg 2θ)	4
End angle (deg 2θ)	65
Step size (deg 2θ)	0.02
Time/active length (secs)	150
Active length (deg 2θ)	4.01

SOFTWARE:

Qualitative analysis:
Bruker Diffrac.EVA 4.2 Search/Match
ICDD PDF-2 (2015) database

Quantitative analysis:
SIROQUANT Version 4
ICSD (2018) database

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RESULTS

The quantitative analysis of the crystalline and amorphous content of each sample is given in the file, **735.02_1902747 XRD RESULTS.xlsx**, attached to the report email.

Calculation of the phase abundances has been based on the Brindley contrast corrections using a particle diameter of 4 µm.

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NOTES

NONE

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QUALITY CONTROL

NIST STANDARD REFERENCE MATERIAL (SRM) 656

This standard is used for quality control on the instrument and software.

The standard reference material is a powder which consists of sub-micrometer, equi-axial, non-aggregated grains that do not display the effects of absorption contrast, extinction or preferred orientation.

An aliquot of this SRM, spiked with 10% Al2O3 (SRM 676a) for the amorphous content determination, was prepared as un-oriented powder mount of the total sample and the pattern analysed with SIROQUANT™.

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Sample ID **α 656 (High α Phase Powder)**

		1902747	method std dev	SRM certified	SRM uncert
Phase	**Formula**	**wt%**	**wt%**	**wt%**	**wt%**
Amorphous content		9.4	0.5	9.5	0.61
Si3N4, alpha	Si3N4	87.5	0.5	87.5	0.59
Si3N4, beta	Si3N4	3.1	0.1	3.0	0.05

Each interval defined by the certified value and its uncertainty is a 95% confidence interval for the true value of the mean in the absence of systematic error.

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METHOD DESCRIPTION

Quantification is determined from the chosen software package: this uses the full-profile Rietveld method of refining the profile of the calculated XRD pattern against the profile of the measured XRD pattern. The total calculated pattern is the sum of the calculated patterns of the individual phases.

Results are given as weight % of the total crystalline phases and amorphous content.

The amorphous content quantifies the amorphous material and unknown minerals or known minerals for which there is not a suitable crystal structure.

Corrections are incorporated into the process that allows for a more accurate description of the mineral's contribution to the measured pattern and to allow for variation due to atomic substitution, layer disordering, preferred orientation, and other factors that affect the acquisition of the XRD scan.

The limitations of qualitative XRD analysis are as follows:

There is a limit of detection of approximately 1 wt% on the crystalline phases.
The detection of a phase may be dependent on its crystallinity.
Where there exist multiple phases, overlap of diffracted reflections can occur, thus rendering some ambiguity into the interpretation.
Overlapping reflections of a major phase can mask the presence of minor or trace phases.

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Some phases cannot be unambiguously identified as they are present in minor or trace amounts.

The limitations of quantitative XRD analysis by a full-profile Rietveld method are as follows:

The limitations for qualitative XRD analysis apply.
The method as described is standardless: it relies solely on the published crystallographic data available for each phase. Some data may not exactly describe the phases present.

Particle size is important with respect to the absorption of the X-rays by the sample. Micronising reduces the particle size to that more suitable for quantitative analysis.

The accuracy of the analysis is dependent on sampling and sample preparation in addition to the calculated profiles being exactly representative of the chemistry of the component phases and their crystallinity. Some preferred orientation effects and reflection overlaps may occur which cannot be adequately resolved.

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AMORPHOUS CONTENT

INTERNAL STANDARD METHOD

Single scan (SIROQUANT™ and TOPAS)

The amorphous content is determined from the addition of a known spike of a well-crystalline internal standard to each sample.

When amorphous material is present, the weight percentage of the spike found is larger than actually weighed out. The amount of amorphous material that causes the difference in the spike weight percentages is then calculated and all weight percentages are normalised to include the amorphous content.

Double scan (SIROQUANT only)

SIROQUANT™ also allows the choice of using the spiked pattern completely, or combining the run with a previous unspiked pattern result. This choice is given because the weight percentages from an unspiked pattern are more accurate since the intensities are not diluted by the spike addition. The percentages from the unspiked sample are normalised to the amorphous content calculated from the spiked sample pattern.

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EXTERNAL STANDARD METHOD (SIROQUANT™ and TOPAS)

The amorphous content is determined from the external standard method[1].

The normalisation constant is determined from the external standard which allows the calculated weight fractions to be placed on an absolute scale.

Reference:

1. O'Connor, B.H., and Raven, M.D., "Application of the Rietveld refinement procedure in assaying powdered mixtures", Powder Diffraction 3(1), (1988), 2-6.

Modelling

A pattern representing a poorly crystalline form of silica is used in the SIROQUANT program.[2]

Reference:

2. Ward, C.R. and French, D., "Determination of glass content and estimation of glass composition in fly ash using quantitative X-ray diffractometry." Fuel 85 (2006), 2268-2277.

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Appendix D: ABA and NAG Test Data

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ABA and NAG Data

Sample ID	Location	Lithology	Paste pH	Paste EC	NAGpH	NAG pH 4.5	NAG pH 7	ANC	Total C	TIC	TOC	Total S	MPA	NAPP	Class
			pH Units	µS/cm	pH Units	kgH_2SO_4/t			%	%	%	%	kgH_2SO_4/t		AMIRA
HWL255	Bedded Hilltop	Detritals	5.7	168	6.2	<0.1	0.4	<0.5	0.14	0.05	0.09	0.03	0.9	0.4	UC(NAF)
IEZ059	Bedded Hilltop	Detritals	8.5	441	9.2	<0.1	<0.1	13	0.26	0.17	0.09	0.03	0.9	-12	NAF
IEX071	Bedded Hilltop	Detritals	7.7	133	7	<0.1	<0.1	33	0.3	0.04	0.26	0.03	0.9	-32	NAF
IEX144	Bedded Hilltop	Detritals	8.5	321	8.4	<0.1	<0.1	2.6	0.5	0.4	0.1	0.02	0.6	-2.0	NAF-Barren
IDS997	Bedded Hilltop	Detritals	7.6	69	7	<0.1	<0.1	15	0.09	0.02	0.07	0.02	0.6	-14	NAF
IDL399	Bedded Hilltop	Detrital Lignite	4.5	1930	2.5	67	138	6.2	32.2	2.5	29.7	2.2	67	61	PAF
IDL538	Bedded Hilltop	Detrital Lignite	1.9	21100	1.8	626	699	5.9	10.1	2.12	7.98	33	1019	1013	PAF
IDL765	Bedded Hilltop	Detrital Lignite	3.9	4670	2	200	285	6.9	38.5	4.9	33.6	9.6	294	287	PAF
IER771	Bedded Hilltop	Detrital Lignite	5.6	2590	2.2	148	212	<0.5	41	4.3	36.7	6.6	201	201	PAF
IEX186	Bedded Hilltop	Detrital Lignite	4.6	3040	2.1	165	250	<0.5	42.5	5.1	37.4	7.0	215	215	PAF
IEX193	Bedded Hilltop	Detrital Lignite	3.9	3290	2.5	64	128	<0.5	25.2	4	21.2	4.2	127	127	PAF
ICW891	Bedded Hilltop	Detrital Lignite	3.6	2070	2.2	152	230	<0.5	48.9	7.3	41.6	6.7	205	204	PAF
ICW899	Bedded Hilltop	Detrital Lignite	3.1	4560	2.1	185	264	<0.5	39.6	9	30.6	8.7	267	267	PAF
ICV737	Bedded Hilltop	Detrital Lignite	2.4	5780	2.6	19	42.3	<0.5	0.51	0.1	0.41	1.3	39	38	PAF
ICV974	Bedded Hilltop	Detrital Lignite	3.8	4570	2.3	85	139	<0.5	43.1	4.7	38.4	3.0	93	93	PAF
HWK433	Bedded Hilltop	Dales Gorge	5.6	107	4.9	<0.1	2.4	<0.5	0.11	-	-	0.03	0.9	0.4	UC(NAF)
HSS954	Bedded Hilltop	Dales Gorge	5.2	62	3.9	0.8	2.4	<0.5	0.22	-	-	0.05	1.5	1.0	PAF-LC
HSS955	Bedded Hilltop	Dales Gorge	4.9	61	5.3	<0.1	0.5	<0.5	0.1	-	-	0.02	0.6	0.1	UC(NAF)
IDQ084	Bedded Hilltop	Dales Gorge	5.6	49	5.2	<0.1	0.7	<0.5	0.07	-	-	0.02	0.6	0.1	UC(NAF)
IER035	Bedded Hilltop	Dales Gorge	6.4	79	6.5	<0.1	0.3	<0.5	0.09	-	-	0.02	0.6	0.1	UC(NAF)
IER036	Bedded Hilltop	Dales Gorge	6	56	6.2	<0.1	0.3	<0.5	0.06	-	-	0.02	0.6	0.1	UC(NAF)
IER123	Bedded Hilltop	Dales Gorge	8.8	161	7	<0.1	<0.1	0.9	0.11	-	-	0.02	0.6	-0.3	NAF-Barren
IET896	Bedded Hilltop	Dales Gorge	4.6	461	5.3	<0.1	1	<0.5	0.25	-	-	0.07	2.1	1.6	UC(NAF)
IEW193	Bedded Hilltop	Dales Gorge	6.6	271	6.5	<0.1	0.6	<0.5	0.05	-	-	0.02	0.6	0.1	UC(NAF)
IEW194	Bedded Hilltop	Dales Gorge	6.8	148	6.3	<0.1	0.6	<0.5	0.05	-	-	<0.01	0.3	-0.2	NAF-Barren
IEW862	Bedded Hilltop	Dales Gorge	6.5	40	5.8	<0.1	0.8	<0.5	0.05	-	-	0.02	0.6	0.1	UC(NAF)
IEW882	Bedded Hilltop	Dales Gorge	7.6	86	6.4	<0.1	1	<0.5	0.06	-	-	0.02	0.6	0.1	UC(NAF)
IEX556	Bedded Hilltop	Dales Gorge	6.8	56	6.2	<0.1	0.7	<0.5	0.06	-	-	0.02	0.6	0.1	UC(NAF)
IEX557	Bedded Hilltop	Dales Gorge	6.1	72	6.2	<0.1	0.4	<0.5	0.06	-	-	0.02	0.6	0.1	UC(NAF)
IGV835	Bedded Hilltop	Dales Gorge	6.6	63	5	<0.1	1.2	<0.5	0.16	-	-	0.04	1.2	0.7	UC(NAF)
HWK820	Bedded Hilltop	Footwall Zone	4.5	149	5.6	<0.1	4.7	<0.5	0.05	-	-	0.02	0.6	0.1	UC(NAF)
IDL631	Bedded Hilltop	Footwall Zone	6.3	117	6.8	<0.1	0.3	<0.5	0.03	-	-	<0.01	0.3	-0.2	NAF-Barren
IER083	Bedded Hilltop	Footwall Zone	6.8	96	6.7	<0.1	<0.1	<0.5	0.06	-	-	<0.01	0.3	-0.2	NAF-Barren
IER142	Bedded Hilltop	Footwall Zone	3.9	254	5.3	<0.1	1.9	<0.5	0.06	-	-	0.02	0.6	0.1	UC(NAF)
IEW143	Bedded Hilltop	Footwall Zone	4	1540	4.1	0.8	3.8	<0.5	0.08	-	-	0.15	4.6	4.1	PAF-LC
IEZ446	Bedded Hilltop	Footwall Zone	4.7	521	4.6	<0.1	1.8	<0.5	0.15	-	-	0.07	2.1	1.6	UC(NAF)
ICW973	Bedded Hilltop	Footwall Zone	6.8	140	6.8	<0.1	<0.1	0.5	0.06	-	-	<0.01	0.3	-0.2	NAF-Barren
IEX525	Bedded Hilltop	Footwall Zone	6	43	6.2	<0.1	0.3	<0.5	0.15	-	-	0.03	0.9	0.4	UC(NAF)
IGV812	Bedded Hilltop	Footwall Zone	6.1	45	6.2	<0.1	0.4	<0.5	0.12	-	-	0.03	0.9	0.4	UC(NAF)
HWK845	Bedded Hilltop	Mount McRae Shale	5.3	257	6.1	<0.1	0.5	<0.5	0.04	-	-	0.02	0.6	0.1	UC(NAF)
HSS744	Bedded Hilltop	Mount McRae Shale	6.7	115	5.9	<0.1	1.6	0.7	0.06	-	-	0.02	0.6	-0.1	NAF-Barren
IDP446	Bedded Hilltop	Mount McRae Shale	4.5	190	5.6	<0.1	2	<0.5	0.13	-	-	0.04	1.2	0.7	UC(NAF)
HWL294	Bedded Hilltop	Mount McRae Shale	7	150	7.2	<0.1	<0.1	0.8	0.08	-	-	0.02	0.6	-0.2	NAF-Barren
HWL551	Bedded Hilltop	Mount McRae Shale	7.1	214	7.1	<0.1	<0.1	0.9	0.11	-	-	0.03	0.9	0.0	UC(NAF)
IER194	Bedded Hilltop	Mount McRae Shale	6.3	370	5.6	<0.1	1.8	<0.5	0.08	-	-	0.02	0.6	0.1	UC(NAF)
IEZ598	Bedded Hilltop	Mount McRae Shale	7.1	575	6.9	<0.1	0.2	1	0.08	-	-	0.03	0.9	-0.1	NAF-Barren
HWL528	Bedded Hilltop	Mount Sylvia Formation	6.2	96	7	<0.1	<0.1	0.8	0.14	-	-	<0.01	0.3	-0.5	NAF-Barren
IDS102	Bedded Hilltop	Mount Sylvia Formation	6.6	169	6.4	<0.1	0.4	<0.5	0.07	-	-	0.02	0.6	0.1	UC(NAF)
IEZ052	Bedded Hilltop	Wittenoom Formation	9.4	120	10	<0.1	<0.1	968	10.8	10.7	0.1	<0.01	0.3	-968	NAF
IET246	Bedded Hilltop	Wittenoom Formation	9.8	325	10.2	<0.1	<0.1	774	8.94	8.6	0.34	<0.01	0.3	-774	NAF
IEZ176	Bedded Hilltop	Wittenoom Formation	8.9	259	10.2	<0.1	<0.1	697	8.02	7.93	0.09	<0.01	0.3	-697	NAF
IEZ199	Bedded Hilltop	Wittenoom Formation	7.9	445	8.7	<0.1	<0.1	22.2	0.46	0.29	0.17	<0.01	0.3	-22	NAF
ICV792	Bedded Hilltop	Wittenoom Formation	6	358	8.6	<0.1	<0.1	23.8	1.13	1.06	0.07	0.14	4.3	-20	NAF
ICX396	Hope Downs 2	Detritals	7.5	119	6.7	<0.1	<0.1	2	0.13	-	-	0.02	0.6	-1.4	NAF-Barren
ICI037	Hope Downs 2	Detritals	8.6	100	7.5	<0.1	<0.1	1.7	0.08	-	-	0.03	0.9	-0.8	NAF-Barren
ICY932	Hope Downs 2	Detritals	7.4	187	7.5	<0.1	<0.1	3.2	0.25	0.14	0.11	0.02	0.6	-2.6	NAF-Barren
IDR366	Hope Downs 2	Detritals	7.5	194	6.8	<0.1	<0.1	2	0.11	0.05	0.06	<0.01	0.3	-1.7	NAF-Barren
HST198	Hope Downs 2	Detritals	7.5	271	7.4	<0.1	<0.1	3.1	0.06	-	-	<0.01	0.3	-2.8	NAF-Barren
ICW055	Hope Downs 2	Detritals	7.7	272	7.4	<0.1	<0.1	1.9	0.05	-	-	<0.01	0.3	-1.6	NAF-Barren
IEU297	Hope Downs 2	Detritals	8	735	8.1	<0.1	<0.1	5.8	0.04	-	-	<0.01	0.3	-5.5	NAF
ICW617	Hope Downs 2	Detritals	7.3	410	6.8	<0.1	0.4	2.7	0.05	-	-	<0.01	0.3	-2.4	NAF-Barren
IET519	Hope Downs 2	Detritals	7.5	138	7.2	<0.1	<0.1	<0.5	0.1	-	-	<0.01	0.3	-0.2	NAF-Barren
ICY501	Hope Downs 2	Wittenoom Formation	7.6	129	7.5	<0.1	<0.1	<0.5	0.04	-	-	<0.01	0.3	-0.2	NAF-Barren
ICX217	Hope Downs 2	Wittenoom Formation	3.8	283	5.6	<0.1	1.5	<0.5	0.13	-	-	<0.01	0.3	-0.2	NAF-Barren
HST001	Hope Downs 2	Wittenoom Formation	7.3	513	6.8	<0.1	0.4	1.8	0.1	-	-	<0.01	0.3	-1.5	NAF-Barren
ICY868	Hope Downs 2	Wittenoom Formation	7.4	166	7.7	<0.1	<0.1	2.2	0.08	-	-	<0.01	0.3	-1.9	NAF-Barren
ICY871	Hope Downs 2	Wittenoom Formation	7.6	145	8.1	<0.1	<0.1	7	0.09	-	-	<0.01	0.3	-6.7	NAF
ICL231	Hope Downs 2	Wittenoom Formation	8.3	1150	8.5	<0.1	<0.1	661	7.36	7.31	0.05	<0.01	0.3	-661	NAF
IDR802	Hope Downs 2	Wittenoom Formation	7.7	558	8	<0.1	<0.1	6.2	0.1	-	-	<0.01	0.3	-5.9	NAF
HST214	Hope Downs 2	Wittenoom Formation	7.4	241	8.5	<0.1	<0.1	252	4.33	4.28	0.05	<0.01	0.3	-252	NAF
HST257	Hope Downs 2	Wittenoom Formation	7.7	305	8.3	<0.1	<0.1	2.6	0.02	-	-	<0.01	0.3	-2.3	NAF-Barren
ICV188	Hope Downs 2	Wittenoom Formation	7.7	40	8.5	<0.1	<0.1	5.8	0.1	-	-	<0.01	0.3	-5.5	NAF
ICV374	Hope Downs 2	Wittenoom Formation	7.7	55	8.1	<0.1	<0.1	2.3	0.07	-	-	<0.01	0.3	-2.0	NAF-Barren
ICW087	Hope Downs 2	Wittenoom Formation	8.3	1310	8	<0.1	<0.1	6.1	0.07	-	-	<0.01	0.3	-5.8	NAF
IEU427	Hope Downs 2	Wittenoom Formation	7.5	772	7.6	<0.1	<0.1	<0.5	0.05	-	-	<0.01	0.3	-0.2	NAF-Barren
IEV694	Hope Downs 2	Wittenoom Formation	7.6	102	8.1	<0.1	<0.1	<0.5	0.08	-	-	<0.01	0.3	-0.2	NAF-Barren

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Sample ID	Location	Lithology	Paste pH	Paste EC	NAGpH	NAG pH 4.5	NAG pH 7	ANC	Total C	TIC	TOC	Total S	MPA	NAPP	Class
			pH Units	µS/cm	pH Units	kgH_2SO_4/t			%	%	%	%	kgH_2SO_4/t		AMIRA
IET547	Hope Downs 2	Wittenoom Formation	7.2	516	8.1	<0.1	<0.1	7.8	0.12	-	-	<0.01	0.3	-7.5	NAF
ICI031	Hope Downs 2	Newman Member	6.8	78	7	<0.1	<0.1	<0.5	0.1	-	-	<0.01	0.3	-0.2	NAF-Barren
ICP834	Hope Downs 2	Newman Member	7.1	74	7.6	<0.1	<0.1	<0.5	0.1	-	-	<0.01	0.3	-0.2	NAF-Barren
ICY761	Hope Downs 2	Newman Member	7.3	114	6.8	<0.1	<0.1	<0.5	0.03	-	-	<0.01	0.3	-0.2	NAF-Barren
ICL327	Hope Downs 2	Newman Member	8.4	108	7.4	<0.1	<0.1	<0.5	0.06	-	-	<0.01	0.3	-0.2	NAF-Barren
ICL518	Hope Downs 2	Newman Member	7.8	276	7.2	<0.1	<0.1	<0.5	0.03	-	-	<0.01	0.3	-0.2	NAF-Barren
ICL787	Hope Downs 2	Newman Member	7.5	76	6.6	<0.1	0.7	<0.5	0.04	-	-	<0.01	0.3	-0.2	NAF-Barren
ICV072	Hope Downs 2	Newman Member	8.9	125	8.5	<0.1	<0.1	9	0.22	0.11	0.11	<0.01	0.3	-9	NAF
ICV158	Hope Downs 2	Newman Member	7.6	19	6.6	<0.1	0.6	<0.5	0.04	-	-	<0.01	0.3	-0.2	NAF-Barren
IEU414	Hope Downs 2	Newman Member	5.4	76	7.2	<0.1	<0.1	<0.5	0.05	-	-	<0.01	0.3	-0.2	NAF-Barren
ICY563	Hope Downs 2	MacLeod Member	4.4	911	4.6	<0.1	2.1	<0.5	0.05	-	-	0.1	3.1	2.6	UC(NAF)
ICH905	Hope Downs 2	MacLeod Member	4	258	5.8	<0.1	0.8	<0.5	0.08	-	-	0.04	1.2	0.7	UC(NAF)
ICL281	Hope Downs 2	MacLeod Member	7	174	6.5	<0.1	0.5	<0.5	0.06	-	-	<0.01	0.3	-0.2	NAF-Barren
ICL766	Hope Downs 2	MacLeod Member	7.5	80	7.4	<0.1	<0.1	<0.5	0.02	-	-	<0.01	0.3	-0.2	NAF-Barren
ICV067	Hope Downs 2	MacLeod Member	7.4	26	6.6	<0.1	0.6	<0.5	0.03	-	-	<0.01	0.3	-0.2	NAF-Barren
IDV159	Hope Downs 2	MacLeod Member	8.4	46	7.2	<0.1	<0.1	0.5	0.13	-	-	0.04	1.2	0.7	UC(NAF)
ICW468	Hope Downs 2	MacLeod Member	7.2	102	7.2	<0.1	<0.1	<0.5	0.07	-	-	<0.01	0.3	-0.2	NAF-Barren
ICI423	Hope Downs 2	Nammuldi member	6.7	239	6.4	<0.1	0.6	<0.5	0.04	-	-	0.03	0.9	0.4	UC(NAF)
IDR622	Hope Downs 2	Nammuldi member	6	117	6	<0.1	2	<0.5	0.08	-	-	<0.01	0.3	-0.2	NAF-Barren
IEU280	Hope Downs 2	Nammuldi member	7.6	30	6.6	<0.1	0.5	<0.5	0.03	-	-	<0.01	0.3	-0.2	NAF-Barren

Notes: EC – Electrical Conductivity; NAG – Net Acid Generation; ANC – Acid Neutralising Capacity; S – Sulfur; MPA – Maximum Potential Acidity; NAPP – Net Acid Producing Potential; NAF – Non Acid Forming; UC – Uncertain; PAF – Potentially Acid Forming; LC – Low Capacity.

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Appendix E: Acid Buffering Characteristic Curve Data

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IEX071 **DET**

ANC 32.9 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	6.39
1	0.5	1.225	4.78
2	1	2.45	4.04
3	1.5	3.675	3.74
4	2	4.9	3.52
5	2.5	6.125	3.35
6	3	7.35	3.21
7	3.5	8.575	3.10
8	4	9.8	3.00
9	4.5	11.025	2.90
10	5	12.25	2.82
11	5.5	13.475	2.75
12	6	14.7	2.69
13	6.5	15.925	2.63
14	7	17.15	2.58
15	7.5	18.375	2.53
16	8	19.6	2.49

ICV072 **NEW**

ANC 9 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	9.29
1	0.1	0.245	8.97
2	0.2	0.49	8.72
3	0.3	0.735	8.51
4	0.4	0.98	8.34
5	0.5	1.225	8.20
6	0.6	1.47	8.06
7	0.7	1.715	7.94
8	0.8	1.96	7.85
9	0.9	2.205	7.78
10	1	2.45	7.72
11	1.1	2.695	7.67
12	1.2	2.94	7.61
13	1.3	3.185	7.55
14	1.4	3.43	7.51
15	1.5	3.675	7.47
16	1.6	3.92	7.43
17	1.7	4.165	7.39
18	1.8	4.41	7.34
19	1.9	4.655	7.30
20	2	4.9	7.27
21	2.1	5.145	7.23
22	2.2	5.39	7.18
23	2.3	5.635	7.11
24	2.4	5.88	7.10
25	2.5	6.125	7.03
26	2.6	6.37	6.97
27	2.7	6.615	6.92
28	2.8	6.86	6.80
29	2.9	7.105	6.68
30	3	7.35	6.53
31	3.1	7.595	6.32
32	3.2	7.84	6.01
33	3.3	8.085	5.63
34	3.4	8.33	5.26
35	3.5	8.575	4.94
36	3.6	8.82	4.68
37	3.7	9.065	4.46
38	3.8	9.31	4.28
39	3.9	9.555	4.14

ICV072 - Continued

ANC 9 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
40	4	9.8	4.02
41	4.1	10.045	3.92
42	4.2	10.29	3.83
43	4.3	10.535	3.75
44	4.4	10.78	3.68
45	4.5	11.025	3.62
46	4.6	11.27	3.56
47	4.7	11.515	3.50
48	4.8	11.76	3.45
49	4.9	12.005	3.40
50	5	12.25	3.36
51	5.1	12.495	3.32
52	5.2	12.74	3.28
53	5.3	12.985	3.24
54	5.4	13.23	3.20
55	5.5	13.475	3.17
56	5.6	13.72	3.14
57	5.7	13.965	3.11
58	5.8	14.21	3.09
59	5.9	14.455	3.06
60	6	14.7	3.03
61	6.1	14.945	3.01
62	6.2	15.19	2.99
63	6.3	15.435	2.96
64	6.4	15.68	2.95
65	6.5	15.925	2.93
66	6.6	16.17	2.91
67	6.7	16.415	2.89
68	6.8	16.66	2.87
69	6.9	16.905	2.85
70	7	17.15	2.84
71	7.1	17.395	2.82

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IEZ199 **WF**
ANC 22.2 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	7.69
1	0.5	1.225	6.61
2	1	2.45	6.16
3	1.5	3.675	5.86
4	2	4.9	5.62
5	2.5	6.125	5.49
6	3	7.35	5.38
7	3.5	8.575	5.26
8	4	9.8	5.14
9	4.5	11.025	5.02
10	5	12.25	4.89
11	5.5	13.475	4.82
12	6	14.7	4.74
13	6.5	15.925	4.66
14	7	17.15	4.58
15	7.5	18.375	4.50
16	8	19.6	4.41
17	8.5	20.825	4.33
18	9	22.05	4.23
19	9.5	23.275	4.12
20	10	24.5	4.00
21	10.5	25.725	3.85
22	11	26.95	3.71
23	11.5	28.175	3.57
24	12	29.4	3.44
25	12.5	30.625	3.32
26	13	31.85	3.22
27	13.5	33.075	3.12
28	14	34.3	3.03
29	14.5	35.525	2.96
30	15	36.75	2.89
31	15.5	37.975	2.82
32	16	39.2	2.77
33	16.5	40.425	2.72
34	17	41.65	2.67
35	17.5	42.875	2.63
36	18	44.1	2.59
37	18.5	45.325	2.55
38	19	46.55	2.52
39	19.5	47.775	2.49

HST214 **WF**
ANC 252 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	6.05
1	1	12.25	5.37
2	2	24.5	5.13
3	3	36.75	5.06
4	4	49	5.04
5	5	61.25	4.99
6	6	73.5	4.95
7	7	85.75	4.92
8	8	98	4.89
9	9	110.25	4.83
10	10	122.5	4.80
11	11	134.75	4.75
12	12	147	4.69
13	13	159.25	4.62
14	14	171.5	4.53
15	15	183.75	4.42
16	16	196	4.27
17	17	208.25	4.02
18	18	220.5	3.66
19	19	232.75	3.29
20	20	245	2.99
21	21	257.25	2.74
22	22	269.5	2.53
23	23	281.75	2.35

ICV792 **WF**
ANC 23.8 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	8.42
1	0.5	1.225	7.53
2	1	2.45	7.20
3	1.5	3.675	6.96
4	2	4.9	6.89
5	2.5	6.125	6.69
6	3	7.35	6.56
7	3.5	8.575	6.42
8	4	9.8	6.27
9	4.5	11.025	6.14
10	5	12.25	5.96
11	5.5	13.475	5.81
12	6	14.7	5.59
13	6.5	15.925	5.35
14	7	17.15	4.95
15	7.5	18.375	4.63
16	8	19.6	4.39
17	8.5	20.825	4.19
18	9	22.05	4.00
19	9.5	23.275	3.83
20	10	24.5	3.72
21	10.5	25.725	3.62
22	11	26.95	3.54
23	11.5	28.175	3.46
24	12	29.4	3.38
25	12.5	30.625	3.31
26	13	31.85	3.24
27	13.5	33.075	3.17
28	14	34.3	3.11
29	14.5	35.525	3.05
30	15	36.75	2.99
31	15.5	37.975	2.93
32	16	39.2	2.88
33	16.5	40.425	2.83
34	17	41.65	2.78
35	17.5	42.875	2.74
36	18	44.1	2.69
37	18.5	45.325	2.65
38	19	46.55	2.62
39	19.5	47.775	2.59
40	20	49	2.56
41	20.5	50.225	2.53
42	21	51.45	2.50

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ICL231 **WF**
ANC 661 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	9.34
1	2	24.5	7.77
2	4	49	6.80
3	6	73.5	6.46
4	8	98	6.32
5	10	122.5	6.24
6	12	147	6.15
7	14	171.5	6.08
8	16	196	6.00
9	18	220.5	5.93
10	20	245	5.88
11	22	269.5	5.77
12	24	294	5.72
13	26	318.5	5.67
14	28	343	5.61
15	30	367.5	5.55
16	32	392	5.48
17	34	416.5	5.42
18	36	441	5.37
19	38	465.5	5.32
20	40	490	5.25
21	42	514.5	5.18
22	44	539	5.16
23	46	563.5	5.08
24	48	588	4.98
25	50	612.5	4.84
26	52	637	4.46
27	54	661.5	2.89
28	56	686	2.32

IET246 **WF**
ANC 774 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	9.61
1	2	24.5	7.23
2	4	49	6.93
3	6	73.5	6.80
4	8	98	6.71
5	10	122.5	6.65
6	12	147	6.60
7	14	171.5	6.55
8	16	196	6.50
9	18	220.5	6.45
10	20	245	6.40
11	22	269.5	6.35
12	24	294	6.32
13	26	318.5	6.30
14	28	343	6.29
15	30	367.5	6.28
16	32	392	6.27
17	34	416.5	6.25
18	36	441	6.22
19	38	465.5	6.17
20	40	490	6.11
21	42	514.5	6.09
22	44	539	6.07
23	46	563.5	6.01
24	48	588	5.92
25	50	612.5	5.84
26	52	637	5.76
27	54	661.5	5.63
28	56	686	5.54
29	58	710.5	5.43
30	60	735	5.18
31	62	759.5	3.94
32	64	784	2.50

IEZ176 **WF**
ANC 697 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	8.50
1	2	24.5	7.74
2	4	49	6.99
3	6	73.5	6.40
4	8	98	6.10
5	10	122.5	5.96
6	12	147	5.90
7	14	171.5	5.85
8	16	196	5.81
9	18	220.5	5.77
10	20	245	5.74
11	22	269.5	5.71
12	24	294	5.68
13	26	318.5	5.65
14	28	343	5.62
15	30	367.5	5.58
16	32	392	5.56
17	34	416.5	5.54
18	36	441	5.53
19	38	465.5	5.52
20	40	490	5.51
21	42	514.5	5.50
22	44	539	5.48
23	46	563.5	5.44
24	48	588	5.41
25	50	612.5	5.34
26	52	637	5.25
27	54	661.5	5.06
28	56	686	3.40
29	58	710.5	2.29

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IEZ052 **WF**

ANC 968 kgH_2SO_4/t

Addition	mLs added (total)	kgH_2SO_4/t	pH
0	0	0	10.01
1	2	24.5	6.61
2	4	49	6.15
3	6	73.5	6.04
4	8	98	5.97
5	10	122.5	5.93
6	12	147	5.89
7	14	171.5	5.85
8	16	196	5.81
9	18	220.5	5.77
10	20	245	5.74
11	22	269.5	5.70
12	24	294	5.68
13	26	318.5	5.66
14	28	343	5.63
15	30	367.5	5.60
16	32	392	5.57
17	34	416.5	5.55
18	36	441	5.52
19	38	465.5	5.50
20	40	490	5.48
21	42	514.5	5.44
22	44	539	5.45
23	46	563.5	5.42
24	48	588	5.39
25	50	612.5	5.38
26	52	637	5.36
27	54	661.5	5.34
28	56	686	5.32
29	58	710.5	5.30
30	60	735	5.28
31	62	759.5	5.25
32	64	784	5.25
33	66	808.5	5.22
34	68	833	5.19
35	70	857.5	5.16
36	72	882	5.13
37	74	906.5	5.09
38	76	931	5.04
39	78	955.5	4.94
40	80	980	4.75
41	82	1004.5	3.51
42	84	1029	2.61

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Appendix F: Multi-element Chemical Assay and GAI Data

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Global Abundance Indicators

The global abundance index (GAI) values provide a direct comparison of the measured abundances of the elements with the average abundance of elements in the Earth's crust (Bowen, 1979). The GAI indicates which elements are 'enriched' in the sample with respect to the global average and is calculated using the following formula (Förstner, 1993):

$$\text{GAI} = Int\left(\log_2\left(\frac{\text{MeasuredConcentration}}{1.5\times\text{AverageAbundance}}\right)\right)$$

Zero or positive GAI values indicate enrichment of the element in the sample when compared to average-crustal abundances. As a general rule, a GAI of 3 or higher signifies enrichment that warrants further evaluation.

The table below relates GAI values to *n* (the ratio of the measured abundance in the sample to the reference material abundance).

GAI	***n* range**
0	$1 < n < 3$
1	$3 \leq n < 6$
2	$6 \leq n < 12$
3	$12 \leq n < 24$

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Multi-Element Chemical Assay Data

Sample ID	Location	Lithology	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Fe
			ppm	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%
HWL255	Bedded Hilltop	Detritals	0.109	2.74	152.5	10	19	1.03	0.782	0.02	0.045	13.65	5.43	101	3.1	16.9	27.4
IEZ059	Bedded Hilltop	Detritals	0.063	7.66	32.8	30	151	1.15	0.459	0.52	0.09	33.9	11.5	158.5	3.71	38	18.7
IEX071	Bedded Hilltop	Detritals	0.087	8.63	204	70	28	1.48	0.425	0.05	1.29	31.1	11.7	47.4	0.78	31.3	27.4
IEX144	Bedded Hilltop	Detritals	0.02	4.51	28.2	60	120	1.03	0.223	0.77	0.041	58.7	5.97	89.8	1.09	7.85	44.7
IDS997	Bedded Hilltop	Detritals	0.051	5.46	237	30	68	2.07	0.673	0.07	0.256	22.5	20	109.5	4.1	15.7	42.8
ICX396	Hope Downs 2	Detritals	0.206	4.98	41.1	30	162	0.83	0.573	0.09	0.115	42.1	9.08	206	1.24	46.1	41.4
ICI037	Hope Downs 2	Detritals	0.016	5.73	37.2	30	161	0.43	0.532	0.1	0.043	8.05	7.33	120.5	0.26	17.4	31.7
ICY932	Hope Downs 2	Detritals	0.042	9.27	88.6	30	8	2.04	0.75	0.05	0.108	19.35	14.45	195	0.11	115	30
IDR366	Hope Downs 2	Detritals	0.077	6.64	57.1	20	16	0.92	0.482	0.03	0.239	67.9	34	244	0.06	75.8	40.7
HST198	Hope Downs 2	Detritals	0.047	7.86	89.3	50	10	1.42	0.72	0.06	0.135	61.1	13.6	210	0.28	98.2	32.9
ICW055	Hope Downs 2	Detritals	0.007	3.74	15.75	20	33	2.97	0.169	0.04	0.968	14.35	75.1	61.9	0.07	46.2	46
IEU297	Hope Downs 2	Detritals	0.009	8.64	36.2	40	73	1.19	0.502	0.27	0.051	17.3	19.95	195	0.15	50.2	29.3
ICW617	Hope Downs 2	Detritals	0.304	10.6	23	50	59	0.98	0.5	0.1	0.147	22.1	13.25	358	3.11	115	16.15
IET519	Hope Downs 2	Detritals	0.091	5.53	55	20	7	1.39	0.419	0.04	0.062	34.5	6.78	179	0.2	52.7	36.1
IDL399	Bedded Hilltop	Lignite	**0.515**	**0.95**	**25**	400	**14.8**	**2.89**	**1.945**	**1.05**	**0.999**	**14.45**	**2.59**	**52.7**	**0.328**	**68.5**	**4.47**
IDL538	Bedded Hilltop	Lignite	**0.099**	**0.38**	**1810**	200	**11.4**	**0.69**	**0.261**	**0.12**	**5.12**	**17.65**	**29.1**	**11.6**	**1.825**	**31.7**	**30.2**
IDL765	Bedded Hilltop	Lignite	**0.058**	**0.58**	**28**	200	**10.6**	**2.84**	**0.428**	**0.65**	**1.645**	**60.4**	**14.35**	**20.6**	**0.82**	**14.65**	**8.87**
IER771	Bedded Hilltop	Lignite	**0.058**	**0.72**	**147.5**	200	**27.6**	**5.87**	**0.387**	**0.68**	**2.04**	**128.5**	**21.8**	**20.3**	**0.861**	**28.7**	**5.03**
IEX186	Bedded Hilltop	Lignite	**0.052**	**0.76**	**23**	<200	**44.4**	**6.64**	**0.33**	**1.07**	**6.58**	**182**	**16.8**	**28.6**	**0.406**	**29.2**	**5.46**
IEX193	Bedded Hilltop	Lignite	**0.052**	**4.53**	**45.9**	200	**52.3**	**5.44**	**0.474**	**0.63**	**2.34**	**152**	**4.54**	**26.8**	**0.277**	**27.4**	**10.8**
ICW891	Bedded Hilltop	Lignite	**0.045**	**0.66**	**31.8**	<200	**6.3**	**2.01**	**0.336**	**0.65**	**1.27**	**46.7**	**11.55**	**14.05**	**0.357**	**17.6**	**5.1**
ICW899	Bedded Hilltop	Lignite	**0.182**	**0.66**	**68.3**	200	**12.9**	**2**	**0.73**	**0.69**	**2.05**	**206**	**125**	**34.7**	**0.175**	**33.9**	**7.63**
ICV737	Bedded Hilltop	Lignite	0.253	6.99	66.9	40	88	2.92	0.843	0.02	2.12	31.7	72.1	70.8	7.4	32.4	2.49
ICV974	Bedded Hilltop	Lignite	**0.028**	**0.87**	**25.6**	<200	**20.7**	**6.53**	**0.242**	**0.93**	**2.7**	**181**	**23.6**	**11.5**	**0.188**	**19.05**	**1.95**
HWK433	Bedded Hilltop	Dales Gorge	0.018	0.5	4.85	<10	3	1.15	0.029	0.01	0.035	8.14	2.21	14	0.07	5.49	35.4
HSS954	Bedded Hilltop	Dales Gorge	0.014	0.3	9.44	10	2	0.83	0.028	0.01	0.026	7.33	1.99	10.9	0.03	3.51	38.6
HSS955	Bedded Hilltop	Dales Gorge	0.017	1.18	17.15	20	4	1.28	0.486	0.01	0.046	14.75	3.77	18	0.03	11.5	35.2
IDQ084	Bedded Hilltop	Dales Gorge	0.044	0.26	9.1	10	1	1.31	0.014	0.01	0.019	6.03	1.36	17.7	0.02	5.29	34.2
IER035	Bedded Hilltop	Dales Gorge	0.003	0.46	10.4	10	11	0.92	0.017	0.01	0.024	5.97	2.95	15.7	0.04	9.21	37.8
IER036	Bedded Hilltop	Dales Gorge	0.003	0.19	5.92	10	5	0.9	0.008	0.01	0.024	4.49	3.05	16.2	0.03	5.52	36.9
IER123	Bedded Hilltop	Dales Gorge	0.003	2.28	5.13	10	120	0.93	0.081	0.08	0.015	15.45	4.57	23.7	0.08	13.75	27.2
IET896	Bedded Hilltop	Dales Gorge	0.016	6.94	18.75	30	62	0.65	3.17	0.01	0.014	65	1.855	63.8	0.04	9.78	34.8
IEW193	Bedded Hilltop	Dales Gorge	0.004	0.48	3.54	10	18	1.43	0.008	0.01	0.036	19.4	1.285	15.3	0.04	7.13	34.9
IEW194	Bedded Hilltop	Dales Gorge	<0.002	0.36	3.18	10	13	1.4	0.007	0.01	0.028	15.6	1.135	16.5	0.03	5.66	36.5
IEW862	Bedded Hilltop	Dales Gorge	0.015	0.2	3.14	<10	5	1.5	0.009	0.01	0.03	2.72	1.705	45.5	0.04	5.69	34
IEW882	Bedded Hilltop	Dales Gorge	0.009	0.27	4.76	10	33	1.98	0.011	0.01	0.03	3.5	1.75	49.4	0.03	7.09	36.4
IEX556	Bedded Hilltop	Dales Gorge	<0.002	0.48	5.95	10	32	1.17	0.006	0.01	0.026	14.25	1.345	13	0.05	4.9	39.2
IEX557	Bedded Hilltop	Dales Gorge	0.007	0.43	5.29	10	47	1.23	0.007	0.01	0.028	5.61	1.395	23.4	0.06	5.6	38.3
IGV835	Bedded Hilltop	Dales Gorge	0.008	2.2	32.8	10	10	1.6	0.098	0.01	0.044	16.15	2.26	31.2	0.06	22.8	30.5
HWK820	Bedded Hilltop	FWZ	0.015	0.51	16.3	10	44	1.18	0.028	0.01	0.022	12	1.865	22.4	0.13	4.92	43.2
IDL631	Bedded Hilltop	FWZ	0.014	0.69	13.4	<10	3	1.41	0.023	0.02	0.084	9.2	2.74	13	0.04	9.46	46.1
IER083	Bedded Hilltop	FWZ	0.014	0.35	10.65	10	23	2.59	0.005	0.01	0.179	17.75	11.4	33.2	0.06	30.5	37.1
IER142	Bedded Hilltop	FWZ	0.018	0.78	57.5	10	4	1.31	0.052	0.01	0.036	9.79	6.75	18.4	0.03	13.6	37.4
IEW143	Bedded Hilltop	FWZ	0.005	3.3	119	20	195	7.91	0.316	0.02	0.263	47.9	18.05	55.8	0.07	43.6	40.7
IEZ446	Bedded Hilltop	FWZ	0.013	3.46	57.7	30	14	2.62	0.177	0.02	0.116	33.6	11.9	20.6	0.07	29	41.5
ICW973	Bedded Hilltop	FWZ	0.011	2.23	78	10	15	2.04	0.141	0.03	0.119	22.2	19.4	35.9	0.23	18.7	36.8
IEX525	Bedded Hilltop	FWZ	0.02	1.35	37.3	<10	19	1.04	0.053	0.01	0.053	24.9	5.55	20.5	0.05	17.6	39.3
IGV812	Bedded Hilltop	FWZ	0.054	1.03	412	10	51	1.47	0.057	0.01	0.123	6.12	3.44	21.7	0.04	33	38.2
HWK845	Bedded Hilltop	MCS	0.147	8.09	106.5	50	153	5.79	0.71	0.01	0.054	31.6	9.57	92.8	3.03	24.7	18.9
HSS744	Bedded Hilltop	MCS	0.073	8.73	57.4	70	271	2.42	0.731	0.02	0.148	135.5	2.03	88.2	6.76	22.6	2.42
IDP446	Bedded Hilltop	MCS	1.585	10.5	392	50	153	1.29	0.798	0.02	0.032	102	8.92	109	3.26	52	5.48
HWL294	Bedded Hilltop	MCS	0.196	4.05	113.5	20	111	4.53	0.347	0.01	0.598	28	9.8	27.1	2.74	93.6	15.1
HWL551	Bedded Hilltop	MCS	0.113	2.74	855	20	56	1.82	0.816	0.02	0.238	25.2	5.7	67.8	1.77	79.3	25.7
IER194	Bedded Hilltop	MCS	0.102	9.75	61.1	70	223	2.76	0.911	0.02	0.153	129	5.91	89.8	5.22	7.38	4.52
IEZ598	Bedded Hilltop	MCS	0.088	7.41	619	60	248	2.39	0.733	0.03	0.3	56.2	23.7	86.6	6.29	76.1	14.9
HWL528	Bedded Hilltop	MTS	0.171	3.6	41.1	10	23	1.41	0.528	0.02	1.865	58.4	34.2	81	0.36	36.9	3.47
IDS102	Bedded Hilltop	MTS	0.732	5.9	61.5	10	23	1.04	0.637	0.01	0.012	63.6	1.82	102.5	0.19	178	4.79
IEZ052	Bedded Hilltop	WF	0.007	0.13	5.79	<200	29	0.39	0.014	18.65	0.023	5.35	1.435	4.1	0.02	147.5	1.79
IET246	Bedded Hilltop	WF	0.03	1.84	8.2	<200	66	0.37	0.147	14.8	0.085	17.1	3.97	30.4	1.24	12.7	1.5
IEZ176	Bedded Hilltop	WF	0.046	0.42	8.24	<200	30	0.35	0.028	14.2	0.053	7.72	3.15	31.3	0.82	12.2	3.43
IEZ199	Bedded Hilltop	WF	0.054	11.35	106	60	196	0.83	1.79	0.41	0.018	38.2	10.85	555	10.45	53.2	19.4
ICV792	Bedded Hilltop	WF	0.035	5.8	12.6	10	13	0.42	0.019	0.38	0.121	3.24	65	937	0.42	87.5	10.1
ICY501	Hope Downs 2	WF	0.076	4.92	34.3	20	84	2.29	0.467	0.04	0.045	53.6	17.25	62.5	1.68	38.3	17.75
ICX217	Hope Downs 2	WF	0.01	8.54	43.7	60	52	1.25	0.85	0.04	0.086	28.9	38.1	63.3	2.39	49.6	27.7
HST001	Hope Downs 2	WF	0.029	8	35.6	40	20	0.46	0.703	0.07	0.027	3.28	7.67	202	3.97	132	31.6
ICY868	Hope Downs 2	WF	0.039	8.99	50.5	20	293	2.16	0.55	0.07	0.493	389	125	35.9	0.07	85.2	29.6
ICY871	Hope Downs 2	WF	0.105	8.6	49.3	20	520	4.61	0.603	0.18	0.628	224	61.5	59.5	0.39	56.2	26.3
ICL231	Hope Downs 2	WF	0.023	3.52	4.11	<200	64	1.13	0.145	11.3	1.475	35.8	91	50.5	1.3	35.7	5.58
IDR802	Hope Downs 2	WF	0.058	9.1	37.1	30	350	4.51	0.714	0.14	1.005	94.7	68.4	83.3	1.75	59.9	23.9
HST214	Hope Downs 2	WF	0.053	3.94	28.7	20	124	2.93	0.294	0.48	2.97	111.5	68.7	54	0.49	27.9	23
HST257	Hope Downs 2	WF	0.117	7.55	21.7	40	700	6	0.611	0.13	1.65	103	69.8	86.1	2.77	57.6	9.7
ICV188	Hope Downs 2	WF	0.043	0.62	6.39	10	9	0.96	0.046	0.07	0.497	8.5	20.4	27.5	0.1	22.1	28.8
ICV374	Hope Downs 2	WF	0.037	4.37	35.7	20	100	5.5	0.414	0.08	0.129	102	20.7	24.2	0.68	36.4	29.8
ICW087	Hope Downs 2	WF	0.016	6.17	36.6	50	78	1.79	0.584	0.2	0.428	21.8	58	44.1	1.19	44.5	24.1
IEU427	Hope Downs 2	WF	0.011	5.96	62.2	30	77	0.95	0.558	0.02	0.065	24.1	28.3	93.8	1.09	43.4	40.8
IEV694	Hope Downs 2	WF	0.016	0.53	3.74	10	3	0.67	0.051	0.02	0.178	4.7	5.63	12.3	0.04	5.03	27.6
IET547	Hope Downs 2	WF	0.107	7.64	33.9	30	197	2.86	0.641	0.18	0.228	100.5	33.5	49.9	2.95	49	17.65
ICI031	Hope Downs 2	Newman	0.004	0.2	1.57	10	4	0.56	0.011	0.01	0.019	9.44	1.4	12.3	0.02	4.52	37.3
ICP834	Hope Downs 2	Newman	0.006	0.33	1.71	10	3	0.25	0.018	0.01	0.076	3.2	2.42	9.8	0.04	2.72	36.6
ICY761	Hope Downs 2	Newman	0.024	0.94	1.37	10	47	0.13	0.039	0.01	0.038	1.57	2.56	51.1	0.12	22.5	11.2
ICL327	Hope Downs 2	Newman	0.016	0.31	1.24	10	3	0.27	0.013	0.02	0.09	2.52	5.56	26.7	0.05	22	32.8
ICL518	Hope Downs 2	Newman	0.006	0.23	2.24	10	28	0.61	0.009	0.01	0.046	6.36	8.96	96.2	0.06	3.65	28.2
ICL787	Hope Downs 2	Newman	0.022	0.19	1.31	10	4	0.32	0.016	0.01	0.147	1.81	4.09	34.8	0.04	18.75	32.2
ICV072	Hope Downs 2	Newman	0.021	1.95	17.65	20	89	1	0.073	0.35	0.041	15.15	17.4	34.4	0.11	31.2	48.5
ICV158	Hope Downs 2	Newman	0.013	0.17	1.01	10	2	0.3	0.011	0.01	0.158	2.4	2.97	24.4	0.05	10.45	29.1
IEU414	Hope Downs 2	Newman	0.015	0.19	1.9	10	1	0.27	0.012	<0.01	0.006	4.02	1.04	14.9	0.01	2.27	33.5
ICY563	Hope Downs 2	MacLeod	0.003	3.67	12.7	10	8	1.54	0.283	<0.01	0.017	4.86	1.65	49.8	0.05	25.1	48.6
ICH905	Hope Downs 2	MacLeod	0.01	0.49	5.01	10	5	0.8	0.055	<0.01	0.012	2.86	0.958	11.2	0.03	8.21	30.5
ICL281	Hope Downs 2	MacLeod	0.006	0.35	2.12	10	21	0.53	0.019	0.01	0.088	1.52	9.7	32.9	0.03	16	34.3
ICL766	Hope Downs 2	MacLeod	0.009	0.78	1.54	10	11	0.6	0.015	0.01	0.146	7.79	11	24	0.08	19.15	36.4
ICV067	Hope Downs 2	MacLeod	0.156	0.68	1.28	10	70	0.55	0.036	0.01	0.115	5.24	1.985	30.3	0.18	8.82	17.3
IDV159	Hope Downs 2	MacLeod	0.017	2.29	11.1	30	89	0.95	0.136	0.07	0.04	2.97	3.87	53.5	0.28	27	37.3
ICW468	Hope Downs 2	MacLeod	0.028	1.07	6.24	10	7	0.8	0.065	0.01	0.031	5.69	10.6	53.8	0.27	52.2	34.4
ICI423	Hope Downs 2	Nammuldi	0.099	6.03	3.91	10	24	1.31	0.164	0.01	0.028	3.92	3.05	80.5	0.2	152	42.6
IDR622	Hope Downs 2	Nammuldi	0.009	0.64	1.61	10	4	0.3	0.109	<0.01	0.013	2.88	2.03	33.3	0.05	3.89	30.2
IEU280	Hope Downs 2	Nammuldi	0.018	0.17	1.76	10	8	0.27	0.025	0.01	0.14	20.9	1.89	50	0.13	7.21	19.85

Note: Samples digested by 4 acid digest (normal font) and aqua regia digest (**BOLD** font)

DRAFT

Sample ID	Location	Lithology	Ga	Ge	Hf	Hg	In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P
			ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	ppm
HWL255	Bedded Hilltop	Detritals	14.95	0.16	2.15	0.026	0.102	0.22	7.93	4.7	0.07	127	5.32	0.008	4.01	19.25	280
IEZ059	Bedded Hilltop	Detritals	17.7	0.13	3.41	0.011	0.116	0.42	17.25	15.7	0.17	832	2.28	0.079	10.85	55.2	360
IEX071	Bedded Hilltop	Detritals	15.75	2.12	3.22	1.265	0.046	0.02	15.65	55.5	0.06	181	5.24	0.024	17.2	59.6	110
IEX144	Bedded Hilltop	Detritals	12.55	1.12	1.935	0.018	0.063	0.04	28.4	5.4	0.62	114	2.68	0.044	7.36	28.2	240
IDS997	Bedded Hilltop	Detritals	16.85	0.88	2.61	0.078	0.111	0.14	8.04	27.7	0.09	566	6.56	0.019	5.89	50.9	200
ICX396	Hope Downs 2	Detritals	21.4	0.37	3.66	0.011	0.128	0.12	11.25	7	0.07	2030	2.55	0.026	9.38	34.2	360
ICI037	Hope Downs 2	Detritals	13.85	0.33	3.09	0.011	0.053	0.09	3.23	5.7	0.08	869	1.89	0.04	6.02	19.45	270
ICY932	Hope Downs 2	Detritals	23.2	1.75	3.51	0.028	0.168	0.02	5.44	7.4	0.09	253	3.69	0.017	8.16	88.6	230
IDR366	Hope Downs 2	Detritals	16.6	1.22	2.48	0.011	0.153	0.01	12.8	3.3	0.03	721	3.18	0.014	6.14	40.8	230
HST198	Hope Downs 2	Detritals	23	0.75	3.1	0.01	0.159	0.06	20	7.7	0.06	990	4.37	0.019	6.94	67.8	310
ICW055	Hope Downs 2	Detritals	7.36	3.42	1.56	0.024	0.042	0.01	8.57	9.3	0.06	986	1.36	0.009	4.12	107.5	630
IEU297	Hope Downs 2	Detritals	18.05	0.47	2.58	0.008	0.141	0.02	6.78	31.8	0.52	1160	1.58	0.04	6.92	73.9	70
ICW617	Hope Downs 2	Detritals	32	0.43	4.1	0.005	0.278	0.27	14.25	18.3	0.15	369	1.93	0.06	12.6	78.7	320
IET519	Hope Downs 2	Detritals	13.75	0.73	2.05	0.025	0.104	0.04	15.45	4.4	0.05	507	2.43	0.013	4.57	42.9	490
IDL399	Bedded Hilltop	Lignite	**11.15**	**1.535**	**0.955**	**8.87**	**0.121**	**0.01**	**4.11**	**1.4**	**0.41**	**157**	**3.39**	**0.027**	**2.01**	**9.29**	**70**
IDL538	Bedded Hilltop	Lignite	**1.885**	**2.78**	**0.207**	**3.17**	**0.021**	**0.01**	**5.97**	**3.4**	**0.03**	**17**	**2.13**	**0.011**	**0.338**	**105.5**	**10**
IDL765	Bedded Hilltop	Lignite	**4.02**	**1.47**	**0.3**	**4.36**	**0.03**	**0.01**	**31.3**	**2.3**	**0.19**	**224**	**0.74**	**0.021**	**0.722**	**18.5**	**20**
IER771	Bedded Hilltop	Lignite	**4.11**	**1.405**	**0.259**	**3.01**	**0.041**	**0.02**	**57.8**	**2.9**	**0.22**	**599**	**0.86**	**0.021**	**0.72**	**43.8**	**10**
IEX186	Bedded Hilltop	Lignite	**4.29**	**0.892**	**0.229**	**1.265**	**0.029**	**0.01**	**65.3**	**1.5**	**0.33**	**303**	**0.66**	**0.028**	**0.597**	**36.7**	**10**
IEX193	Bedded Hilltop	Lignite	**9.47**	**2.05**	**0.533**	**2.33**	**0.044**	**0.01**	**65.1**	**0.8**	**0.2**	**117**	**1.96**	**0.025**	**1.105**	**9.8**	**1100**
ICW891	Bedded Hilltop	Lignite	**3.65**	**2.02**	**0.214**	**2.17**	**0.03**	**0.01**	**20**	**0.7**	**0.25**	**455**	**0.6**	**0.019**	**0.593**	**15.75**	**10**
ICW899	Bedded Hilltop	Lignite	**6.39**	**4.96**	**0.543**	**3.58**	**0.061**	**0.01**	**19.85**	**0.5**	**0.23**	**217**	**1.61**	**0.021**	**1.39**	**133**	**30**
ICV737	Bedded Hilltop	Lignite	17.3	<0.05	3.49	0.079	0.131	1.47	22.1	69	0.27	272	1.83	0.021	8.32	231	80
ICV974	Bedded Hilltop	Lignite	**3.14**	**1.07**	**0.209**	**1.9**	**0.027**	**0.01**	**75.2**	**2.2**	**0.41**	**210**	**0.63**	**0.031**	**0.582**	**42.4**	**20**
HWK433	Bedded Hilltop	Dales Gorge	0.98	0.08	0.189	0.01	0.011	0.01	1.595	0.7	0.02	241	0.29	0.004	0.795	5.04	790
HSS954	Bedded Hilltop	Dales Gorge	0.55	0.1	0.149	0.02	0.009	<0.01	2.85	0.5	0.01	116	0.38	0.003	0.443	3.1	730
HSS955	Bedded Hilltop	Dales Gorge	1.75	0.08	0.375	0.009	0.03	<0.01	6.21	1.2	0.02	248	0.74	0.006	1.085	9.58	1060
IDQ084	Bedded Hilltop	Dales Gorge	0.55	0.08	0.077	0.009	0.009	<0.01	1.97	0.3	0.01	98	0.6	0.002	0.437	3.29	950
IER035	Bedded Hilltop	Dales Gorge	0.49	0.09	0.137	0.005	0.01	<0.01	6.79	1	0.02	129	0.37	0.005	0.356	5.23	660
IER036	Bedded Hilltop	Dales Gorge	0.36	0.09	0.091	0.007	0.008	<0.01	4.85	0.8	0.02	124	0.39	0.005	0.3	5.14	680
IER123	Bedded Hilltop	Dales Gorge	2.65	0.1	0.654	0.008	0.022	0.03	4.86	1.8	0.05	81	0.67	0.029	1.79	8.84	620
IET896	Bedded Hilltop	Dales Gorge	11.55	4.33	3.26	0.023	0.193	0.01	35.4	4.2	0.02	53	2.58	0.026	5.3	36.9	600
IEW193	Bedded Hilltop	Dales Gorge	0.5	0.1	0.145	0.005	0.009	0.01	22.7	1.7	0.02	154	0.38	0.014	0.365	5.81	530
IEW194	Bedded Hilltop	Dales Gorge	0.41	0.11	0.104	0.006	0.008	<0.01	20.9	1.4	0.02	124	0.39	0.01	0.337	5.4	540
IEW862	Bedded Hilltop	Dales Gorge	0.46	0.09	0.14	0.009	0.011	<0.01	4.11	1.3	0.02	125	0.62	0.005	0.362	6.94	470
IEW882	Bedded Hilltop	Dales Gorge	0.54	0.09	0.173	0.007	0.01	0.01	1.085	0.9	0.01	187	0.84	0.015	0.455	9.07	510
IEX556	Bedded Hilltop	Dales Gorge	0.47	0.12	0.119	0.007	0.008	<0.01	22.9	1.4	0.02	175	0.86	0.009	0.345	5.48	600
IEX557	Bedded Hilltop	Dales Gorge	0.41	0.09	0.102	0.006	0.009	<0.01	6.51	1.2	0.02	175	0.79	0.009	0.361	4.88	790
IGV835	Bedded Hilltop	Dales Gorge	3.9	0.09	0.868	0.007	0.022	<0.01	6.65	0.7	0.01	206	1.93	0.005	2.39	13.15	1480
HWK820	Bedded Hilltop	FWZ	1.02	0.12	0.196	0.01	0.011	0.03	6.33	0.7	0.02	154	0.56	0.03	0.804	4.83	690
IDL631	Bedded Hilltop	FWZ	1.06	0.12	0.292	0.005	0.014	<0.01	5.34	2.6	0.02	163	0.94	0.004	0.817	13.25	1180
IER083	Bedded Hilltop	FWZ	0.35	0.12	0.104	0.069	0.009	0.01	46.9	2.2	0.02	246	0.77	0.008	0.362	19.2	640
IER142	Bedded Hilltop	FWZ	1.53	0.14	0.27	0.008	0.017	0.01	9.35	0.9	0.01	166	1.34	0.006	0.912	19.5	1130
IEW143	Bedded Hilltop	FWZ	8.25	1.1	1.535	0.015	0.076	0.04	17.85	2.4	0.3	3290	4.45	0.075	2.43	68.2	1610
IEZ446	Bedded Hilltop	FWZ	5.28	1.36	0.948	0.012	0.041	0.01	12.6	1.1	0.07	1230	2.3	0.018	2.89	25.3	2030
ICW973	Bedded Hilltop	FWZ	4.49	0.95	0.746	0.02	0.036	0.09	9.86	4.8	0.05	770	2.71	0.006	1.815	41	1120
IEX525	Bedded Hilltop	FWZ	2.06	0.14	0.546	0.01	0.022	<0.01	3.91	0.6	0.01	361	3.6	0.01	1.375	14.05	910
IGV812	Bedded Hilltop	FWZ	1.44	0.21	0.275	0.016	0.018	0.01	4.03	1	0.01	211	2.18	0.006	0.853	35.2	1090
HWK845	Bedded Hilltop	MCS	18.8	0.24	3.54	0.021	0.105	1.9	21.3	17.9	0.45	219	0.54	0.03	7.45	64.2	540
HSS744	Bedded Hilltop	MCS	19.75	0.12	3.77	0.005	0.117	2.71	67.3	25.9	0.63	24.9	4.68	0.026	10.7	28.4	260
IDP446	Bedded Hilltop	MCS	14.9	0.12	2.82	0.026	0.198	1.67	69.5	27.8	0.36	34.1	16.4	0.021	7.07	68.1	160
HWL294	Bedded Hilltop	MCS	10.7	0.09	2.93	0.103	0.062	1.2	17.9	30.4	0.22	384	3.76	0.017	4.43	28.6	230
HWL551	Bedded Hilltop	MCS	10.25	0.13	1.77	0.027	0.144	0.71	10.25	8.8	0.15	163	12.75	0.022	3.11	21.9	200
IER194	Bedded Hilltop	MCS	17.15	0.11	3.6	0.005	0.091	2.17	73.4	19.4	0.49	66.6	9.86	0.034	8.05	86	430
IEZ598	Bedded Hilltop	MCS	18.5	0.1	4.07	0.045	0.091	2.09	31.3	19.8	0.54	2220	5.48	0.049	8.08	90	410
HWL528	Bedded Hilltop	MTS	8.35	0.1	1.405	0.163	0.063	0.13	23.3	23.4	0.03	316	2.72	0.006	4.37	62.5	90
IDS102	Bedded Hilltop	MTS	10.45	0.06	1.625	0.133	0.091	0.06	11.2	6.2	0.02	103	5.92	0.007	4.98	31.9	90
IEZ052	Bedded Hilltop	WF	0.35	<0.05	0.055	0.013	<0.005	0.01	3.07	1.7	11.85	3300	0.33	0.01	0.128	8.27	80
IET246	Bedded Hilltop	WF	4.24	<0.05	0.797	0.031	0.016	1.42	8.91	6.4	9.01	3920	0.71	0.033	2.36	22.1	130
IEZ176	Bedded Hilltop	WF	1.05	<0.05	0.176	0.137	<0.005	0.03	4.99	2.5	7.28	407	0.31	0.03	0.588	8.33	30
IEZ199	Bedded Hilltop	WF	49	0.92	7.08	0.019	0.218	0.39	19.7	15.8	0.43	668	7.18	0.06	13.95	51.8	220
ICV792	Bedded Hilltop	WF	10.2	<0.05	0.782	0.016	0.042	0.07	1.19	29	7.13	2310	0.28	0.023	0.728	318	40
ICY501	Hope Downs 2	WF	10.95	0.13	2.21	0.024	0.062	0.47	34.7	10	0.21	2460	0.93	0.021	3.69	63.7	250
ICX217	Hope Downs 2	WF	20	0.72	4.64	0.01	0.086	0.65	10.45	12.2	0.27	5430	2.29	0.044	7.52	73.8	240
HST001	Hope Downs 2	WF	19.6	2.57	3.49	0.005	0.185	0.23	3.05	11.6	0.11	33	1.22	0.056	7.12	33.5	120
ICY868	Hope Downs 2	WF	18.5	1.39	3.04	0.073	0.073	0.02	59.9	207	0.39	>50000	3.5	0.024	1.94	442	800
ICY871	Hope Downs 2	WF	19.9	1.41	3.63	0.099	0.082	0.12	73.2	127	0.33	>50000	3.42	0.028	2.59	217	1220
ICL231	Hope Downs 2	WF	6.67	0.08	1.09	0.019	0.05	0.14	17.45	34.6	8.88	4380	0.27	0.025	2.47	158.5	110
IDR802	Hope Downs 2	WF	21.1	1.03	3.82	0.09	0.086	1.25	95.8	100.5	0.52	48900	0.87	0.037	4.28	214	920
HST214	Hope Downs 2	WF	10.75	1.61	1.48	0.562	0.038	0.13	74.7	18.3	0.54	>50000	0.63	0.011	2.85	94.8	780
HST257	Hope Downs 2	WF	18.8	0.29	3.02	0.148	0.063	2.12	142.5	50.8	0.59	40800	0.41	0.029	3.85	205	700
ICV188	Hope Downs 2	WF	1.65	0.1	0.215	0.02	0.008	0.03	5.2	3.2	0.08	3480	0.69	0.003	0.45	29.1	300
ICV374	Hope Downs 2	WF	11.75	0.86	2.17	0.019	0.062	0.32	53.6	10.3	0.25	25200	1.62	0.012	2.82	76.5	930
ICW087	Hope Downs 2	WF	13.6	0.36	2.9	0.015	0.053	0.38	10.4	13.6	0.24	4400	0.7	0.072	4.4	131	370
IEU427	Hope Downs 2	WF	13.35	1.47	2.55	0.009	0.08	0.56	9.18	3.8	0.17	2750	2.16	0.044	5.17	68.5	360
IEV694	Hope Downs 2	WF	1.14	0.09	0.186	0.013	<0.005	0.02	4.38	2.4	0.06	1010	0.27	0.002	0.424	14.2	200
IET547	Hope Downs 2	WF	20.2	0.68	3.75	0.075	0.076	1.2	60.2	40.2	0.44	46700	0.55	0.035	4.43	135.5	790
ICI031	Hope Downs 2	Newman	0.86	0.12	0.049	0.005	<0.005	0.01	1.605	1.3	0.02	176	0.17	0.003	0.147	5.07	620
ICP834	Hope Downs 2	Newman	0.88	0.11	0.141	0.007	<0.005	0.01	5.54	2.6	0.03	406	0.17	0.004	0.315	10.55	320
ICY761	Hope Downs 2	Newman	1.98	<0.05	0.266	0.023	0.012	0.01	0.908	6.3	0.02	74	0.37	0.005	0.587	8.45	100
ICL327	Hope Downs 2	Newman	0.77	0.31	0.125	0.009	0.005	0.01	1.375	2.3	0.04	133	0.31	0.007	0.369	11.6	270
ICL518	Hope Downs 2	Newman	0.48	0.18	0.062	0.006	<0.005	0.01	5.53	5.6	0.03	674	0.67	0.009	0.22	23.2	310
ICL787	Hope Downs 2	Newman	0.51	0.1	0.065	0.009	0.005	0.01	1.175	2.8	0.02	179	0.61	0.006	0.181	13.25	250
ICV072	Hope Downs 2	Newman	2.73	4.67	0.76	0.014	0.021	0.04	3.87	0.9	0.1	52	0.36	0.041	1.055	16.2	540
ICV158	Hope Downs 2	Newman	0.41	0.2	0.056	0.006	<0.005	0.01	0.737	3	0.03	194	0.19	0.003	0.171	7.99	240
IEU414	Hope Downs 2	Newman	0.41	0.09	0.058	0.005	<0.005	0.01	0.949	0.7	0.01	285	0.24	0.001	0.179	3.26	320
ICY563	Hope Downs 2	MacLeod	7.74	3.66	1.61	0.005	0.045	0.01	1.26	0.9	0.01	129	0.87	0.019	3.82	22.6	210
ICH905	Hope Downs 2	MacLeod	1.14	0.12	0.215	0.005	0.007	0.01	0.65	1	0.01	71	0.27	0.003	0.557	7.49	230
ICL281	Hope Downs 2	MacLeod	0.97	0.12	0.13	0.005	<0.005	0.01	1.41	1.5	0.04	180	0.45	0.007	0.335	14.75	240
ICL766	Hope Downs 2	MacLeod	0.44	0.14	0.047	0.01	<0.005	0.01	6.41	6.8	0.03	233	0.4	0.005	0.207	16.75	390
ICV067	Hope Downs 2	MacLeod	2.46	0.05	0.417	0.005	0.009	0.02	3.05	7.2	0.01	43	0.28	0.004	1.085	9.31	300
IDV159	Hope Downs 2	MacLeod	5.25	2.54	1.16	0.015	0.077	0.08	1.455	3.1	0.03	46	0.91	0.037	2.28	13.5	200
ICW468	Hope Downs 2	MacLeod	2.61	0.22	0.462	0.005	0.028	0.03	1.23	3.7	0.02	81	0.67	0.005	1.165	26.6	390
ICI423	Hope Downs 2	Nammuldi	8.58	2.32	1.3	0.009	0.095	0.03	2.58	5.6	0.02	21	0.67	0.01	3.28	27.8	1050
IDR622	Hope Downs 2	Nammuldi	1.74	0.1	0.374	0.005	0.006	0.01	0.835	1.7	0.02	86	0.3	0.001	0.8	5.84	360
IEU280	Hope Downs 2	Nammuldi	1.09	0.06	0.126	0.018	0.006	0.02	12.5	8.4	0.01	112	0.71	0.004	0.395	5.05	70

Note: Samples digested by 4 acid digest (normal font) and aqua regia digest (**BOLD** font)

DRAFT

Sample ID	Location	Lithology	Pb	Rb	Re	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U
			ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm
HWL255	Bedded Hilltop	Detritals	31.8	21.7	<0.002	0.02	6.45	10.65	1.6	1.61	2.72	0.3	0.56	9.43	0.142	0.166	1.92
IEZ059	Bedded Hilltop	Detritals	24.9	40.6	<0.002	0.02	2.9	20.6	1	2.8	23.9	0.87	0.19	12.65	0.482	0.311	1.76
IEX071	Bedded Hilltop	Detritals	42.3	2.72	<0.002	0.03	3.65	9.7	1.1	4.03	7	1.36	0.07	7.98	0.581	0.736	3.31
IEX144	Bedded Hilltop	Detritals	19.7	5.37	<0.002	0.02	2.1	11.4	0.6	1.92	18.85	0.68	0.12	7.68	0.292	0.239	2.96
IDS997	Bedded Hilltop	Detritals	47.1	19	<0.002	0.02	6.05	12.75	1.2	2.58	5.32	0.45	0.44	12.7	0.217	0.45	2.85
ICX396	Hope Downs 2	Detritals	20.7	10.7	<0.002	0.03	4.66	20.2	2.3	2.75	17.7	0.67	0.53	13.75	0.418	0.249	2.09
ICI037	Hope Downs 2	Detritals	8.84	4.82	<0.002	0.04	4.43	10	3.9	1.94	24.5	0.44	0.61	9.42	0.264	0.041	0.96
ICY932	Hope Downs 2	Detritals	28.5	1.06	<0.002	0.03	4.63	26.8	0.7	3.38	3.06	0.66	0.45	7.37	0.422	0.013	3.95
IDR366	Hope Downs 2	Detritals	17.15	0.41	<0.002	0.01	3.11	21.2	0.6	2.53	3.17	0.45	0.62	5.88	0.38	0.014	2.04
HST198	Hope Downs 2	Detritals	39.5	2.95	<0.002	0.01	4.91	24.1	0.6	3.08	3.29	0.58	0.48	5.73	0.361	0.03	3.43
ICW055	Hope Downs 2	Detritals	8.91	0.44	<0.002	0.02	1.36	10.05	0.2	0.88	2.83	0.33	0.13	4.04	0.213	0.616	1.3
IEU297	Hope Downs 2	Detritals	14.1	1.22	<0.002	0.02	2.81	22.6	0.5	2.78	22.8	0.5	0.57	6.78	0.47	0.09	1.24
ICW617	Hope Downs 2	Detritals	31.5	33.1	<0.002	0.02	1.99	38.5	1.1	4.4	20.2	0.88	0.43	9.63	0.781	0.429	1.51
IET519	Hope Downs 2	Detritals	20.8	2.3	<0.002	0.01	2.8	19.55	0.4	1.77	2.33	0.35	0.23	5.57	0.301	0.032	1.86
IDL399	Bedded Hilltop	Lignite	**62.1**	**1.045**	**0.004**	**3.93**	**5.27**	**5.95**	**21.9**	**3.02**	**14.25**	**0.056**	**1.04**	**13.05**	**0.059**	**0.166**	**4.75**
IDL538	Bedded Hilltop	Lignite	**27.6**	**2.03**	**0.033**	**>10**	**0.555**	**0.992**	**6.7**	**0.54**	**3.87**	**<0.005**	**0.1**	**1.775**	**0.013**	**1.385**	**1.37**
IDL765	Bedded Hilltop	Lignite	**20.7**	**1.365**	**0.004**	**9.23**	**0.781**	**1.89**	**7.3**	**0.92**	**8.38**	**0.009**	**0.07**	**3.7**	**0.031**	**0.192**	**3.39**
IER771	Bedded Hilltop	Lignite	**32**	**1.56**	**0.01**	**5.67**	**0.85**	**2.65**	**4.9**	**0.86**	**14.9**	**0.006**	**0.06**	**3.8**	**0.031**	**0.512**	**3.68**
IEX186	Bedded Hilltop	Lignite	**30.9**	**1.07**	**0.01**	**6.81**	**1.14**	**3.59**	**3.4**	**0.63**	**14.75**	**0.006**	**0.08**	**4.14**	**0.025**	**0.784**	**4.01**
IEX193	Bedded Hilltop	Lignite	**65.8**	**0.952**	**0.008**	**3.67**	**1.145**	**3.67**	**10.9**	**0.99**	**50.3**	**0.023**	**0.12**	**5.43**	**0.035**	**0.17**	**7.33**
ICW891	Bedded Hilltop	Lignite	**12.95**	**0.528**	**0.005**	**6.42**	**0.654**	**1.46**	**4.1**	**0.6**	**9.07**	**0.016**	**0.07**	**2.74**	**0.018**	**0.217**	**1.97**
ICW899	Bedded Hilltop	Lignite	**38.7**	**0.741**	**0.03**	**8.74**	**2.81**	**2.92**	**16.8**	**1.05**	**8.67**	**0.032**	**0.36**	**6.09**	**0.038**	**15.4**	**2.69**
ICV737	Bedded Hilltop	Lignite	19.15	121	0.032	1.48	7.56	11.8	2.1	2.55	4.56	0.65	0.51	9.92	0.247	13.3	4.27
ICV974	Bedded Hilltop	Lignite	**27.4**	**1.035**	**0.007**	**3.27**	**0.72**	**1.915**	**3.5**	**0.56**	**14.85**	**0.01**	**0.06**	**2.59**	**0.02**	**0.853**	**3.74**
HWK433	Bedded Hilltop	Dales Gorge	2.58	1.05	<0.002	0.04	0.55	1.29	<0.2	0.16	0.6	0.04	0.04	0.695	0.018	0.131	0.44
HSS954	Bedded Hilltop	Dales Gorge	2.37	0.12	<0.002	0.06	0.48	0.67	0.2	0.11	0.56	0.02	<0.04	0.484	0.007	0.042	0.47
HSS955	Bedded Hilltop	Dales Gorge	6.57	0.21	<0.002	0.03	1.27	1.8	0.2	0.49	3.47	0.08	0.14	1.5	0.029	0.037	1.17
IDQ084	Bedded Hilltop	Dales Gorge	1.42	0.12	<0.002	0.03	0.31	0.58	<0.2	0.11	0.41	0.02	<0.04	0.275	0.009	0.02	0.47
IER035	Bedded Hilltop	Dales Gorge	0.96	0.27	<0.002	0.01	0.18	1.18	0.2	0.11	2.04	0.02	<0.04	0.227	0.018	0.016	0.26
IER036	Bedded Hilltop	Dales Gorge	0.92	0.19	<0.002	0.01	0.15	0.81	<0.2	0.08	2.34	0.01	<0.04	0.162	0.014	0.013	0.16
IER123	Bedded Hilltop	Dales Gorge	3.6	1.5	<0.002	0.02	0.47	3.17	0.4	0.4	6.89	0.13	0.06	1.975	0.089	0.026	0.62
IET896	Bedded Hilltop	Dales Gorge	54.3	0.41	<0.002	0.08	4.74	9.64	1.5	3.15	8.44	0.43	0.39	8.79	0.163	0.012	1.66
IEW193	Bedded Hilltop	Dales Gorge	0.66	0.4	<0.002	0.02	0.2	1.12	<0.2	0.08	5.01	0.02	<0.04	0.227	0.019	0.018	0.32
IEW194	Bedded Hilltop	Dales Gorge	0.62	0.27	<0.002	0.01	0.16	1.09	<0.2	0.09	3.74	0.02	<0.04	0.169	0.019	0.014	0.29
IEW862	Bedded Hilltop	Dales Gorge	1.17	0.31	<0.002	0.02	0.44	1.34	0.4	0.1	0.85	0.02	<0.04	0.277	0.018	0.006	0.16
IEW882	Bedded Hilltop	Dales Gorge	1.27	0.32	<0.002	0.03	0.47	1.58	1.3	0.11	2.16	0.02	<0.04	0.532	0.019	0.018	0.19
IEX556	Bedded Hilltop	Dales Gorge	1.21	0.35	<0.002	0.02	0.23	1.31	0.3	0.08	2.96	0.01	<0.04	0.237	0.015	0.011	0.17
IEX557	Bedded Hilltop	Dales Gorge	1.1	0.34	<0.002	0.02	0.2	1.21	0.2	0.09	1.26	0.01	<0.04	0.183	0.017	0.012	0.2
IGV835	Bedded Hilltop	Dales Gorge	3.87	0.28	<0.002	0.05	0.55	5.2	0.2	0.54	8.16	0.19	0.09	2.63	0.124	0.1	3.46
HWK820	Bedded Hilltop	FWZ	4.31	1.11	<0.002	0.01	0.48	1.95	0.4	0.18	4.69	0.04	0.04	0.66	0.023	0.04	0.39
IDL631	Bedded Hilltop	FWZ	0.99	0.19	<0.002	0.01	0.27	1.47	<0.2	0.18	0.84	0.05	<0.04	0.636	0.045	0.013	0.8
IER083	Bedded Hilltop	FWZ	2.21	0.49	<0.002	0.01	0.18	1.04	0.3	0.08	2.95	0.01	<0.04	0.177	0.016	0.158	1.4
IER142	Bedded Hilltop	FWZ	3.17	0.4	<0.002	0.03	0.79	1.72	0.3	0.22	2.68	0.06	<0.04	1.11	0.026	0.017	0.9
IEW143	Bedded Hilltop	FWZ	29.9	1.46	<0.002	0.21	2.98	9.02	2.6	0.8	24.4	0.19	0.28	6.16	0.101	0.311	4.26
IEZ446	Bedded Hilltop	FWZ	10.5	0.48	<0.002	0.09	2.09	6.32	0.4	0.7	11.5	0.22	0.19	3.94	0.09	0.092	4.79
ICW973	Bedded Hilltop	FWZ	6.98	3.34	<0.002	0.01	1.93	4.16	0.2	0.53	1.4	0.14	0.08	3.28	0.059	0.065	1.48
IEX525	Bedded Hilltop	FWZ	2.79	0.27	<0.002	0.04	0.7	3.01	0.6	0.28	0.82	0.1	0.04	1.54	0.077	0.025	0.64
IGV812	Bedded Hilltop	FWZ	6.44	0.36	<0.002	0.04	1.58	2.06	0.8	0.21	0.56	0.06	0.04	1.08	0.023	0.046	2.13
HWK845	Bedded Hilltop	MCS	41.6	94.6	<0.002	0.03	6.26	17.1	0.3	2.83	8.27	0.67	0.3	15.9	0.256	0.416	3.55
HSS744	Bedded Hilltop	MCS	60.3	145	<0.002	0.01	7.05	19.4	1.6	2.96	10.5	0.95	0.4	17.05	0.331	0.617	3.18
IDP446	Bedded Hilltop	MCS	102.5	71.5	<0.002	0.04	7.14	17.4	2.4	2.39	6.09	0.65	0.3	14.05	0.223	0.518	4.09
HWL294	Bedded Hilltop	MCS	23.4	56.2	<0.002	0.02	1.45	6.89	1.6	1.56	3.48	0.38	0.2	10.95	0.08	0.688	3.17
HWL551	Bedded Hilltop	MCS	32.7	29.8	<0.002	0.04	5.4	7.76	11.1	1.63	4.17	0.25	1.14	6.66	0.1	0.29	2.1
IER194	Bedded Hilltop	MCS	93	97.4	<0.002	0.02	4.35	15.8	0.6	2.61	10.3	0.68	0.38	14.7	0.253	0.576	2.57
IEZ598	Bedded Hilltop	MCS	46.6	111	<0.002	0.04	6.69	16.4	1.1	2.75	9.76	0.66	0.41	15.35	0.244	0.499	4.46
HWL528	Bedded Hilltop	MTS	20.9	9.71	<0.002	0.01	2.33	9.05	0.4	1.29	4.06	0.38	0.2	6.06	0.158	1.67	2.3
IDS102	Bedded Hilltop	MTS	29.3	4.16	<0.002	0.02	3.12	11.5	4.1	1.57	2.51	0.43	0.27	7.1	0.182	0.027	1.52
IEZ052	Bedded Hilltop	WF	1.02	0.34	<0.002	<0.01	0.4	0.31	0.3	0.24	16.1	0.01	<0.04	0.189	0.007	0.184	0.13
IET246	Bedded Hilltop	WF	4.71	36.8	<0.002	0.02	1.06	4.18	0.4	0.63	18.85	0.2	<0.04	3	0.099	0.162	0.86
IEZ176	Bedded Hilltop	WF	1.84	3.03	<0.002	0.02	0.32	1.48	0.3	0.16	40.3	0.04	<0.04	0.601	0.028	0.028	0.41
IEZ199	Bedded Hilltop	WF	38	44.9	<0.002	0.02	27.1	26.6	1.1	5.02	13.8	1.18	0.72	35.8	0.518	0.182	3.31
ICV792	Bedded Hilltop	WF	1.42	1.86	0.002	0.17	0.62	40.8	0.5	0.23	1.58	0.05	<0.04	0.176	0.194	0.184	0.28
ICY501	Hope Downs 2	WF	15.1	20.9	<0.002	0.01	3.96	11.85	0.2	1.47	5.02	0.31	0.23	7.74	0.163	0.142	1.72
ICX217	Hope Downs 2	WF	14.6	41.1	<0.002	0.03	6.34	14.55	1.3	2.82	10.2	0.64	0.3	12.65	0.295	0.177	2.96
HST001	Hope Downs 2	WF	15.2	13.15	<0.002	0.04	6.27	15.25	1.3	3.16	9.73	0.53	0.38	7.81	0.381	0.084	1.23
ICY868	Hope Downs 2	WF	21.2	0.76	<0.002	0.02	4.67	21.1	0.4	1.66	24.2	0.17	0.18	10.1	0.095	0.807	4.19
ICY871	Hope Downs 2	WF	20.8	4.51	<0.002	0.01	5.45	15.8	0.5	2.04	83.6	0.23	0.23	12.2	0.128	1.235	6.48
ICL231	Hope Downs 2	WF	7.72	7.91	<0.002	0.02	0.82	9.17	0.4	1	21.8	0.19	0.06	2.65	0.16	0.211	0.64
IDR802	Hope Downs 2	WF	21.7	40.3	<0.002	0.01	4.2	21.5	0.5	2.64	77.8	0.36	0.23	12.85	0.23	0.726	3.37
HST214	Hope Downs 2	WF	19.95	5.11	<0.002	<0.01	1.98	10.3	0.7	1.01	22.7	0.25	0.12	5.46	0.144	0.425	2.11
HST257	Hope Downs 2	WF	20.5	69.6	<0.002	0.01	3.9	17.05	0.5	2.23	88.3	0.35	0.16	11.5	0.201	1.48	2.84
ICV188	Hope Downs 2	WF	2.93	1.49	<0.002	0.01	0.66	2.16	0.2	0.18	1.23	0.03	<0.04	0.889	0.02	0.093	0.76
ICV374	Hope Downs 2	WF	14.55	14.25	<0.002	0.01	2.01	10.4	0.3	1.2	20.9	0.25	0.1	6.12	0.14	0.219	2.45
ICW087	Hope Downs 2	WF	11.6	16.8	<0.002	0.04	3.43	14.9	0.5	1.58	14.5	0.37	0.1	8.96	0.195	0.478	2.08
IEU427	Hope Downs 2	WF	19.55	23.5	<0.002	0.03	4.87	13.5	0.6	1.78	8.76	0.43	0.22	8.97	0.236	0.158	1.51
IEV694	Hope Downs 2	WF	2.01	0.77	<0.002	0.01	0.49	1.12	<0.2	0.15	0.6	0.03	<0.04	0.55	0.021	0.019	0.71
IET547	Hope Downs 2	WF	20.4	46.4	<0.002	0.01	4.77	17.65	0.5	2.22	68.5	0.41	0.26	11.85	0.211	0.486	2.47
ICI031	Hope Downs 2	Newman	0.75	0.32	<0.002	0.01	0.16	0.5	<0.2	0.04	3.15	0.01	<0.04	0.132	0.006	0.009	0.16
ICP834	Hope Downs 2	Newman	0.85	0.62	<0.002	<0.01	0.21	0.68	<0.2	0.12	0.58	0.03	<0.04	0.384	0.015	0.008	0.25
ICY761	Hope Downs 2	Newman	1.68	0.82	<0.002	0.01	0.18	2.02	0.3	0.34	2.15	0.04	<0.04	0.476	0.042	0.01	0.07
ICL327	Hope Downs 2	Newman	1.15	0.63	<0.002	0.01	0.16	1.01	<0.2	0.13	1.52	0.03	<0.04	0.344	0.027	0.013	0.09
ICL518	Hope Downs 2	Newman	0.63	0.73	<0.002	0.01	0.18	0.44	<0.2	0.09	1.04	0.01	<0.04	0.161	0.013	0.071	0.17
ICL787	Hope Downs 2	Newman	1.1	0.55	<0.002	0.01	0.17	0.83	0.2	0.13	0.72	0.01	<0.04	0.197	0.008	0.036	0.21
ICV072	Hope Downs 2	Newman	6.07	2.11	<0.002	0.03	1.25	8.01	1	0.45	21.8	0.07	<0.04	1.895	0.054	0.037	0.52
ICV158	Hope Downs 2	Newman	0.54	0.67	<0.002	<0.01	0.12	1.05	<0.2	0.07	0.34	0.01	<0.04	0.159	0.008	0.031	0.17
IEU414	Hope Downs 2	Newman	0.49	0.26	<0.002	0.01	0.19	0.37	<0.2	0.07	0.2	0.01	<0.04	0.152	0.008	0.007	0.09
ICY563	Hope Downs 2	MacLeod	5.62	0.25	<0.002	0.17	2.11	8.22	0.6	1.23	0.29	0.3	0.2	4.31	0.166	0.008	0.64
ICH905	Hope Downs 2	MacLeod	2.82	0.45	<0.002	0.07	0.92	1.56	0.2	0.17	0.14	0.04	0.06	0.55	0.027	<0.004	0.19
ICL281	Hope Downs 2	MacLeod	1.5	0.36	<0.002	0.01	0.3	1.87	0.3	0.16	2.2	0.03	<0.04	0.321	0.019	0.019	0.09
ICL766	Hope Downs 2	MacLeod	1.16	0.65	<0.002	0.01	0.18	1.29	<0.2	0.1	1.51	0.02	<0.04	0.197	0.009	0.121	0.12
ICV067	Hope Downs 2	MacLeod	1.6	2.46	<0.002	0.01	0.45	1.52	<0.2	0.48	3.2	0.08	<0.04	0.525	0.055	0.065	0.1
IDV159	Hope Downs 2	MacLeod	3.91	3.52	<0.002	0.07	1.69	6.58	2.6	1.18	14.35	0.16	0.1	2.87	0.116	0.04	0.49
ICW468	Hope Downs 2	MacLeod	5.41	2.06	<0.002	0.02	0.62	6.02	0.3	0.5	1.25	0.08	<0.04	0.731	0.087	0.035	0.18
ICI423	Hope Downs 2	Nammuldi	8.63	1.65	<0.002	0.05	1.27	32.4	1.2	1.82	2.25	0.23	0.23	1.785	0.232	0.039	0.38
IDR622	Hope Downs 2	Nammuldi	2.26	0.6	<0.002	0.01	0.2	1.44	<0.2	0.24	0.4	0.07	0.04	1.045	0.034	0.029	0.33
IEU280	Hope Downs 2	Nammuldi	3.11	1.88	<0.002	0.02	0.45	0.9	<0.2	0.17	2.75	0.03	<0.04	0.469	0.02	0.103	0.05

Note: Samples digested by 4 acid digest (normal font) and aqua regia digest (**BOLD** font)

DRAFT

Sample ID	Location	Lithology	V	W	Y	Zn	Zr	NO_2+NO_3 as N	TKN	Total N
			ppm	ppm	ppm	ppm	ppm	mg/kg	mg/kg	mg/kg
HWL255	Bedded Hilltop	Detritals	94.6	2.38	7.12	26.5	76.9	<0.1	30	30
IEZ059	Bedded Hilltop	Detritals	137.5	2.11	17.05	69.2	138	<0.1	60	60
IEX071	Bedded Hilltop	Detritals	62.6	5.34	22.4	135	141	0.2	<20	<20
IEX144	Bedded Hilltop	Detritals	65.3	2.18	18.6	5.7	78.8	<0.1	<20	<20
IDS997	Bedded Hilltop	Detritals	95.9	2.54	8.05	59.8	105	<0.1	<20	<20
ICX396	Hope Downs 2	Detritals	196	2.05	11.6	58.7	128	0.2	30	30
ICI037	Hope Downs 2	Detritals	107.5	1.595	5.44	20.1	107	<0.1	100	100
ICY932	Hope Downs 2	Detritals	186.5	2.01	14.2	370	122.5	0.2	<20	<20
IDR366	Hope Downs 2	Detritals	178	1.535	18.55	270	85.2	0.2	<20	<20
HST198	Hope Downs 2	Detritals	186	1.74	23.6	235	113	<0.1	<20	<20
ICW055	Hope Downs 2	Detritals	77.6	0.657	22.9	826	59.3	0.1	<20	<20
IEU297	Hope Downs 2	Detritals	155.5	1.545	11.35	184.5	90.9	0.1	20	20
ICW617	Hope Downs 2	Detritals	328	1.77	13.2	216	145	0.7	70	70
IET519	Hope Downs 2	Detritals	120	1.455	20.1	77.1	65.6	0.5	<20	<20
IDL399	Bedded Hilltop	Lignite	**69.6**	**0.584**	**9.76**	**23.2**	**30.1**	<0.1	3760	3760
IDL538	Bedded Hilltop	Lignite	**12.5**	**1.13**	**10.4**	**266**	**8.98**	<0.1	840	840
IDL765	Bedded Hilltop	Lignite	**29.9**	**0.55**	**22.1**	**155.5**	**10.75**	0.1	120	120
IER771	Bedded Hilltop	Lignite	**35.6**	**0.612**	**53.3**	**187**	**8.39**	<0.1	2940	2940
IEX186	Bedded Hilltop	Lignite	**37.2**	**0.557**	**56.4**	**545**	**7.81**	<0.1	4670	4670
IEX193	Bedded Hilltop	Lignite	**85.1**	**1.41**	**57**	**152.5**	**19.2**	<0.1	1720	1720
ICW891	Bedded Hilltop	Lignite	**20.4**	**0.583**	**16.85**	**100.5**	**6.88**	0.1	180	180
ICW899	Bedded Hilltop	Lignite	**42.1**	**0.878**	**55.7**	**664**	**17.7**	<0.1	1460	1460
ICV737	Bedded Hilltop	Lignite	59.7	3.16	16.05	1350	151.5	<0.5	160	160
ICV974	Bedded Hilltop	Lignite	**25.6**	**0.631**	**68.3**	**287**	**6.57**	<0.1	3060	3060
HWK433	Bedded Hilltop	Dales Gorge	9.6	0.733	4.65	21.1	11.9	0.8	<20	<20
HSS954	Bedded Hilltop	Dales Gorge	4.3	0.753	4.34	11.9	7.7	<0.1	<20	<20
HSS955	Bedded Hilltop	Dales Gorge	10.8	1.37	8.54	38	17.4	<0.1	<20	<20
IDQ084	Bedded Hilltop	Dales Gorge	5.8	1.015	5.82	19.1	5.7	<0.1	<20	<20
IER035	Bedded Hilltop	Dales Gorge	7.4	0.819	3.82	13.3	8.2	<0.1	<20	<20
IER036	Bedded Hilltop	Dales Gorge	6.1	1.15	3.71	12.3	5.6	<0.1	<20	<20
IER123	Bedded Hilltop	Dales Gorge	19	0.861	4.96	21.3	29.6	<0.1	<20	<20
IET896	Bedded Hilltop	Dales Gorge	75.3	5.24	4.76	16	142	<0.1	20	20
IEW193	Bedded Hilltop	Dales Gorge	8.3	0.617	5.49	18.5	9.2	<0.1	<20	<20
IEW194	Bedded Hilltop	Dales Gorge	7.4	0.528	4.68	17.4	6.8	<0.1	<20	<20
IEW862	Bedded Hilltop	Dales Gorge	7.5	3.32	6.7	23.9	8.1	0.5	<20	<20
IEW882	Bedded Hilltop	Dales Gorge	7.9	1.035	5.81	33.3	9.4	0.1	<20	<20
IEX556	Bedded Hilltop	Dales Gorge	9.2	1.22	5.67	17.1	8.2	<0.1	<20	<20
IEX557	Bedded Hilltop	Dales Gorge	7.1	0.803	5.24	15.6	6.5	<0.1	<20	<20
IGV835	Bedded Hilltop	Dales Gorge	31.1	0.852	8.18	78.5	39.2	<0.1	<20	<20
HWK820	Bedded Hilltop	FWZ	9.9	0.603	4.9	13.1	11.2	<0.1	<20	<20
IDL631	Bedded Hilltop	FWZ	10.9	0.523	10.65	58.1	14.2	<0.1	<20	<20
IER083	Bedded Hilltop	FWZ	7.1	1.37	8.51	36.2	6.2	<0.1	<20	<20
IER142	Bedded Hilltop	FWZ	9.5	1.36	6.97	120.5	12.7	<0.1	<20	<20
IEW143	Bedded Hilltop	FWZ	53.5	2.39	15.65	199.5	65	<0.1	<20	<20
IEZ446	Bedded Hilltop	FWZ	36.6	1.365	16.6	94.2	40.3	<0.1	<20	<20
ICW973	Bedded Hilltop	FWZ	25.8	1.375	22.7	166.5	33	<0.1	<20	<20
IEX525	Bedded Hilltop	FWZ	16.1	1.22	12	76	24.5	<0.1	<20	<20
IGV812	Bedded Hilltop	FWZ	14.3	1.39	8.15	112	12.2	<0.1	<20	<20
HWK845	Bedded Hilltop	MCS	111	4.72	36.8	340	145.5	0.4	610	610
HSS744	Bedded Hilltop	MCS	197.5	6.59	47.9	62.3	151	0.2	920	920
IDP446	Bedded Hilltop	MCS	150	4.16	16.45	15.5	115	<0.1	520	520
HWL294	Bedded Hilltop	MCS	23	1.7	25.1	73.4	119	<0.1	260	260
HWL551	Bedded Hilltop	MCS	98.4	2.03	11.95	102	66.3	<0.1	160	160
IER194	Bedded Hilltop	MCS	84.6	5.12	28.9	365	126	<0.1	880	880
IEZ598	Bedded Hilltop	MCS	99.6	5.38	22.4	319	150	<0.1	960	960
HWL528	Bedded Hilltop	MTS	80.9	3.1	20.6	64.5	47	<0.1	20	20
IDS102	Bedded Hilltop	MTS	98.2	1.845	8.83	8.1	55.6	<0.1	<20	<20
IEZ052	Bedded Hilltop	WF	2.2	0.255	5.57	8.9	2.4	<0.1	<20	<20
IET246	Bedded Hilltop	WF	28	0.782	12.6	21	26.9	0.4	50	50
IEZ176	Bedded Hilltop	WF	11.8	0.29	9.7	4.1	6.8	<0.1	<20	<20
IEZ199	Bedded Hilltop	WF	504	3.94	13.15	12.4	235	0.2	20	20
ICV792	Bedded Hilltop	WF	207	0.208	4.74	158	27	0.3	20	20
ICY501	Hope Downs 2	WF	66.8	1.69	84.4	65	78.1	0.3	30	30
ICX217	Hope Downs 2	WF	120.5	2.38	14.3	65.9	160	<0.1	60	60
HST001	Hope Downs 2	WF	204	1.545	5.32	243	125.5	2.2	30	30
ICY868	Hope Downs 2	WF	108.5	1	88.4	328	106	0.2	50	50
ICY871	Hope Downs 2	WF	118	1.27	91.3	256	127.5	0.3	80	80
ICL231	Hope Downs 2	WF	40.7	0.621	54.1	1635	36.4	0.2	40	40
IDR802	Hope Downs 2	WF	113	2.03	122	340	130.5	0.2	110	110
HST214	Hope Downs 2	WF	49.4	1.505	107.5	162	50.7	0.2	140	140
HST257	Hope Downs 2	WF	104.5	2.01	250	651	103	0.2	110	110
ICV188	Hope Downs 2	WF	15.8	1.035	12.9	300	7.2	0.2	<20	<20
ICV374	Hope Downs 2	WF	63	2	54.1	91.9	74.9	0.2	40	40
ICW087	Hope Downs 2	WF	74.2	3.33	31.2	959	101.5	<0.1	<20	<20
IEU427	Hope Downs 2	WF	92.7	1.895	15.6	74.5	90.6	<0.1	30	30
IEV694	Hope Downs 2	WF	7.1	0.642	5.75	256	6.8	0.1	<20	<20
IET547	Hope Downs 2	WF	87.2	2	92.1	79.2	135	0.8	80	80
ICI031	Hope Downs 2	Newman	2.7	0.398	3.62	14.8	2	<0.1	<20	<20
ICP834	Hope Downs 2	Newman	4.5	0.519	3.17	118.5	4.9	0.1	<20	<20
ICY761	Hope Downs 2	Newman	9.1	1.64	1.84	68.5	9.2	0.5	<20	<20
ICL327	Hope Downs 2	Newman	4.1	1.99	3.69	114.5	4.4	0.1	<20	<20
ICL518	Hope Downs 2	Newman	3.6	1.025	5.95	159.5	2.3	0.4	<20	<20
ICL787	Hope Downs 2	Newman	5.4	2.83	3.18	155	2.3	0.6	<20	<20
ICV072	Hope Downs 2	Newman	22.7	0.951	5.67	20.2	27.8	0.2	<20	<20
ICV158	Hope Downs 2	Newman	2.3	0.753	2.73	132.5	2	<0.1	<20	<20
IEU414	Hope Downs 2	Newman	2.5	1.66	1.36	6.2	2.1	<0.1	<20	<20
ICY563	Hope Downs 2	MacLeod	55.7	1.01	7.81	36.6	59	0.7	<20	<20
ICH905	Hope Downs 2	MacLeod	8.7	0.46	3.28	14.4	7.9	<0.1	<20	<20
ICL281	Hope Downs 2	MacLeod	7	1.05	3.71	46.9	5.1	<0.1	<20	<20
ICL766	Hope Downs 2	MacLeod	3.9	2.12	4.92	156.5	2.8	0.2	<20	<20
ICV067	Hope Downs 2	MacLeod	10	1.185	2.18	80	14.5	0.1	<20	<20
IDV159	Hope Downs 2	MacLeod	43.5	0.65	4.89	41.7	41.5	0.2	20	20
ICW468	Hope Downs 2	MacLeod	23.8	2.13	3.38	151	16.1	0.1	<20	<20
ICI423	Hope Downs 2	Nammuldi	50.2	0.566	5.32	110.5	52.1	<0.1	<20	<20
IDR622	Hope Downs 2	Nammuldi	8.3	2.42	2.58	8.5	13.5	<0.1	<20	<20
IEU280	Hope Downs 2	Nammuldi	13.7	2.64	6.29	70.7	5.4	<0.5	<20	<20

Note: Samples digested by 4 acid digest (normal font) and aqua regia digest (**BOLD** font); NO_2 - Nitrite; NO_3 - Nitrate, TKN - Total Kjeldahl Nitrogen.

DRAFT

GAI Data

Sample ID	Location	Lithology	Ag	As	B	Bi	Cd	Hg	Mn	Re	S	Sb	Se	Te	Tl	Zn
HWL255	Bedded Hilltop	Detritals	0	6	0	3	0	0	0	1	0	4	4	6	0	0
IEZ059	Bedded Hilltop	Detritals	0	3	1	2	0	0	0	1	0	3	3	4	0	0
IEX071	Bedded Hilltop	Detritals	0	6	2	2	2	4	0	1	0	3	3	3	0	0
IEX144	Bedded Hilltop	Detritals	0	3	2	1	0	0	0	1	0	2	3	4	0	0
IDS997	Bedded Hilltop	Detritals	0	6	1	3	0	0	0	1	0	4	4	5	0	0
ICX396	Hope Downs 2	Detritals	0	4	1	2	0	0	0	1	0	3	4	6	0	0
ICI037	Hope Downs 2	Detritals	0	4	1	2	0	0	0	1	0	3	5	6	0	0
ICY932	Hope Downs 2	Detritals	0	5	1	3	0	0	0	1	0	3	3	5	0	1
IDR366	Hope Downs 2	Detritals	0	4	0	2	0	0	0	1	0	3	3	6	0	1
HST198	Hope Downs 2	Detritals	0	5	1	3	0	0	0	1	0	4	3	6	0	1
ICW055	Hope Downs 2	Detritals	0	2	0	1	2	0	0	1	0	2	1	4	0	2
IEU297	Hope Downs 2	Detritals	0	4	1	2	0	0	0	1	0	3	2	6	0	0
ICW617	Hope Downs 2	Detritals	1	3	1	2	0	0	0	1	0	2	3	5	0	0
IET519	Hope Downs 2	Detritals	0	4	0	2	0	0	0	1	0	3	2	4	0	0
IDL399	Bedded Hilltop	Lignite	2	3	4	4	2	6	0	2	6	4	8	7	0	0
IDL538	Bedded Hilltop	Lignite	0	9	3	1	4	5	0	5	8	0	6	3	0	1
IDL765	Bedded Hilltop	Lignite	0	3	3	2	3	5	0	2	7	1	6	3	0	0
IER771	Bedded Hilltop	Lignite	0	6	3	2	3	5	0	4	7	1	6	3	0	0
IEX186	Bedded Hilltop	Lignite	0	3	<3	2	5	4	0	4	7	1	5	3	0	2
IEX193	Bedded Hilltop	Lignite	0	4	3	2	3	4	0	3	6	1	7	4	0	0
ICW891	Bedded Hilltop	Lignite	0	3	<3	2	2	4	0	3	7	1	5	3	0	0
ICW899	Bedded Hilltop	Lignite	0	4	3	3	3	5	0	5	7	3	7	5	4	2
ICV737	Bedded Hilltop	Lignite	1	4	1	3	3	0	0	5	5	4	4	6	3	3
ICV974	Bedded Hilltop	Lignite	0	3	<3	1	4	4	0	3	6	1	5	3	0	1
HWK433	Bedded Hilltop	Dales Gorge	0	1	0	0	0	0	0	1	0	0	1	2	0	0
HSS954	Bedded Hilltop	Dales Gorge	0	2	0	0	0	0	0	1	0	0	1	2	0	0
HSS955	Bedded Hilltop	Dales Gorge	0	2	0	2	0	0	0	1	0	2	1	4	0	0
IDQ084	Bedded Hilltop	Dales Gorge	0	2	0	0	0	0	0	1	0	0	1	2	0	0
IER035	Bedded Hilltop	Dales Gorge	0	2	0	0	0	0	0	1	0	0	1	2	0	0
IER036	Bedded Hilltop	Dales Gorge	0	1	0	0	0	0	0	1	0	0	1	2	0	0
IER123	Bedded Hilltop	Dales Gorge	0	1	0	0	0	0	0	1	0	0	2	3	0	0
IET896	Bedded Hilltop	Dales Gorge	0	3	1	5	0	0	0	1	1	3	4	5	0	0
IEW193	Bedded Hilltop	Dales Gorge	0	0	0	0	0	0	0	1	0	0	1	2	0	0
IEW194	Bedded Hilltop	Dales Gorge	0	0	0	0	0	0	0	1	0	0	1	2	0	0
IEW862	Bedded Hilltop	Dales Gorge	0	0	0	0	0	0	0	1	0	0	2	2	0	0
IEW882	Bedded Hilltop	Dales Gorge	0	1	0	0	0	0	0	1	0	0	4	2	0	0
IEX556	Bedded Hilltop	Dales Gorge	0	1	0	0	0	0	0	1	0	0	2	2	0	0
IEX557	Bedded Hilltop	Dales Gorge	0	1	0	0	0	0	0	1	0	0	1	2	0	0
IGV835	Bedded Hilltop	Dales Gorge	0	3	0	0	0	0	0	1	0	0	1	3	0	0
HWK820	Bedded Hilltop	FWZ	0	2	0	0	0	0	0	1	0	0	2	2	0	0
IDL631	Bedded Hilltop	FWZ	0	2	0	0	0	0	0	1	0	0	1	2	0	0
IER083	Bedded Hilltop	FWZ	0	2	0	0	0	0	0	1	0	0	2	2	0	0
IER142	Bedded Hilltop	FWZ	0	4	0	0	0	0	0	1	0	1	2	2	0	0
IEW143	Bedded Hilltop	FWZ	0	5	0	2	0	0	1	1	2	3	5	5	0	0
IEZ446	Bedded Hilltop	FWZ	0	4	1	1	0	0	0	1	1	2	2	4	0	0
ICW973	Bedded Hilltop	FWZ	0	5	0	0	0	0	0	1	0	2	1	3	0	0
IEX525	Bedded Hilltop	FWZ	0	4	0	0	0	0	0	1	0	1	3	2	0	0
IGV812	Bedded Hilltop	FWZ	0	7	0	0	0	0	0	1	0	2	3	2	0	0
HWK845	Bedded Hilltop	MCS	0	5	1	3	0	0	0	1	0	4	2	5	0	1
HSS744	Bedded Hilltop	MCS	0	4	2	3	0	0	0	1	0	4	4	5	0	0
IDP446	Bedded Hilltop	MCS	3	7	1	3	0	0	0	1	0	4	5	5	0	0
HWL294	Bedded Hilltop	MCS	0	5	0	2	1	0	0	1	0	2	4	4	0	0
HWL551	Bedded Hilltop	MCS	0	8	0	3	0	0	0	1	0	4	7	7	0	0
IER194	Bedded Hilltop	MCS	0	4	2	3	0	0	0	1	0	3	3	5	0	1
IEZ598	Bedded Hilltop	MCS	0	8	2	3	0	0	0	1	0	4	3	5	0	1
HWL528	Bedded Hilltop	MTS	0	4	0	2	3	1	0	1	0	2	2	4	0	0
IDS102	Bedded Hilltop	MTS	2	4	0	3	0	0	0	1	0	3	5	5	0	0
IEZ052	Bedded Hilltop	WF	0	1	<3	0	0	0	1	1	0	0	2	2	0	0
IET246	Bedded Hilltop	WF	0	1	<3	1	0	0	1	1	0	1	2	2	0	0
IEZ176	Bedded Hilltop	WF	0	1	<3	0	0	0	0	1	0	0	2	2	0	0
IEZ199	Bedded Hilltop	WF	0	5	2	4	0	0	0	1	0	6	3	6	0	0
ICV792	Bedded Hilltop	WF	0	2	0	0	0	0	0	1	2	1	2	2	0	0
ICY501	Hope Downs 2	WF	0	3	0	2	0	0	0	1	0	3	1	4	0	0
ICX217	Hope Downs 2	WF	0	4	2	3	0	0	1	1	0	4	4	5	0	0
HST001	Hope Downs 2	WF	0	3	1	3	0	0	0	1	0	4	4	5	0	1
ICY868	Hope Downs 2	WF	0	4	0	2	1	0	5	1	0	3	2	4	0	1
ICY871	Hope Downs 2	WF	0	4	0	3	1	0	5	1	0	4	2	4	0	1
ICL231	Hope Downs 2	WF	0	0	<3	1	3	0	1	1	0	1	2	3	0	3
IDR802	Hope Downs 2	WF	0	4	1	3	2	0	5	1	0	3	2	4	0	1
HST214	Hope Downs 2	WF	0	3	0	2	4	2	5	1	0	2	3	4	0	0
HST257	Hope Downs 2	WF	0	3	1	3	3	0	4	1	0	3	2	4	0	2
ICV188	Hope Downs 2	WF	0	1	0	0	1	0	1	1	0	1	1	2	0	1
ICV374	Hope Downs 2	WF	0	3	0	2	0	0	4	1	0	2	2	3	0	0
ICW087	Hope Downs 2	WF	0	4	1	3	1	0	1	1	0	3	2	3	0	3
IEU427	Hope Downs 2	WF	0	4	1	2	0	0	0	1	0	4	3	4	0	0
IEV694	Hope Downs 2	WF	0	0	0	0	0	0	0	1	0	0	1	2	0	1
IET547	Hope Downs 2	WF	0	3	1	3	0	0	5	1	0	3	2	5	0	0
ICI031	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICP834	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICY761	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	2	2	0	0
ICL327	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICL518	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICL787	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICV072	Hope Downs 2	Newman	0	2	0	0	0	0	0	1	0	2	3	2	0	0
ICV158	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
IEU414	Hope Downs 2	Newman	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICY563	Hope Downs 2	MacLeod	0	2	0	1	0	0	0	1	2	2	3	4	0	0
ICH905	Hope Downs 2	MacLeod	0	1	0	0	0	0	0	1	0	1	1	3	0	0
ICL281	Hope Downs 2	MacLeod	0	0	0	0	0	0	0	1	0	0	2	2	0	0
ICL766	Hope Downs 2	MacLeod	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ICV067	Hope Downs 2	MacLeod	0	0	0	0	0	0	0	1	0	0	1	2	0	0
IDV159	Hope Downs 2	MacLeod	0	2	1	0	0	0	0	1	0	2	5	3	0	0
ICW468	Hope Downs 2	MacLeod	0	1	0	0	0	0	0	1	0	1	2	2	0	0
ICI423	Hope Downs 2	Nammuldi	0	0	0	1	0	0	0	1	0	2	4	4	0	0
IDR622	Hope Downs 2	Nammuldi	0	0	0	0	0	0	0	1	0	0	1	2	0	0
IEU280	Hope Downs 2	Nammuldi	0	0	0	0	0	0	0	1	0	0	1	2	0	0

Note: Elements that are enriched (GAI ≥3) are shown in shaded cells

DRAFT

Appendix G: Leach Test Data

DRAFT

Static Deionised Water Leach Data

Sample ID	Location	Lithology	pH	EC	Tot Alk	Acidity	SO_4	Cl	F	SiO_2	Ag	Al	As	Ba	Be	Bi	Ca
				µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HWL255	Bedded Hilltop	Detritals	6.29	148	3	3	30	15	0.4	20.6	<0.0001	0.034	0.0004	0.705	<0.0001	<0.00005	3
IEX071	Bedded Hilltop	Detritals	7.48	194	47	2	34	14	1.7	11.7	0.0001	0.069	0.0028	1.08	<0.0001	<0.00005	6
ICI037	Hope Downs 2	Detritals	7.53	154	40	1	10	9	0.5	15.5	<0.0001	0.186	0.0011	0.838	<0.0001	<0.00005	8
IDL538	Bedded Hilltop	Lignite	1.88	24900	<1	22900	28600	<20	<0.1	13.1	<0.0001	596	25.9	0.23	0.302	0.0001	399
ICV737	Bedded Hilltop	Lignite	2.33	8430	<1	7680	9640	<20	<0.1	7.25	0.0007	89.2	6.8	0.0668	0.053	<0.00005	48
IEX186	Bedded Hilltop	Lignite	4.55	4050	<1	64	3200	74	0.5	6.88	0.0001	1.97	0.056	0.258	0.0055	<0.00005	464
IDL399	Bedded Hilltop	Lignite	5.7	2610	7	8	1620	66	0.3	9.25	<0.0001	0.387	0.0188	0.0336	<0.0001	<0.00005	245
IET896	Bedded Hilltop	Dales Gorge	6.22	490	3	4	167	38	0.1	43.9	<0.0001	<0.005	0.001	0.702	<0.0001	<0.00005	8
IGV835	Bedded Hilltop	Dales Gorge	6.62	85	4	2	8	13	0.3	16	<0.0001	0.061	0.0002	0.171	<0.0001	<0.00005	<1
IEW143	Bedded Hilltop	FWZ	5.36	1860	<1	14	425	366	0.8	35.6	<0.0001	0.787	0.0004	0.522	0.0029	<0.00005	24
IGV812	Bedded Hilltop	FWZ	6.56	78	5	2	11	8	0.2	13.5	<0.0001	0.034	0.0006	0.801	<0.0001	<0.00005	2
ICY563	Hope Downs 2	MacLeod	5.9	1170	2	5	173	277	0.1	30.6	<0.0001	0.017	0.0007	0.877	<0.0001	<0.00005	10
IDV159	Hope Downs 2	MacLeod	7.67	93	33	1	5	3	0.5	29.4	<0.0001	0.224	0.0007	0.694	<0.0001	<0.00005	7
IDP446	Bedded Hilltop	MCS	6.11	404	3	3	86	55	0.3	6.26	<0.0001	0.075	0.0022	1.19	0.0001	<0.00005	10
IEZ598	Bedded Hilltop	MCS	6.79	1140	9	2	137	229	3.6	5.96	<0.0001	0.029	0.0021	0.825	<0.0001	<0.00005	24
HWL551	Bedded Hilltop	MCS	6.87	297	14	2	56	30	1.9	9.01	<0.0001	0.145	0.0012	0.825	<0.0001	<0.00005	7
IDS102	Bedded Hilltop	MTS	6.48	244	6	2	45	27	1	10.4	<0.0001	0.022	0.0006	0.984	<0.0001	<0.00005	7
HWL528	Bedded Hilltop	MTS	6.63	132	8	2	14	16	0.5	9.22	<0.0001	0.037	0.0006	0.655	<0.0001	<0.00005	5
ICI423	Hope Downs 2	Nammuldi	6.51	301	4	2	83	28	0.9	18.2	<0.0001	0.019	0.0003	0.89	<0.0001	<0.00005	8
ICV072	Hope Downs 2	Newman	7.81	184	61	<1	9	9	0.8	31.9	<0.0001	0.013	0.0029	0.405	<0.0001	<0.00005	6
ICX217	Hope Downs 2	WF	5.7	313	2	15	38	55	0.2	37.5	<0.0001	0.118	<0.0002	1.5	<0.0001	<0.00005	2
HST257	Hope Downs 2	WF	7.04	426	22	2	80	54	0.6	12.1	<0.0001	0.013	0.0008	1.2	<0.0001	<0.00005	20
HST214	Hope Downs 2	WF	7.36	375	81	1	38	26	0.9	6.22	<0.0001	<0.005	0.0016	1.02	<0.0001	<0.00005	19
ICW087	Hope Downs 2	WF	7.37	1580	36	2	385	282	1.1	9.78	0.0001	0.015	0.0005	0.638	<0.0001	<0.00005	67
IEZ199	Bedded Hilltop	WF	7.43	559	154	<1	39	40	0.4	16.6	<0.0001	<0.005	0.0017	1.13	0.0002	<0.00005	24

Sample ID	Location	Lithology	Cd	Ce	Co	Cr	Cs	Cu	Fe	Ga	Hf	Hg	K	La	Li	Mg	Mn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HWL255	Bedded Hilltop	Detritals	0.0002	<0.001	0.0007	<0.0002	<0.001	<0.0005	0.012	<0.001	<0.01	<0.0001	2	<0.001	0.0032	4	0.0325
IEX071	Bedded Hilltop	Detritals	0.00018	<0.001	0.0008	0.0016	<0.001	0.002	1.2	<0.001	<0.01	<0.0001	4	<0.001	0.0041	7	0.0035
ICI037	Hope Downs 2	Detritals	0.00031	<0.001	0.0001	0.0003	<0.001	0.0008	0.29	<0.001	<0.01	<0.0001	3	<0.001	0.0017	4	0.0056
IDL538	Bedded Hilltop	Lignite	0.734	6.5	6.88	0.874	0.026	0.084	12200	0.53	<0.05	<0.0001	3	2.12	0.639	122	9.44
ICV737	Bedded Hilltop	Lignite	1.08	0.116	33.4	0.514	0.002	11.1	3310	0.045	<0.01	<0.0005	1	0.03	0.0782	31	53.8
IEX186	Bedded Hilltop	Lignite	0.0395	0.058	0.356	0.0011	<0.001	0.0058	8.1	0.001	<0.01	<0.0001	12	0.03	0.006	394	13.8
IDL399	Bedded Hilltop	Lignite	0.00103	<0.001	0.0025	0.0012	<0.001	0.0132	0.092	<0.001	<0.01	<0.0001	9	<0.001	0.0065	262	1.43
IET896	Bedded Hilltop	Dales Gorge	0.0005	<0.001	0.0072	<0.0002	<0.001	0.0023	0.01	<0.001	<0.01	<0.0001	7	<0.001	0.0033	22	0.589
IGV835	Bedded Hilltop	Dales Gorge	<0.00005	<0.001	<0.0001	<0.0002	<0.001	<0.0005	0.25	<0.001	<0.01	<0.0001	<1	<0.001	0.0012	<1	0.0023
IEW143	Bedded Hilltop	FWZ	0.00073	0.004	0.0108	<0.0002	<0.001	0.0016	0.029	<0.001	<0.01	<0.0001	23	<0.001	0.0211	69	1.8
IGV812	Bedded Hilltop	FWZ	0.00025	<0.001	<0.0001	<0.0002	<0.001	<0.0005	0.102	<0.001	<0.01	<0.0001	<1	<0.001	0.0007	2	0.0104
ICY563	Hope Downs 2	MacLeod	0.00053	<0.001	0.0007	<0.0002	<0.001	0.017	0.01	<0.001	<0.01	<0.0001	16	<0.001	0.0012	49	0.205
IDV159	Hope Downs 2	MacLeod	0.00009	<0.001	0.0001	0.0004	<0.001	0.0007	1.72	<0.001	<0.01	<0.0001	2	<0.001	0.0022	2	0.0014
IDP446	Bedded Hilltop	MCS	0.0006	0.002	0.0138	0.0006	<0.001	0.0099	0.031	<0.001	<0.01	<0.0001	12	<0.001	0.0096	14	0.273
IEZ598	Bedded Hilltop	MCS	0.00059	<0.001	0.0001	<0.0002	<0.001	<0.0005	0.007	<0.001	<0.01	<0.0001	14	<0.001	0.0016	51	0.004
HWL551	Bedded Hilltop	MCS	0.00033	<0.001	0.0006	<0.0002	<0.001	0.0008	0.059	<0.001	<0.01	<0.0001	6	<0.001	0.0035	7	0.0153
IDS102	Bedded Hilltop	MTS	0.00033	<0.001	<0.0001	<0.0002	<0.001	0.0006	0.005	<0.001	<0.01	<0.0001	2	<0.001	0.0007	10	0.0182
HWL528	Bedded Hilltop	MTS	0.00085	<0.001	0.013	<0.0002	<0.001	0.0011	0.01	<0.001	<0.01	<0.0001	1	<0.001	0.0091	5	0.331
ICI423	Hope Downs 2	Nammuldi	0.00028	<0.001	0.0002	<0.0002	<0.001	<0.0005	0.025	<0.001	<0.01	<0.0001	1	<0.001	0.0019	10	0.0094
ICV072	Hope Downs 2	Newman	0.00005	<0.001	0.0001	<0.0002	<0.001	0.001	0.104	<0.001	<0.01	<0.0001	1	<0.001	<0.0005	3	0.0041
ICX217	Hope Downs 2	WF	0.00079	<0.001	0.0058	<0.0002	<0.001	0.002	5.46	<0.001	<0.01	<0.0001	8	<0.001	0.0048	3	0.199
HST257	Hope Downs 2	WF	0.0005	<0.001	0.0003	0.0016	<0.001	0.0042	0.002	<0.001	<0.01	<0.0001	4	<0.001	0.0008	14	0.0019
HST214	Hope Downs 2	WF	0.00045	<0.001	0.0007	0.0012	<0.001	0.0026	0.035	<0.001	<0.01	<0.0001	2	<0.001	0.0023	21	0.353
ICW087	Hope Downs 2	WF	0.00056	<0.001	<0.0001	0.0003	<0.001	<0.0005	<0.002	<0.001	<0.01	<0.0001	10	<0.001	0.0035	61	0.0011
IEZ199	Bedded Hilltop	WF	0.00046	<0.001	0.006	0.0004	<0.001	0.0017	0.025	<0.001	<0.01	<0.0001	6	<0.001	0.0011	24	0.389

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Notes: Tot Alk - Total Alkalinity; Acidity as CaCO3; TKN - Total Kjeldahl Nitrogen.

Sample ID	Location	Lithology	Mo	Na	Nb	Ni	P	Pb	Rb	Sb	Se	Sn	Sr	Ta	Te	Th	Ti
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HWL255	Bedded Hilltop	Detritals	<0.0001	14	<0.001	0.0024	<0.01	<0.0001	0.002	<0.0002	0.0028	<0.0002	0.019	<0.001	<0.0002	<0.001	<0.001
IEX071	Bedded Hilltop	Detritals	0.0007	23	<0.001	0.0024	0.02	0.0001	0.002	0.0004	0.0135	<0.0002	0.024	<0.001	<0.0002	<0.001	<0.001
ICI037	Hope Downs 2	Detritals	0.0018	15	<0.001	0.0006	<0.01	0.0001	0.002	0.0008	0.0004	<0.0002	0.057	<0.001	<0.0002	<0.001	0.004
IDL538	Bedded Hilltop	Lignite	0.0021	17	<0.005	19.1	8.57	0.255	0.08	0.0006	0.063	0.007	0.523	0.006	0.0005	0.276	4.38
ICV737	Bedded Hilltop	Lignite	0.0344	5	<0.001	85	3.1	0.0512	0.007	0.0189	0.146	<0.0002	0.129	<0.001	0.0039	0.256	0.024
IEX186	Bedded Hilltop	Lignite	<0.0001	45	<0.001	0.266	0.02	0.0036	0.03	0.001	0.0081	<0.0002	0.669	<0.001	<0.0002	<0.001	0.001
IDL399	Bedded Hilltop	Lignite	0.0012	60	<0.001	0.0022	0.03	0.0012	0.013	0.004	0.114	<0.0002	0.245	<0.001	0.001	<0.001	<0.001
IET896	Bedded Hilltop	Dales Gorge	<0.0001	39	<0.001	0.0302	0.04	0.0001	0.007	<0.0002	0.0054	<0.0002	0.047	<0.001	<0.0002	<0.001	<0.001
IGV835	Bedded Hilltop	Dales Gorge	<0.0001	8	<0.001	<0.0005	<0.01	<0.0001	<0.001	<0.0002	0.0005	<0.0002	0.012	<0.001	<0.0002	<0.001	0.001
IEW143	Bedded Hilltop	FWZ	<0.0001	216	<0.001	0.0355	0.02	0.0005	0.021	<0.0002	0.0005	<0.0002	0.475	<0.001	<0.0002	<0.001	<0.001
IGV812	Bedded Hilltop	FWZ	<0.0001	8	<0.001	0.0006	0.02	<0.0001	<0.001	<0.0002	0.0005	<0.0002	0.013	<0.001	<0.0002	<0.001	<0.001
ICY563	Hope Downs 2	MacLeod	<0.0001	118	<0.001	0.0038	0.01	0.0028	0.02	<0.0002	0.0006	<0.0002	0.1	<0.001	<0.0002	<0.001	<0.001
IDV159	Hope Downs 2	MacLeod	0.0013	13	<0.001	0.0007	<0.01	0.0001	0.002	0.0004	0.0006	<0.0002	0.075	<0.001	<0.0002	<0.001	0.006
IDP446	Bedded Hilltop	MCS	<0.0001	30	<0.001	0.0395	0.02	0.0002	0.006	<0.0002	0.0057	<0.0002	0.039	<0.001	<0.0002	<0.001	<0.001
IEZ598	Bedded Hilltop	MCS	0.0004	107	<0.001	0.0005	<0.01	<0.0001	0.012	0.0003	0.0021	<0.0002	0.195	<0.001	<0.0002	<0.001	<0.001
HWL551	Bedded Hilltop	MCS	0.0002	33	<0.001	0.0012	<0.01	0.0001	0.004	<0.0002	0.0017	<0.0002	0.043	<0.001	<0.0002	<0.001	0.002
IDS102	Bedded Hilltop	MTS	0.0008	20	<0.001	0.0006	<0.01	<0.0001	0.002	0.0002	0.002	<0.0002	0.034	<0.001	<0.0002	<0.001	0.003
HWL528	Bedded Hilltop	MTS	0.0003	10	<0.001	0.026	<0.01	<0.0001	0.001	0.0005	0.0003	<0.0002	0.019	<0.001	<0.0002	<0.001	<0.001
ICI423	Hope Downs 2	Nammuldi	<0.0001	30	<0.001	0.001	<0.01	<0.0001	0.001	<0.0002	0.0012	<0.0002	0.066	<0.001	<0.0002	<0.001	<0.001
ICV072	Hope Downs 2	Newman	0.0027	26	<0.001	0.0016	0.04	<0.0001	0.001	0.0006	0.001	<0.0002	0.051	<0.001	<0.0002	<0.001	<0.001
ICX217	Hope Downs 2	WF	<0.0001	39	<0.001	0.0067	<0.01	0.0003	0.008	<0.0002	0.0006	<0.0002	0.038	<0.001	<0.0002	<0.001	<0.001
HST257	Hope Downs 2	WF	<0.0001	30	<0.001	0.0006	<0.01	0.0002	0.002	<0.0002	0.0016	<0.0002	0.07	<0.001	<0.0002	<0.001	<0.001
HST214	Hope Downs 2	WF	0.0002	21	<0.001	0.0141	<0.01	0.0002	0.002	<0.0002	0.0008	<0.0002	0.011	<0.001	<0.0002	<0.001	<0.001
ICW087	Hope Downs 2	WF	0.0025	135	<0.001	0.0008	<0.01	<0.0001	0.011	0.0005	0.0011	<0.0002	0.401	<0.001	<0.0002	<0.001	<0.001
IEZ199	Bedded Hilltop	WF	0.0008	44	<0.001	0.155	<0.01	0.0002	0.01	0.0021	0.0008	<0.0002	0.108	<0.001	<0.0002	<0.001	<0.001

Sample ID	Location	Lithology	Tl	U	V	W	Y	Zn	Zr	B	TKN	TN	NH_3 as N	NO_2 as N	NO_3 as N	NO_2+NO_3 as N
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HWL255	Bedded Hilltop	Detritals	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.08	<0.005	0.263	<0.1	<0.1	0.06	<0.01	<0.01	<0.01
IEX071	Bedded Hilltop	Detritals	<0.00002	0.00006	0.0006	<0.001	<0.001	0.049	<0.005	0.329	0.2	0.3	<0.01	0.09	0.04	0.13
ICI037	Hope Downs 2	Detritals	<0.00002	<0.00005	0.0005	<0.001	<0.001	0.086	<0.005	0.187	<0.1	<0.1	0.04	<0.01	0.04	0.04
IDL538	Bedded Hilltop	Lignite	0.0266	0.316	4.15	<0.005	3.46	111	0.106	0.984	2.1	3.4	<5	0.81	0.47	1.28
ICV737	Bedded Hilltop	Lignite	0.0064	0.538	1.47	<0.001	0.218	703	0.108	0.778	0.4	1.2	<2.5	<1	<1	0.76
IEX186	Bedded Hilltop	Lignite	0.00124	0.00013	0.0024	<0.001	0.019	6.36	<0.005	2.21	0.2	0.2	<0.01	<0.01	0.01	0.01
IDL399	Bedded Hilltop	Lignite	<0.00002	<0.00005	0.0068	<0.001	<0.001	1.12	<0.005	3.06	0.6	0.7	0.18	<0.01	0.06	0.06
IET896	Bedded Hilltop	Dales Gorge	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.402	<0.005	0.487	<0.1	<0.1	0.05	<0.01	0.01	0.01
IGV835	Bedded Hilltop	Dales Gorge	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.031	<0.005	0.055	<0.1	<0.1	0.06	<0.01	0.02	0.02
IEW143	Bedded Hilltop	FWZ	0.00013	0.00068	<0.0002	<0.001	0.002	1.11	<0.005	0.797	<0.1	<0.1	0.06	<0.01	<0.01	<0.01
IGV812	Bedded Hilltop	FWZ	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.08	<0.005	0.114	0.1	0.1	0.04	<0.01	<0.01	<0.01
ICY563	Hope Downs 2	MacLeod	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.644	<0.005	0.436	0.2	0.5	0.1	<0.01	0.26	0.26
IDV159	Hope Downs 2	MacLeod	<0.00002	<0.00005	0.0006	<0.001	<0.001	0.028	<0.005	0.316	<0.1	<0.1	0.03	<0.01	<0.01	<0.01
IDP446	Bedded Hilltop	MCS	<0.00002	0.00072	<0.0002	<0.001	0.002	0.702	<0.005	0.473	0.1	0.1	0.07	<0.01	0.02	0.02
IEZ598	Bedded Hilltop	MCS	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.161	<0.005	0.471	<0.1	<0.1	0.04	<0.01	<0.01	<0.01
HWL551	Bedded Hilltop	MCS	<0.00002	<0.00005	0.0002	<0.001	<0.001	0.118	<0.005	0.298	<0.1	<0.1	0.08	0.01	0.01	0.02
IDS102	Bedded Hilltop	MTS	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.059	<0.005	0.184	<0.1	<0.1	0.02	<0.01	<0.01	<0.01
HWL528	Bedded Hilltop	MTS	<0.00002	<0.00005	0.0003	<0.001	<0.001	0.066	<0.005	0.196	<0.1	<0.1	0.05	<0.01	0.01	0.01
ICI423	Hope Downs 2	Nammuldi	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.075	<0.005	0.297	<0.1	<0.1	0.04	<0.01	<0.01	<0.01
ICV072	Hope Downs 2	Newman	<0.00002	0.00013	0.0008	0.001	<0.001	0.006	<0.005	0.156	0.1	0.1	0.01	<0.01	<0.01	<0.01
ICX217	Hope Downs 2	WF	<0.00002	0.00041	<0.0002	<0.001	<0.001	1.39	<0.005	0.745	<0.1	<0.1	0.06	<0.01	0.02	0.02
HST257	Hope Downs 2	WF	<0.00002	<0.00005	<0.0002	<0.001	<0.001	0.091	<0.005	0.285	<0.1	<0.1	<0.01	<0.01	<0.01	<0.01
HST214	Hope Downs 2	WF	0.00002	<0.00005	<0.0002	<0.001	<0.001	0.196	<0.005	0.267	<0.1	<0.1	0.02	0.02	0.01	0.03
ICW087	Hope Downs 2	WF	<0.00002	0.00007	<0.0002	<0.001	<0.001	0.097	<0.005	0.374	<0.1	<0.1	0.05	<0.01	<0.01	<0.01
IEZ199	Bedded Hilltop	WF	0.00014	0.00081	0.0002	<0.001	<0.001	0.199	<0.005	0.375	<0.1	<0.1	0.07	0.03	0.04	0.07

Notes: Tot Alk - Total Alkalinity; Acidity as CaCO3; TKN - Total Kjeldahl Nitrogen.

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Name/Title	Company
Steven Lee	Rio Tinto Iron Ore

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Appendix 11: SCARD Management Plan

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Iron Ore (WA)

Spontaneous Combustion and ARD (SCARD) Management Plan

for Operations

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1 Purpose

The Spontaneous Combustion and Acid Rock Drainage (SCARD) Management Plan for operations outline the activities and groups accountable for the management of the environmental, safety, health, reputational and business risks associated with:

- Black shale
- Sulfidic material within detritals
- Sulfidic material within Banded Iron Formation (BIF)
- Elevated-sulfur material within shale, waste and ore.

Due to differing risks, the management of sulfides within black shale has been delineated from that associated with sulfides within detritals and BIF, and material containing sulfates.

This plan enables the development and implementation of appropriate risk reduction measures to lower risk. It sets and implements the appropriate monitoring plans that quantify the actual impacts and compares them with that predicted, to determine if risk reduction methods have been effective.

2 Definitions

2.1 Abbreviations

ABA	Acid Base Accounting
AMD	Acid and Metalliferous Drainage
ANC	Acid Neutralising Potential
ARD	Acid Rock Drainage
BIF	Banded Iron Formation
BS	Black Shale
DG	Dales Gorge Member
FWZ	Footwall Zone
MCS	Mount McRae Shale
NAF	Non-Acid Forming
PAF	Potentially Acid Forming (including black shale and sulfides in BIF and detritals)
SWP	Safe Work Practice
WS	Whaleback Shale Member

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2.2 Hazards Definitions

The risks associated with black shale, BIF and detritals are triggered by the presence of sulfides, in particular pyrite (FeS_2) within these material types. Pyrite will remain stable if constantly water-saturated with no exposure to oxygen or ferric iron. Alunite ($KAl_3(SO_4)_2(OH)_6$) and jarosite ($KFe_3(SO_4)_2(OH)_6$) have been identified in AWT waste and ore. When excavated during mining, pyrite can oxidise and sulfate minerals dissolve and generate the following risks to the operation:

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ARD (also known as Acid and Metalliferous Drainage (AMD))

The process of pyrite oxidation results in the release of dissolved acidity, sulfate, iron and other metal ions into drainage waters. The acidic conditions can often induce weathering of clay minerals in the host material and also release dissolved metals such as aluminium, manganese, zinc and/or copper into the drainage. The Acid Neutralising Capacity (ANC) of many of the other waste materials in the Hamersley Group is low and insufficient to neutralise the acidity released from most pyritic waste rocks.

Alunite weathers to an aluminium oxyhydroxide phase (e.g. gibbsite or boehmite, etc.) via dissolution; it can produce acid and buffer the pH in the region of 4.0 to 4.5. The rate of acid release is low and the acidity can be neutralised by any minerals that have the capacity to consume acid.

Risk Areas: Contamination of surface and/or ground water and soil, and potential disturbance to surrounding ecosystems from ARD generated within waste rock dumps and pits or voids. Potential health risks from direct handling or accidental consumption of ARD products.

Premature Blast Detonation

Spontaneous combustion is a major safety concern to RTIO (WA) due to the risk of reaction with explosives in loaded blast holes potentially leading to premature detonation. Ammonium nitrate (NH_4NO_3) based explosives, commonly known as ANFO, are typically used however due to the risk of spontaneous combustion, explosives based on inhibited emulsion blended with ANFO are used if spontaneous combustion may occur.

Risk areas: Potential safety risk from the premature and unexpected detonation of explosives.

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Spontaneous Combustion within Dumps

In waste dumps where self-heating occurs, heat may be transferred from hot to cold regions of the dump through the evaporation of moisture (water vapour) in hot areas and subsequent condensation in colder areas. This heat transfer is in addition to the transport of heat by natural convection. Water vapour transport is an important heat transfer mechanism within waste dumps and therefore it is not recommended that water is added to a hot spot. The added water may shift the heat from one region to another. This may be the reason that self-heating is observed in black shale after increases in humidity and rain. If the rate of energy generated by oxidation is greater than the rate at which energy can be dissipated to the environment via conduction, convection and evaporation then the dump will self-heat.

Risk areas: Gas venting from waste dumps, geotechnical instability and increased rates of ARD generation due to the elevated temperatures and oxygen exposures.

Gas Exposures

The major gases produced from the spontaneous combustion of the black shale (and possibly lignite in detritals) are likely to be sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrogen sulfide (H_2S), carbon monoxide (CO) and methane (CH_4). In the open air, the rate of reaction is slow and the heat of reaction is quickly dissipated to the environment. Within waste dumps, the heat cannot dissipate as readily and there can be localised hot spots that promote SO_2 generation. The SO_2 generated can then vent from the waste, potentially causing problems with the establishment of vegetation.

Risk areas: Human exposure to toxic gases and safety risks.

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Dust Exposure

Black shale can be fine and powdery with elevated concentrations of alumina and silica.

Risk areas: Human exposure to dust and safety risks.

2.3 Waste Definition

Waste containing sulfur can have the potential to generate ARD and some materials can also spontaneous combust. The potential for wastes to generate ARD or spontaneously combust is defined at Rio Tinto Iron Ore (WA) operations as:

ARD/AMD potential: The propensity for a material to generate ARD/AMD is determined using a series of tests referred to as Acid Base Accounting (ABA). Without site-specific ABA data, a total sulfur concentration of 0.1% is used as the approximate boundary between non-acid forming and potentially acid forming material. Marra Mamba Iron Formation BIF and detritals are the only material that can use a 0.3% sulfur cut-off value and this is due to the presence of some acid neutralising materials.

Spontaneous Combustion potential: The spontaneous combustion mechanisms of pyritic black shale are poorly understood. However, it is likely to be associated with the following properties of the shale: high surface area, high porosity, small particle size distribution, moisture content, carbon content and sulfur content. All black shale and lignite material is deemed by RTIO (WA) to pose a spontaneous combustion risk (although significant tonnages of lignite are yet to be mined so spontaneously combust has not been observed).

Depending on the potential for ARD generation and/or spontaneous combustion (risk), waste should be classified into one of three categories and it should be dumped in accordance with the specifications for that category (Appendix 1).

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Inert waste: Material is currently classified as inert by RTIO (WA) if it does not contain sulfur or carbonaceous material (i.e., S < 0.3% for BIF and detritals located below the water table (BWT); S < 0.1% for elevated-sulfur material located above the water table (AWT); and not including any black shale or lignites). Black shale within the Whaleback Shale Member may be classified as inert waste when it represents a small fraction of a mine block and the average sulfur content of the block is < 0.1%.

Cold black shale/sulfidic BIF/sulfidic siderite: This material is not likely to spontaneously combust within the dump and is managed only to control the ARD risk. Typical material within this category includes:

- Cold black shale (MCS): Represents black shale with low sulfur concentrations. Due to possible variability within the unit, this material requires special management. Whilst the sulfur content is low (i.e., < 0.1%), there is still the potential for metalliferous drainage as a result of oxidation of the organic carbon material within the black shale.
- Dales Gorge Member (DG) black shale: Represents black shale with sulfur concentrations up to 2% and containing some acid neutralising capacity (e.g.,15 kgH_2SO_4/t). Samples are mostly non-acid forming but may be potentially acid forming with low capacity.
- Sulfides within BIF and detritals (siderite): The sulfur concentration in these materials is generally in the range of 0.1% to 0.3% but can reach 15%. The risk of spontaneous combustion in the dump is considered low due to the lack of organic carbon associated with this material.
- Whaleback Shale Member (WS) black shale: If the average sulfur content is > 0.1% or black shale accounts for the majority of the block material, then this material should be placed in a cold black shale dump as there is very low potential for acid generation.

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Hot black shale/Lignite: This material may spontaneously combust in the dump and is managed to control combustion within the dump. Typical material within this category is:

- Hot black shale (MCS): Black shale which generally has significantly higher sulfur concentrations and high organic carbon concentrations typically > 2%.
- Sulfides in lignite: The risk of spontaneous combustion of sulfidic lignite material is currently unknown. Until proven otherwise, sulfidic lignites should be managed to minimise the risk of spontaneous combustion.

Elevated sulfur: The sulfate minerals alunite and jarosite can be found AWT, predominantly in the Dales Gorge Member, Whaleback Shale Member and oxidised MCS. These are found particularly in close proximity to those units containing sulfide minerals, and/or a source of potassium such as dolerite dykes. When alunite or jarosite occur in significant quantities (termed elevated-sulfur material) it will need to be specially managed due to its propensity to release acid and associated metals. Without site specific test work for sulfates, a total sulfur concentration of 0.1% is used as the approximate boundary between non-acid and potentially acid forming material due to the low solubility of these minerals and presence of some acid neutralising materials.

3 Assessing if a Site needs to implement this Management Plan

The RTIO (WA) Mineral Waste Management Plan describes the ARD, spontaneous combustion and mineral waste characterisation work that must be undertaken during Resource Evaluation, Studies and Mine Operations. A detailed ARD Risk Assessment should be undertaken for any new deposits or significant expansions of current operations to identify whether excavated sulfides will represent a risk to health, safety and environment (including the impacts on-site, off-site and to the receiving environment). If risks are deemed to be minimal then a management plan will not be required. If a risk assessment has already been undertaken at a site then for any additional significant resource drilling or expansions of the operation the risk assessment should be updated. For any mine site that exposes or could potentially expose sulfidic or elevated-sulfur material, then this SCARD Management Plan will need to be implemented.

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The accountability for the identification and subsequent management of spontaneous combustion and ARD risks associated with black shale and sulfidic BIF and detritals are listed in Section 4 and Section 5. It provides an overview of management at RTIO (WA) operations from initial characterisation and modelling, through project development, mine planning, production and closure. The RTIO (WA) SCARD management strategy is broadly based upon the following principles:

1) Identification of PAF material distribution and character;
2) Minimising the exposure and mining of PAF material to the extent possible;
3) Identification and special handling of PAF material that must be mined;
4) Encapsulation of PAF material inside inert waste rock dumps to limit water contact and allow the dumps to be revegetated, or placement of PAF material below the water table in backfilled open pits to limit oxygen contact; and
5) Monitoring impacts and taking corrective actions (when necessary).

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4 Requirements, Accountabilities and References for Black Shale

Black shale management during mining operations is conducted in accordance with Figure 1 and Figure 2. The mining protocols are designed to:

1) Minimise the risk of unplanned detonations in charged blast holes;
2) Ensure that hot and cold black shale truck loads are transported and placed in designated black shale dumps according to design requirements;
3) Ensure that the location and geometry of all black shale repositories is recorded;
4) Minimise environmental impacts of AMD products; and
5) Refine geological block models and block-out procedures.

Requirements	
4.1	**Mine Planning and Closure**
4.1.1	Mine plans must include estimates for hot and cold BS production and compare to inert waste production to ensure that sufficient material will be available for dump construction.
4.1.2	Ensure that BS dumps are sited to minimise long term environmental impacts and financial liabilities. Obtain signoff from Environment, Hydrogeology and Hydrology.
4.1.3	Ensure that final pit and dump designs are consistent with Appendix 1, Appendix 3, Appendix 4 and the RTIO Landform Design Guidelines. Waste dump designs must be coupled with a rehabilitation design showing how the dump is proposed to be rehabilitated upon closure. The rehabilitation design should be provided to the Rehabilitation team for review. Obtain signoff from Environment, Hydrogeology and Hydrology.
4.1.4	During the mine planning process identify areas that are available for rehabilitation and inform the rehabilitation and closure team.
4.2	**Mine Technical Services - Planning**
4.2.1	Ensure that Medium Term plans predict hot and cold BS production from each pit and delivery to each dump. Ensure that sufficient inert waste will be produced for encapsulation in accordance with the specifications in Appendix 1 and that sequencing will allow dump construction to occur as required.
4.2.2	Major changes to waste dump designs must be reflected in changes to the associated rehabilitation design. Receive sign-off from Environment, Rehabilitation Team, Hydrogeology and Hydrology before major modifications to BS dump designs are implemented.
4.2.3	Plan and design works for final waste rock dump surfaces and inactive open pits in a manner consistent with Appendix 4, Appendix 7 and the RTIO Landform Design Guidelines. Waste dump designs must be coupled with a rehabilitation design showing how the dump is proposed to be rehabilitated for closure. The design should be provided to the Rehabilitation Team for review. Obtain sign-off from Environment, Hydrogeology and Hydrology.
4.2.4	During the mine planning process identify areas that are available for rehabilitation and inform the rehabilitation and closure team.
4.2.5	When planning open pits that will intersect BS, the possibility of dewatering discharge/groundwater becoming acidic must be considered so that appropriate mitigation infrastructure can be installed.
4.2.6	Black shale exposed on the waste rock dumps must be minimised during the wet season (November to April).

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Requirements

4.3 Mine Geology

Blasting

4.3.1 Identify BS in blast hole cones and demarcate using agreed methods.

4.3.2 Alert key personnel in Mine Technical Services Planning and Pit Operations of the location of BS blast holes via e-mail.

Dumping

4.3.3 Based on visual inspection, total S values and stratigraphy, designate holes as cold BS, hot BS or inert waste. Create Block-outs that show contacts between waste types within blast patterns.

4.3.4 Perform periodic reconciliations between the Block-outs and the geological block model.

4.3.5 Collect (as required) representative samples of hot and cold black shale for full ABA and NAG analysis.

4.3.6 Regularly review the boundary between cold BS and hot BS to ensure it is still valid and has not changed as mining progresses deeper. Advise the relevant teams of the results and undertake change management if necessary.

4.4 Survey

4.4.1 Maintain as-built dump designs that include a 3D plan showing approximate locations and volumes of BS.

4.4.2 Ensure that monthly face pick-up surveys are conducted on all active BS waste dumps.

4.5 Operational Planning

4.5.1 Create a “Waste Dump Progression Plan” at least every three months to implement the detailed dump designs in the field.

4.5.2 Create “PLOD” sheets to aid dig operators in waste assignment and check that CAES is working.

4.5.3 Monitor and adjust to reconcile rehabilitation plans with original designs as appropriate.

4.5.4 Perform field inspections to ensure that BS is transported to the proper dump locations and placed as required. Register non-conformances in SAP.

4.5.5 Ensure reports contain hot and cold BS volumes delivered to every dump.

4.5.6 In consultation with Mine Geology perform regular reconciliations between Block-outs, survey and ORDW data for hot and cold BS volumes.

4.5.7 Black shale exposures on the waste rock dumps must be minimised during the wet season.

4.6 Drill, Blast and Development

4.6.1 Ensure all safety procedures related to BS management are followed during the charging and firing of blast holes i.e., temperature logging, timing.

4.6.2 Maintain site specific Drill and Blast SWPs and ensure it is consistent with this management plan and other SWPs and guidance notes.

4.6.3 Submit samples for isothermal reactivity testing for compatibility with ANFO explosives.

4.7 Load and Haul

4.7.1 Ensure that BS is properly identified and placed in the correct dump location consistent with PLOD sheets, CAES mining assignments and the Waste Dump Progression Plan from Operations Planning.

4.7.2 Perform field inspections to ensure that BS is transported to the proper dump locations and placed as required. Register non-conformances in SAP.

4.7.3 Ensure that “Exclusions” in CAES are reviewed and corrected in the field as required.

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Requirements	
4.7.4	The time between blasting and hauling of BS should be minimised and generally should occur within three weeks or less during the wet season (November to April) and within 12 weeks during the dry season (May to October). This will limit the amount of time the material has to oxidise in an uncontrolled manner.
4.7.5	Whenever possible the outer inert waste rock "skin" of a BS lift should be constructed first. This will ensure that BS lifts are not extended beyond the design footprint of the BS dump, will limit convective oxygen transport through the uncompacted sides of the dump lift, and will help contain contaminated contact water on the dump.
4.7.6	Hot BS lifts should be covered as rapidly as possible with the overlying inert waste rock layer, particularly during the wet season. Ideally, hot BS should be covered within two weeks of placement in the waste rock dump. If rapid covering is not possible the paddock-dumped hot BS piles should at least be dozed into a planar surface as soon as possible. This will help minimise infiltration and oxygen transport into the material.
4.7.7	The locations, volumes and sulfur concentrations (if available) of all BS repositories should be recorded so that a three dimensional plan of BS distribution within each dump is maintained by the survey group.

4.8 Hydrogeology/Technical Services

4.8.1	Maintain and implement a site specific "Acid Water Management Plan" and SWPs to deal with poor quality water that has contacted BS exposures or waste dumps. This should include information regarding bunding requirements, water quality monitoring (including the action response and relevant corrective actions including treatment) and disposal or use.
4.8.2	Ensure that water management and storage practices do not cause offsite surface water impacts or groundwater quality degradation in down gradient aquifers.
4.8.3	Provide technical overview and support during planning for above-ground and in-pit BS waste disposal.
4.8.4	Ensure that routine sampling, visual inspection, and analysis is performed for in-pit locations, including: • groundwater monitoring wells (surrounding BS dumps and pits; • dewatering water; and • surface water bodies (including temporary or permanent pit lakes within inactive open pits that contain BS exposures). This should be consistent with the master monitoring schedule for the site.

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4.9 WRE Mineral Waste Management Team

4.9.1	Provide site support for the management of mineral waste, as necessary. Facilitate the transfer of knowledge between RTIO sites and studies.
4.9.2	Undertake or update AMD Risk Assessments for significant changes to the pit shell or geochemical risks. Advise the site leadership and environment group for significant changes to risk.
4.9.3	Ensure the SCARD management plan is updated at least every 2 years. More frequent updates may be required for significant changes to risk or the knowledge base.
4.9.4	For pits that intersect the water table, ensure the following information is available which would contribute to a conceptual understanding: • Catchment size; • Depth to pre-mining water table; • Current and ultimate pit depth; • Available water storage within the entire ultimate pit and above the pre-mining water table in the pit; • Predicted runoff volume for a 100 year storm event; • Distance to closest down-gradient permanent surface water body; and • Down-gradient water use. Determine the geochemical risk of the pit. Update this report for any significant changes.

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Requirements

4.9.5 Geochemical, hydrogeology and hydrology modelling to determine contaminant release from the pit should be undertaken if the report (in Item 4.9.4) finds a significant geochemical risk (i.e., a significant amount of PAF material exposed on the pit wall, a significant amount of dewatering occurring over many years, a likely saline and flow through water body, etc.).

4.9.6 For PAF material waste dumps, compile a 'Conceptual Model' report for each site. This report should contain the following information for each waste dump on the site:

- Footprint;
- Up-gradient catchment area;
- Likely material types in the waste dump i.e., oxidised MCS, DG1 BIF;
- Quantify the PAF tonnes and the total tonnes of material within each waste dump;
- Dumping methodology;
- Underlying and down-gradient geology;
- Distance to the closest regionally significant aquifer;
- Distance to closest down-gradient permanent surface water body;
- Down-gradient water use; and
- Closure/rehabilitation plans for the dump (or reference to the appropriate document).

4.9.7 Geochemical modelling to determine long-term contaminant release from the waste dump should be undertaken if the 'Conceptual Model' finds a significant geochemical risk (i.e., a significant amount of PAF material within the waste dump or significant receptors nearby).

4.10 Environment

4.10.1 Perform field inspections to ensure BS management, dump construction, rehabilitation and store and release cover performance is consistent with the requirements of the SCARD Management Plan.

4.10.2 Undertake relevant ecological assessment (appropriate for the scale of the SCARD generation and predicted level of pollution/ecological impacts), develop and implementation appropriate risk reduction measures and monitoring programmes.

4.10.3 Ensure that routine sampling, visual inspection, and analysis is performed for out of pit locations that could potentially be impacted by AMD. This may include

- groundwater monitoring wells surrounding BS dumps and pits (if they can be accessed outside the pit)
- surface water bodies (including abandoned pit lakes, permanent or seasonal natural water bodies, dewatering discharge to creeks).

This should be consistent with the master monitoring schedule for the site.

4.10.4 Record the environment risks related to BS in a site risk register and annually review/verify/validate these risks; verify that the ministerial conditions, legal and other requirements and obligations are met.

4.11 Rehabilitation and Closure

4.11.1 In consultation with relevant stakeholders identify monitoring requirements (e.g. lysimeters) for BS waste dumps following rehabilitation.

4.11.2 Coordinate the review and approval of the BS waste dump design by relevant stakeholders, including the Mineral Waste Management Team to ensure compliance with this document.

4.11.3 Assess the risks that need to be managed as part of the rehabilitation process for BS dump designs, focussing on the SCARD risks and ensure that all key stakeholders are consulted.

4.12 Health and Safety

4.12.1 Monitor the occupational gas and dust exposures surrounding BS. Ensure data is captured in a user friendly database. Ensure problems are brought to the attention of the site Mineral Waste Management Team.

4.12.2 Train occupational exposure groups on the correct use of respiratory equipment and monitors. Competency should be assessed and recorded in SAP.

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Requirements
4.12.3 Ensure the site specific guidance notes on acceptable gas levels, monitoring and demarcation are periodically refined and updated so it is consistent with current best practice.
4.12.4 Record health and safety risks associated with BS in a site risk register and annually review these risks.
4.13 Site Mineral Waste Management Team
4.13.1 A site based Mineral Waste Management Team should be formed and meet on a regular basis (e.g., monthly). It should include representatives of every department that has accountabilities related to SCARD management.
4.13.2 The primary function of the Site Mineral Waste Management Team is to ensure on-going improvement and implementation of the SCARD Management Plan.
4.13.3 Agenda items and meeting minutes should be produced for every meeting.
4.13.4 An overview of issues relating to BS must be included in any introductory training provided to new employees and contractors. The level of training should be commensurate to the level of risk BS poses to the site.
4.13.5 Develop emergency and contingency plans related to spontaneous combustion, ARD and BS management on an as need basis.
4.13.6 Coordinate a technical review of BS management by an external expert every four years. Track progress against outstanding actions at each meeting.
4.13.7 Coordinate all research related to BS characterisation, BS management, spontaneous combustion and ARD.
4.13.8 Ensure that SCARD related SWPs and guidance notes represent current practise and are up to date.
4.13.9 Changes to the SCARD management plan need to be provided to the Water Resource Evaluation Mineral Waste team to be included in future updates.
4.14 Management
4.14.1 Ensure progress is made against outstanding spontaneous combustion and AMD audit actions.

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Figure 1: Black shale (BS) management overview.

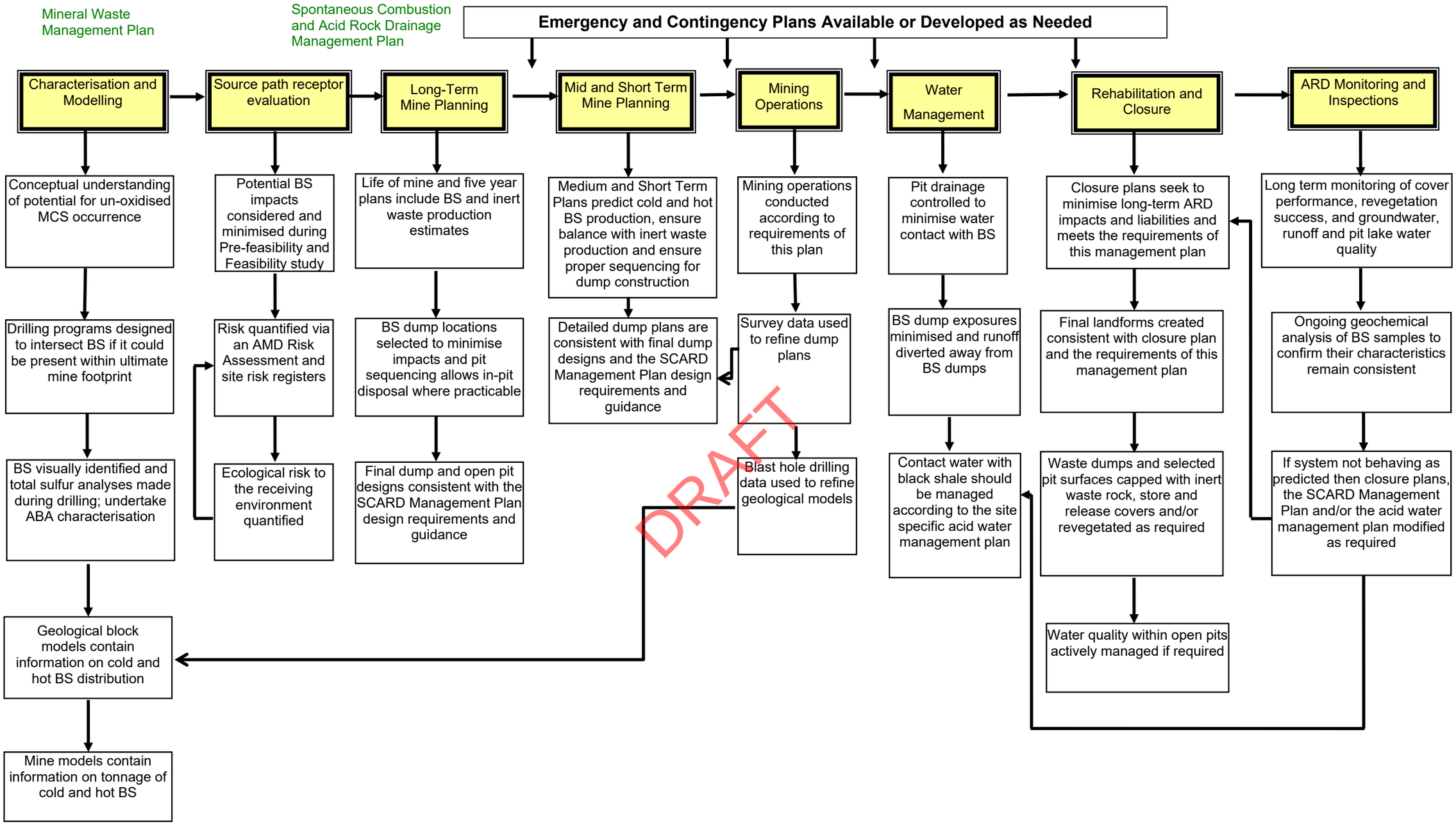

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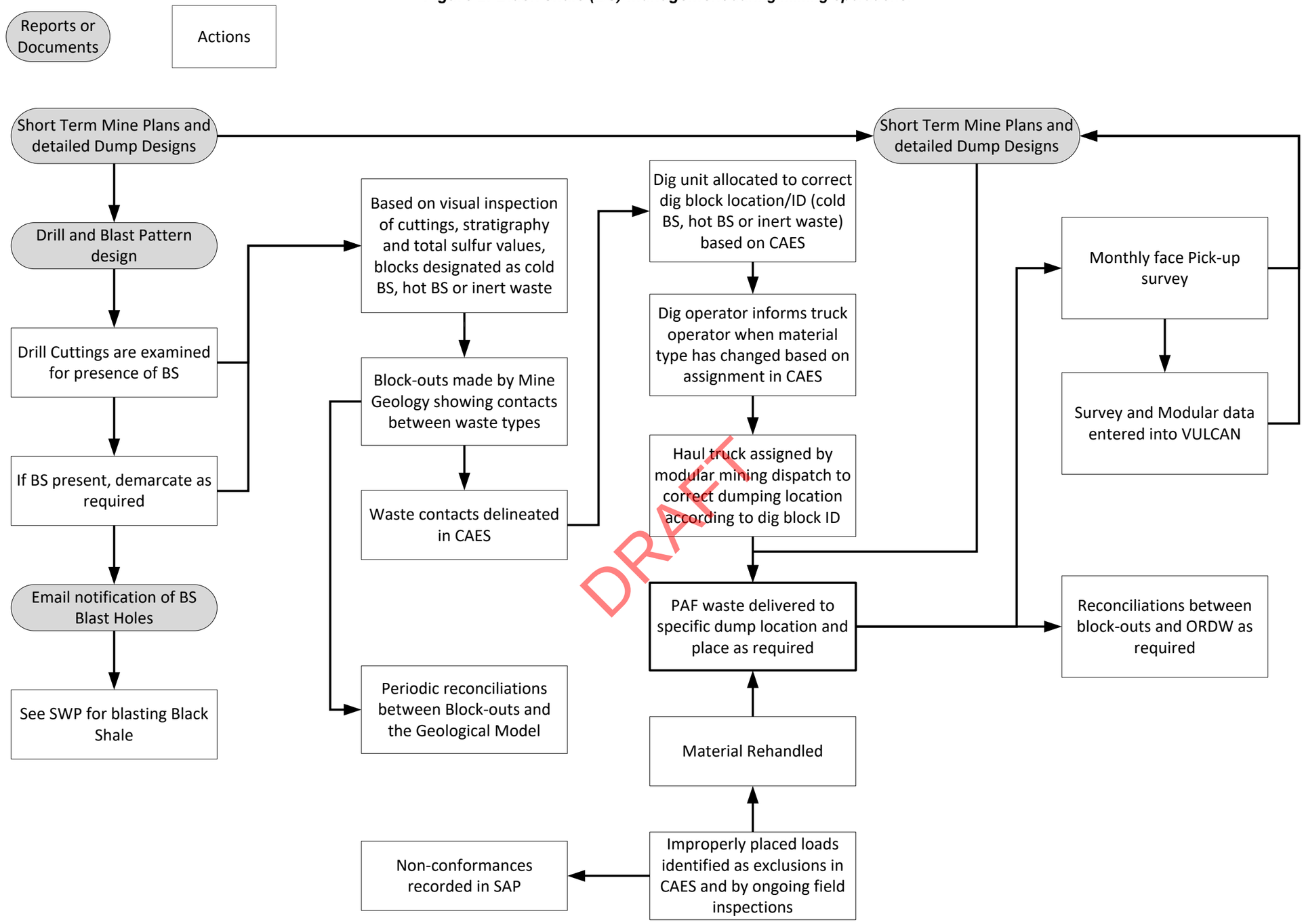
Figure 2: Black shale (BS) management during mining operations.



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5 Requirements, Accountabilities and References for Sulfides within BIF and Detritals

Management of sulfidic BIF and detritals during mining operations is conducted in accordance with Figure 3 and Figure 4. The mining protocols are designed to:

1) Minimise the risk of unplanned detonations in charged blast holes;
2) Ensure that sulfidic BIF and detrital truck loads are transported and placed in PAF dumps according to design requirements;
3) Ensure that the location and geometry of all PAF repositories is recorded;
4) Minimise environmental impacts of ARD products; and
5) Refine geological block models and block-out procedures.

Requirements	
5.1	**Mine Planning and Closure**
5.1.1	Mine Plans must include estimates for production of PAF, neutralising and inert waste material.
5.1.2	Ensure that PAF dumps are sited to minimise long-term environmental impacts and financial liabilities. Obtain signoff from Environment, Hydrogeology and Hydrology.
5.1.3	Ensure that final pit and dump designs are consistent with Appendix 4, Appendix 5, Appendix 6, Appendix 7 and the RTIO Landform Design Guidelines. Waste dump designs must be coupled with a rehabilitation design showing how the dump is proposed to be rehabilitated upon closure. The rehabilitation design should be provided to the Rehabilitation Team for review. Obtain signoff from Environment and Hydrogeology and Hydrology.
5.1.4	During the mine planning process identify areas that are available for rehabilitation and inform the rehabilitation specialist.
5.2	**Mine Technical Services - Planning**
5.2.1	Ensure that Medium term plans predict PAF material and net neutralising material production from each pit and delivery to each dump. Ensure that sufficient inert and net neutralising waste will be produced for encapsulation in accordance to the specifications in Appendix 1 and that sequencing will allow dump construction to occur as required. The tonnes of material with neutralising potential should be quantified and used with PAF dump designs in accordance with Appendix 2.
5.2.2	Major changes to waste dump designs must be reflected in changes to the associated rehabilitation design. Receive sign-off from Environment, Rehabilitation Team, Hydrogeology and Hydrology before major modifications to BS dump designs are implemented.
5.2.3	When planning open pits that will intersect sulfidic material, the possibility of dewatering discharge/groundwater becoming acidic must be considered so that appropriate mitigation infrastructure can be installed.
5.2.4	Lignite exposed on the waste rock dumps must be minimised during the wet season (November to April).
5.3	**Geology**
5.3.1	Identify lignite in blast hole cones and demarcate using agreed method.
5.3.2	Alert key personnel in Mine Technical Services and Pit Operations of the location of lignite blast holes via e-mail.
5.3.3	If the geological block model indicates that sulfur grades may be > 0.3%, then samples from drill hole cuttings should be collected for total sulfur concentration analysis.

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Requirements	
5.3.4	Review total S results and demarcate holes that contain > 0.3% S (for drill and blast identification).
5.3.5	Based on visual inspections, total S values and stratigraphy, designate holes as PAF, net neutralising or inert waste. Create Block-outs that show contacts between waste, net neutralising material and the PAF material within blast pattern.

Material blocked out for the PAF dump include:

- BIF: S > 0.3%
- Detrital Siderite: S > 0.3%
- Detrital Lignite: All (to manage neutral mine drainage risks in additional to PAF risks)

5.3.6	Perform periodic reconciliations between the Block-outs and the geological block model.
5.3.7	Collect (as required) representative samples of sulfidic material associated with BIF and detritals for full ABA and NAG analysis. Ensure results are communicated to the relevant teams.

5.4 Survey

5.4.1	Maintain as-built dump designs in Vulcan that include a 3D plan showing approximate locations and volumes of sulfidic material.
5.4.2	Ensure that monthly face pick-up surveys are conducted on all active sulfidic material waste dumps.

5.5 Operational Planning

5.5.1	Create a “Waste Dump Progression Plan” at least every three months to implement the detailed dump designs in the field.
5.5.2	Create “PLOD” sheets to aid dig operators in waste assignment and check modular mining system is working.
5.5.3	Monitor and adjust to reconcile rehabilitation plans with original designs as appropriate.
5.5.4	Ensure that operational reports contain sulfidic material volumes delivered to every dump. Confirm that sulfidic material has been transported to the correct dump and register non-conformances in SAP.
5.5.5	In consultation with Mine Geology perform six-monthly reconciliations between Block-outs, survey and operational data for sulfidic material volumes.
5.5.6	Sulfidic material exposures on the waste rock dumps must be minimised during the wet season. Lignites should be covered rapidly during the wet season to reduce the spontaneous combustion risk (i.e. 1 month)
5.5.7	The location, volume and sulfur concentration (if available) of all PAF (sulfidic material) repositories should be recorded so that a three dimensional plan of the distribution within each dump is maintained.

5.6 Drill and Blast

5.6.1	Ensure all safety procedures related to pyritic material and in particular lignite are followed during the charging and firing of blast holes.
5.6.2	Annually submit samples for isothermal reactivity testing for compatibility with ANFO explosives.

5.7 Load and Haul

5.7.1	Ensure that sulfidic material is properly identified and placed in the correct dump location consistent with PLOD sheets, CAES mining assignments and the Waste Dump Progression Plan from Operations Planning.
5.7.2	Ensure that “Exclusions” in CAES Mining are reviewed and corrected in the field as required.
5.7.3	The outer inert waste rock “skin” of a sulfidic material lift should be constructed first. This will ensure that sulfidic material lifts are not extended beyond the design footprint of the sulfidic material dump, will limit convective oxygen transport through the uncompacted sides of the dump lift, and will help contain contaminated contact water on the dump.

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Requirements	
5.7.4	Lignite material should be covered rapidly (i.e. 1 month) with net neutralising material during the wet season to reduce the risk of spontaneous combustion.

5.8 Hydrogeology/Technical Services

5.8.1 Maintain and implement the site specific "Acid Water Management Plan" and SWPs to deal with poor quality water that has contacted sulfidic material exposures or waste dumps. This should include information regarding bunding requirements, water quality monitoring (including the action response and relevant corrective actions including treatment) and disposal or use.

5.8.2 Ensure that water management and storage practices do not cause offsite surface water impacts or groundwater quality degradation in down gradient aquifers.

5.8.3 Provide technical overview and support during planning for above-ground and in-pit sulfidic material waste disposal.

5.8.4 Ensure that routine sampling, visual inspection, and analysis is performed for in-pit locations, including:

- groundwater monitoring wells (surrounding BS dumps and pits;
- dewatering water; and
- surface water bodies (including temporary or permanent pit lakes within inactive open pits that contain BS exposures).

This should be consistent with the master monitoring schedule for the site.

5.9 WRE Mineral Waste Management Team

5.9.1 Provide site support for the management of mineral waste, as necessary. Facilitate the transfer of knowledge between RTIO sites and studies.

5.9.2 Undertake or update AMD Risk Assessments for significant changes to the pit shell or geochemical risks. Advice the site leadership and environment group for significant changes to risk.

5.9.3 Ensure the SCARD management plan is updated at least every 2 years. More frequent updates may be required for significant changes to risk or the knowledge base.

5.9.4 For pits that intersect the water table, ensure the following information is available which would contribute to a conceptual understanding:

- Catchment size;
- Depth to pre-mining water table;
- Current and ultimate pit depth;
- Available water storage within the entire ultimate pit and above the pre-mining water table in the pit;
- Predicted runoff volume for a 100 year storm event;
- Distance to closest down-gradient permanent surface water body; and
- Down-gradient water use.

Determine the geochemical risk of the pit. Update this report for any significant changes.

5.9.5 Geochemical, hydrogeology and hydrology modelling to determine contaminant release from the pit should be undertaken if the report (in Item 5.9.4) finds a significant geochemical risk (i.e. a significant amount of PAF material exposed on the pit wall, a significant amount of dewatering occurring over many years, a likely saline and flow through water body etc).

5.9.6 For PAF material waste dumps, compile a 'Conceptual Model' report for each site. This report should contain the following information for each waste dump on the site:

- Footprint;
- Up-gradient catchment area;
- Likely material types in the waste dump i.e., LIG, SID, CAL.
- Quantify the PAF tonnes and the total tonnes of material within each waste dump;
- Dumping methodology;
- Underlying and down-gradient geology;
- Distance to the closest regionally significant aquifer;
- Distance to closest down-gradient permanent surface water body;

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Requirements

- Down-gradient water use; and
- Closure/rehabilitation plans for the dump (or reference to the appropriate document).

5.9.7 Geochemical modelling to determine long term contaminant release from the waste dump should be undertaken if the 'Conceptual Model' finds a significant geochemical risk (i.e. a significant amount of PAF material within the waste dump or significant receptors nearby).

5.10 Environment

5.10.1 Perform field inspections to ensure sulfidic material management, dump construction, rehabilitation and store and release cover performance is consistent with the requirements of the SCARD Management Plan.

5.10.2 Undertake relevant ecological assessment (appropriate for the scale of the SCARD generation and predicted level of pollution/ecological impacts), develop and implementation appropriate risk reduction measures and monitoring programmes.

5.10.3 Ensure that routine sampling, visual inspection, and analysis is performed for out of pit locations that could potentially be impacted by AMD. This may include

- groundwater monitoring wells surrounding BS dumps and pits (if they can be accessed outside the pit)
- surface water bodies (including abandoned pit lakes, permanent or seasonal natural water bodies, dewatering discharge to creeks).

This should be consistent with the master monitoring schedule for the site.

5.10.4 Record sulfidic material environment risks in a site risk register and annually review/verify/validate these risks; verify that the ministerial conditions, legal and other requirements and obligations are met.

5.11 Rehabilitation and Closure

5.11.1 Ensure that the rehabilitation process is completed as outlined within the Progressive rehabilitation – process and responsibilities and Rehabilitation design and approval process documents.

5.11.2 In consultation with relevant stakeholders identify monitoring requirements (e.g. lysimeters) for waste dumps following rehabilitation.

5.11.3 Coordinate the review and approval of the design by relevant stakeholders including the mineral waste team to ensure compliance with this document.

5.11.4 Assess the risks that need to be managed as part of the rehabilitation process for BS dump designs, focussing on the SCARD risks and ensure that all key stakeholders are consulted.

5.12 Health and Safety

5.12.1 Monitor the occupational gas and dust exposures surrounding sulfidic material (and gas generation if appropriate for lignite material). Ensure problems are brought to the attention of the site Mineral Waste Management Team.

5.12.2 If spontaneous combustion is likely to occur, train occupational exposure groups on the correct use of respiratory equipment and monitors. Competency should be assessed and recorded in SAP.

5.12.3 Ensure health and safety guidance notes relating to spontaneous combustion gas generation and dust are developed, periodically refined and updated so it is consistent with the current best practice.

5.12.4 Record sulfidic material health and safety risks in a site risk register and annually review these risks.

5.13 Site Mineral Waste Management Team

5.13.1 A site based Mineral Waste Management Team should be formed and meet on a regular basis. It must include representatives of every Department that has responsibilities related to ARD management.

5.13.2 The primary function of the Mineral Waste Management Team is to ensure on-going improvement and implementation of the SCARD Management Plan.

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Requirements	
5.13.3	Agenda items and meeting minutes should be produced for every meeting.
5.13.4	An overview of PAF issues must be included in any introductory training provided to new employees and contractors. Further training of those groups involved in the mining of PAF should be commensurate to the level of risk PAF material poses to the operation.
5.13.5	Develop site specific emergency and contingency plans related to spontaneous combustion, ARD and sulfidic material management on an as needs basis.
5.13.6	Coordinate a technical review of ARD management by an external expert every four years. Track progress against outstanding actions at each meeting.
5.13.7	Coordinate all research related to sulfidic material characterisation, management, spontaneous combustion and ARD.
5.13.8	Ensure that related SWPs and guidance notes represent current practise and are up to date.
5.13.9	Changes to the SCARD management plan need to be provided to the Water Resource Evaluation Mineral Waste Team to be included in future updates.
5.14 Management	
5.14.1	Ensure progress is made against outstanding spontaneous combustion and AMD audit actions.

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Figure 3: Sulfidic material in BIF and detritals management during mining operations

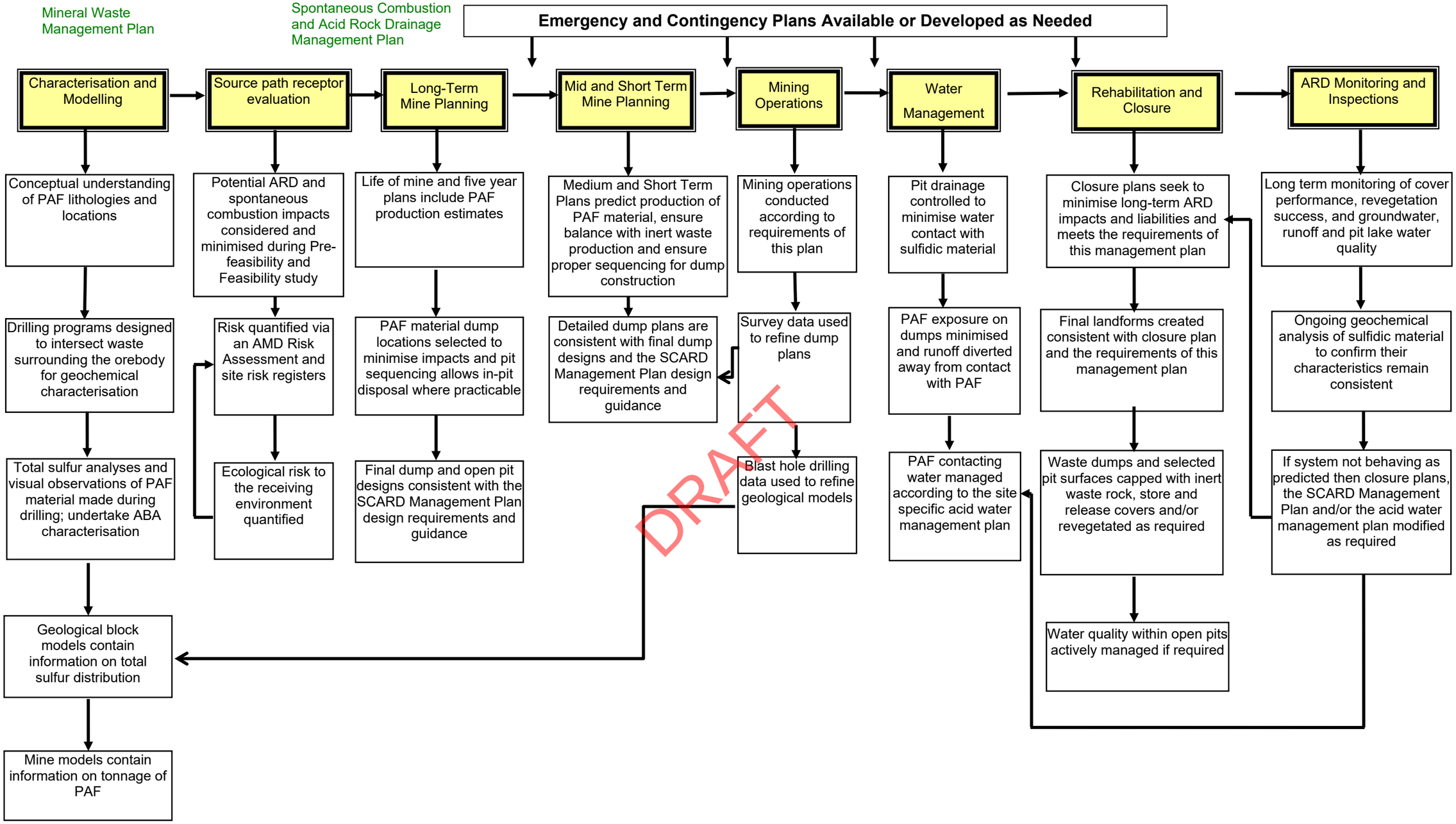

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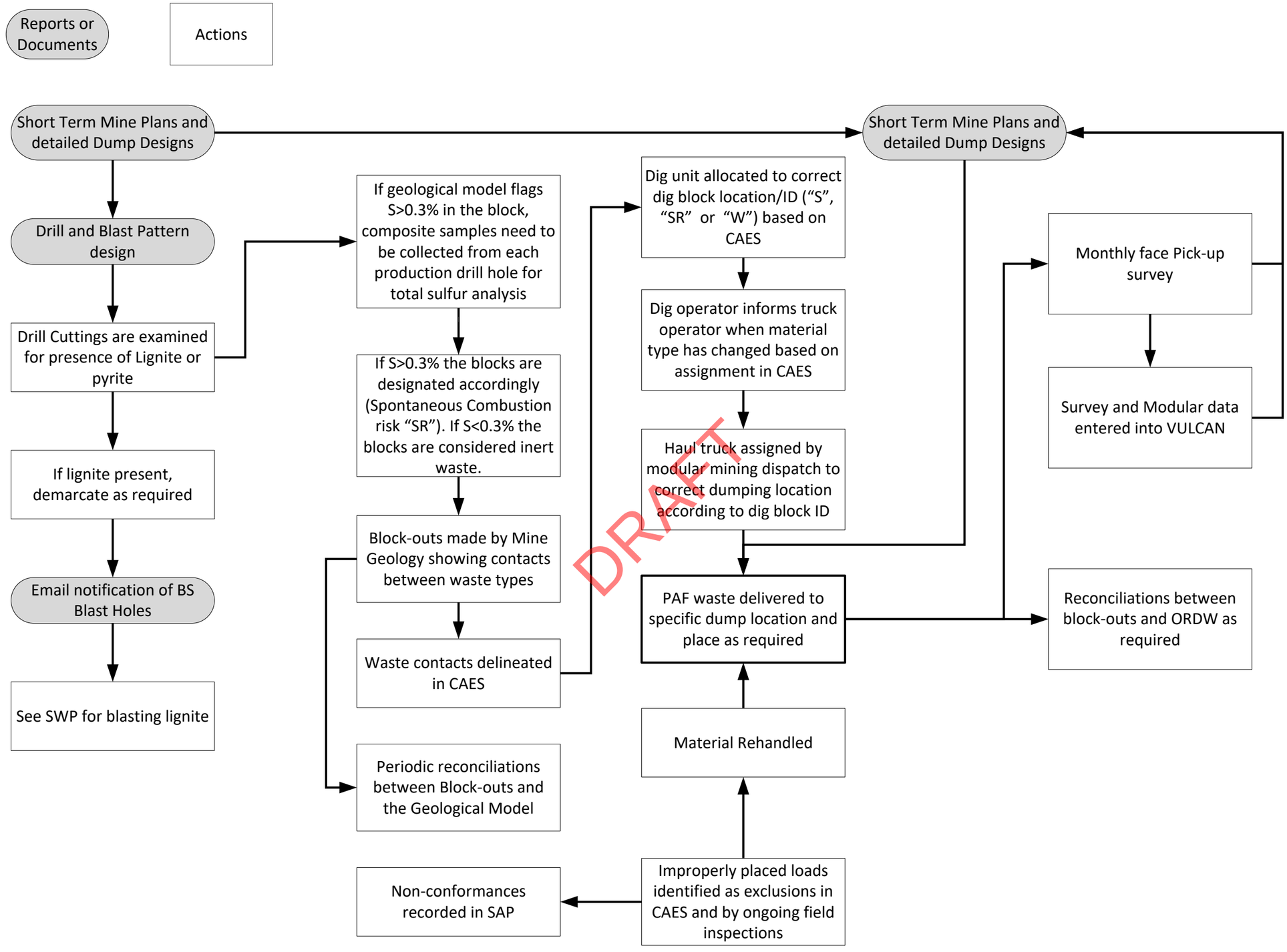
Figure 4: Sulfidic material in BIF and detritals management during mining operations



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6 Requirements, Accountabilities and References for Elevated Sulfur Material (including alunite)

It is expected that elevated sulfur presents an ARD risk but not a spontaneous combustion risk. This is based on the fact that the sulfur bearing mineral is sulfates rather than sulfides (AEISG, 2017).

Requirements	
6.1	**Mine Geology**
6.1.1	Identify from the geological model waste and low grade blocks estimated to contain elevated sulfur. Use these to create block-outs to show the contacts between elevated sulfur material and waste and low grade types within the blast patterns.
6.1.2	Collect (at least every five years) representative samples of elevated sulfur material for full ABA and NAG analysis. Ensure results are communicated to the relevant teams.
6.2	**Mine Technical Services - Planning**
6.2.1	Design elevated sulfur waste dump and low grade stockpiles such that the elevated sulfur material is not located within one metre of the outer surface at closure.
6.3	**Survey**
6.3.1	Monitor the construction of the dump such that elevated sulfur will not be located on the outer surface.
6.4	**Operational Planning**
6.4.1	Ensure material flagged as elevated sulfur is scheduled in CAES such that material is sent to the correct dump/stockpile.
6.5	**Load and Haul**
6.5.1	Ensure that elevated sulfur material is delivered to the correct location as assigned by mine geology.
6.5.2	Ensure that elevated sulfur material is dumped (where possible) from a tip head to ensure blending with inert material. If this is not achievable then paddock dumping will be satisfactory.
6.6	**Hydrogeology**
6.6.1	Ensure background water quality is established from water bores surrounding dumps and stockpiles where elevated sulfur material is stored. Undertake analysis of monitoring bores as required during dump construction and at closure.

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Appendices

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Appendix 1 Dump Specifications for Black Shale and Elevated Sulfur Material

Management of sulfates or sulfides within black shale, BIF or detritals needs to be considered during all phases of waste rock dump design, from initial selection of dump locations during the long-term planning process (five year and longer time horizon) to the detailed dump designs generated during short term planning (time horizon less than a year). The Waste Dump Design Checklist is to be filled in for all new waste dump designs to help ensure environmental issues are adequately considered.

A1.1 Selection of Dump Locations

When designing new PAF material dumps, the dump location and footprint should be selected to minimise potential long term environmental impacts and financial liabilities. Selection and design criteria that must be considered include:

- Under no circumstances should PAF material be used for works such as windrows, construction fill, ramps, fantails, roads or any other use that would disperse the material over a broad area in an uncontrolled manner.
- The PAF dump location should not receive runoff from surrounding areas. In particular waste dumps must not be sited in established drainages with significant upstream catchments.
- In pit disposal should be considered a priority instead of the construction of above ground waste rock dumps. However, hydrogeology investigations are required to evaluate water recovery levels and timeframes, and connection of the void to receptors.
- Placement of PAF material within pits that already contain PAF wall exposures is preferable to placement in pits that do not have these exposed on the pit walls.
- PAF dumps should not be placed over or adjacent to significant regional aquifers such as saturated valley fill alluvial deposits or fractured bedrock aquifers such as the Wittenoom Formation.
- PAF dumps should not be placed over ore grade or near ore grade CID or BIF-derived deposits. These not only have potential economic value, but may act as significant local aquifers.
- PAF dumps should not be placed over, adjacent to, or where there is a connection to significant seeps or springs.
- Avoid siting new PAF dumps in catchment basins that do not already contain PAF material.
- The number of sites containing PAF material and the footprint of these dumps should be kept to a minimum.
- PAF dumps should be located near sources of clean waste rock for encapsulation.
- Background groundwater quality surrounding the dump location must be measured before any material is dumped. This will require the installation of groundwater monitoring bores. These bores will be used to provide a temporal record of groundwater quality in the vicinity of the dump.

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A1.2 In-Pit Disposal Requirements

In pit disposal of PAF material is generally more secure than disposal in above ground waste rock dumps. Where practicable, in pit disposal should be considered the preferred disposal alternative because it:

- Reduces the risk of erosion exposing PAF material in the long term;
- Inhibits convective oxygen transport because the waste is surrounded by relatively impermeable rock walls;

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- Reduces the footprint of the waste disposal facilities;
- Reduces the volume of inert or net neutralising waste needed to encapsulate the PAF material; and
- May help to prevent the formation of acidic or hyper-saline pit lakes if the pit can be filled to above the post-mining water table.

Note that in some pits it may be possible to place PAF material both above and below the water table with a minimum 10 metre thick inert waste layer placed against the predicted mean post-mining water table. If PAF material is placed BWT, hydrogeology investigations are required to determine the water recovery level, rate of recovery and if there are any connections to receptors.

A4.2.1 In Pit Disposal Below the Water Table

If PAF material is placed below the post-mining water table, it will become permanently flooded which will control subsequent oxidation and acid release. In the long term, placement below the water table is the most secure and low risk disposal option. It is particularly beneficial for hot black shale because it removes the long-term risk of spontaneous combustion. If a pit can be backfilled so that the fill elevation is above the pre-mining water table level, it is possible that the water table will eventually rebound to or near the pre-mining elevation. If the pit is only partially backfilled to below the pre-mining water table, it is likely that a shallow intermittent, seasonal or permanent pit lake will form on top of the fill material.

Elevated sulfur material (i.e., containing sulfate minerals such as alunite or jarosite) should not be placed below the post-mining water table as the release of acid is controlled by the dissolution of the minerals and is not a kinetic controlled reaction as is the case for sulfidic PAF materials.

For sulfidic PAF material placed below the post-mining water table the following minimum design criteria apply:

- For pits backfilled above the predicted post-mining water table, the top of the PAF material backfill must be at least 5 metres below the mean predicted post-mining water table (Figure 19).

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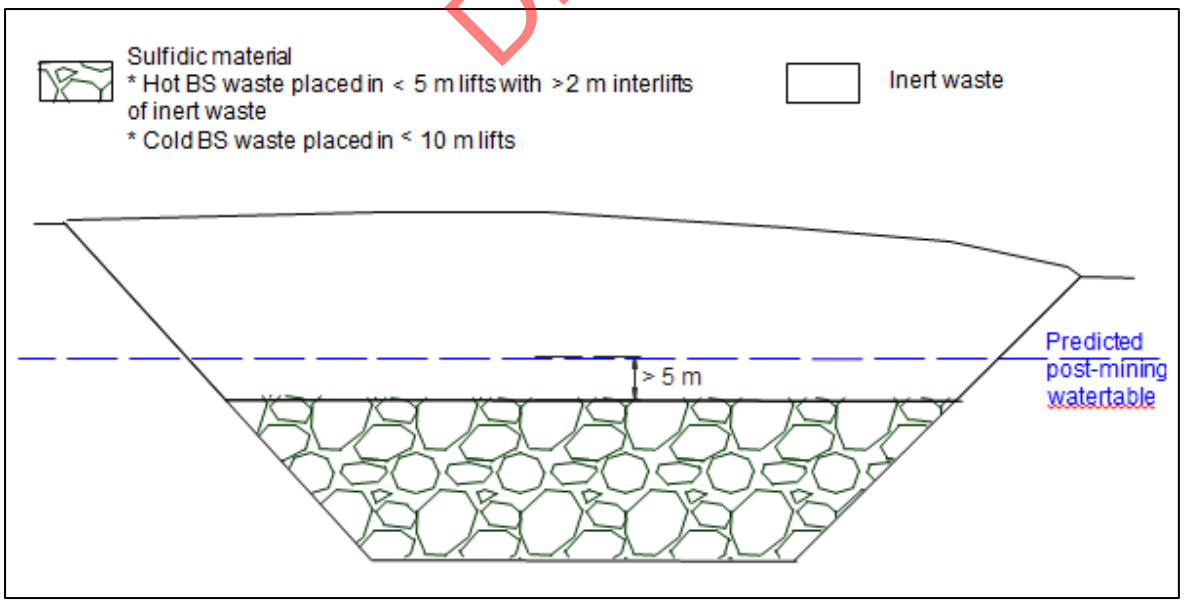

Figure 5: Example of PAF material placed BWT and with the pit completely backfilled.

- For pits that are only partially backfilled to below the pre-mining water table, the top of the PAF material backfill must be at least 5 metres below the estimated mean pre-mining water table and at least 5 metres below the predicted post-backfilling water table (Figure 20). In this situation it can generally be assumed that the mean post-mining water table will be at the top of the backfill. Thus, the PAF waste will be covered by at least 5 metres of inert waste.

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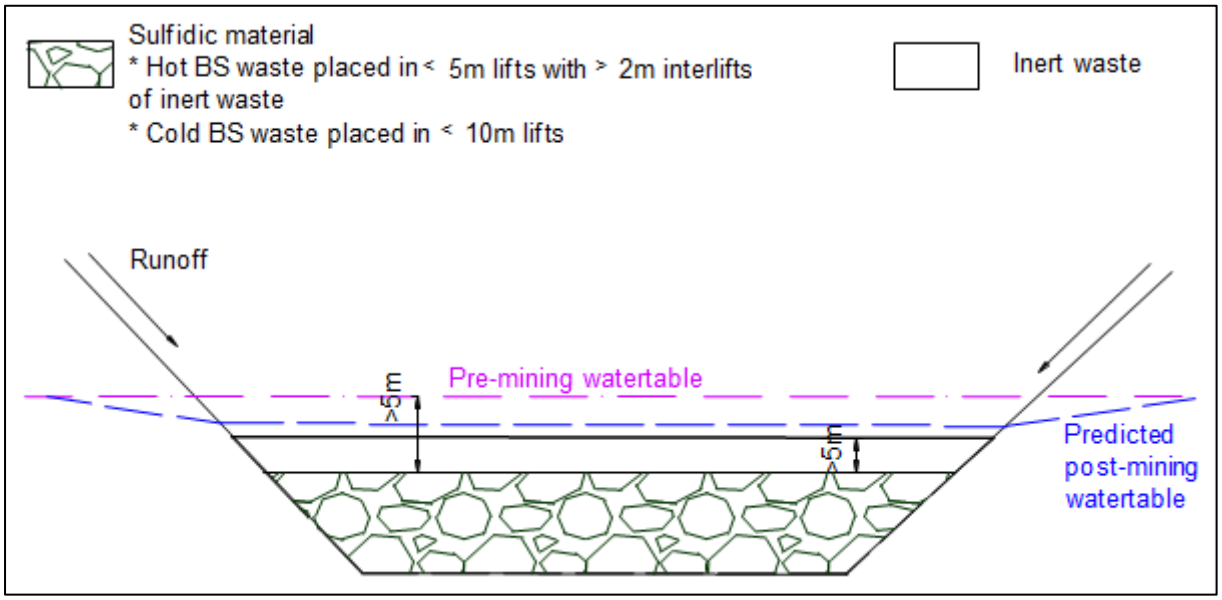

Figure 6: Example of PAF material placed below the water table and with the pit partially backfilled.

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- The thickness of each hot black shale material lift must not exceed 5 metres followed by a minimum 2 metre lift of inert or net neutralising waste rock between each hot black shale layer.
- The thickness of each cold black shale material lift must not exceed 10 metres. No inert or net neutralising waste rock layer is needed between cold black shale lifts.
- The uppermost lift of both cold and hot black shale material must be covered with a minimum 5 metre layer of inert or net neutralising waste rock.
- Each lift must be placed so that it ties into the pit walls on all sides to minimise the risk of convective oxygen transport until the waste is flooded.
- If backfilled to above the post-mining water table, the upper inert waste rock surface must be revegetated.
- A store and release cover is not needed if all PAF material in a pit is placed below the water table.

In addition to the minimum design requirements listed above, the optimum design for in-pit disposal below the water table also includes:

- Enough inert or net neutralising backfill should be placed on top of the PAF waste to raise the fill level to at least above the post-mining water table (preventing the formation of a pit lake) and preferably above the pit walls so that runoff is not directed into the pit fill (see Figure 19).
- If required, flooding of the backfilled pit should be enhanced by diverting surface water flows into the pit or directing dewatering water from active open pits into the backfilled pit. The more rapidly the waste can be inundated, the less pyrite will ultimately oxidise. Rapid flooding will minimise the build-up of soluble sulfide oxidation products in the material. As long as geotechnical safety requirements are met, construction of waste lifts into standing water on the pit floor is acceptable. Figure 21 demonstrates that less than 50% of the sulfidic material oxidises if the water table is recovered within 100 years and less than 15% oxidises if the water table is recovered in 30 years. This may differ from site to site, however this example clearly demonstrates the advantage of BWT PAF storage and rapid water recovery.

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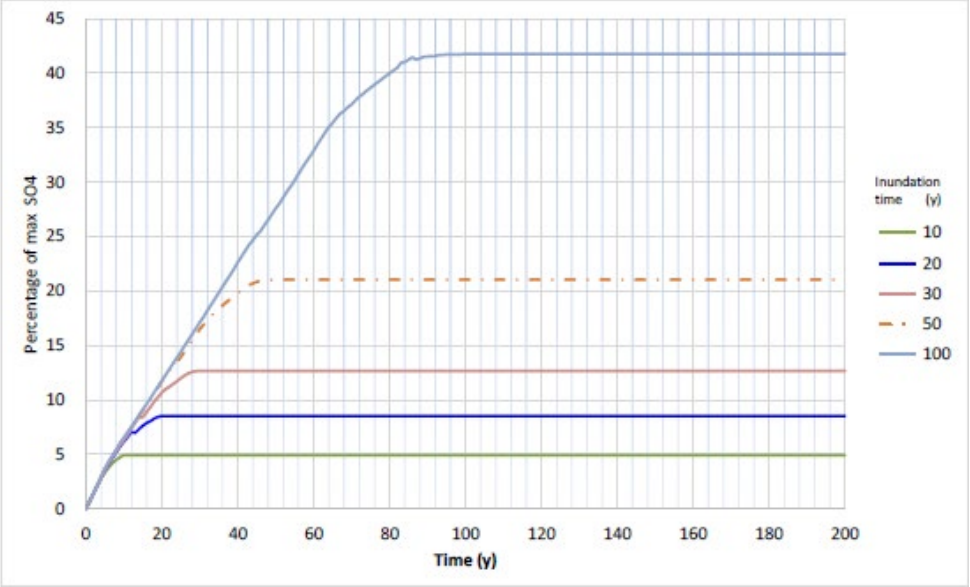

Figure 7: An example of modelling the effects of different inundation time on sulfate generation.

A4.2.2 In Pit Disposal Above the Water Table

If PAF material is placed above the post-mining water table, it must be ensured that long-term variations in the water table elevation do not allow water to rise into the overlying PAF material. Intermittent contact with infiltrating water from above must also be minimised. For PAF material placed above the post-mining water table the following minimum design criteria apply:

- The base of the PAF material backfill must be at least 5 metres above the predicted mean post-mining water table.
- At least 5 metres of inert or net neutralising waste rock must be placed at the base of the open pit before PAF backfill is placed. The most likely location for a perched water table to form is at the base of the backfilled pit because of the permeability contrast between the bedrock and the backfill.
- The thickness of each hot black shale material lift must not exceed 5 metres followed by a minimum 2 metre lift of inert or net neutralising waste rock between each hot black shale layer.
- The thickness of each cold black shale material lift must not exceed 10 metres. No inert or net neutralising waste rock layer is needed between cold black shale material lifts.
- The uppermost lift of both cold and hot black shale material must be covered with a minimum 2 metre layer of inert or net neutralising waste rock. This will prevent runoff water from contacting the underlying PAF material until the store and release cover can be constructed.
- If the pit can be completely backfilled so that no high walls are exposed above the inert waste rock fill, then each inert, cold and hot black shale material layer should tie into the pit walls on all sides to minimise the risk of convective oxygen transport (see Figure 22 and Figure 23 for examples).

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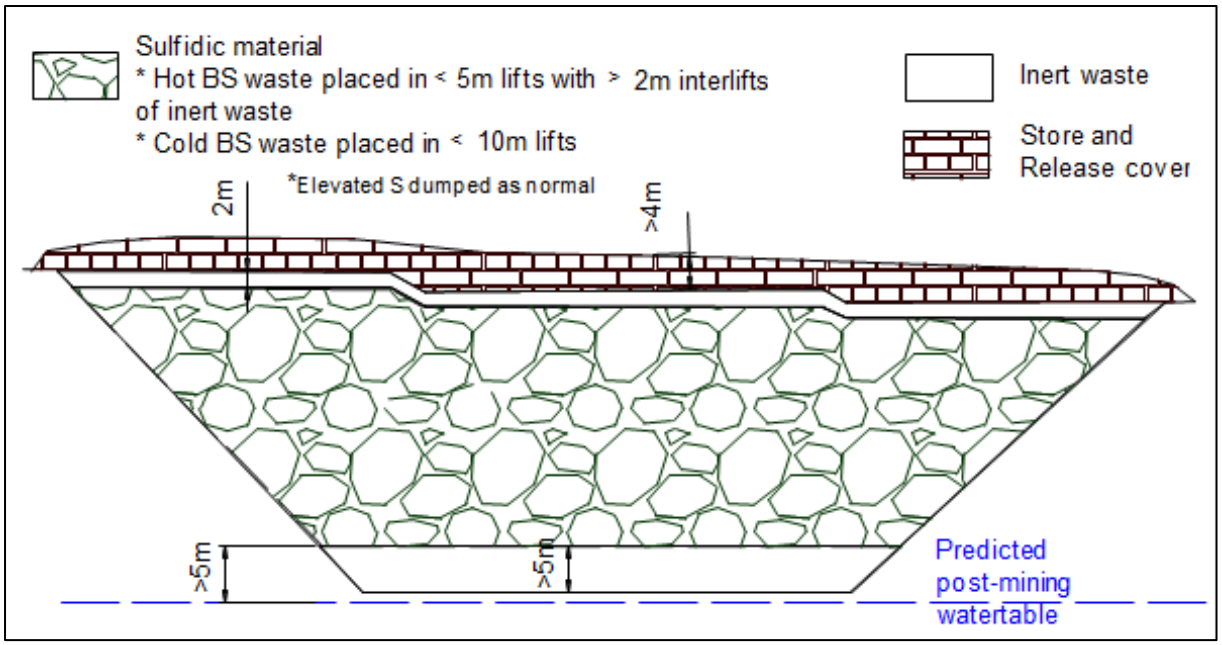

Figure 8: Example of PAF material placed in a dry pit that is completely backfilled.

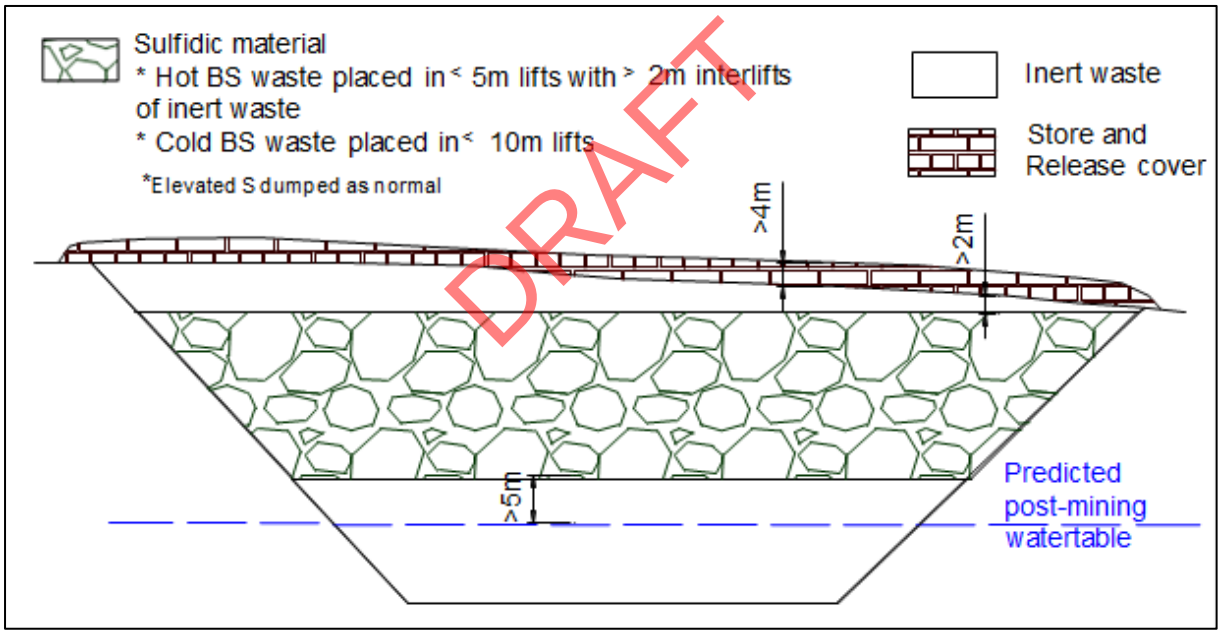

Figure 9: Example of PAF material placed above the water table and with the pit completely backfilled.

- If the pit will only be partially backfilled so that highwalls are exposed above the final backfill surface and that the runoff from the remaining highwalls will flow towards the backfill, a minimum five metre (measured both horizontally and vertically) buffer of inert waste rock must be placed between the pit walls and each PAF material lift where possible (see Figure 23 for an example). A 2 metre high by 5 metre wide abandonment bund will also need to be placed adjacent to the exposed high walls to prevent run on water from infiltrating into the cover over the PAF material.

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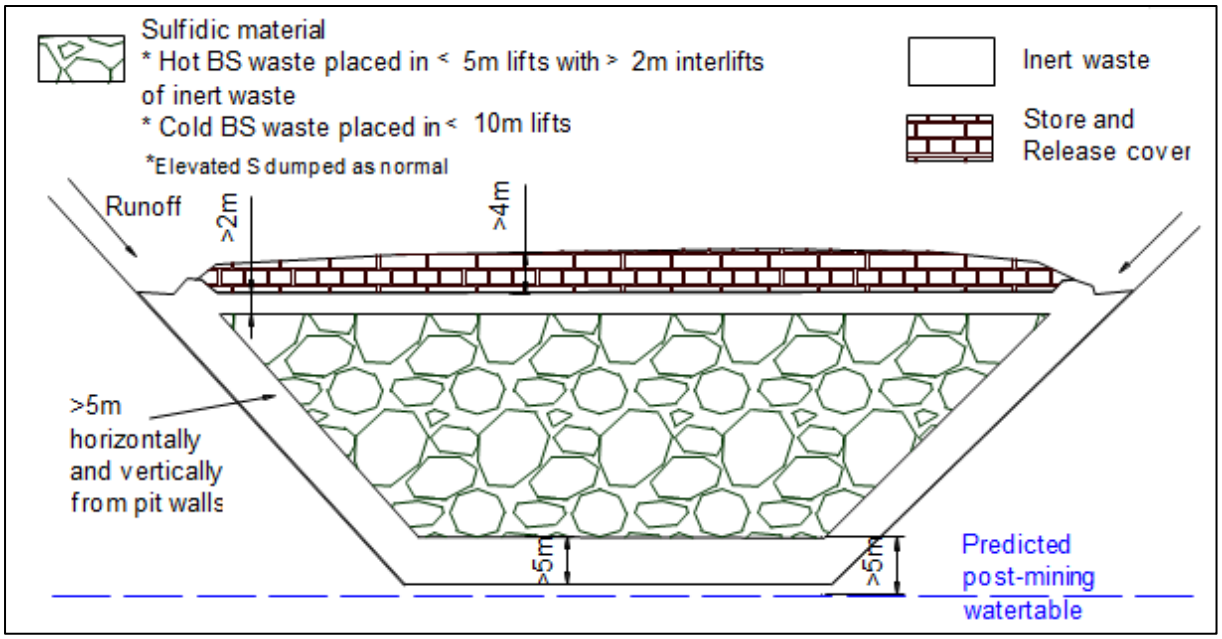

Figure 10: Example of PAF material placed above the water table and with the pit partially backfilled.

In addition to the minimum design requirements listed above, the optimum design for in-pit disposal above the water table also includes:

- If possible, the pit should be backfilled above the lowest point on the pits walls so that the final backfill surface can be sloped to allow runoff water to flow out of the pit footprint.
- The optimum design would be to backfill the pit so that there are no highwalls exposed that could direct runoff onto the store and release cover and underlying PAF material (see Figure 22 and Figure 23).

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A1.3 Above Ground Disposal Requirements

If PAF material waste rock dumps are to be constructed on top of the original ground surface, more stringent design criteria are required than for in-pit disposal because of the risk of erosion exposing encapsulated PAF material and because of the likelihood of the convective transport of oxygen through the side slopes of the dump. Design criteria for hot black shale dumps are also more stringent than for cold black shale dumps and elevated-sulfur dumps.

A1.3.1 *Design of Outer Waste Rock Dump Slopes*

To the extent possible, cold and hot black shale material should be excluded from beneath final waste rock dump slopes. There are several issues associated with the placement of cold and hot black shale beneath waste rock dump slopes:

- There is an increased risk of slope erosion damaging vegetation and covers in the short term, or in the long term exposing the underlying material.
- The probability of convective oxygen transport to the sulfidic material is higher than for cold and hot black shale material only placed in the dump interior.
- Store and release covers cannot be built on slopes because they are constructed with more erodible fine-grained materials. It is likely that infiltration rates into the underlying cold and hot black shale material will be higher on slopes than on flat surfaces with a store and release cover, which could result in increased AMD.

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- Uncertainties with the requirements for final dump slopes may require the importation of additional inert material to achieve the final landform design to ensure the preservation of the minimum 5 metres of inert cover over the sulfidic material.
- The berm and batter design of final slopes would direct water through the slopes and into the underlying PAF material.

The minimum design criteria in the following section reduce but do not completely mitigate these risks. **For this reason, hot black shale should not be placed under final slopes, and the volume of cold black shale should be minimised wherever possible**[1]**.** The greatest benefit can be derived from excluding hot black shale material from beneath the slopes because it not only has the potential to spontaneously combust, but also has anywhere from 2 to 70 times more acid producing potential on average than the cold black shale material.

A1.3.2 *Hot Black Shale*

Figure 25 shows the optimum design for the waste rock dumps in which hot black shale is completely excluded from beneath the footprint of the final recontoured slope.

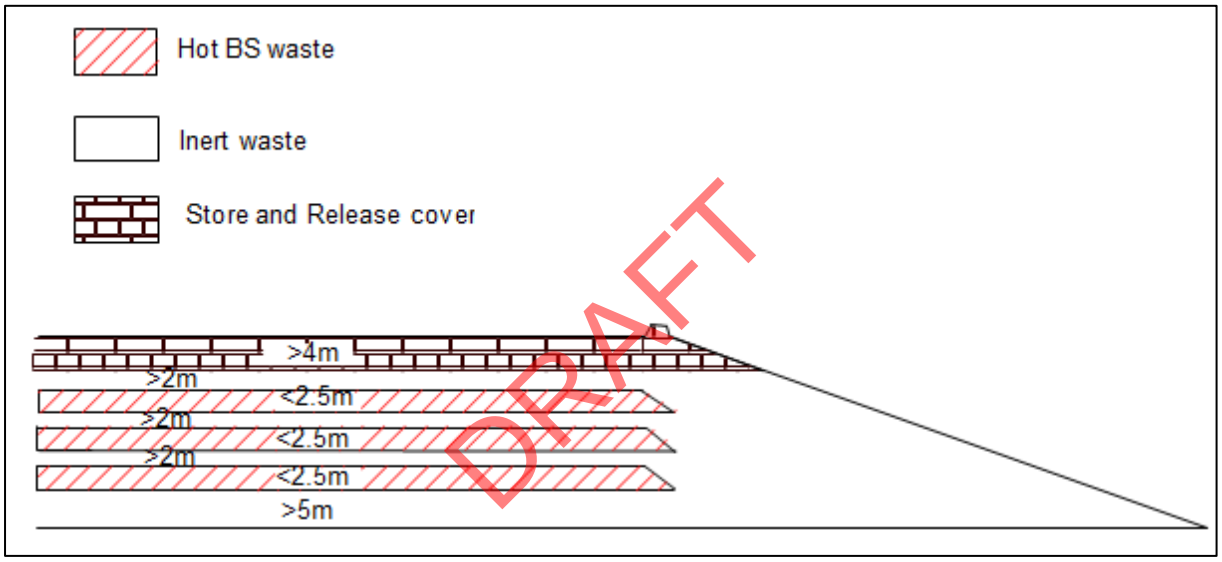

Figure 11: Example of the design for hot black shale dumps.

The minimum design criteria for hot black shale dumps are:

- A minimum of 5 metres of inert or net neutralising waste rock must be placed on the original land surface at the base of the dump.
- Enough inert waste rock must be placed against hillsides so that PAF material is not located within 5 metres of the hillside as measured both vertically and horizontally.
- The thickness of each hot black shale material lift must not exceed 2.5 metres followed by a minimum 2 metre lift of inert or net neutralising waste rock. Lifts are to be constructed by paddock dumping (or reverse paddock dumping and pushing out) so that the hot black shale can cool and so that incident vehicle traffic helps create a compacted layer every 2 to 2.5 metres to inhibit water movement and convective oxygen transport.
- Enough inert or net neutralising waste rock must be placed on the outer skin of the hot black shale waste rock dump so that no hot black shale material is located under the final slopes.[2]

[1] Effective from the 2016 SCARD update. Earlier designs and dumps can still contain hot black shale under slopes.

[2] Effective from the 2016 SCARD update. Dumps designed and built prior to 2016 can continue to dump hot black shale under slopes, however it must be located > 5 metres (measured across the shortest distance) from the final dump slope.

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- Hot black shale may be mixed with Elevated S material in dumps, however elevated sulfur material should not be used on the outer slopes.
- The final lift on a hot black shale waste rock dump must be composed of a minimum 2 metre-thick inert or net neutralising layer. This will prevent runoff water from contacting the underlying PAF material until the minimum 4 metre-thick store and release cover can be constructed.
- During construction and at closure, the upper dump surface of the hot black shale waste dump should be designed so that it only receives incident rainfall with no run-on from adjacent areas.

A1.3.3 *Cold Black Shale*

An example of a cold black shale waste rock dump constructed according to the minimum dump design criteria is shown in Figure 26. The minimum design criteria for cold black shale dumps are:

- A minimum of 5 metres of inert or net neutralising waste rock must be placed on the original land surface at the base of the dump.
- Enough inert waste rock must be placed against hillsides so that cold black shale is not located within 5 metres of the hillside as measured both vertically or horizontally.
- The thickness of each lift of cold black shale must not exceed 10 metres. This will create a vehicle compacted layer every 10 metres in the dump to inhibit water movement and convective oxygen transport[3].
- No inert or net neutralising waste rock layer is needed between cold black shale lifts.
- Enough inert or net neutralising waste rock must be placed on the outer skin of the cold black shale waste rock dump so that no material is located within 5 metres of the final dump surface after the slope has been re-contoured at closure.
- The final lift on a cold black shale waste rock dump must be composed of a minimum 2 metre-thick inert or net neutralising layer. This will prevent runoff water from contacting the underlying material until the minimum 4 metre-thick store and release cover can be constructed.
- During construction and at closure, the upper dump surface of the cold black shale dump should be designed so that it only receives incident rainfall with no run-on from adjacent areas.

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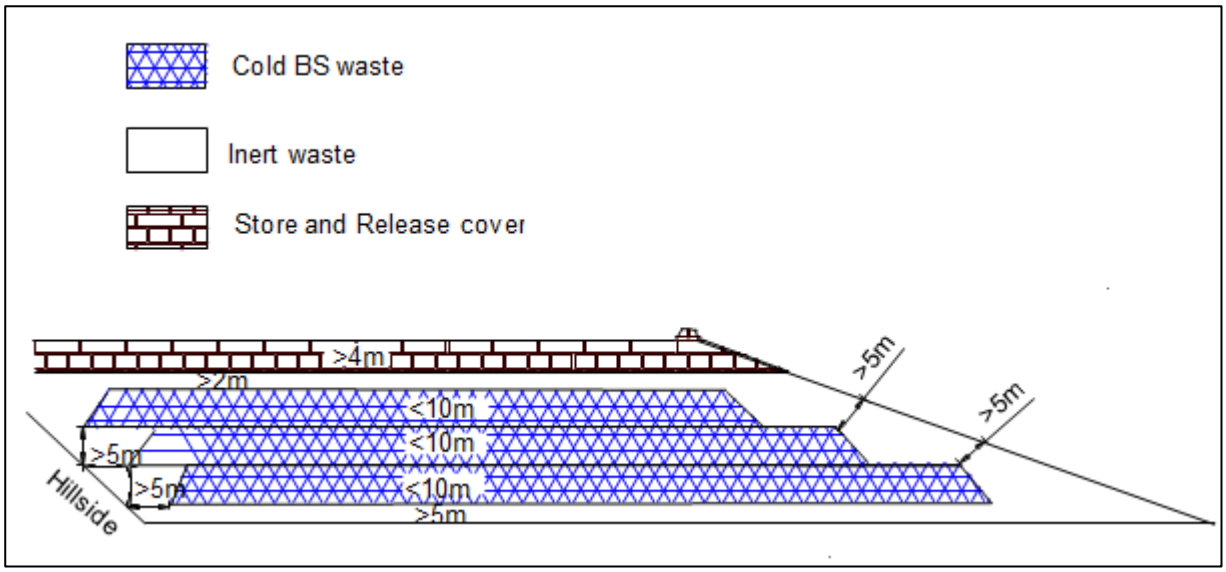

[3] Note that this has been changed from 5 m lifts as the gas movement through waste dumps has been shown during ANSTO testing to be diffusive and it is likely that the difference in ARD generation between 10 and 5 m lifts will be negligible.

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Figure 12: Example of the minimum design criteria for cold black shale dumps. *Error! Bookmark not defined.*

A1.3.4 *Elevated S*

An example of an Elevated S waste rock dump constructed according to the minimum dump design criteria is shown in Figure 27. The minimum design criteria for elevated-sulfur dumps are:

- Inert or net neutralising waste rock must be placed on the original land surface at the base of the dump.
- At least one (1) metre of inert material is located on the outer surface of the waste dump at closure.
- Elevated-sulfur material can be mixed with inert material and dumped accordingly.
- Co-disposal of elevated-sulfur waste with materials containing excess available neutralising capacity is recommended.
- During construction and at closure, the upper dump surface of the elevated-sulfur dump should be designed so that it only receives incident rainfall with no run-on from adjacent areas.

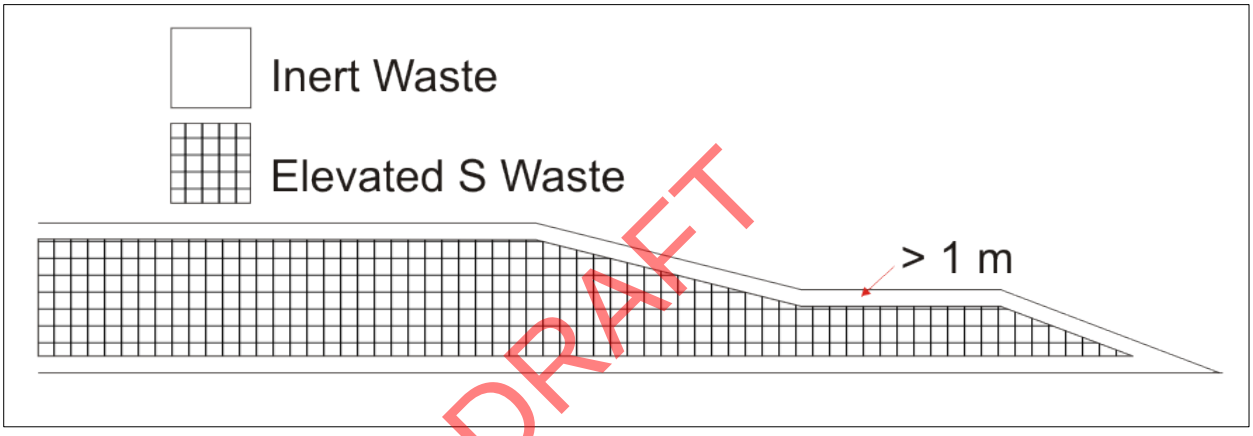

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Figure 13: Example of the minimum design criteria for Elevated S dumps. No store and release cover is required and only 1 metre inert material cover at surface required.

A1.3.5 *Composite Designs*

Figure 28 shows an example of a composite hot and cold black shale dump in which hot black shale is excluded from the beneath the slope and cold black shale is placed below the slope. Composite dumps of this kind may significantly reduce the residual risk associated with the dump slopes without significantly reducing the total storage capacity for sulfidic material within the dump. There must be at least a one metre buffer (measured horizontally or vertically) between the hot and cold black shale material where they are in close contact on the outer slopes of the hot black shale repository.

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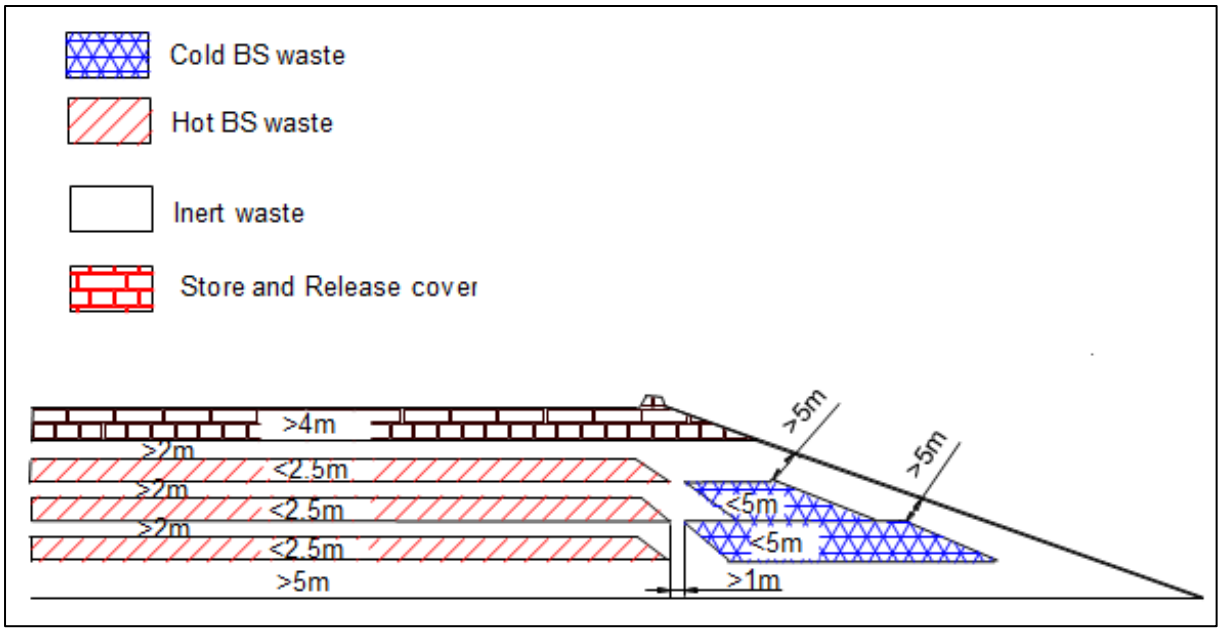

Figure 14: Example of optimum composite designs for cold and hot black shale dumps.

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Appendix 2 Dump Designs for Material with Neutralising Potential

A2.3 Dumping Scenarios

The following dump designs were developed specifically for cases where neutralising material is available. Calcrete is the preferred net neutralising material, however if calcrete is not available then dolomite from the Wittenoom Formation can be used as net neutralising waste. Please note that only the dolomite within the Wittenoom Formation has sufficient neutralising material and it is not mapped separately within geological models and could be difficult to source.

A2.3.1 *Above Ground Disposal Requirements*

An example of the minimum dump design criteria is shown in Figure 29.

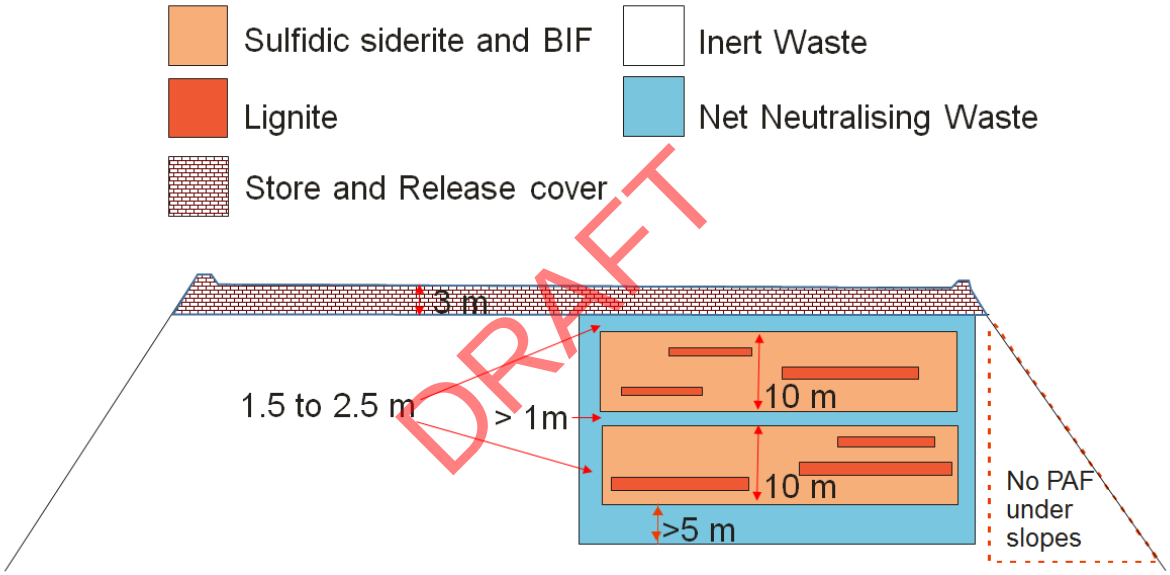

Figure 15: Example of minimum design for a combined sulfidic BIF and siderite with lignite dump – Permanent storage

The minimum design criteria for AWT PAF dumps are:

- No PAF material is to be placed under the final rehabilitation slopes of the waste dump.
- Minimum of 5 metre of net neutralising waste rock must be placed as a basal layer prior to PAF placement within the dump. This material can be end tipped. This basal layer can be reduced in thickness to 2.5m, if the PAF cell is located higher in the waste dump. The mineral waste team should assess this.
- A 1.5 – 2.5 metre layer of net neutralising waste should be placed at the top, sides and base of each PAF lift i.e. a net neutralising waste bund should be created prior to PAF placement. This will reduce the lateral flow of incident rainfall.
- If spontaneous combustion is a risk, the thickness of each lignite material lift must not exceed 2.5 metre followed by a 1.5 to 2.5 metre lift of net neutralising waste rock. Lifts are to be constructed by paddock dumping so that lignite material can cool and so that incident vehicle traffic helps create a compacted layer every 1.5 to 2.5 metres to inhibit water movement and convective oxygen transport.
- The thickness of each lift of sulfidic BIF and siderite material must not exceed 10 metre. A 1.5 – 2.5 metre paddock dumped layer of net neutralising waste should then be placed on top of the PAF lift.

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- The 10 metre PAF layer should be paddock dumped in a number of small lifts to limit the risk of material segregation and tightly compact the waste dump to prevent oxygen ingress i.e. 4 x 2.5 metre thick PAF layers. The dumping of PAF material during the wet season should be avoided, where possible.
- The final lift on the PAF waste rock dump must be composed of a minimum 1.5-2.5 metre thick inert or net neutralising layer. This will prevent runoff water from contacting the underlying sulfidic material until the minimum 3 metre thick store and release cover can be constructed.
- Only incident rainfall and no run-on from adjacent areas should pass through the dump.
- If there is insufficient PAF to create the 10 metre lift, the >1 metre net neutralising waste layer can be constructed at <10 metre.
- If spontaneous combustion is a risk, lignite material should be covered with net neutralising material within 1 month during the wet season (due to the spontaneous combustion risk). Where possible, the sulfidic BIF and sulfidic siderite material should be covered with net neutralising waste during the wet season.
- If PAF is temporarily stored within a waste dump, the previous criteria still applies, however PAF can be stored underneath the final slopes, as long as there is a 10 metre offset (consisting of calcrete closest to the PAF and inert waste) (Figure 30). If PAF is placed on 30m of inert material, it would need to be rehandled within 20 years. If there is a delay in rehandling then the placement of a temporary cover on the dump should be considered.

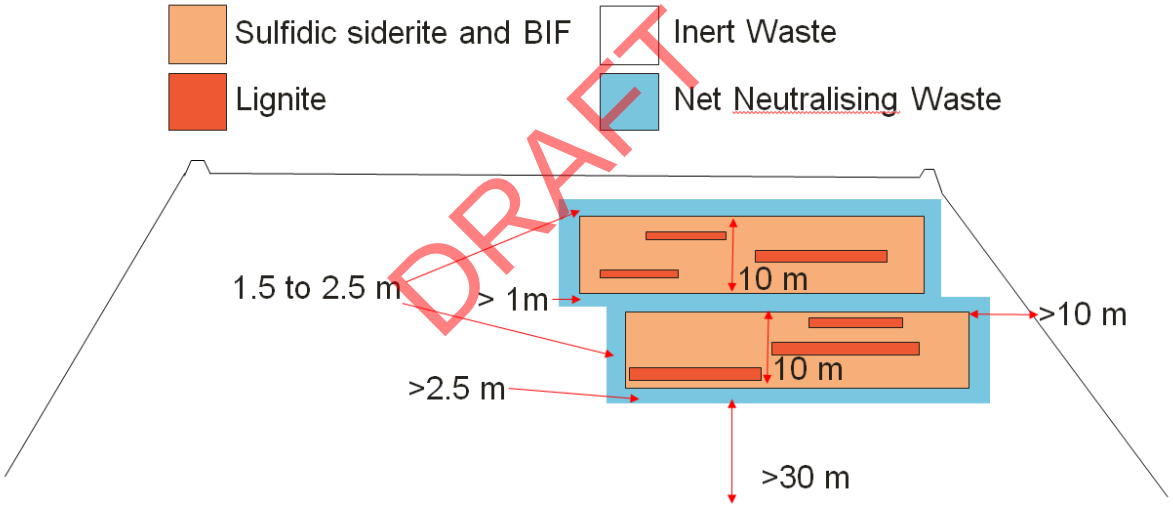

Figure 16: Example of minimum design for a combined sulfidic BIF and siderite with lignite – Temporary storage

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Appendix 3 Rehabilitation and Closure

A3.1 Final Landforms

To reduce the risk of erosion and to minimise infiltration, final landforms should be designed in accordance with the following criteria:

- Final landform design should be designed in accordance with the Rio Tinto Iron Ore (WA) Landform Design Guidelines.
- Final landforms must be designed so that runoff is not directed onto surfaces that are underlain by sulfidic material.
- A back-sloping crest bund must be placed around the top of each dump slope and berm. This will prevent runoff water flowing from the dump surface over the slopes and causing erosion.
- If PAF material is exposed during the re-contouring of waste rock dumps that were created before waste rock segregation was practiced, it must be covered with at least 2 metres of inert waste rock. This will help ensure that the entire final dump surface is able to support vegetation.
- Wrapping the PAF dump is preferred rather than dozing down the slope.

A3.2 Store and Release Covers

A3.2.1 *Design*

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Store and release covers must be constructed on all flat surfaces over PAF waste dump repositories and over some sulfide/black shale exposures within open pits. Store and release covers are designed to limit infiltration into the underlying waste rock by maximising the evapo-transpiration of incident rain water. The cover is designed to store water near the surface during the wet season so that it can be removed from the cover material and returned to the atmosphere during the dry season by evaporation and plant transpiration.

Waste rock that is used to construct store and release covers must contain sufficient fine-grained material to have both a high moisture retention capacity and a relatively low permeability (i.e. large boulders should not be placed on the cover). Waste rock composed of well-graded clayey, silty, sandy gravel or clayey silty gravely sand makes the best store and release cover material. As a rough guide, waste rock containing more than 1/3 coarse sand size and finer particles (< 5 mm) will make a suitable cover material. **Blocky BIF composed of gravel with very little silt, sand or clay is not ideal** for use in cover construction and should be avoided if another more suitable waste type is available (Figure 31).

Where possible, 4 metres of oxidised shale should be used in preference to 4 metres of BIF on flat top covers. If detrital material is available, then a cover constructed out of 4 metres of detrital material overlying 2 metres of oxidised shale has been shown to reduce net percolation and salt uptake. Topsoil should be preferentially placed on covers as the vegetation can significantly reduce the amount of net percolation through the cover. If the cover will be less than 6 metres thick then advice should be sought from the mineral waste management team. For guidance on the covers on slopes please see the Rio Tinto Iron Ore (WA) Landform Design Guidelines.

A3.2.2 *Construction*

During construction there should be regular quality control checks to ensure large boulders have not been placed into the cover.

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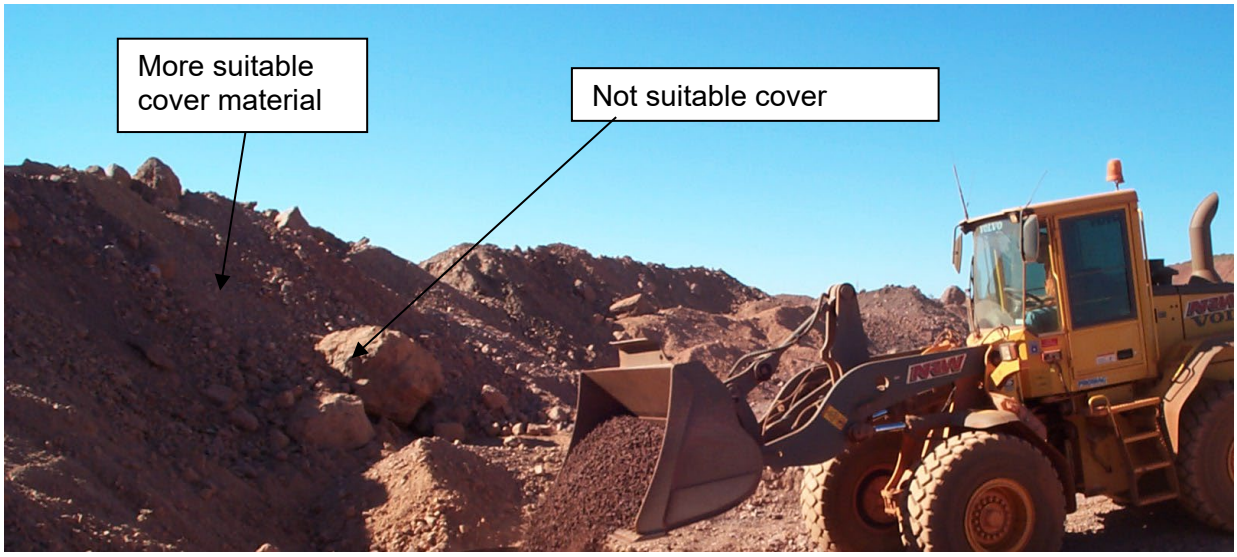

Figure 17: An example of suitable and not suitable material to be used in the construction of a store and release cover.

Waste rock that is used to construct store and release covers must also be able to support vegetation, so materials with high salinity, and acidic or very basic pH should be avoided. The waste rock should be placed in a manner that minimises segregation of the material into coarse and fine particles. For this reason covers should be paddock dumped, they should never be constructed by dumping in four metre lifts.

Store and release covers should be constructed as follows (Figure 32):

- Paddock-dump store and release cover material on top of a vehicle compacted surface so that the average depth of the cover material is greater than 2 metres.
- A dozer should then be used to knock down the crest of each paddock dump pile and to fill in the depressions between piles to create a trafficable surface.
- Paddock-dump a second layer of store and release cover material on top of the first lift so that the average depth of the second lift is greater than 2 metres. Vehicle traffic during this dumping will create a compacted layer on top of the first store and release cover layer.
- A dozer should again knock down the crest of each paddock dump pile in the second layer and fill in the depressions between piles to create a surface that is nearly planar.
- Topsoil should be placed on top of the second store and release cover layer. The surface should then be ripped and seeded. Ripping needs to be deep enough (> 0.3 metres) to mix in the topsoil and to ensure that there are not compacted zones that could inhibit plant growth and rooting on top of the upper layer.

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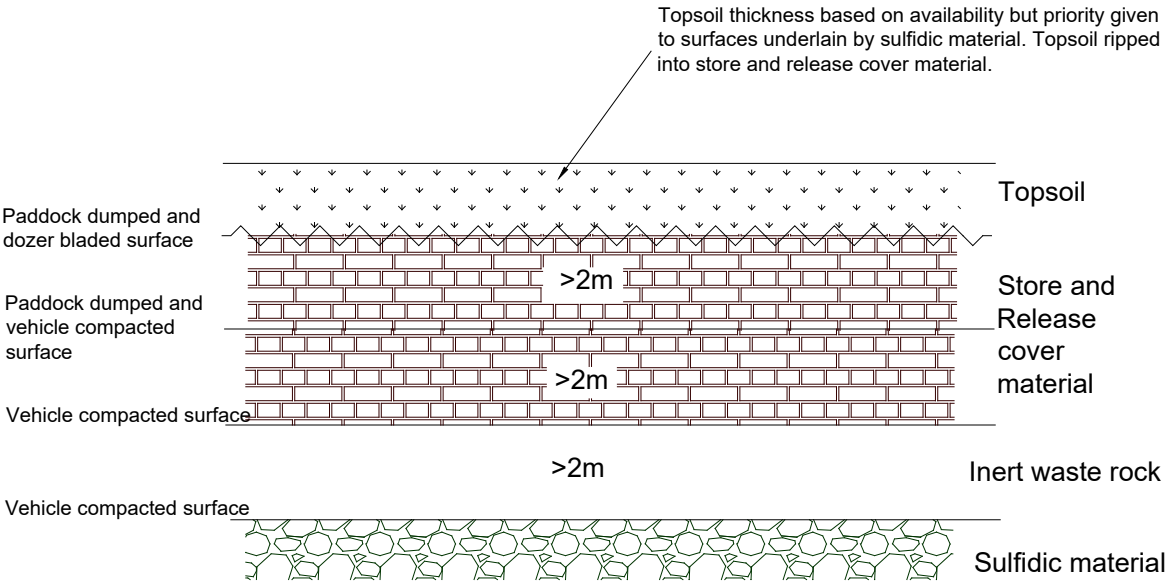

Figure 18: Detail of store and release cover design.

A3.3 Topsoil Management

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Topsoil placement can greatly accelerate the establishment of native vegetation on waste rock surfaces. This in turn will help to maximise evapo-transpiration, minimise infiltration into the underlying waste rock and inhibit erosion on dump slopes. If topsoil resources are limited, the most benefit for ARD management can be gained by preferentially utilising topsoil for the revegetation of waste rock dumps that contain sulfidic material. In decreasing order of importance, topsoil should be placed on:

1. Dump slopes underlain by hot black shale/lignites material;
2. Dump slopes underlain by cold black shale/sulfidic BIF/sulfidic siderite material;
3. Flat store and release cover dump surfaces underlain by hot black shale/lignites material;
4. Flat store and release cover dump surfaces underlain by cold black shale/sulfidic BIF/sulfidic siderite material;
5. Store and release covers within open pits;
6. Waste rock dumps that were created before waste rock segregation was practiced and which may contain dispersed black shale or material containing sulfides;
7. Assessable inert waste rock surfaces within pits that contain black shale or sulfidic material exposures; and
8. Waste rock dumps that do not contain any black shale or sulfidic material.

For further information on topsoil management refer to the RTIO Soil Resource Management Work Practice.

A3.4 Open Pit Closure

The geology and hydrogeology of an open pit will largely control the potential closure issues associated with the final void. Open pits that are located above the water table and which do not contain any black shale or sulfidic material exposures should not pose any geochemical risks at closure. Open pits that intersect the water table but do not contain any black shale or sulfidic

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material exposures may ultimately contain saline water bodies with neutral pH that could impact down gradient groundwater. Open pits that contain black shale or sulfidic material exposures will likely contain ephemeral or permanent acidic and potentially saline water bodies that could impact down gradient groundwater and could represent a direct exposure risk to wildlife or humans.

Hypersaline pit lakes may be considered acceptable on relinquishment as long as down-gradient beneficial use is not impacted. Further consultation with stakeholders would be required for specific locations. Mitigation measures will likely be required if net acid generating materials such as pyritic black shale are exposed on the final pit walls. In pits with extensive exposures of pyritic black shale that will not be backfilled to above the water table, long term mitigation measures will likely be required to attain the proposed water quality criteria.

The hydrogeological and geochemical behaviour of each pit should be predicted so that it can be managed appropriately at closure to minimise significant groundwater impacts and surface water exposures to wildlife and humans. As discussed previously, the most protective pit closure strategy is to completely backfill the pit or to backfill the pit to above the estimated pre-mining water table where practicable. Backfilling to above the pre-mining water table should lead to a near complete recovery of the water table elevation and should cut off oxygen to the majority of black shale or sulfidic material exposed on the pit walls.

In order of decreasing benefit, pit backfilling should be prioritised as follows: 1) pits with black shale or sulfidic material exposures that intersect the water table and will discharge to groundwater at closure, 2) pits with black shale or sulfidic material exposures that intersect the water table but that will not discharge to groundwater at closure, 3) pits with black shale or sulfidic material exposures that are above the water table, 4) pits without black shale or sulfidic material exposures that intersect the water table and that will discharge water to groundwater at closure, 5) pits without black shale or sulfidic material exposures that intersect the water table but that will not discharge to groundwater at closure, and 6) pits that do not contain any black shale or sulfidic material exposures and that are above the water table. The proximity to nearby regionally significant aquifers or ecologically significant seeps and springs should also be considered when evaluating potential pit closure issues.

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Extensive backfilling is not practicable for many open pits because of the size of the final void and because of pit sequencing issues. Where backfilling is not practicable the following actions should be taken:

- Haul roads and accessible benches that are underlain by inert waste rock should be ripped and seeded to minimise runoff, to promote vegetation establishment and to maximise evapo-transpiration.
- A minimum 4 metre store and release cover system should be constructed on top of accessible black shale or sulfidic material exposures for those portions of the pit that will be located above the water table and that will not be periodically flooded by cyclone events.
- A minimum 5 metre lift of inert or net neutralising rock should be placed on top of accessible black shale or sulfidic material exposures for those portions of the pit that will be located below the water table or that will be periodically flooded by cyclone events.
- Consideration should be given to covering black shale or sulfidic material exposed on pit highwalls with inert or net neutralising material pushed or dumped from the sides.

An example of these pit closure strategies is illustrated in Figure 33.

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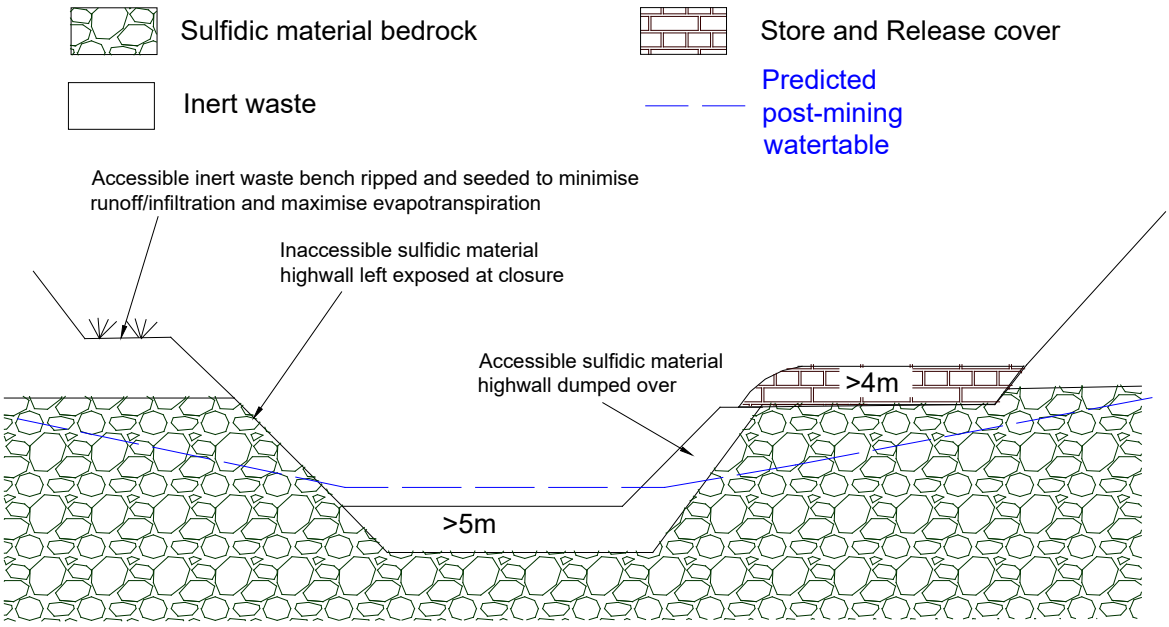

Figure 19: Examples of closure strategies for a pit with sulfidic material that will not be backfilled.

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Appendix 4 Contingency Planning

Contingency plans for most upset conditions and unexpected impacts related to sulfidic material management will need to be developed on a case by case basis. Contingency plans will generally be developed by the site Mineral Waste Management team or at a minimum they must be approved by the Team. Contingency plans for spontaneous combustion and inert materials shortages are outlined in the following sections.

A4.1 Spontaneous Combustion

Site specific pit safety procedures should be followed.

All occurrences of burning black shale or lignites must be reported to the mine supervisor and the pit safety team as soon as possible. If possible, fires should be extinguished by rapid burial of the burning material under at least five metres of inert waste rock (see relevant SWPs). For locations where this may be difficult such as beneath pit ramps, the black shale or lignite should be covered with as much inert material as practicable. The inert material should be placed so that the upper surface is well compacted and so that side slopes are adequately covered to prevent lateral convective transport of oxygen to the burning rock mass. If rapid coverage is not an option, the material can be excavated and transported to the toe of an advancing inert dump lift where it can be rapidly buried. Water should not be used to extinguish the fire because this could actually enhance the spontaneous combustion risk of black shale or lignite that is not already burning and because the volumes of water that would be required are generally prohibitively high.

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A4.2 Inert Materials Shortages

Medium and short term mine plans should be designed so that inert waste rock is produced in adequate volumes and at appropriate times to allow timely encapsulation of PAF material. Hot black shale and lignite material requires the highest volumes of inert material (approximately 1:1) because of the requirement for an inert interlayer every 2.5 metres. If there were temporary shortages of inert material, hot black shale or lignite dumps could be designed with cold black shale or sulfidic BIF and siderite material if it contains a low sulfide concentration, some neutralising potential and low organic carbon (i.e. no black shale or lignite) material. The appropriate material to use in the heat dissipating interlayer should be confirmed as appropriate by Mine Geology. But under no circumstances should black shales or lignites with both elevated sulfide and organic carbon concentrations be used. If acid base accounting tests prove the material to be non-acid forming, coarse tails could be used as inert waste in dumps. If there is a shortage of inert material then inert waste in other waste dumps may need to be rehandled and transported to the black shale waste dump.

A4.3 Surface Water Management

Every endeavour should be made to divert surface water runoff from contacting black shale or sulfides exposed on pit walls. Site specific acid water and flood management plans should be developed that plan for the appropriate disposal of potentially acidic water in pits with PAF exposures. Some strategies to manage surface water runoff include:

- Slope pit floor away from pit PAF exposure
- A sump should be constructed below the PAF exposure to collect acidic water.
- Surface water runoff from inert exposures should be segregated from coming in contact with acidic water.

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- Bund upper catchment to run over competent material such as BIF rather than PAF exposures.

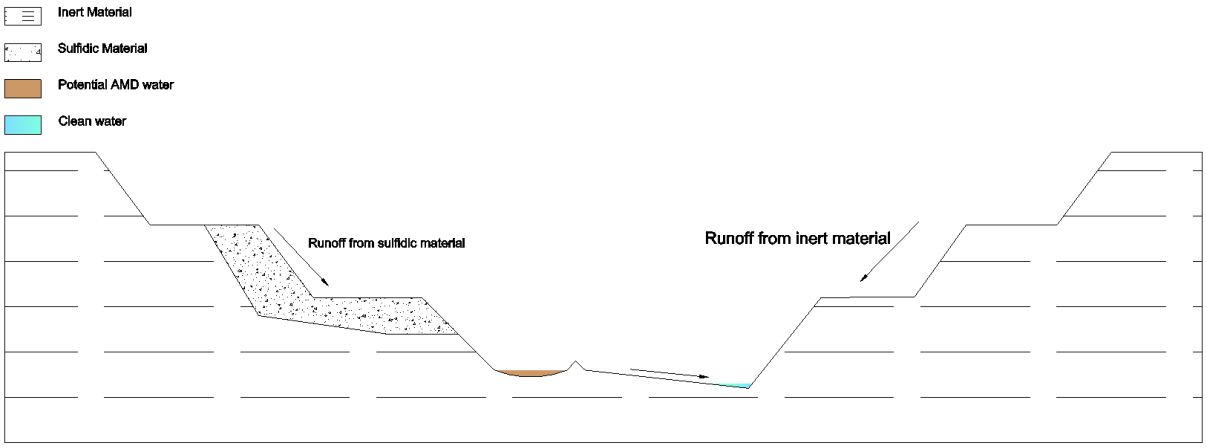

Figure 20: Suggested surface water management for sulfide exposures.

Where possible, PAF exposures in waste dumps should be covered with inert material during the wet season, particularly hot black shale and lignites. A bund at the top of the waste dump surface will reduce any surface water from travelling over the sulfidic material and transporting contaminated drainage into the surrounding environment.

Pipelines transporting acidic water should be shut down and repaired if there is a leak. Acid water pipelines should be labelled with purple stripes and non-acidic pipelines can be labelled with green stripes (as per Australian Standards).

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A4.4 Geotechnical Stability

A6.4.1 Pit Walls

Pit walls excavated in MCS are designed with the same concept as for other stratigraphic units. That is, generally the design is for a Factor of Safety of at least 1.20 and a Probability of Failure of around 10% on the inter-ramp scale and up to 30% for the batter scale. The management of slopes excavated in MCS is therefore no different from that of any other stratigraphic unit, whereby a process called Geotechnical Design Management is utilised. This involves identifying hazards and hence risks associated with the geotechnical design and undertaking a risk management strategy to minimise these risks. Actions include design review, geotechnical investigation, mapping, conformance to design and monitoring. Contingency plans are established through Slope Management Plans in consultation with mine management.

The occurrence of MCS is of little consequence to the geotechnical management process.

A6.4.2 Dump failures

Whilst no specific stability analyses have been undertaken on black shale waste dumps, they can generally be considered stable due to the process of encapsulation of the material well within a dump. Also, the process of undertaking earthworks to prepare the encapsulation is considered to add a significant contribution to the stability of the dump location. It is anticipated that future stability analyses may be documented in a Waste Dump Management Plan.

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Appendix 12: Summary of Hydrology and Flood Protection

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RTIO Water Resource Evaluation

Hope Downs 2 & Bedded Hilltop

Summary of hydrology and flood protection

December 2021

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1. OVERVIEW

The purpose of this report is to assess the potential surface water risks associated with the closure of Hope Downs 2 (HD2) and Bedded Hilltop (BHT) mine sites.

Two-dimensional hydraulic modelling has been used to characterise the surface flow regime associated with surrounding surface water catchments interacting with the Life of Mine (LOM) pit and dump designs for both deposits. Modelling presented in this report has considered design flood flows from rare to very rare flood events. These models will be used to assess the risk and suitability of final closure landforms as closure planning progresses.

2. HYDROLOGY SUMMARY

HD2 and BHT deposits are located within the upper reaches of the Weeli Wolli Creek catchment that forms part of the Fortescue River Region (BoM, 2012). Weeli Wolli Creek has a total catchment area of approximately 4,770 km^2 to Waterloo Bore gauging station and drains north into the Fortescue Marsh; an extensive, intermittent wetland. The upper reaches of the Weeli Wolli Creek catchment include Pebble Mouse Creek, a major tributary of Weeli Wolli Creek, which has a catchment area of 340 km^2. Locations of these catchments is illustrated in Figure 1 and the catchment areas are summarised in Table 1.

Table 1: Catchment areas of Weeli Wolli Creek

Catchment	Catchment Area	Downstream Location
Weeli Wolli Creek	4,770 km^2	Fortescue Marsh
Weeli Wolli Creek	1,340 km^2	Tarina gauging station
Pebble Mouse Creek	340 km^2	Confluence with Weeli Wolli Creek

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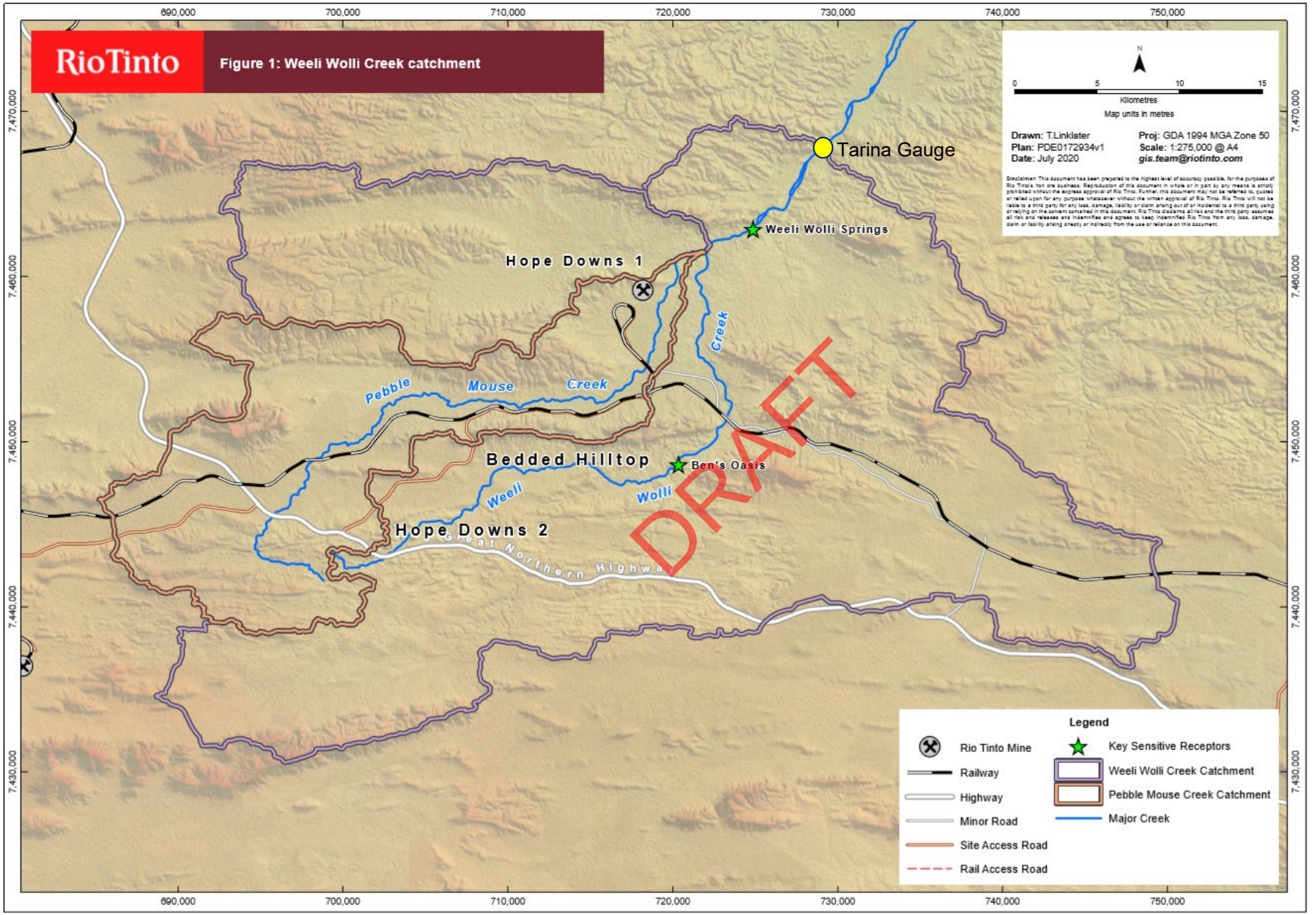

Figure 1: Weeli Wolli Creek catchment

Extensive surface water analysis of the Weeli Wolli Creek catchment has been undertaken in this and previous RTIO studies. A summary of regional and local catchment characteristics and hydrological modelling is provided below:

- Pilbara streamflow is predominantly short-lived, ephemeral and in direct response to rainfall, therefore it has a similar seasonality and variability to rainfall.
- There is a distinct lack of high quality, long-term streamflow data in the region.
- Pebble Mouse Creek catchment has a slope of 3.5 m/km, comparable with the Weeli Wolli Creek catchment (to Tarina gauge) with a slope of 3.65 m/km
- The Tarina gauging station is the closest stream flow gauge to the study area and is located on Weeli Wolli Creek, approximately 13 km downstream from the Pebble Mouse/Weeli Wolli Creek confluence (Figure 1).
- In the absence of local streamflow data, the streamflow regime in Pebble Mouse Creek is assumed to be similar to the flows at Tarina, which experienced two flow events per year (pre-mining record) on average.
- Gridded rainfall data indicates the study area experiences on average two rainfall events exceeding 35 mm per year which, compared with local streamflow data, suggests that 35 mm of rainfall is required in the catchment to produce flow. This result is also supported by Charles et. al. (2015) suggesting that the minimum rainfall required to produce flow in the catchment is 36 mm.
- Significant variation in estimated flood peaks of the 1:100 Annual Exceedance Probability (AEP) at Tarina is observed when comparing regional methods and Flood Frequency Analysis (FFA), with results ranging between 670 m^3/s and 3,180 m^3/s.
- A RORB rainfall-runoff routing model was developed for the Weeli Wolli catchment up to the Tarina gauge, with the Kc parameter calibrated using catchment rainfall and five recorded streamflow events at the gauge.
- The RORB model was configured to extract hydrographs at the BHT deposit by changing the design rainfall and areal reduction factor based on the Pebble Mouse Creek catchment upstream of BHT.

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3. SURFACE WATER MANAGEMENT INFRASTRUCTURE

HD2 and BHT are bisected by the Pebble Mouse Creek and Weeli Wolli Creek catchment divide and do not interact with the flood plains of either creek (Figure 2). Proposed operational surface water management measures consist of levees, drains and culverts located across the active mining areas and are designed for flood magnitudes ranging between 1:20 and 1:100 AEP with design criteria adopted using a risk based approach.

Significant flood protection features include the Pebble Mouse Creek haul road crossing (Figure 3), with culverts designed for a 1:20 AEP event, which will be removed at closure; and the HD2 levee and diversion drains (Figure 4), designed to convey up to the 1:100 AEP flow rate, which will remain at closure.

There are three other potential crossings of Pebble Mouse Creek included in the HD2 proposal associated with options related to ore transport and the realignment of Great Northern Highway (GNH). These crossings include a conveyor crossing, an access road crossing and a bridge crossing on GNH. All these structures will be removed at closure, if constructed.

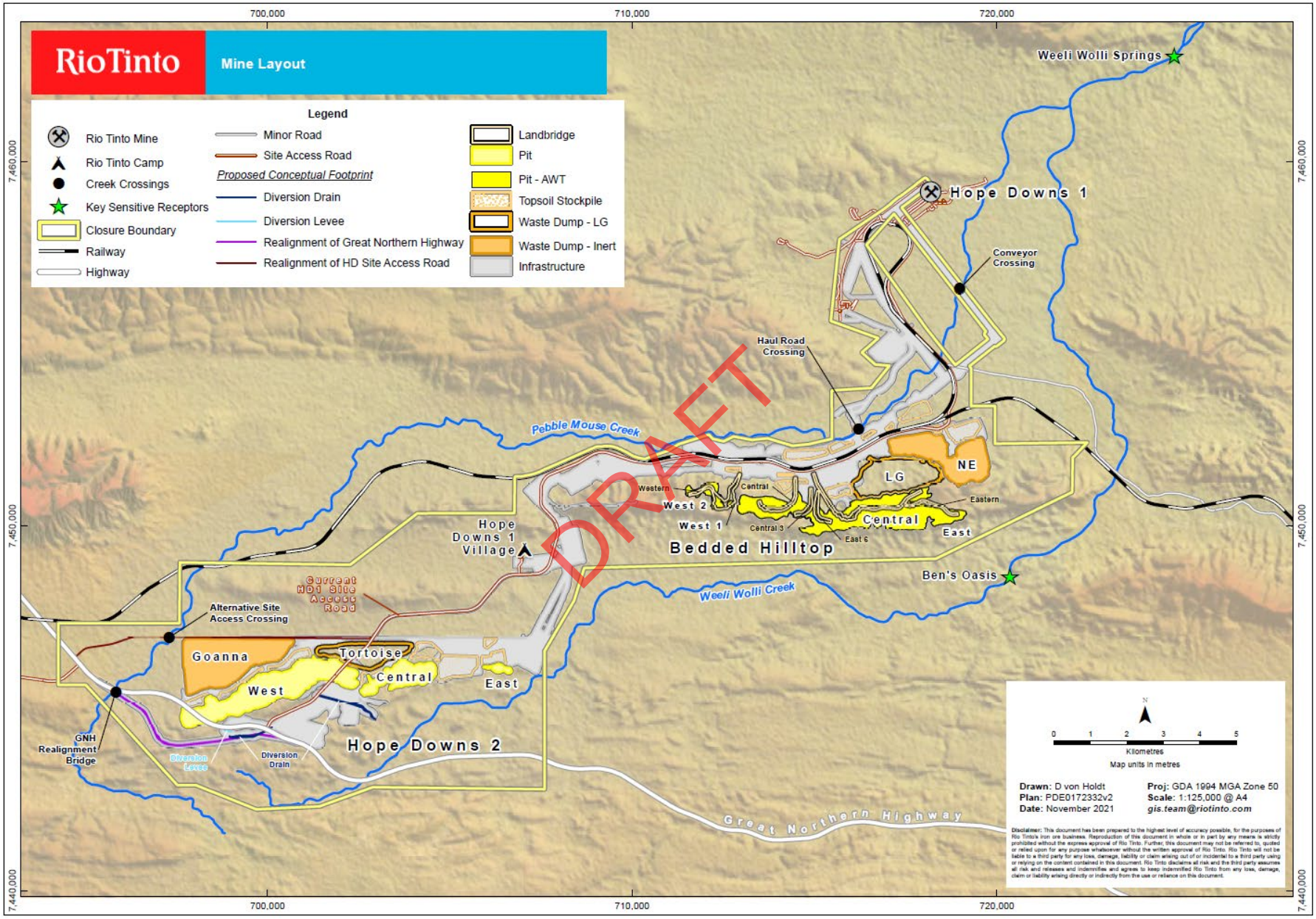

Figure 2: Hope Downs 2 & Bedded Hilltop Mine Layout

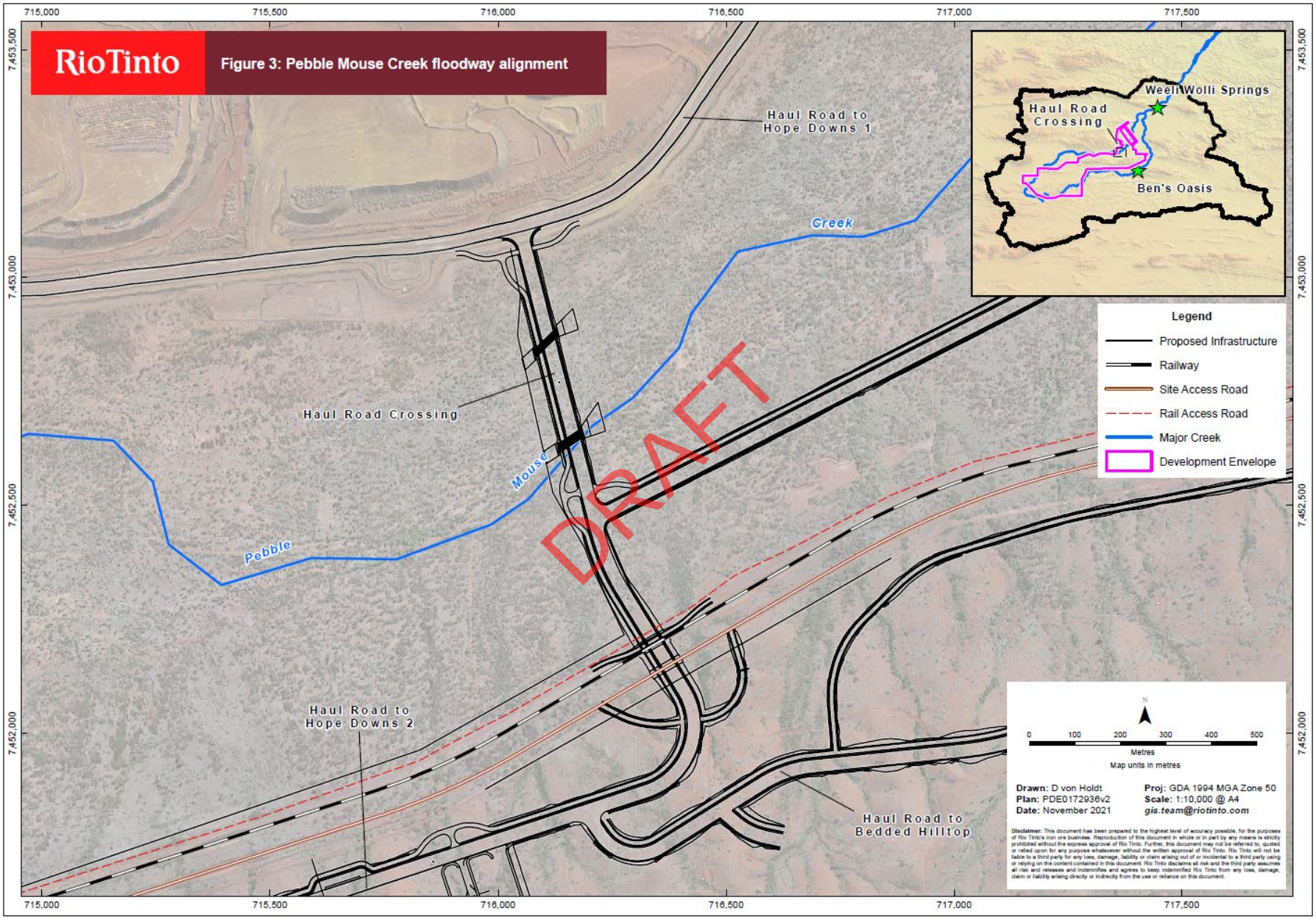

Figure 3: Pebble Mouse Creek floodway alignment

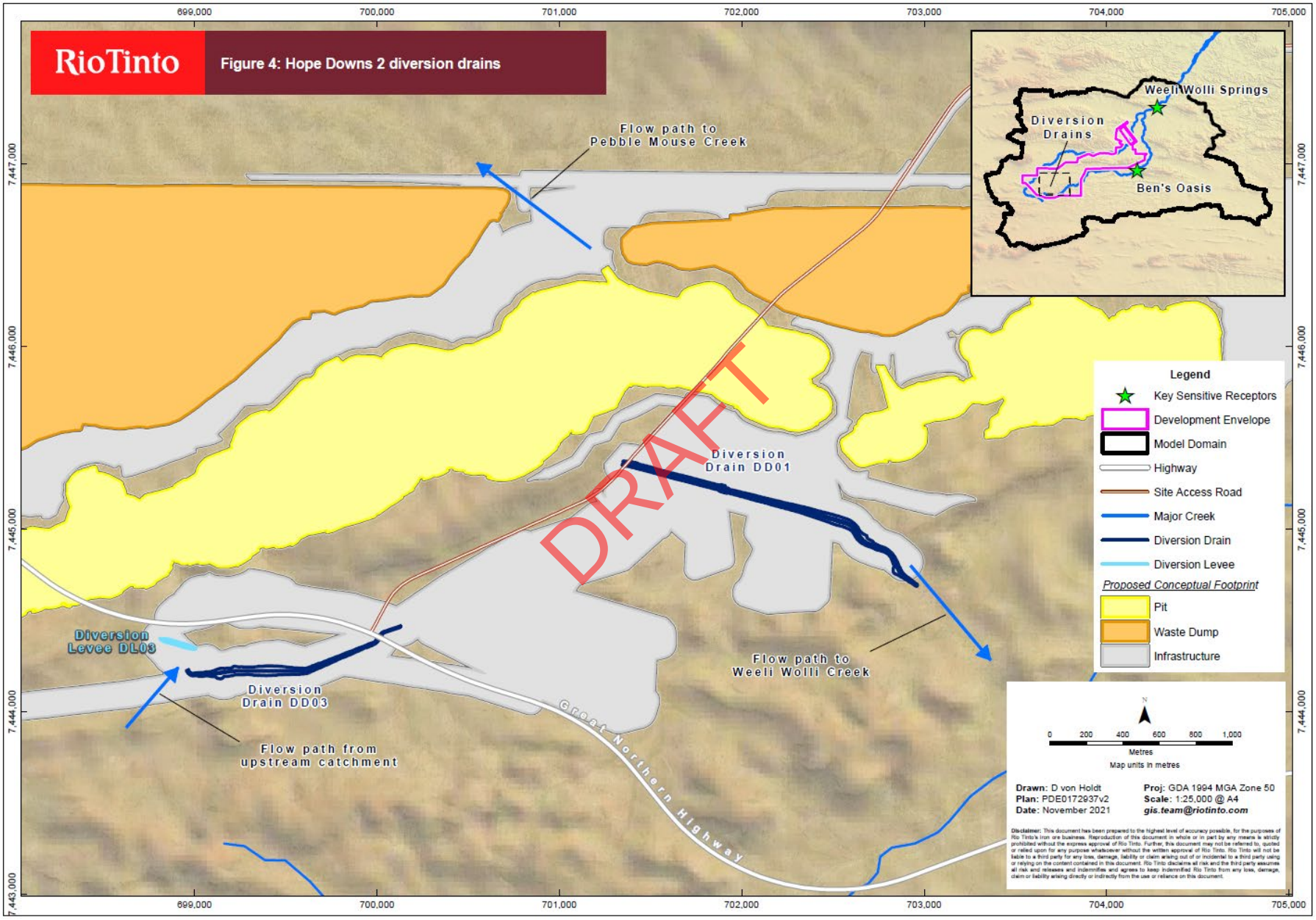

Figure 4: Hope Downs 2 diversion drains

4. DESIGN RAINFALL

Rainfall intensity frequency duration (IFD) data was extracted from the Bureau of Meteorology ARR2016 online data hub for a point located at the centroid of the Tarina RORB model. IFD data is available for durations between 1 minute and 168 hours and for AEPs between 63% and 1:2000. For rainfall AEPs over 1:200 and sub-daily durations the Jordan et al (2005) growth factors published in Book 8 of ARR2016 (Ball J 2016) were used to estimate rainfall depths. Areal reduction factors (ARFs) were adopted from the ARR data hub obtained for the Tarina catchment centroid.

The resultant rainfall IFD curves are shown in Figure 5.

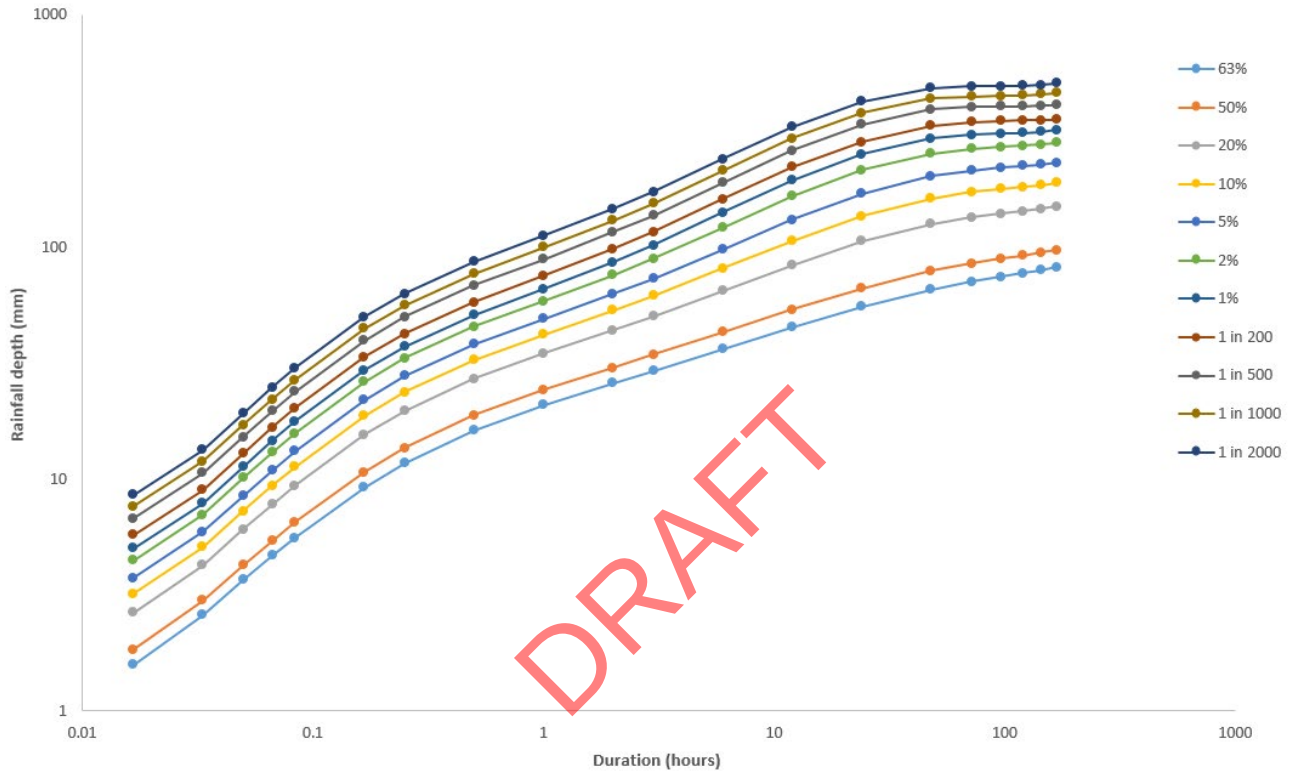

Figure 5: Design rainfall depths for AEPs used in the Tarina RORB model

5. FLOOD ESTIMATION

Using methods outlined in Australian Rainfall and Runoff (ARR2016), flood estimation of the upper Weeli Wolli Creek catchment was undertaken to provide site-wide estimates of design floods for rare to extreme events for Pebble Mouse Creek at the BHT deposit.

Catchment hydrological modelling (RORB) was combined with 2D hydraulic modelling (TUFLOW) to characterise the surface water flow regime across RTIO tenure at HD2 and BHT. Design flood quantiles were developed for the 1:2 AEP event up to the 1:1000 AEP event using a flood frequency analysis (FFA) at Department of Water and Environment (DWER) Tarina flow gauge and Monte Carlo simulation applied to a RORB model, which was calibrated to streamflow records at the same gauging station. The Tarina RORB model was refined to include a number of sub-catchments upstream of the area of interest (Pebble Mouse Creek) as recommended by Laurenson (2006) (Figure 6). This allowed estimates of design peak flows at the Bedded Hilltop deposit. Monte Carlo simulation was used to define design peak flows between the 1:5 AEP and the probable maximum precipitation flood (PMPF) using the regional RORB model with loss parameters calibrated to historical flood events, and a suite of design rainfalls and temporal patterns.

An ensemble rainfall simulation approach was used to calculate the Probable Maximum Flood (PMF) event, by determining the PMP storm pattern and duration which produces the largest peak flow with very low catchment losses.

The adopted peak flows used for inflow boundary in the BHT hydraulic simulations are listed in Table 2.

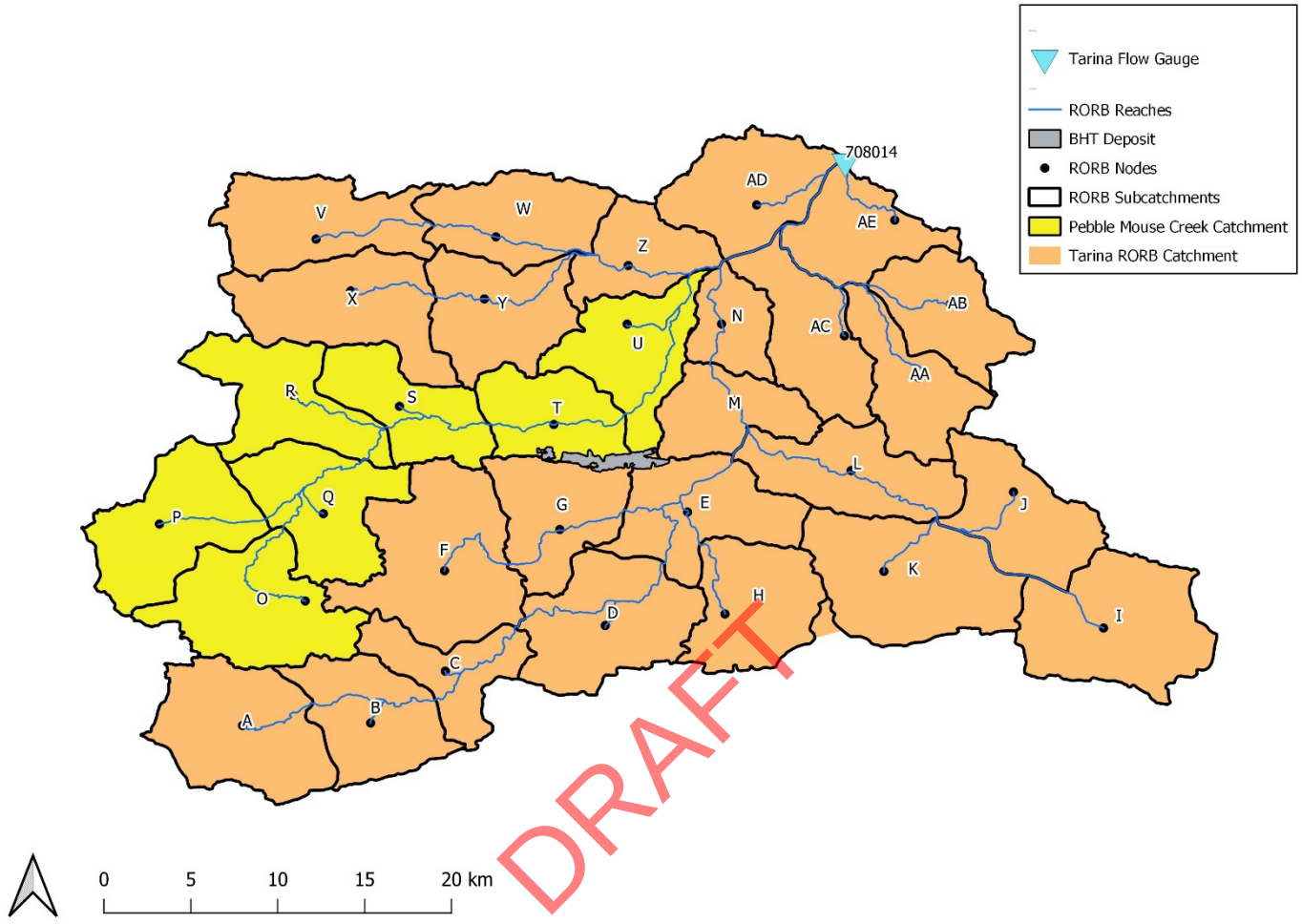

Figure 6: Pebble Mouse Creek/Tarina RORB model structure

Table 2: Adopted design peak flows for Pebble Mouse Creek upstream of Bedded Hilltop deposit

AEP (1:x)	5	10	20	50	100	1000	10,000	PMPF	PMF
PMC (m3/s)	69	190	370	618	858	1,722	3,353	9,373	10,860

There is a large uncertainty associated with peak flow estimates for the rare to extreme events, which are probabilistically unlikely to occur, with the result that there are limited, or no real-world examples of floods of this size. In order to put the magnitude of flood flows into perspective, the estimated design flood flows at Tarina gauging station were compared with the world maximum flood envelope curve (Rodier & Roche, 1984) and the largest recorded flood events for Australian catchments (Figure 7). The largest event recorded at Tarina gauging station reached a flow rate of 2,047 m^3/s, following rainfall from tropical cyclone John in December 1999, and this event was estimated at around a 1:50 AEP event.

For extreme events such as the 1:10,000 AEP, estimated peak flows fall above the world maximum flood envelope curve which is at 11,500 m^3/s for a 1,340 km^2 catchment. Although this does not rule out larger events as impossible, it does illustrate that the magnitude of flood flows considered for extreme events (1:10,000 AEP and above) is above the global precent set for catchments of this size. In particular, the peak flow estimated for the PMF event is more than four times the flow estimated by the curve.

Paleo flood investigations could be applied in the Weeli Wolli catchment to better constrain the limit of the extreme flood events but have not been commissioned by Rio Tinto at this stage.

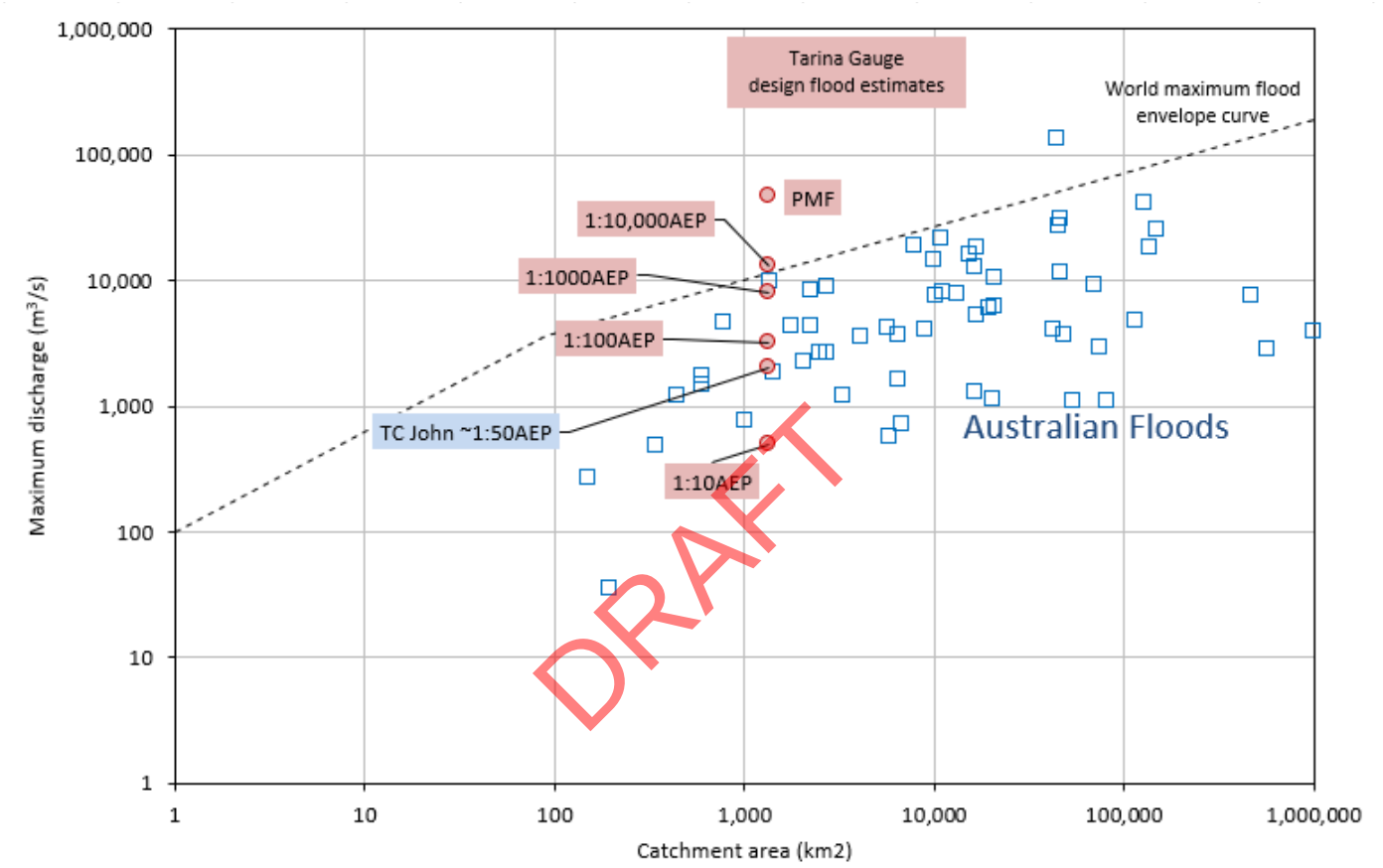

Figure 7: Select design peak flows for Weeli Wolli Creek catchment outlet, Tarina gauge, plotted against large Australian flood events and the world maximum flood envelope curve

5.1. Context for design flood estimates used in floodplain assessments

When considering the flood hazard associated with rare to extreme events, it is important to recognise the uncertainty and limitations in estimating flood events with a very low probability of occurrence. As noted in ARR2016 the uncertainties involved with the flood estimation process increase with increasing size of the flood. Events of between 1:100 AEP and 1:10,000 AEP are termed “very rare” but are considered within the range of largest direct observations and the credible limit of extrapolation (limit of plausible extrapolation from other sources of information). Extreme events are in the range between 1:10,000 AEP event and the PMF and represent the range of floods which borders on the ‘unknowable’, where even a high level of expertise cannot substantially reduce the level of uncertainty (ARR 2016). Figure 8 illustrates the nature of increasing uncertainty with increasing event size.

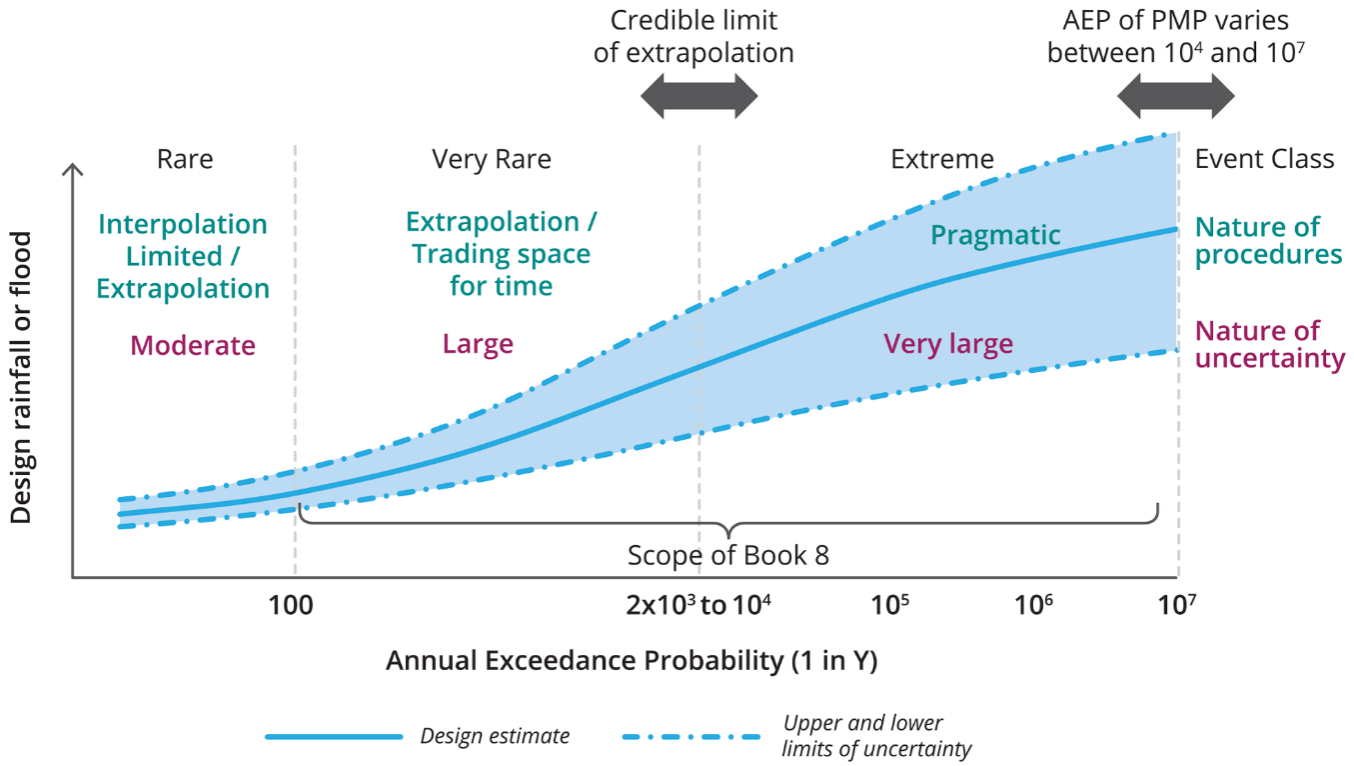

Figure 8: Design characteristics of notional event classes (ARR 2016)

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The PMF is a design concept that notionally represents the upper limit on flood magnitude but for which an AEP cannot be readily assigned (ARR2016). Although it is possible to produce an estimate of the PMF and simulate the associated flood hydraulics, this needs to be viewed in an appropriate context. There is no precedent for events of this magnitude in a catchment of this size in Australia or globally. Furthermore, the probability of the PMP event occurring in a catchment this size (1,340 km^2) is 1:1,000,000, but the probability of the PMF cannot be reliably estimated as it requires both the PMP rainfall and extremely wet antecedent catchment conditions to coincide. Furthermore, it is possible that a catchment may change its behaviour when subjected to extreme rainfalls (ARR 2016), with geomorphological mechanisms and changes in storage and routing behaviour possible. Extreme floods can be landscape altering even in the natural (undeveloped) environment which can in turn alter the magnitude of the flood flows. Typically, estimates of the PMF would only be applied in very limited circumstances, for example, in the design of spillways for water or tailings dams which fall into a high-risk category.

Because of the reasons described above, it is suggested that the following events are appropriate for use in assessing performance of operational flood protection and to inform closure planning:

- The 1:100 AEP flood can be reliably estimated using the methods adopted and is appropriate for use in floodplain assessments for operational infrastructure.
- The 1:1,000 AEP flood is a realistic event to use when identifying risks associated with greater than design flood events for closure, as it falls within the credible limit of extrapolation, and below the world maximum flood envelope curve (for Weeli Wolli Creek catchment).
- As an extreme case, the 1:10,000 AEP flood event may be considered, as this event is at the upper end of the credible limit of extrapolation and falls just above the envelope curve.

Application of the PMF is not appropriate for a generalised site-wide floodplain assessment. It may be appropriate to further refine flood estimates of the PMF in future for application in risk assessments of specific infrastructure approaching closure.

6. HYDRAULIC MODELLING

Two-dimensional hydraulic models were developed, using TUFLOW hydraulic modelling software, in order to characterise the surface water flow regime around both HD2 and BHT mining infrastructure. The methodology and results are outlined below.

6.1. Modelling assumptions and limitations

Note the following modelling assumptions and limitations:

- All flood simulations consider only current land surfaces, and life of mine designs. As such they represent the approximate “end of mining” surface and are not closure landforms. Based on the proposed closure strategy for operational flood protection infrastructure at both sites, the PMC haul road crossing at BHT has been removed and the diversion structures at HD2 remain in place as permanent features.
- No consideration has been given to proposed backfill areas.
- Note that downstream flood hydrology may be significantly impacted by upstream closure strategies, and this inter-relationship has not been considered since only operational landforms have been included in simulations.
- Detailed drainage features such as smaller stormwater drains around mining infrastructure (such as buildings), culverts proposed for the haul road and mine access roads are only represented at a coarse level.
- This assessment identifies likely areas of initial over-topping of operational flood protection for above-design flows, and highlights locations where pit voids are proximal to the floodplain of creek systems. However, terrain surfaces are considered static and as such no erosion or infrastructure failure has been considered.

Despite these limitations, the operational flood modelling provides a reasonable indication of relative risk across operations at HD2 and BHT and highlights focus areas for closure planning.

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6.2. BHT model domain

The model domain included the full extent of the BHT catchments to the south, Baby Hope (an existing mine providing sustaining tonnes to the HD1 mine operations) catchments to the north and the section of Pebble Mouse Creek that these surface water catchments discharge to (Figure 9). The eastern boundary extended to the HD1 rail line but this infrastructure has not been included.

6.3. BHT digital terrain model

The digital elevation model (DEM) was developed based on current topography (LIDAR datasets) and BHT and Baby Hope ultimate pit and dump designs, referred to as Life of Mine (LOM) designs. Terrain surfaces required to cover the full extent of the model domain varied in resolution. A 10 m computational grid was adopted for TUFLOW model simulations.

6.4. BHT boundary conditions and surface roughness

Boundary conditions in the model included an inflow hydrograph for PMC (extracted from the RORB model – see Section 5), an outflow boundary at the downstream (eastern) end of PMC but upstream of the HD1 rail line, and an open boundary along the southern extent of the model domain to account for a small section of an adjacent catchment that drains south, away from BHT and PMC, thus not impacting the mines.

Design rainfall applied as rain-on-grid to all active cells, using a representative rainfall temporal pattern equivalent to the adopted critical duration events for Pebble Mouse Creek, which is 18 hours for the 1:100 AEP and 12 hours for the 1:1000 AEP and 1:10,000 AEP. Model simulation time was set to 27 hours.

Losses were incorporated into the model through soil infiltration with no initial loss and a continuing loss of 5.5 mm/hr. These are significantly lower than the ARR2016 recommended loss values for this area however they were adopted based on a calibration to match RORB peak flows at a downstream location.

A global Manning's n roughness of 0.04 was applied across the model domain.

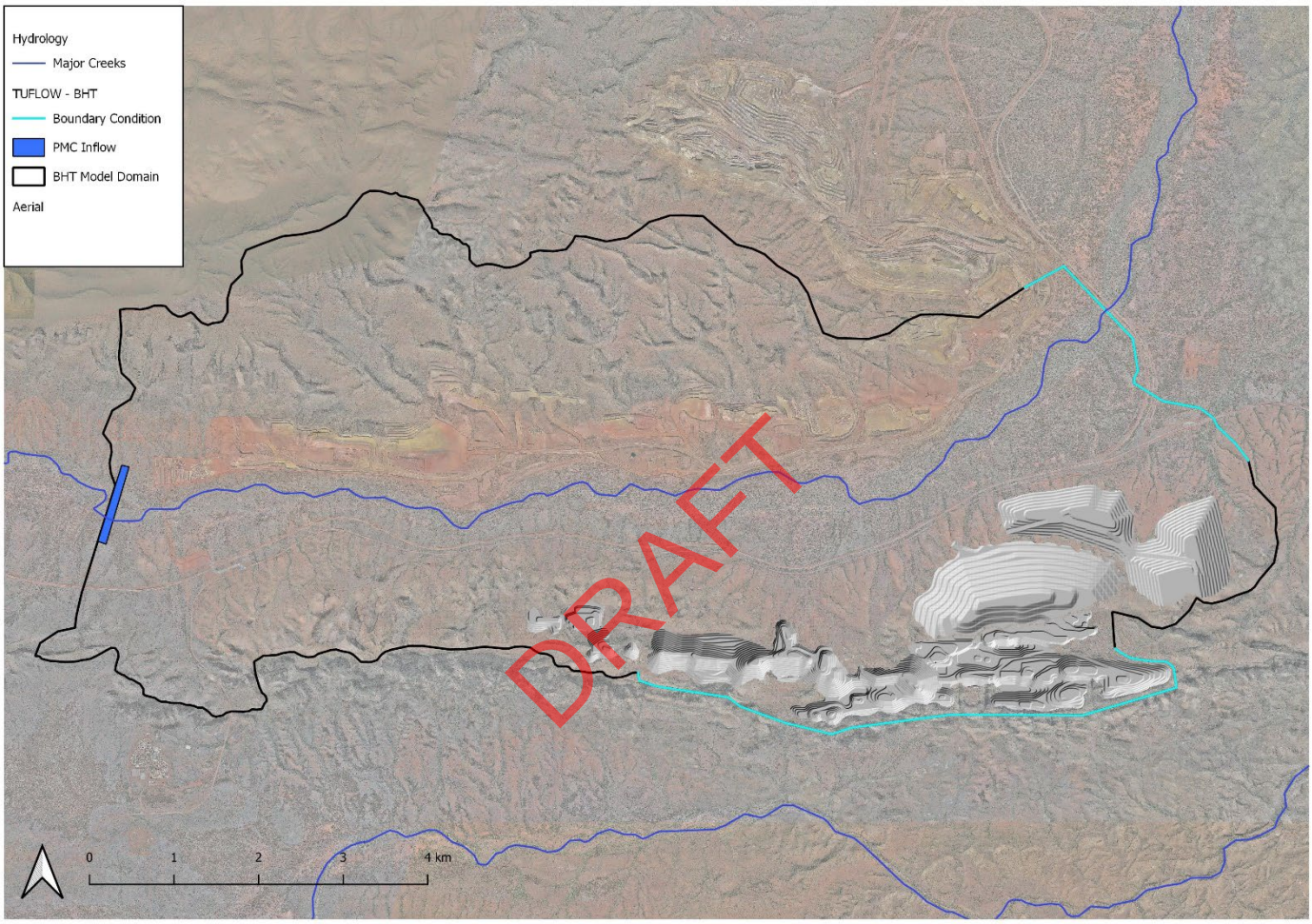

Figure 9: BHT hydraulic model extent, boundary conditions and modelled LOM designs

6.5. HD2 model domain

The model domain included the upper catchment of the named section of Weeli Wolli Creek, south of the HD2 mining area. The western boundary was limited to the extent of the western pit and waste dump but excluded the main flow channel of Pebble Mouse Creek to the north east. The northern boundary was limited to a natural ridgeline, dividing the Pebble Mouse Creek and Weeli Wolli Creek catchments (Figure 10).

6.6. HD2 digital terrain model

The DEM was developed based on current topography (LIDAR datasets) and HD2 LOM designs. Terrain surfaces required to cover the full extent of the model domain varied in resolution. A 10 m computational grid was adopted for TUFLOW simulations.

6.7. HD2 boundary conditions and surface roughness

Five critical outflow boundaries have been used in this model. Two along the western boundary to allow flow out to the west, and three along the eastern boundary, one of which represents flow from Weeli Wolli Creek.

Design rainfall was applied as rain-on-grid to all active cells, using a representative rainfall temporal pattern equivalent to the adopted critical duration events for Weeli Wolli Creek in that part of the catchment, which is 2 hours for the 1:100 AEP and 1 hour for the 1:1000 AEP and 1:10,000 AEP. Model simulation time was set to 6 hours.

Losses were incorporated into the model through soil infiltration with no initial loss and a continuing loss of 5.5 mm/hr. These are significantly lower than the ARR2016 recommended loss values for this area however they were adopted based on a calibration to match RORB peak flows at a downstream location.

A global Manning's n of 0.04 was applied across the model domain.

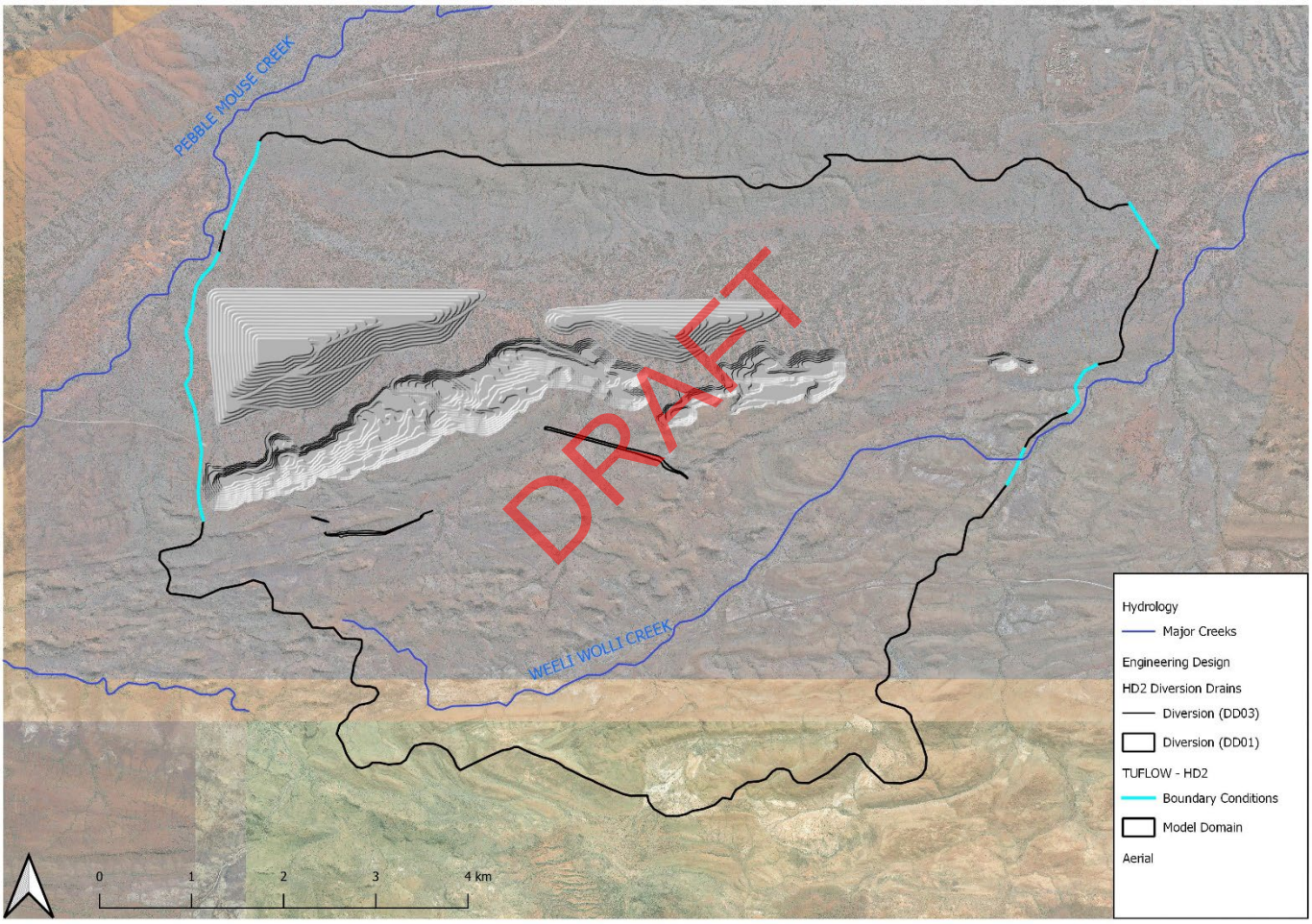

Figure 10: HD2 hydraulic model extent, boundary conditions and modelled LOM designs

7. RESULTS

This section presents the hydraulic modelling results for the 1:100, 1:1000 and 1:10,000 AEP for both models.

Results for the BHT model are presented in Figures 11 – 15, while results for the HD2 model are presented in Figures 16 – 22.

Maximum flood depths are shown for the full model domain extent for each model. Peak velocities are also presented for the full extent of the BHT model and the HD2 diversion structures in the HD2 model.

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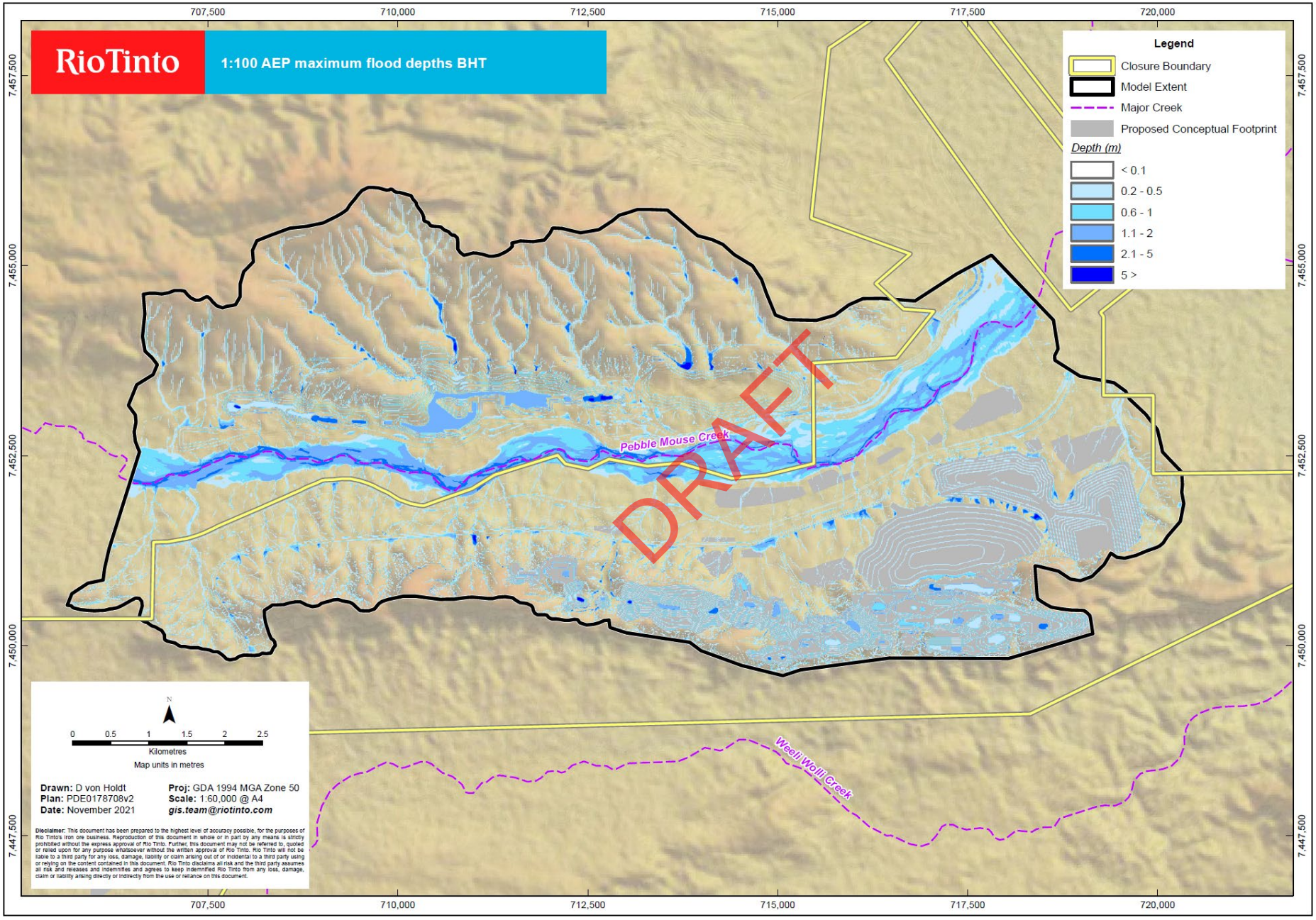

Figure 11: 1:100 AEP Maximum Flood Depths at BHT

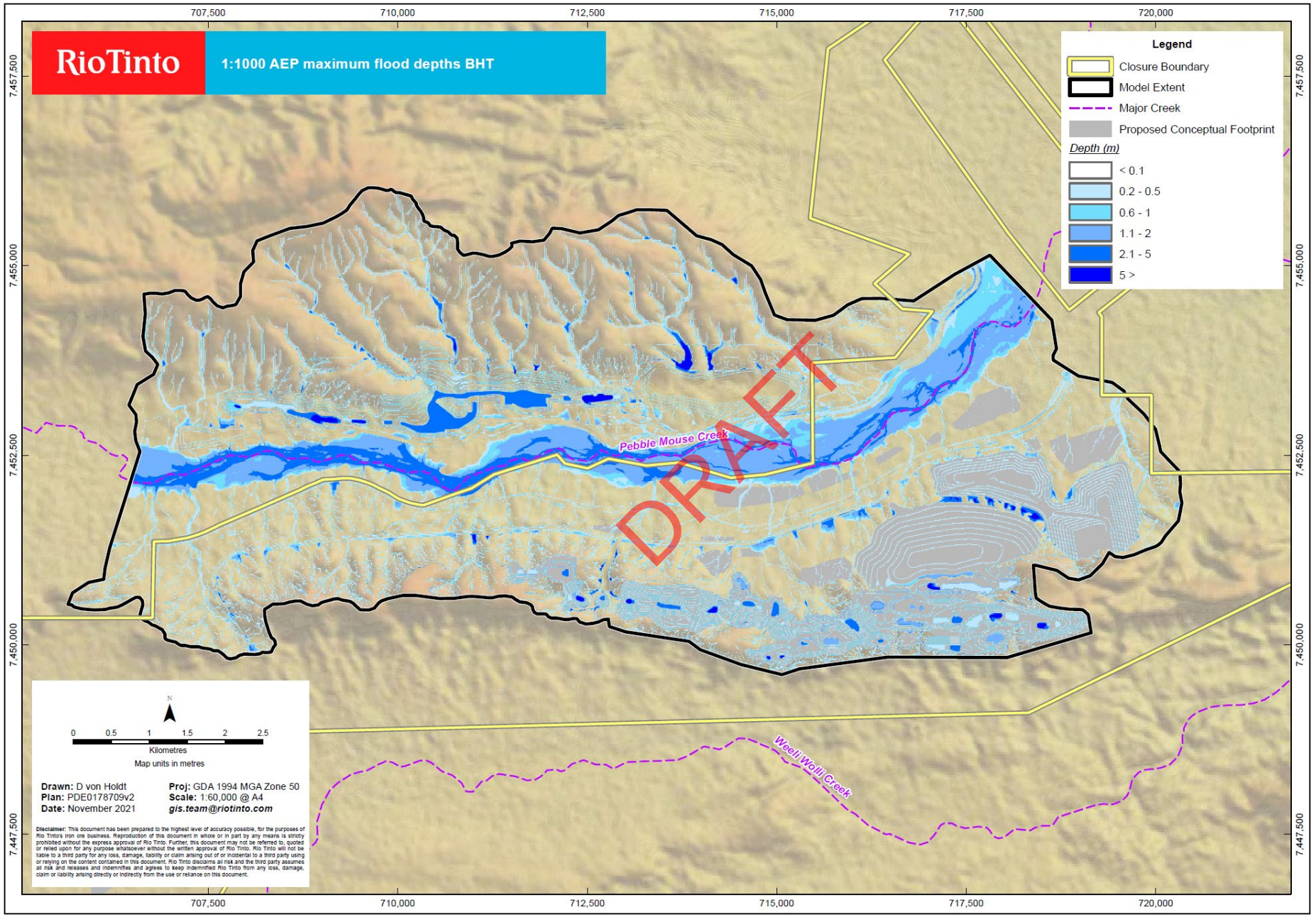

Figure 12: 1:1000 AEP Maximum Flood Depths at BHT

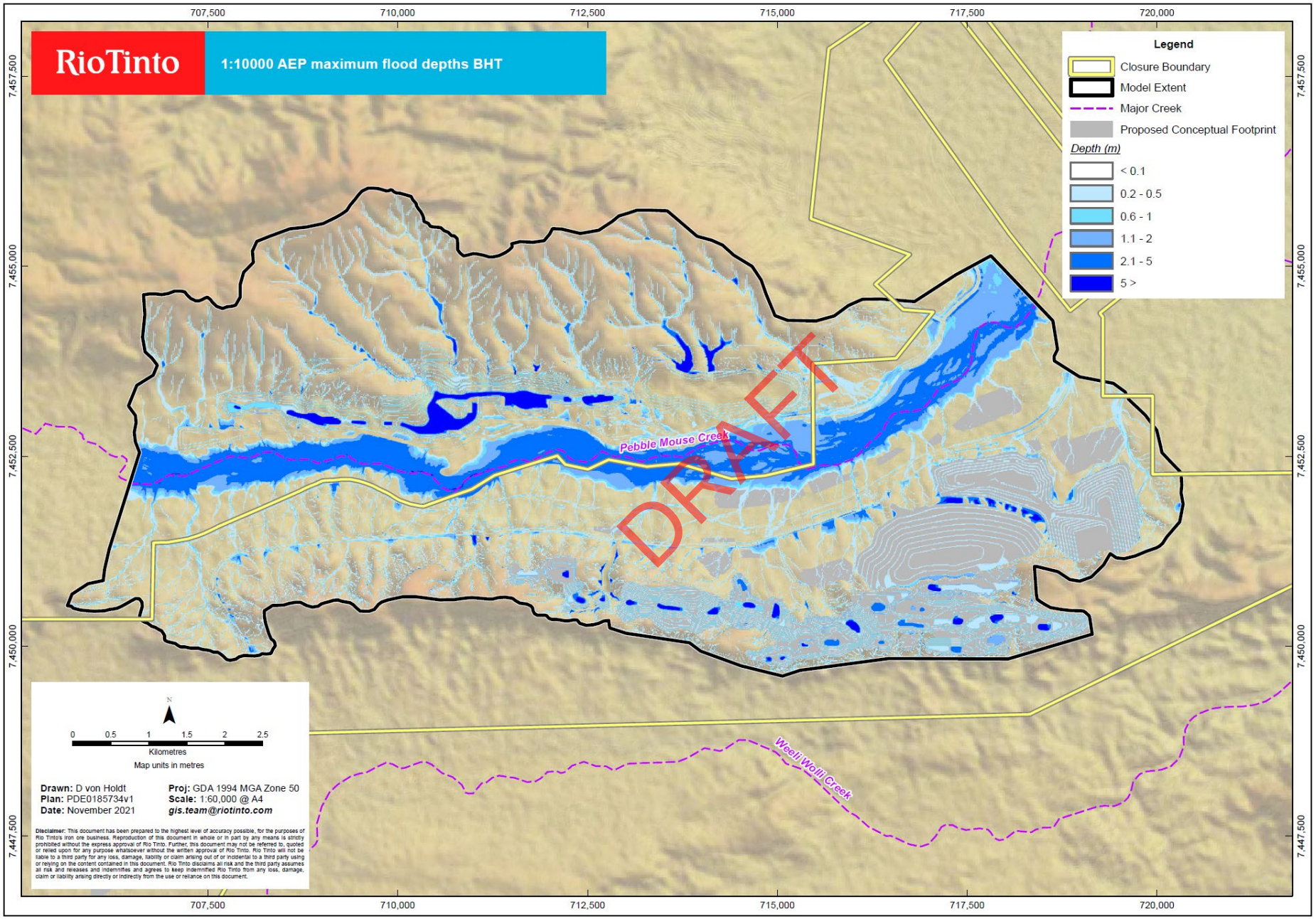

Figure 13: 1:10,000 AEP Maximum Flood Depths at BHT

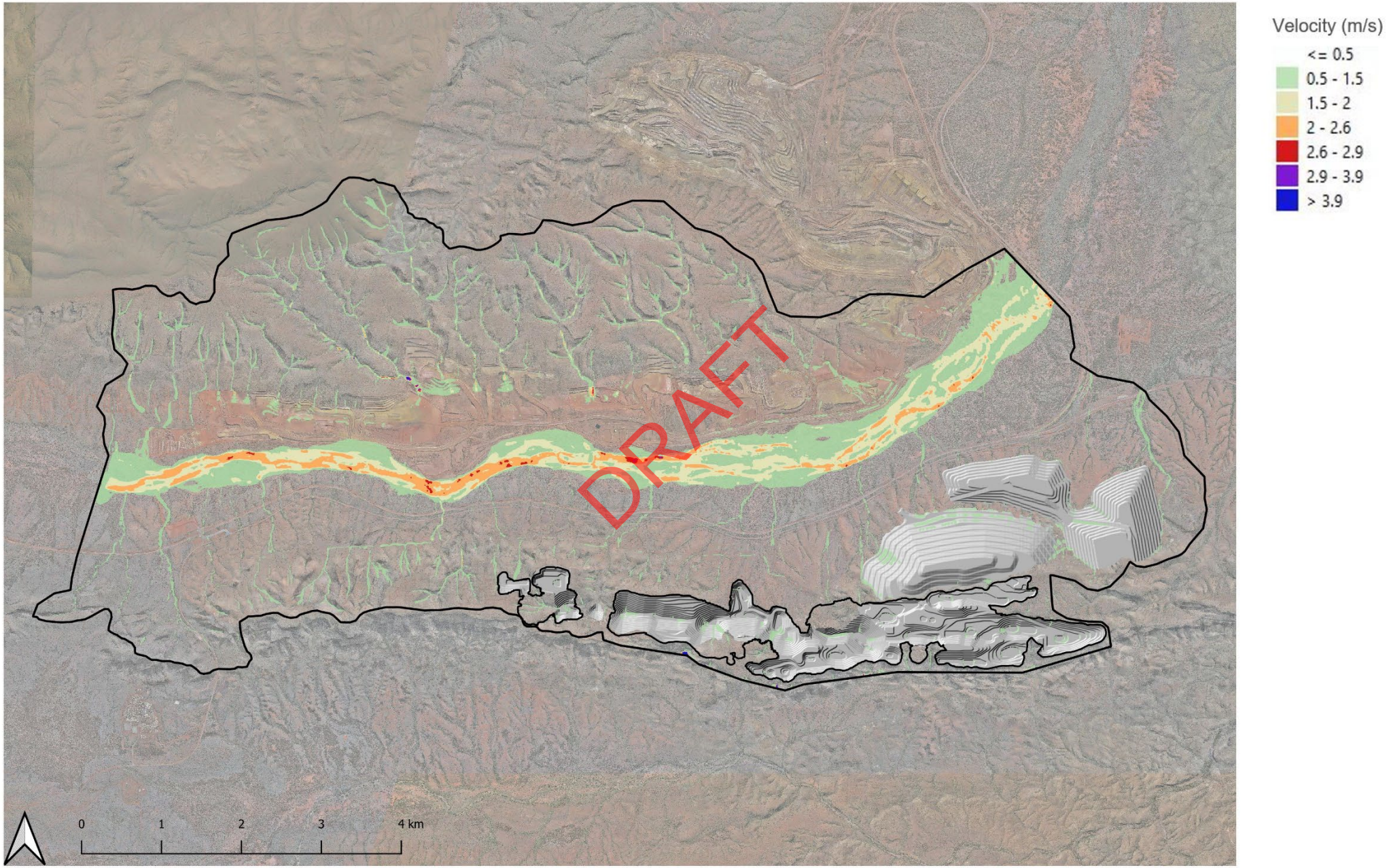

Figure 14: 1:100 AEP Maximum Velocities at BHT

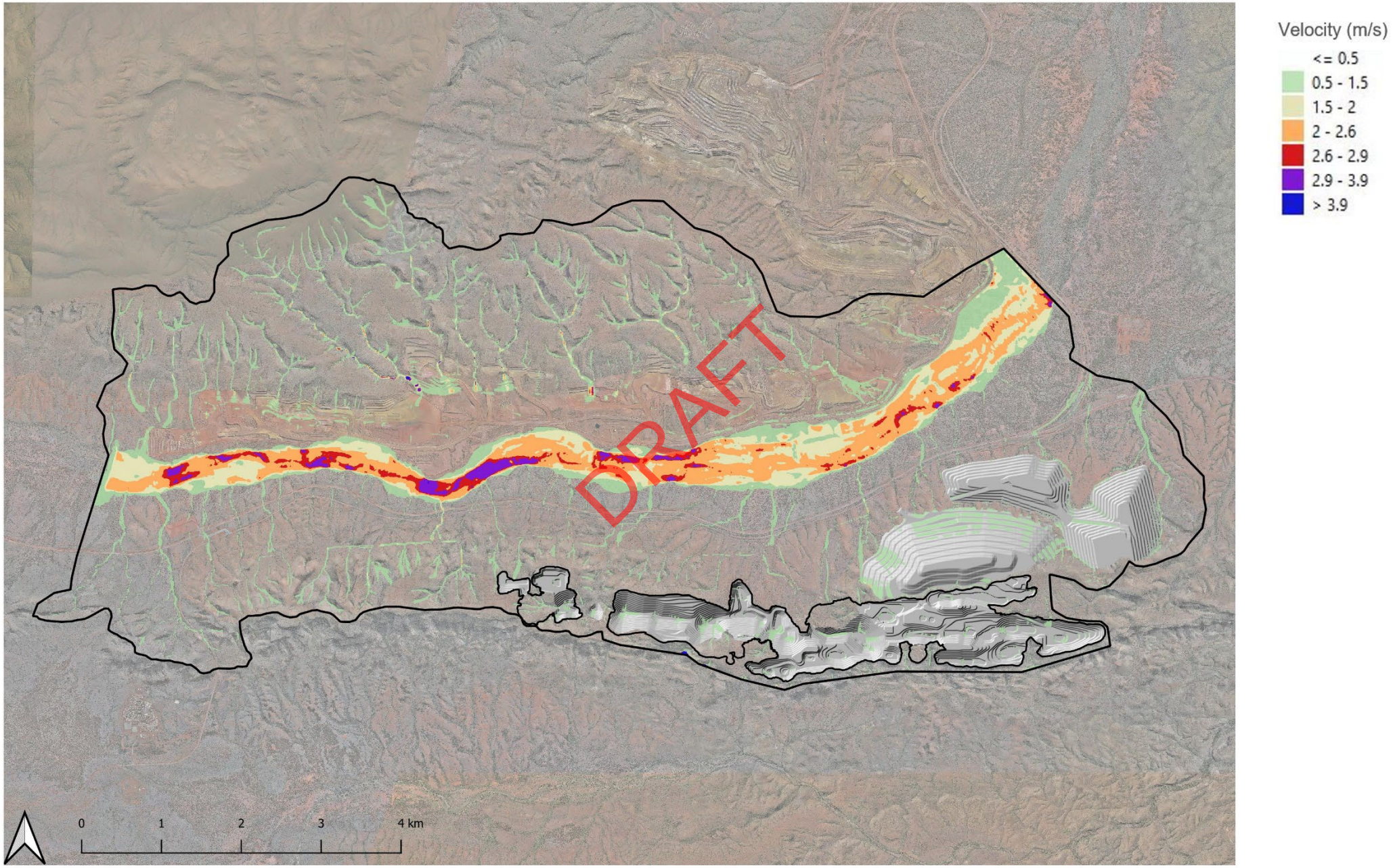

Figure 15: 1:1000 AEP Maximum Velocities at BHT

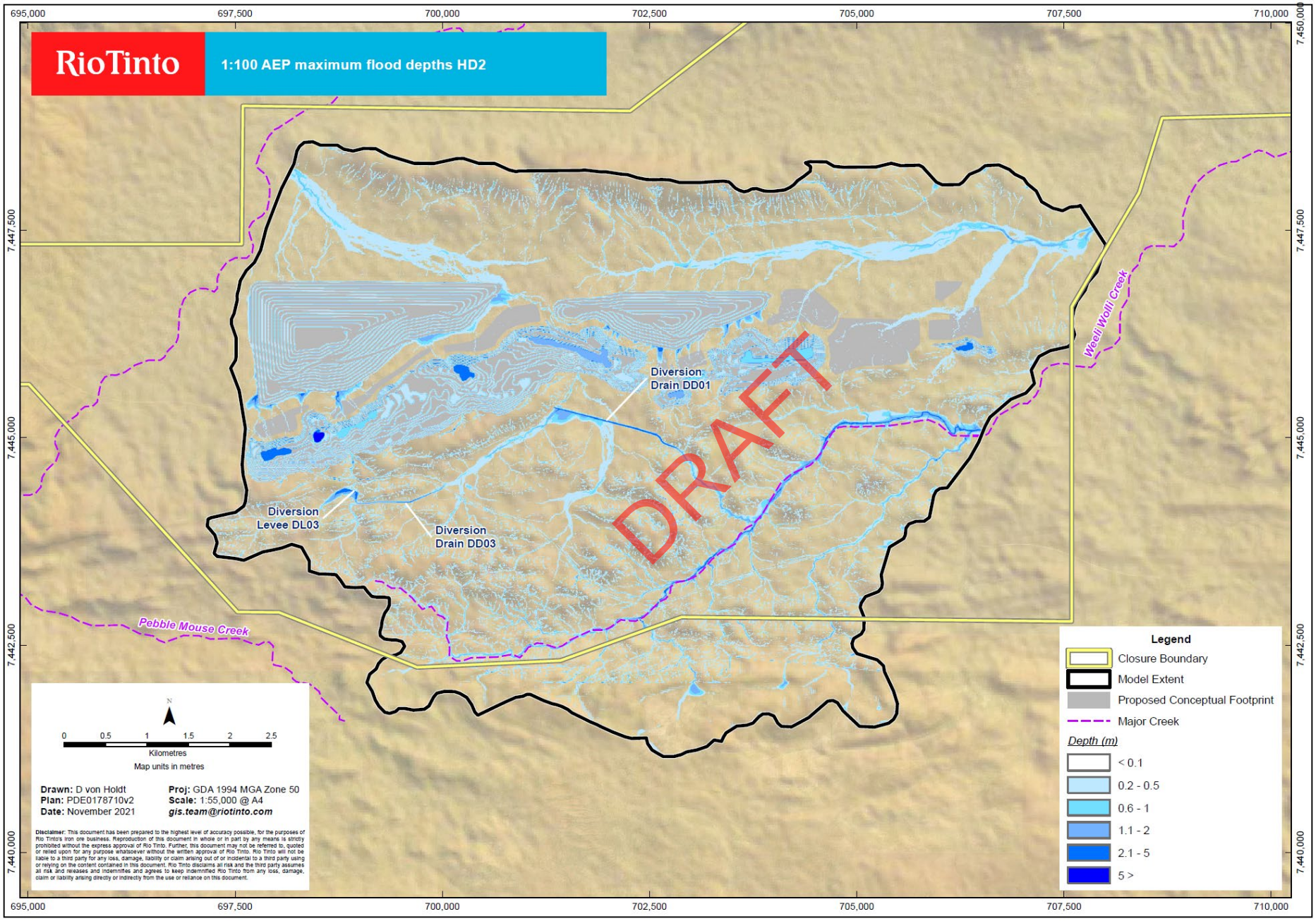

Figure 16: 1:100 AEP Maximum flood depths at HD2

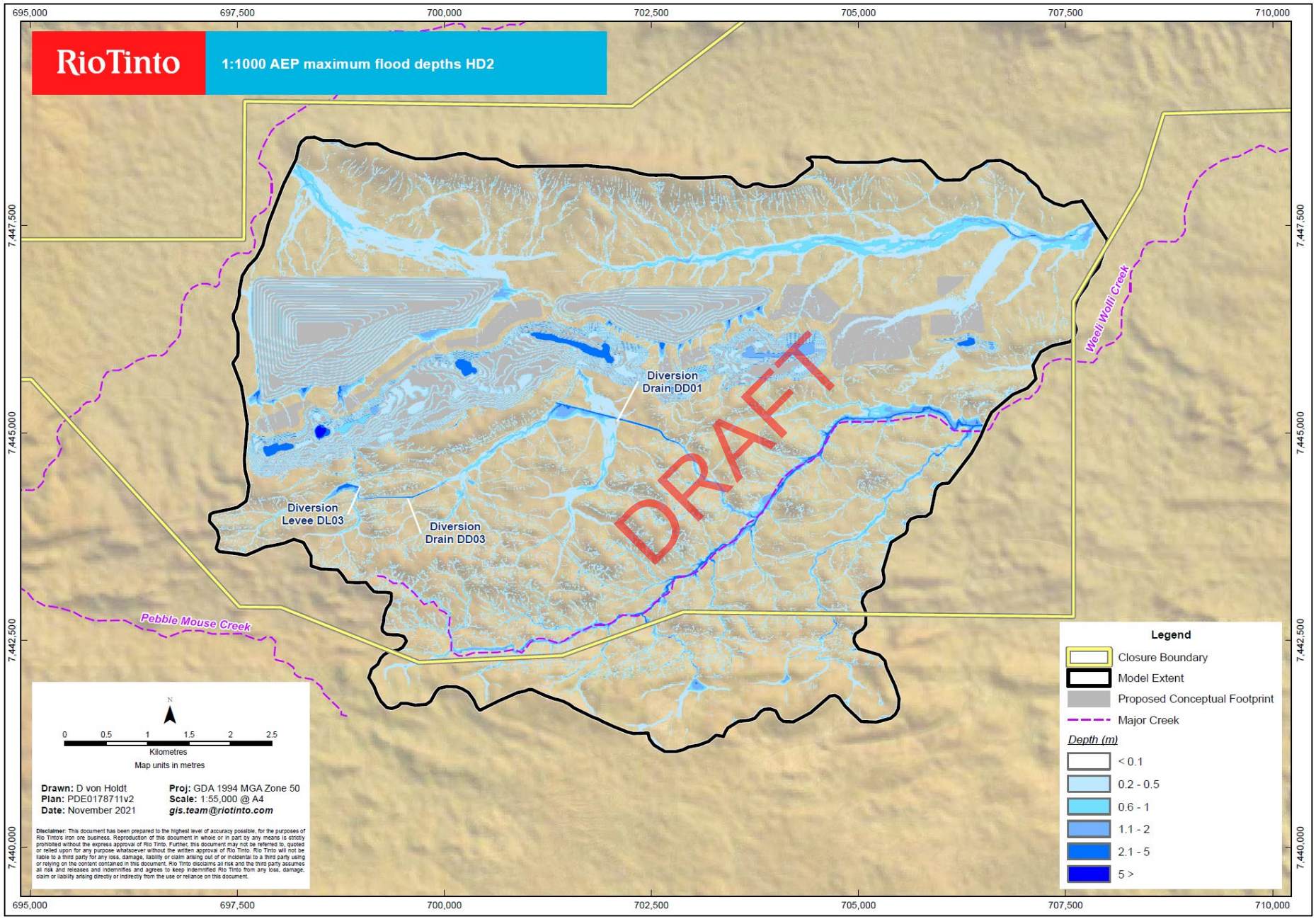

Figure 17: 1:1000 AEP Maximum flood depths at HD2

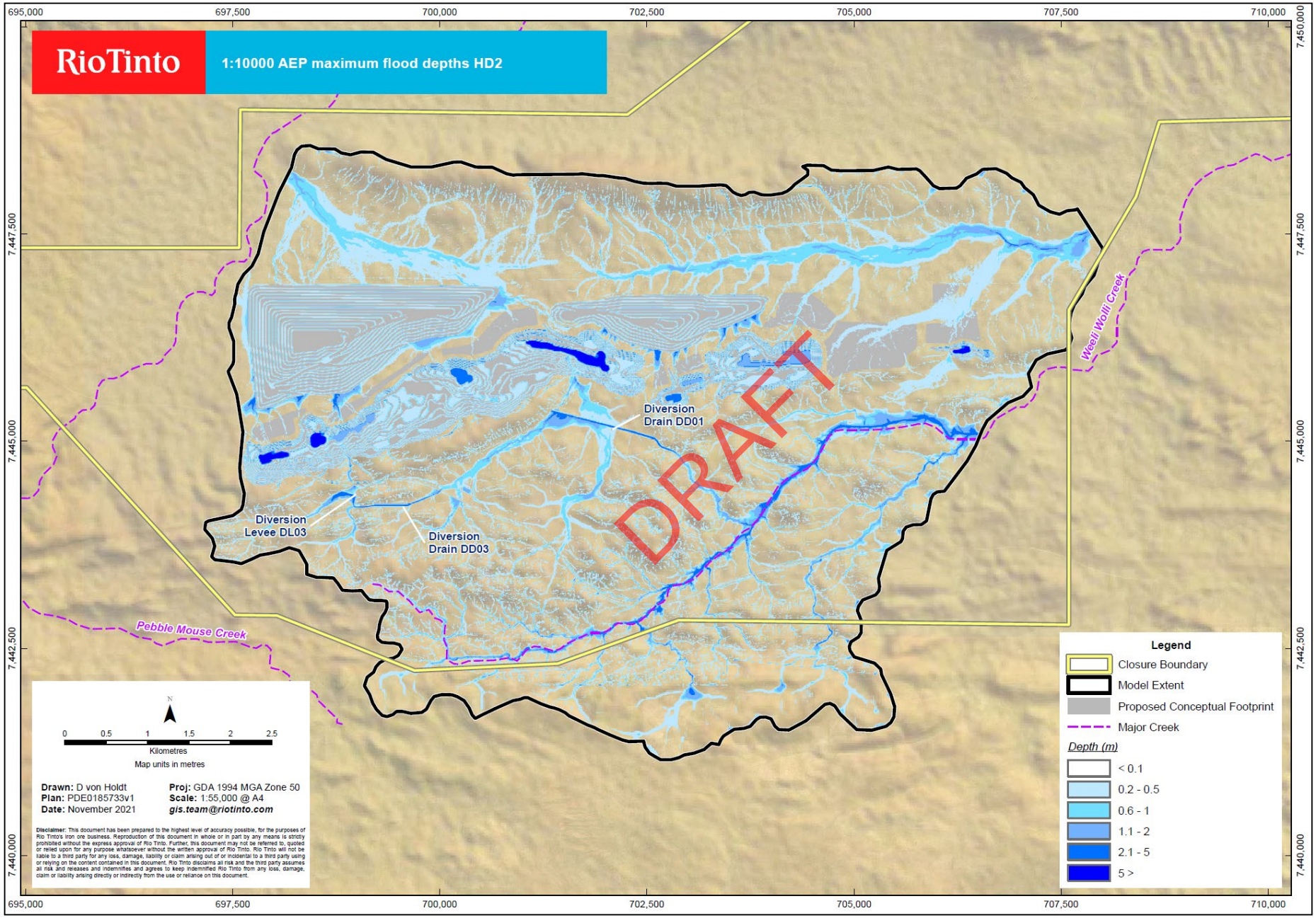

Figure 18: 1:10,000 AEP Maximum flood depths at HD2

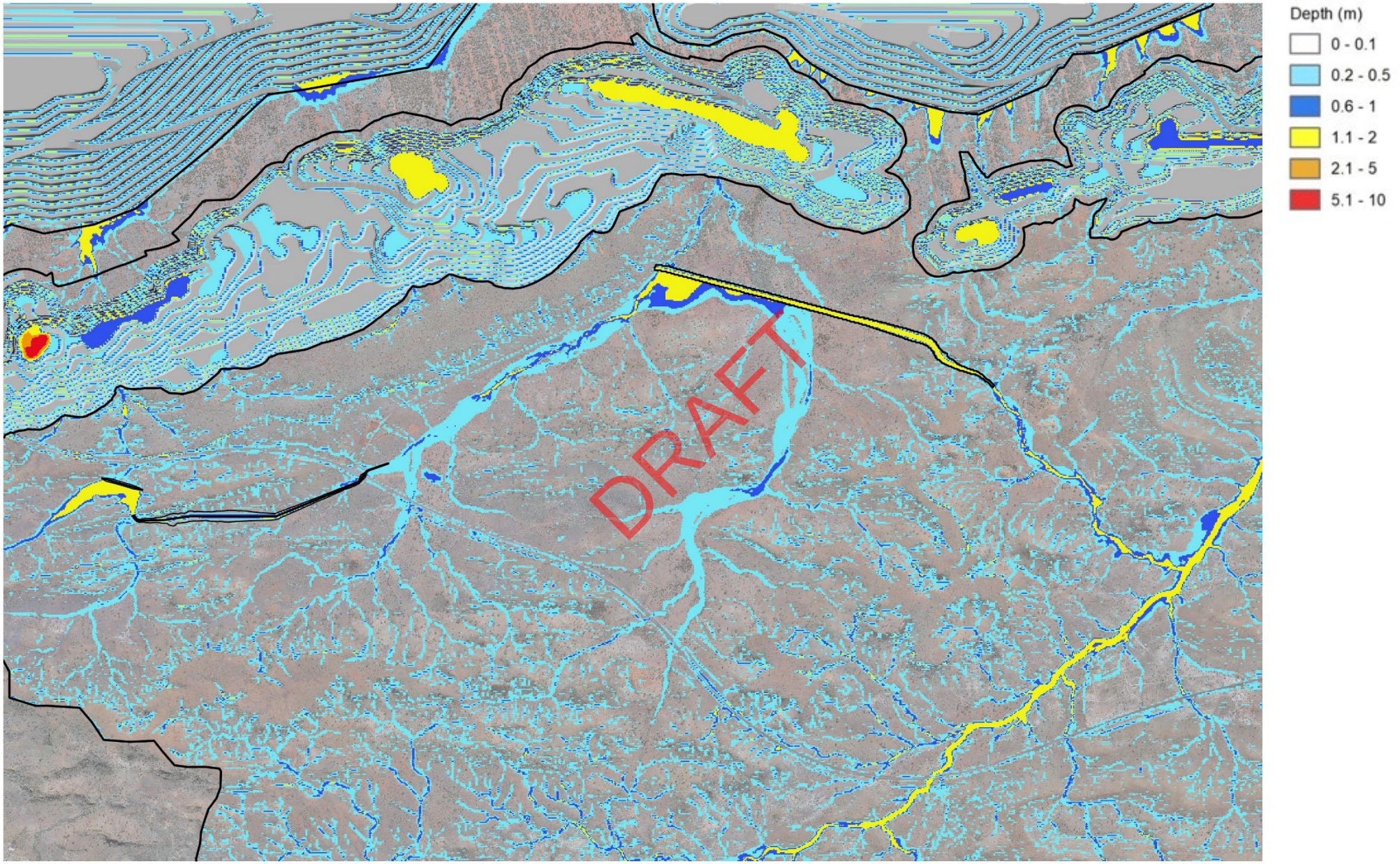

Figure 19: 1:100 AEP Maximum flood depths at HD2 diversion structures

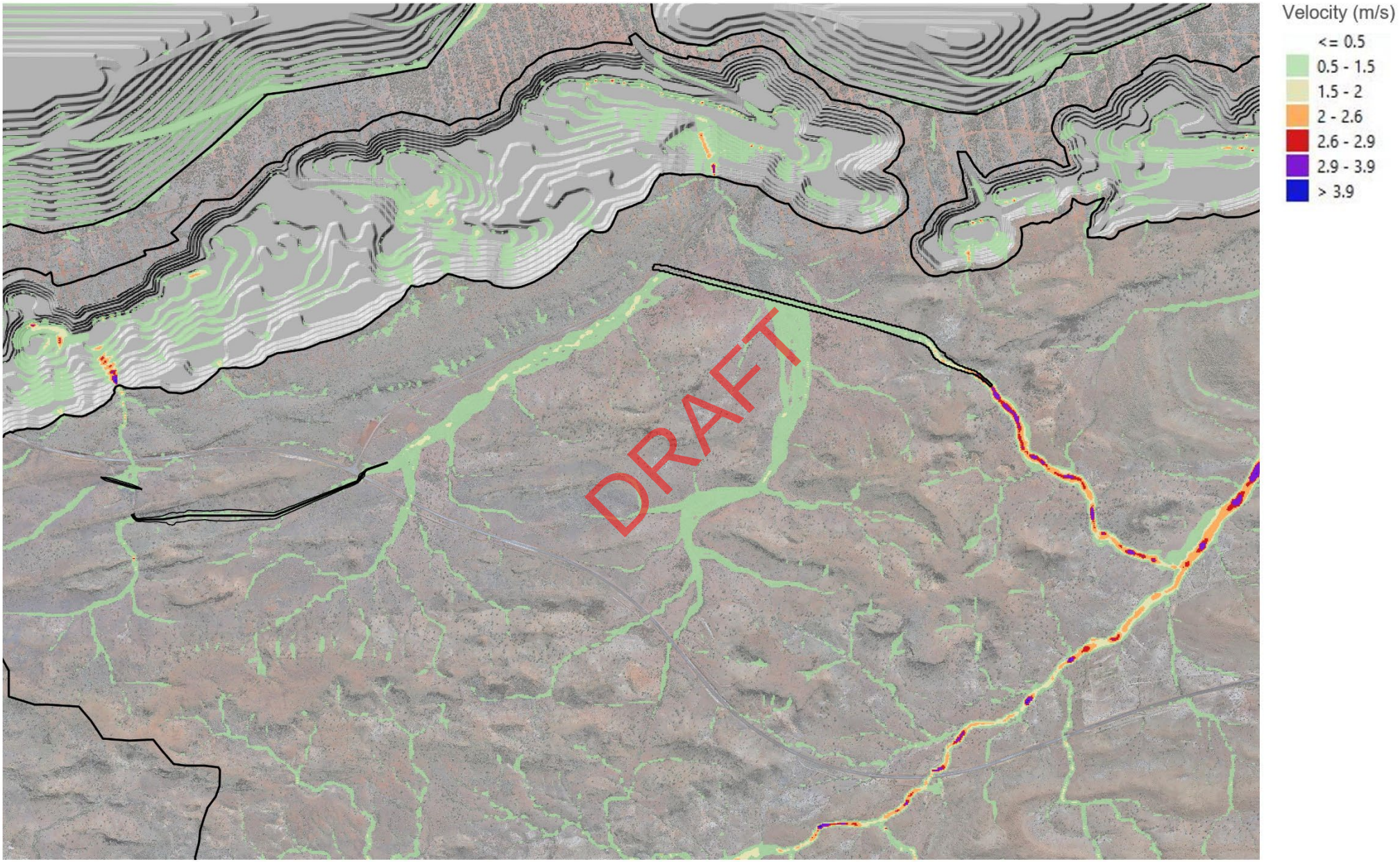

Figure 20: 1:100 AEP Maximum velocities at HD2 diversion structures

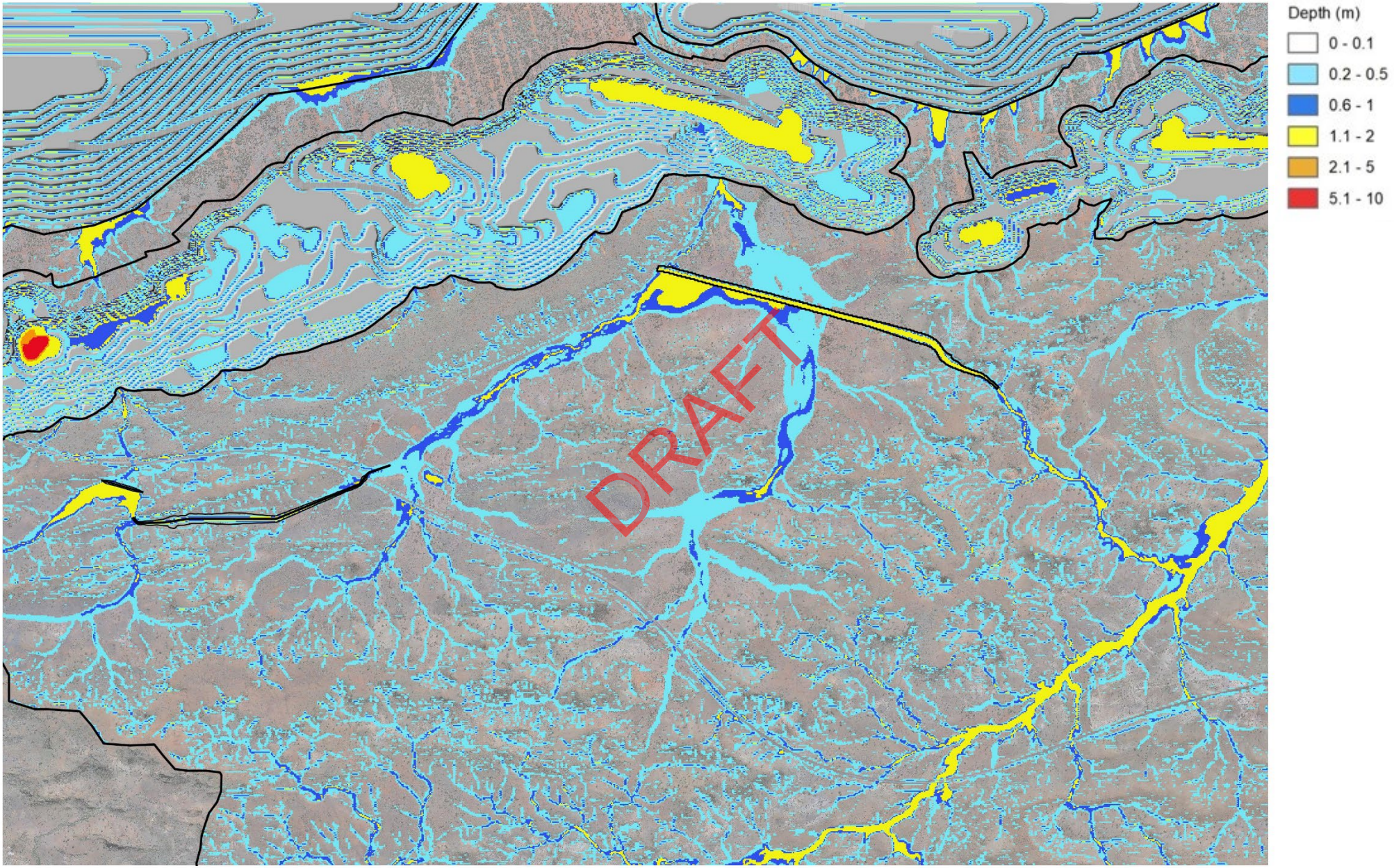

Figure 21: 1:1000 AEP Maximum flood depths at HD2 diversion structures

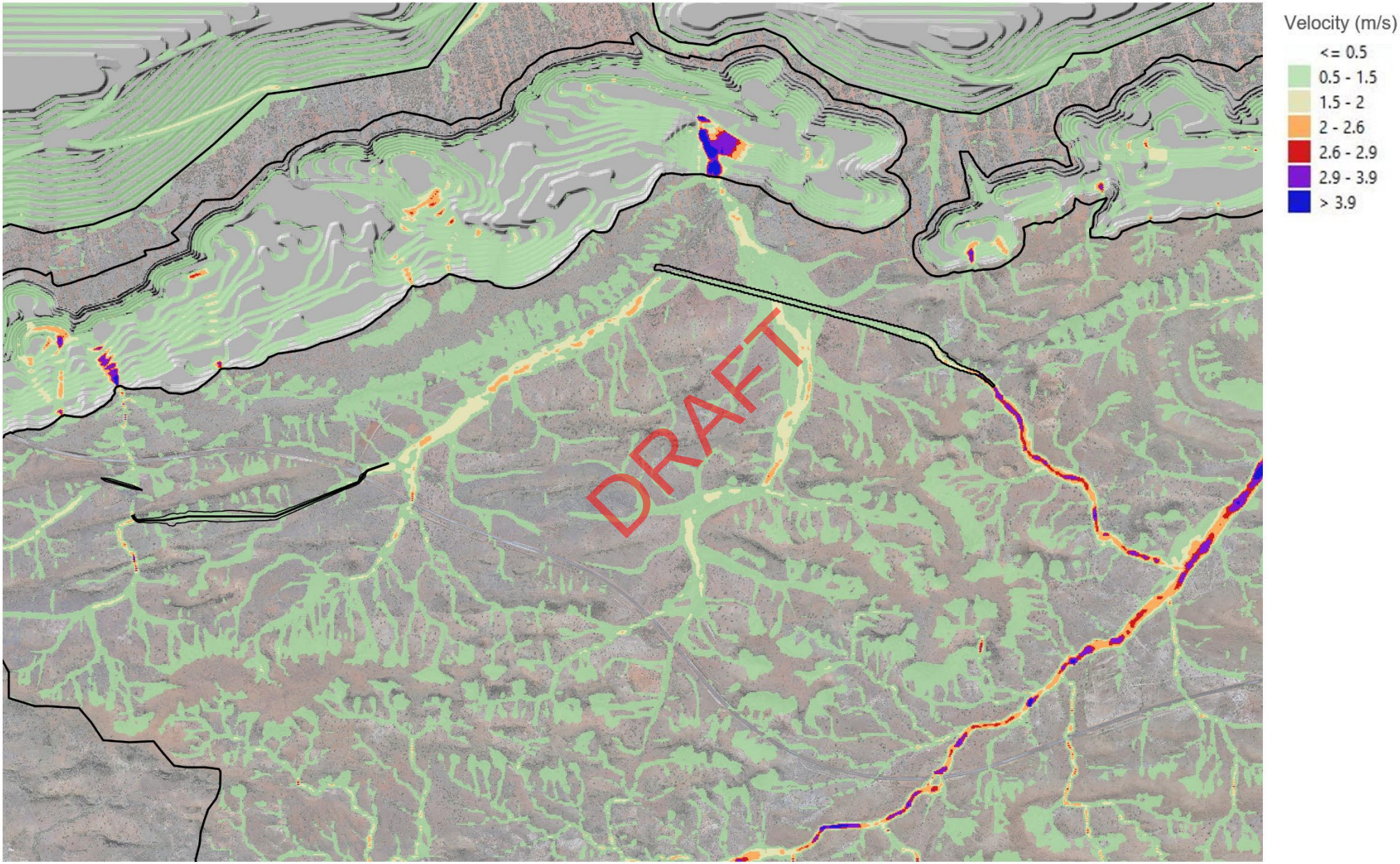

Figure 22: 1:1000 AEP Maximum velocities at HD2 diversion structures

8. SURFACE WATER RISKS

8.1. Bedded Hilltop

Rare (1:100 AEP), very rare (1:1000 AEP) and extreme (1:10,000 AEP) flood modelling of Pebble Mouse Creek indicates there are relatively low flood risks associated with the pit and waste dump designs at Bedded Hilltop. End of mine landforms associated with BHT do not interact directly with the floodplain of the creek. Results show no risk of pits overtopping or significant flooding around waste dumps, even in the very rare event.

Removal of the haul road crossing at Pebble Mouse Creek allows the creek to return its natural (pre mining) flow regime.

8.2. Hope Downs 2

Rare to extreme flood modelling of the catchments intersected by HD2 mine site also indicates relatively low flood risks associated with pit and waste dump designs.

The permanent feature of the diversion drains south of the western pit allow the upstream catchment to continue contributing runoff to Weeli Wolli Creek. Alternatively, if the diversions were to be removed this volume of water would be lost to the pit void.

The diversion structures are designed for the 1:100 AEP event, therefore in the very rare event results indicate overtopping of the drains with runoff flowing north into the western pit. Significantly high velocity rates are estimated at the pit crest during the very rare event, increasing the risk of erosion, potentially causing pit instability at these locations. As a result, it is recommended these drainage structures be designed to withstand a minimum 1:1000 AEP event at closure. This would allow for continued contribution of flows to the downstream WWC catchment and maintain the integrity of the diversion levee and drains.

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9. POST CLOSURE MANAGEMENT

The hydrologic risks associated with the closure of Hope Downs 2 and Bedded Hilltop are relatively low.

Detailed closure landform designs are yet to be developed. But as part of future closure planning Rio Tinto plans to design, upgrade and/or construct landforms which will improve landform stability over closure time frames.

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Appendix 13: Assessment of Surface Water Impacts on Sensitive Receptors in the Weeli Wolli Creek Catchment

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RioTinto

RTIO Water Resource Evaluation

Hope Downs 2 & Bedded Hilltop

Assessment of surface water impacts on sensitive receptors in the Weeli Wolli Creek catchment

May 2022

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EXECUTIVE SUMMARY

This report presents an assessment of the potential impacts on surface water quantity and quality at Weeli Wolli Spring and Ben's Oasis from mining infrastructure proposed for the HD2 Proposal which includes deposits at Bedded Hilltop (BHT) and Hope Downs 2 (HD2). Weeli Wolli Spring and Ben's Oasis are located within the Weeli Wolli Creek catchment and are referred to as sensitive receptors due to their Aboriginal heritage and environmental significance.

A two-dimensional (2D) hydraulic model was developed to characterise the surface water flow regime of Weeli Wolli Creek and Pebble Mouse Creek (a major tributary of Weeli Wolli Creek) in their existing conditions. This regional model was used to quantify the total volume and peak flows estimated at the sensitive receptors. An operational mining scenario was also modelled to simulate estimated surface water flows once HD2 and BHT mining infrastructure had been constructed. Comparison of results from the two scenarios highlighted areas within Weeli Wolli Creek and Pebble Mouse Creek that experienced a change in maximum water depths due to mining infrastructure, in particular the addition of diversion drains at HD2 and a haul road crossing at Pebble Mouse Creek.

The water quality component of the assessment considered the potential for sediments at the Pebble Mouse Creek haul road crossing to be transported 14 km downstream and impacting Weeli Wolli Spring. A refined, localised 2D hydraulic model was developed focusing on flows within Pebble Mouse Creek at the location of the floodway crossing as well as the HD1 rail crossing (consisting of multiple culverts and located 4 km downstream of the floodway). Evaluation of velocities at these crossings and assumptions of sediment transport behaviour formed the basis of the water quality analysis.

Results from the regional model indicated that mining operations associated with the HD2 Proposal (including pits, dumps and drainage infrastructure) truncated approximately 3.5% of the total catchment reporting to Weeli Wolli Spring. This resulted in the loss of 1 % of the total runoff volume at the Spring and a reduction of the peak flow by 1.4 %, based on the 1:100 annual exceedance probability (AEP) 24 hour rainfall event. At Ben's Oasis, the catchment reporting to this location was truncated by 0.2 %, which resulted in a reduction to peak flow of 1.1%.

Results from the localised model indicated that during frequent (1:5 AEP) and rare (1:100 AEP) rainfall events, flood depths are increased on the upstream side of the floodway and rail culverts due to the attenuation and backwater impacts of these structures. Velocities modelled at these locations are observed to be lower on the upstream side as flow is throttled by the crossing obstruction, with a distinct increase in velocity at and immediately downstream of the crossing as flow is concentrated through the floodway or culvert.

The slight loss of runoff demonstrated through the regional modelling is expected to have little effect on the flow regime at either sensitive receptor and is therefore expected to have insignificant impact of the environmental and heritage values of Weeli Wolli Spring or Ben's Oasis. This is further reinforced by the fact that water levels in Weeli Wolli Spring are supplemented by Hope Downs 1 dewatering discharge and Ben's Oasis is a groundwater sustained system.

High flood depths and low velocities observed on the upstream side of the rail crossing in results from the local model support the increased deposition of sediment at the rail culvert inlets and most likely poor transport of sediment through the culverts. Therefore, sediment transported from haul road crossings over Pebble Mouse Creek is considered unlikely to impact water quality at Weeli Wolli Spring.

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1. INTRODUCTION

The purpose of this report is to assess the potential surface water impacts to the sensitive receptors, Weeli Wolli Spring and Ben's Oasis, within the Weeli Wolli Creek catchment from the mining infrastructure proposed for the HD2 Proposal which includes deposits at Bedded Hilltop (BHT) and Hope Downs 2 (HD2).

The cumulative effects of mining and interventions resulting from the HD2 Proposal in the Weeli Wolli Creek catchment have the potential to alter the flooding characteristics and flooding frequency of the creek system. Activities such as construction of diversion structures and haul/access road crossings can potentially modify the existing surface flow regimes. Existing pits at HD1 and development of future pits for the HD2 Proposal may also truncate local catchments thus reducing flow contribution to Weeli Wolli Creek and its tributaries. These changes in surface flow regime may result in reductions to peak and total flow volumes, with the potential to impact water quality through a change in sediment loading.

Two-dimensional hydraulic modelling has been utilised to characterise the surface flow regime in Weeli Wolli Creek and assess the changes in surface water quantity and quality, in particular at Weeli Wolli Spring and Ben's Oasis.

2. REGIONAL HYDROLOGY

HD2 and BHT deposits are located within the upper reaches of the Weeli Wolli Creek catchment that forms part of the Fortescue River Region (BoM, 2021). Weeli Wolli Creek has a total catchment area of approximately 4,770 km^2 to Waterloo Bore gauging station and drains north to the Fortescue Marsh.

The upper reaches of the Weeli Wolli Creek catchment include Pebble Mouse Creek, a major tributary of Weeli Wolli Creek, which has a catchment area of 340 km^2. HD2 and BHT deposits are bisected by the Pebble Mouse Creek and Weeli Wolli Creek catchment divide and do not interact with the flood plains of either creek.

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The Tarina gauging station (operated by DWER) is the closest stream flow gauge to the study area and is located on Weeli Wolli Creek, about 7 km downstream of Weeli Wolli Spring. The Weeli Wolli Creek catchment area reporting to the Tarina gauge is about 1,530 km^2 and this area is illustrated in Figure 1.

Table 1: Catchment areas of Weeli Wolli Creek

Catchment	Area	Downstream Location
Weeli Wolli Creek	4,770 km^2	Fortescue Marsh
Weeli Wolli Creek	1,530 km^2	Tarina gauging station
Weeli Wolli Creek	1,340 km^2	Weeli Wolli Spring
Weeli Wolli Creek	420 km^2	Ben's Oasis
Pebble Mouse Creek	340 km^2	Confluence with Weeli Wolli Creek

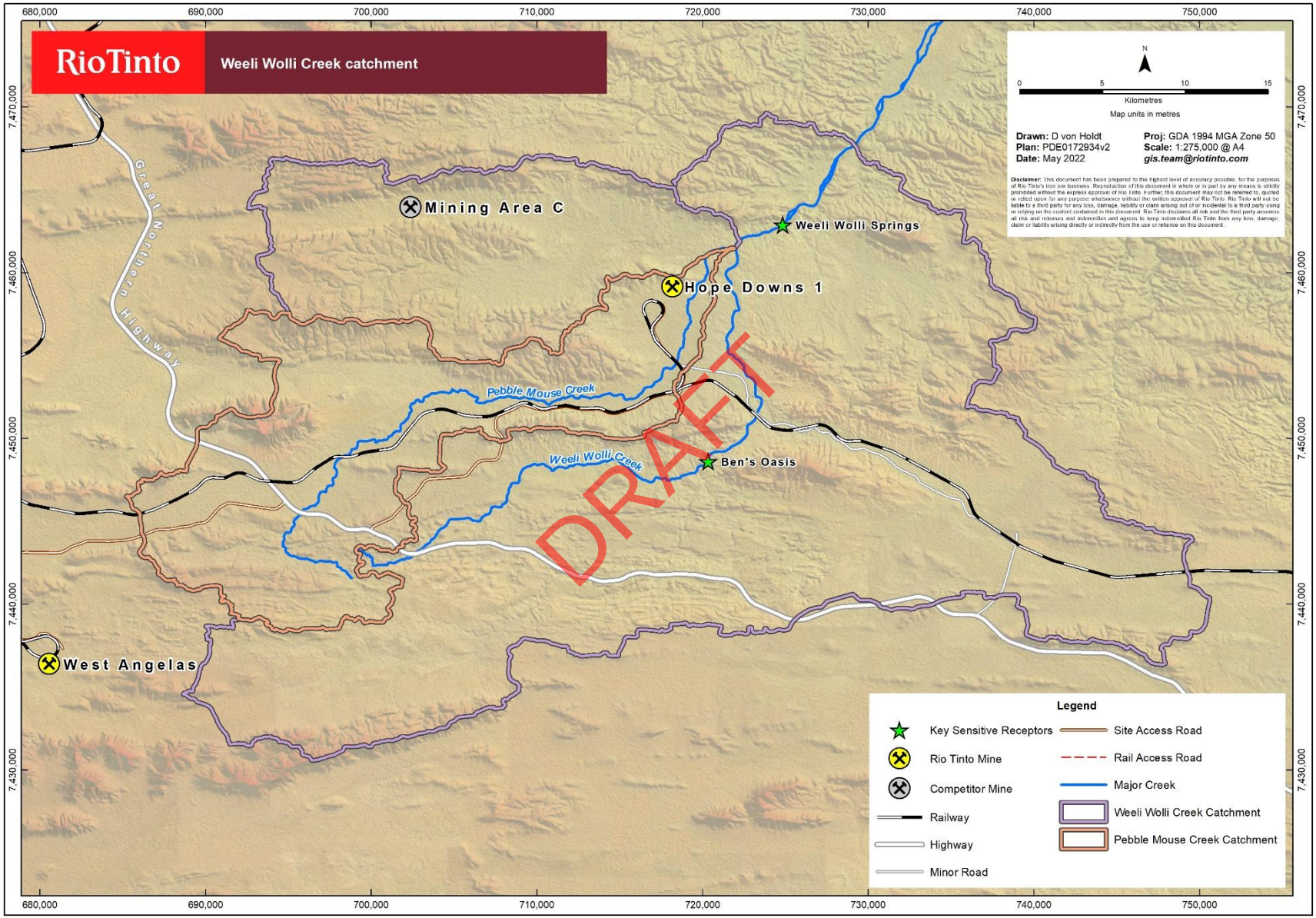

Figure 1: Weeli Wolli Creek catchment

3. MINING INFRASTRUCTURE

The proposed mine layout for HD2 and BHT is shown in Figure 2.

This report focused on the drainage infrastructure proposed to assist with surface water management at the HD2 and BHT pits, in particular the Pebble Mouse Creek Haul Road crossing, the Pebble Mouse Creek Road Train crossing and the diversion drains at HD2 as highlighted in Figure 2.

Consideration of additional waterway crossings proposed are also provided in this report. These crossings are associated with alternative transport options being explored as part of the study and include: the realignment of Great Northern Highway (GNH); an alternative mine access road; and an overland conveyor from HD2 to HD1.

Preliminary engineering designs for most of the infrastructure have been included in the hydraulic modelling undertaken for this report's analysis.

3.1. Pebble Mouse Creek Haul Road Crossing

Pebble Mouse Creek is a significant waterway separating the existing mining facilities at HD1 and the deposits of BHT and HD2. It is proposed that the haul road connecting the BHT deposit to the HD1 processing infrastructure will cross Pebble Mouse Creek. An engineered crossing will be constructed to manage flood risk and allow continuity of production. The width of Pebble Mouse Creek bed at the proposed crossing location is approximately 350 m, as shown in Figure 3**Error! Reference source not found.**.

During the development of the proposed engineered solution for the creek crossing a haul road with culverts was defined, and three different concept design options, providing varying levels of flood serviceability, were evaluated. These options along with their design criteria are summarised in Table 2.

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Table 2: Pebble Mouse Creek haul road crossing design options

Option	Design AEP	Design flow rate	Crossing structure
1	1% (1:100)	827.3 m^3/s	41 x DN2700 culverts
2	5% (1:20)	257.7 m^3/s	13 x DN2700 culverts
3	Low flow (assumed 50%, 1:2)	Not specified	4 X DN900 relief culverts

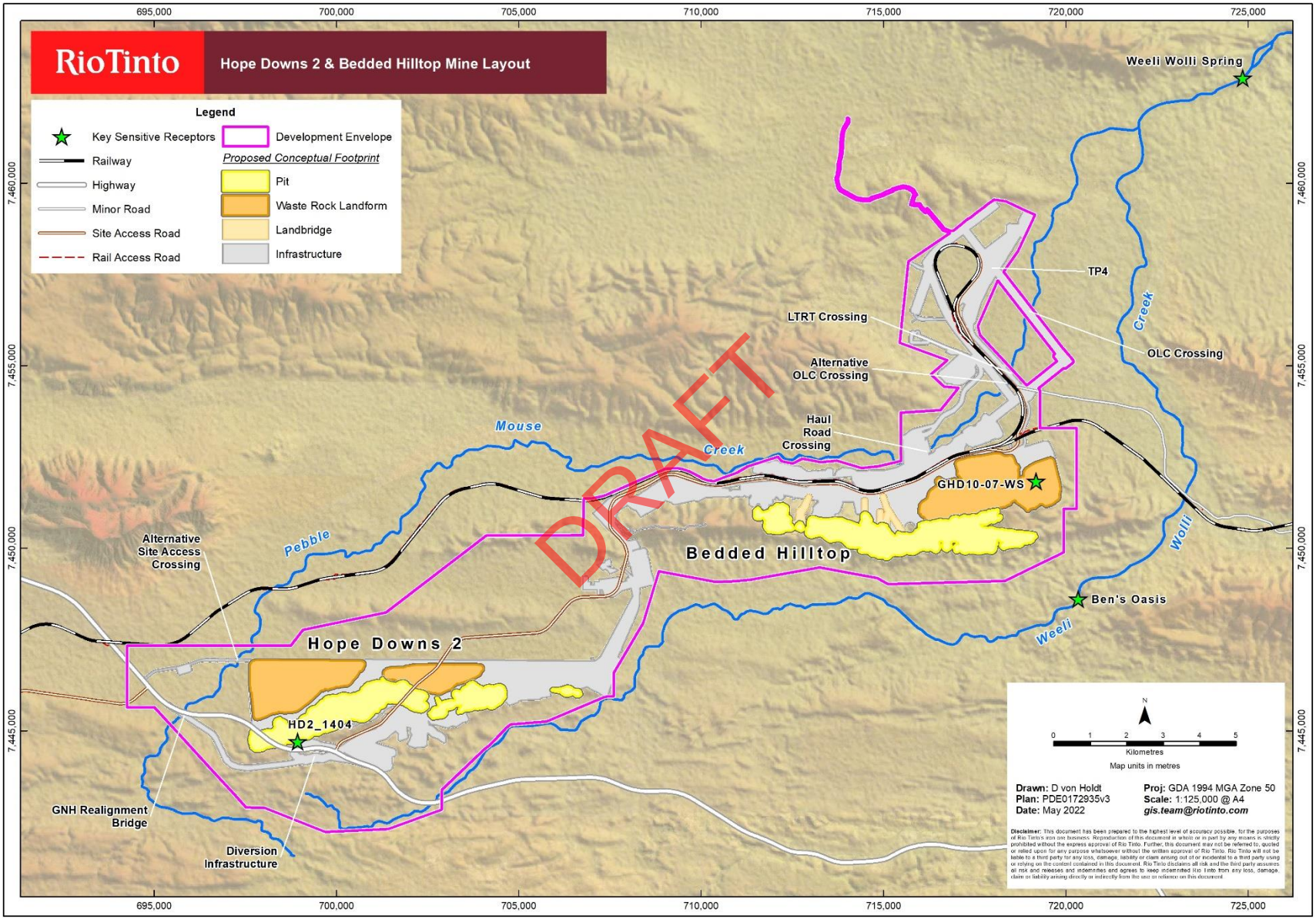

Figure 2: Hope Downs 2 & Bedded Hilltop Mine Layout

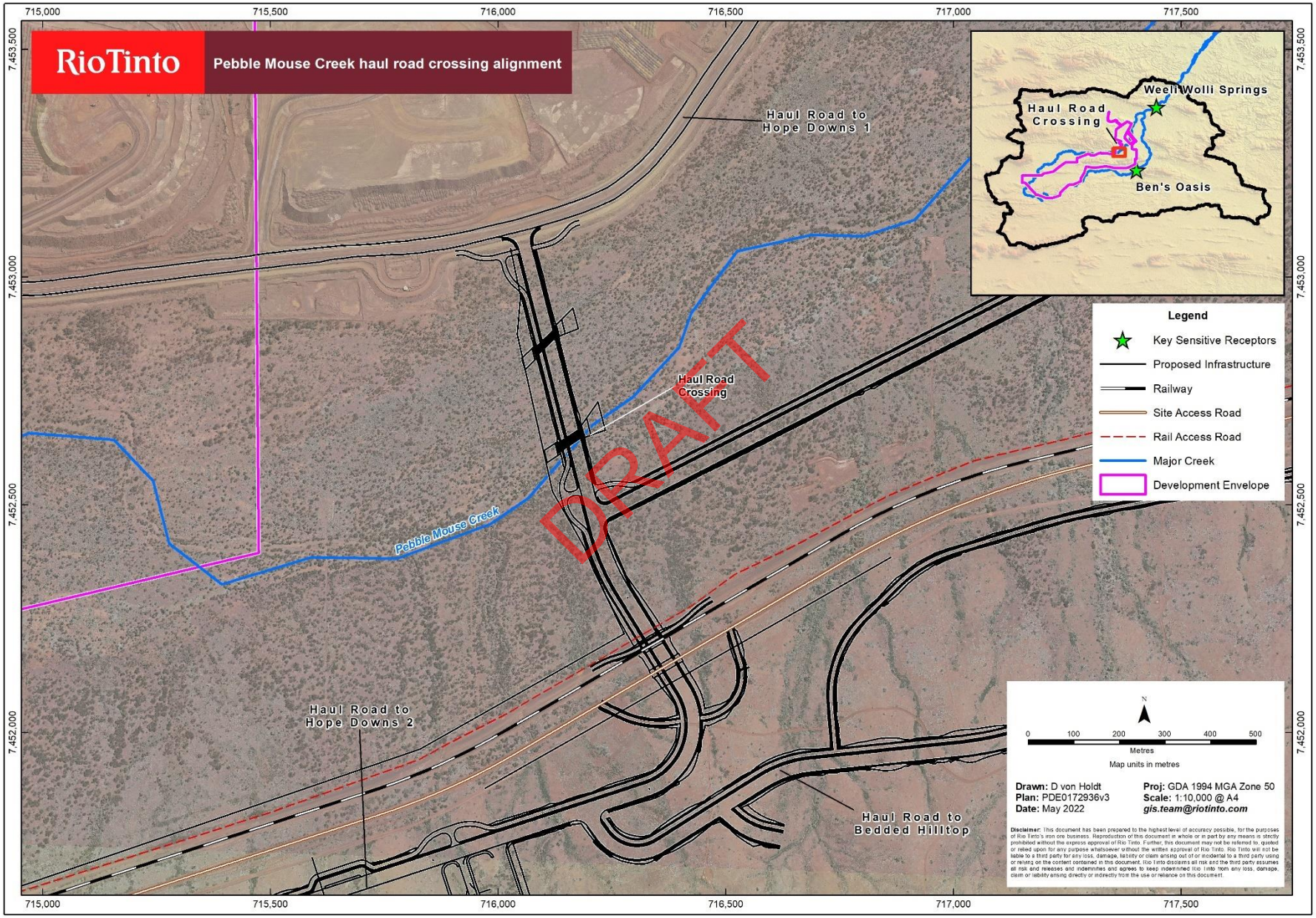

Figure 3: Pebble Mouse Creek haul road crossing alignment

3.2. HD2 Diversion Levee and Drains

Diversion infrastructure have been proposed at HD2 to manage the surface water flow around the pit. Several options were evaluated with the final design consisting of a levee (DL03) and two drains, referred to as DD01 and DD03. The drain configuration aims to divert flow from a tributary of Pebble Mouse Creek, that originally travelled north, towards Weeli Wolli Creek in the southeast. The levee and drains have been designed to convey the 1:100 AEP event. Proposed alignments of these structures are shown in Figure 4.

3.3. Pebble Mouse Creek Road Train Crossing

Long term road trains (LTRT) have been identified as the preferred ore transport option by the Prefeasibility Study (PFS). The proposed LTRT haul road will consist of a sealed road extending 27 km from HD2 to HD1 north crusher. Several options for the road alignment have been investigated and all options include a crossing over Pebble Mouse Creek, directly downstream of the existing rail line crossing.

LTRT Option 1 design includes multiple large culverts (aligned similarly to the existing railway culverts) at the creek crossing, designed to convey the 1:100 AEP flow rates. A transfer pad (TP4) will be located at the end of the haul road, close to the HD1 north crusher. Placement of TP4 has been restricted to be outside the 1% AEP flood extent of Pebble Mouse Creek.

Figure 5 includes the LTRT Option 1 road alignment and associated infrastructure (TP4).

3.4. Optional Waterway Crossings

3.4.1. Great Northern Highway Realignment

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Due to the extent of the HD2 ore body, realignment of the GNH has been proposed to allow access to the ore currently situated under a section of the existing highway. Subsequently, to prevent the construction of road infrastructure that would ultimately become redundant once the GNH is realigned, an alternative mine access road has also been proposed. The GNH crossing will require a bridge structure, whereas the alternative mine access road crossing will require culverts. At this stage, preliminary designs are not available to model however the existing bridge along GNH currently crossing PMC provides the minimum design criteria expected for the new bridge on GNH. Austroads (1994) and Main Roads WA (MRWA, 2003) standard design guidelines dictate the design criteria for bridges along a main public highway, which include a serviceability design of 1% AEP and a survivability design of 1:2000 AEP.

3.4.2. Overland Conveyor (OLC)

An overland conveyor transport option was investigated, extending from HD2 to the HD1 north, as an alternative to the extensive haulage route required from HD2. The conveyor alignment requires a crossing over Pebble Mouse Creek. Several alignments were assessed including:

1. The OLC directly upstream of the existing HD1 rail line, running parallel to the rail crossing.
2. The OLC about 2 km downstream from the rail line.

The proposed design consists of an earth embankment with pipe culverts designed to convey the 1% AEP flow rates.

Figure 5 includes the OLC alignment positioned directly upstream of the rail line.

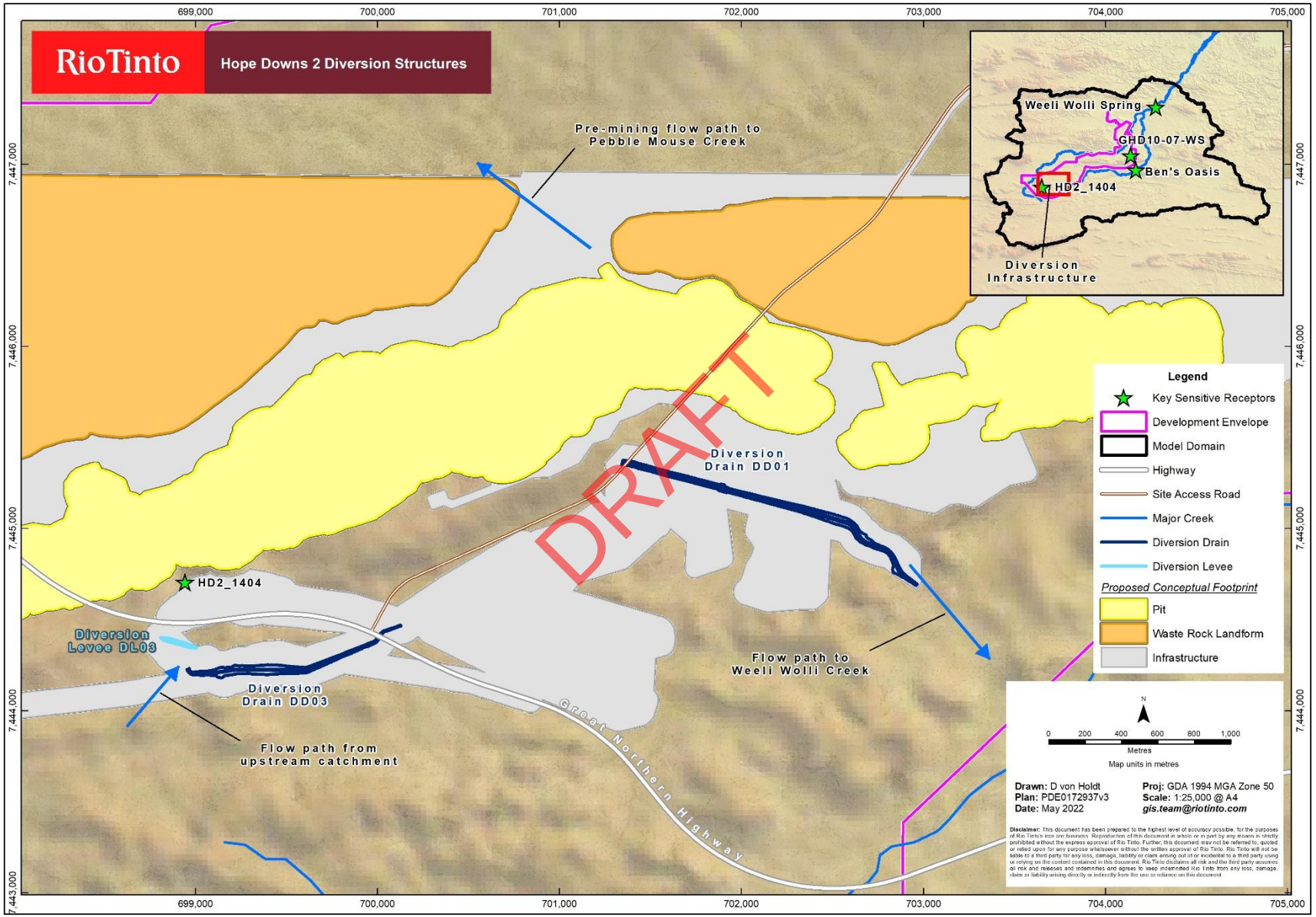

Figure 4: Hope Downs 2 diversion structures

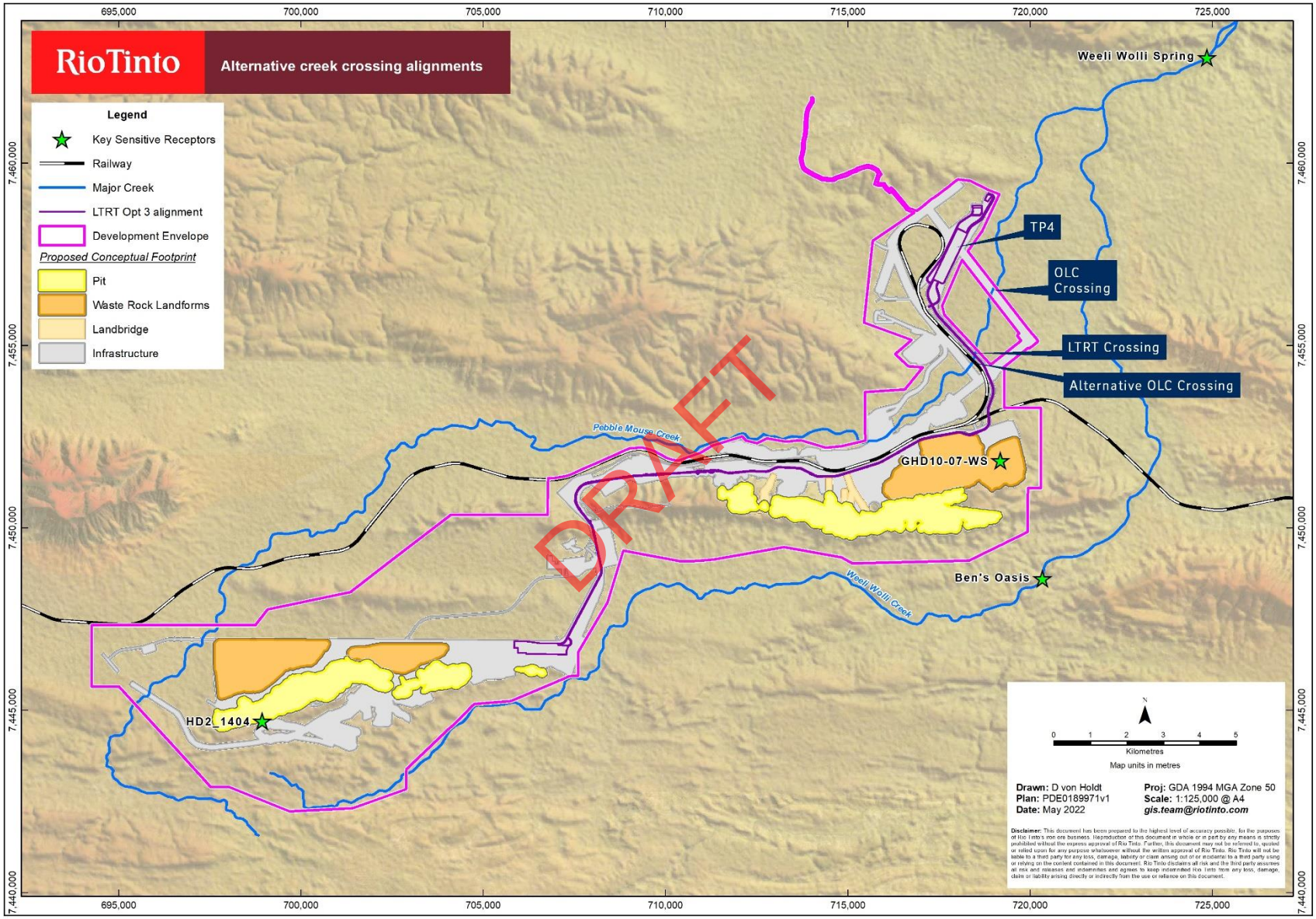

Figure 5: Alternative creek crossing alignments

4. KEY SENSITIVE RECEPTORS

Locations with heritage or environmental significance are referred to as sensitive areas or receptors. These locations require special consideration of the direct and potentially cumulative impact of all mining activities due to their high heritage or environmental value.

Regarding surface water, sensitive receptors may be impacted where modifications to the creek morphology or hydrologic regime adversely influence the heritage or environmental value of the site. The sensitive environmental receptors that have been identified as part of the HD2 Proposal are Weeli Wolli Spring and Ben's Oasis, and two waterholes situated within the Development Envelope. Locations for these sites are shown in Figure 2. The hydraulic modelling presented in this report was completed to assess the potential surface water impact on these receptors.

4.1. Weeli Wolli Spring

Weeli Wolli Spring is located approximately 7 km downstream of the confluence of Pebble Mouse Creek and Weeli Wolli Creek to the north-east of the study area. It is protected under the *Aboriginal Heritage Act 1972* and the riparian vegetation supported by the spring is categorised as a Priority 1 Ecological Community. The Spring was naturally groundwater controlled (pre-mining) and is currently maintained by discharge of surplus water from dewatering from HD1, which has occurred since 2007. Upstream of the permanent flowing portion of the Spring are several permanent and semi-permanent pools scattered over a distance of 2 km as illustrated in Figure 7.

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Figure 6: Weeli Wolli Spring (photographed in October 2020)

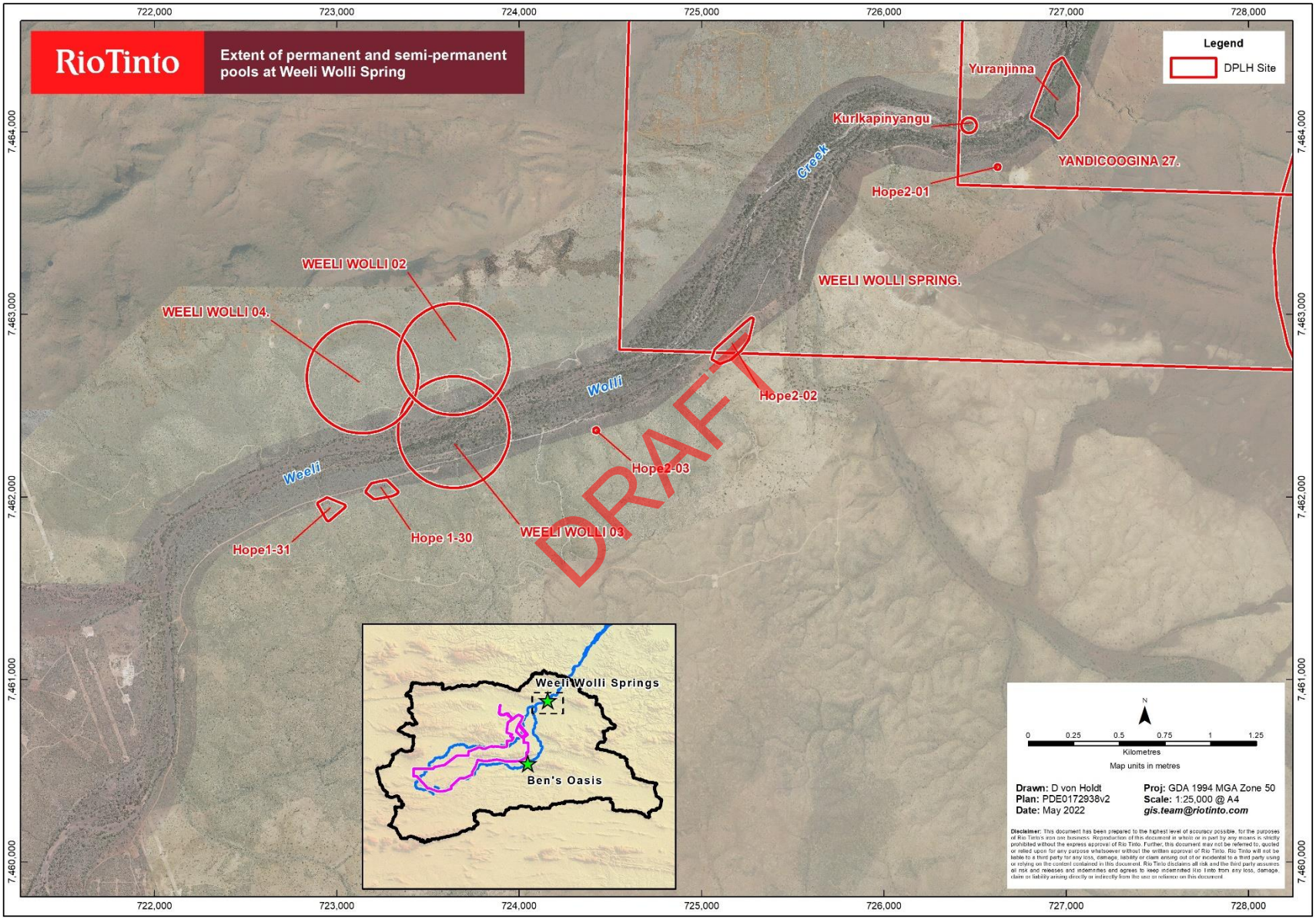

Figure 7: Extent of permanent and semi-permanent pools at Weeli Wolli Spring

Table 3 summarises the area reduction of the catchment reporting to Weeli Wolli Spring due to mining operations at both HD2 and BHT. The catchment area reduction incurred from mining the HD2 and BHT deposits will be approximately 45 km^2 based on the proposed pits and the placement of dumps provided in the current mine layouts. This area is equivalent to 3.5 % of the contributing catchment area to Weeli Wolli Spring. A catchment reduction of 3.5 % is considered relatively negligible and is therefore unlikely to impact the hydrological regime of this key sensitive receptor. Further validation of this assumption is provided in Section 6 where an impact assessment of peak flows and volumes is also discussed.

Table 3: Area reduction of catchment reporting to Weeli Wolli Spring

Mining Factor Affecting Catchment	Total Catchment Area (km^2)	Operational mining Catchment Area (km^2)	Area Reduction (km^2)	Difference (%)
HD2 & BHT pits, dumps	1,340	1,295	- 45	- 3.5

4.2. Ben's Oasis

Ben's Oasis is a significant environmental feature on Weeli Wolli Creek. Ben's Oasis is similar in function to Weeli Wolli Spring in that it is supported via groundwater expression as opposed to surface water.

Figure 8: Ben's Oasis (photographed in Jan 2019)

Table 4 summarises the area reduction of the catchment reporting to Ben's Oasis. The catchment area will be impacted by mining operations at only HD2. Proposed pits and dumps will result in approximately

6 km^2 catchment area reduction. However, this will be largely offset by the proposed HD2 diversion which would contribute an additional 5 km^2 of catchment reporting to Ben's Oasis. Therefore, the net contributing catchment area is reduced by 1 km^2, equivalent to 0.2 % of the total catchment. This is considered negligible and will have negligible impact to the flow regime at Ben's Oasis. This is discussed further in Section 6.

Table 4: Area reduction of catchment reporting to Ben's Oasis

Mining Factor Affecting Catchment	Total Catchment Area (km2)	Operational mining Catchment Area (km^2)	Area Reduction (km2)	Difference (%)
HD pits, dumps	420	414	- 6	- 1.4
HD2 diversion drains	420	425	+ 5	+1.2
	Net Changes	419	-1	- 0.2

4.3. Pebble Mouse Creek

Pebble Mouse Creek is considered to have cultural heritage significance, stemming from its use as a water source for people, plants, and animals and because it is a major tributary feeding into Weeli Wolli Creek. More consultation work is to be undertaken to completely understand the specific cultural heritage values and concerns associated with works impacting Pebble Mouse Creek.

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Table 5 summarises the area reduction to Pebble Mouse Creek. About 8 % of this catchment will be reduced due to the proposed HD2 and BHT mining areas.

Table 5: Area reduction of the Pebble Mouse Creek catchment

Mining Factor Affecting Catchment	Total Catchment Area (km^2)	Operational mining Catchment Area (km^2)	Area Reduction (km^2)	Difference (%)
HD2 & BHT pits, dumps and diversion drains	340	26	314	- 7.6

4.4. Identified waterholes

Two water sources or waterholes are identified within the proposed Development Envelope: HD2_1404 and GHD19-07-WS. Their locations are shown in Figure 2.

HD2_1404 is in very close proximity to the HD2 deposit and has been described as a water source of ethnographic interest. The waterhole is 12 m by 17 m and is at least 1 m deep. The site was visited as part of the November 2021 Nyiyaparli Social Surroundings site visit. The waterhole was observed to be holding an indeterminate amount of water as shown in Figure 9.

Figure 9: Waterhole HD2_1404 (photographed in November 2021)

GHD19-17-WS is in relative proximity to the eastern end of the BHT deposit. The site is a series of five waterholes within a minor creek and measures 11 m by 17 m (covering 187 m^2). The site was also visited during the November 2021 Nyiyaparli Social Surroundings site visit. Two of the five waterholes were observed to be holding small amounts of water as shown in Figure 10.

Figure 10: Waterhole GHD19-07-WS (photographed in November 2021)

5. HYDRAULIC MODELLING

A two-dimensional hydraulic model was developed, using TUFLOW (build 2018-03-AB-iSP-w64 HPC), in order to characterise the surface water flow regime of Weeli Wolli Creek and Pebble Mouse Creek and assess potential impacts on water quantity at the sensitive receptors. The methodology and results are discussed below.

5.1. Methodology

A whole-of-catchment rain-on-grid hydraulic model was constructed for Weeli Wolli Creek, including the Pebble Mouse Creek catchment, to a downstream location of the Tarina gauge. An ensemble of simulations has been run with varying rainfall durations and temporal patterns for comparison with previous and updated rainfall-runoff model (RORB) results. However, for the purpose of this analysis, the adopted scenarios run for pre- and post-mining comparisons were the critical durations for the 1:5 and 1:100 AEP events.

The following input parameters were adopted for this assessment:

- Digital elevation model (DEM) – various LIDAR datasets mosaicked to cover the full model area
- Grid size – 20 m x 20 m, a coarse resolution was chosen to allow the full catchment to be adopted as the model domain, but limit model run times.
- Boundary conditions – height-flow (HQ) boundary downstream of Weeli Wolli Spring
- Roughness coefficient Manning's n – uniform 0.04
- Losses – initial loss of 35 mm/hr and continuing loss of 9 mm/hr (calibrated to match RORB peak flows)
- Scenarios run – pre-mining conditions and post-mining conditions including HD2 and BHT pits, haul roads, diversions and creek crossing
- Rainfall events – 1:5 AEP 12 hr TP04 and 1:100 AEP 24 hr TP02

Figure 11 illustrates the hydraulic model extent and downstream boundary location.

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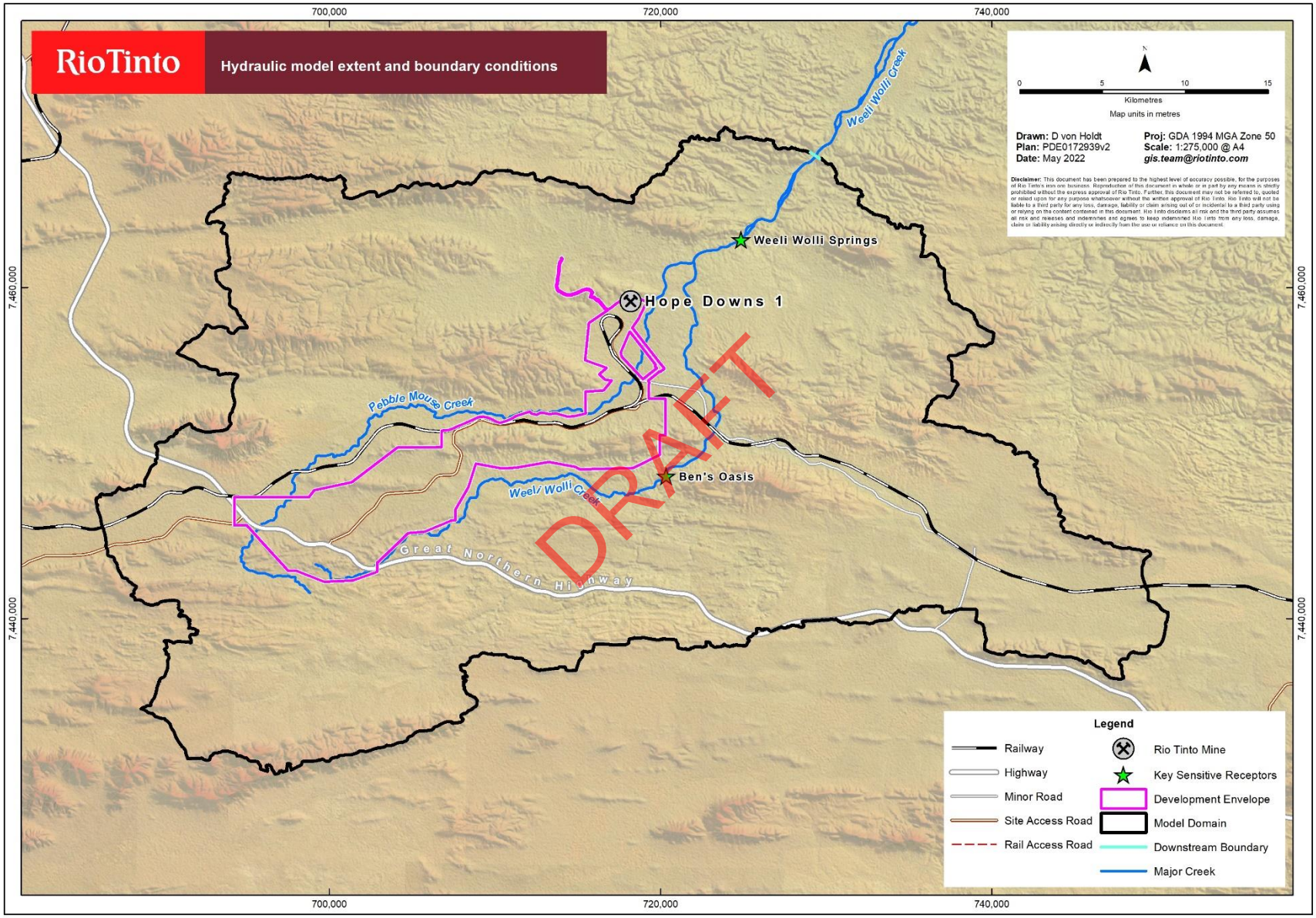

Figure 11: Hydraulic model extent and boundary conditions

5.2. Hydraulic Model Results

Results for the 1% AEP flood depths for pre mining, operational mining and a difference map are presented in Figure 12 to Figure 14. The difference map shows river reaches where modelled flood depths changed because of mining impacts.

Similar results for the 20% AEP flood depths are presented in Figure 15 to Figure 17.

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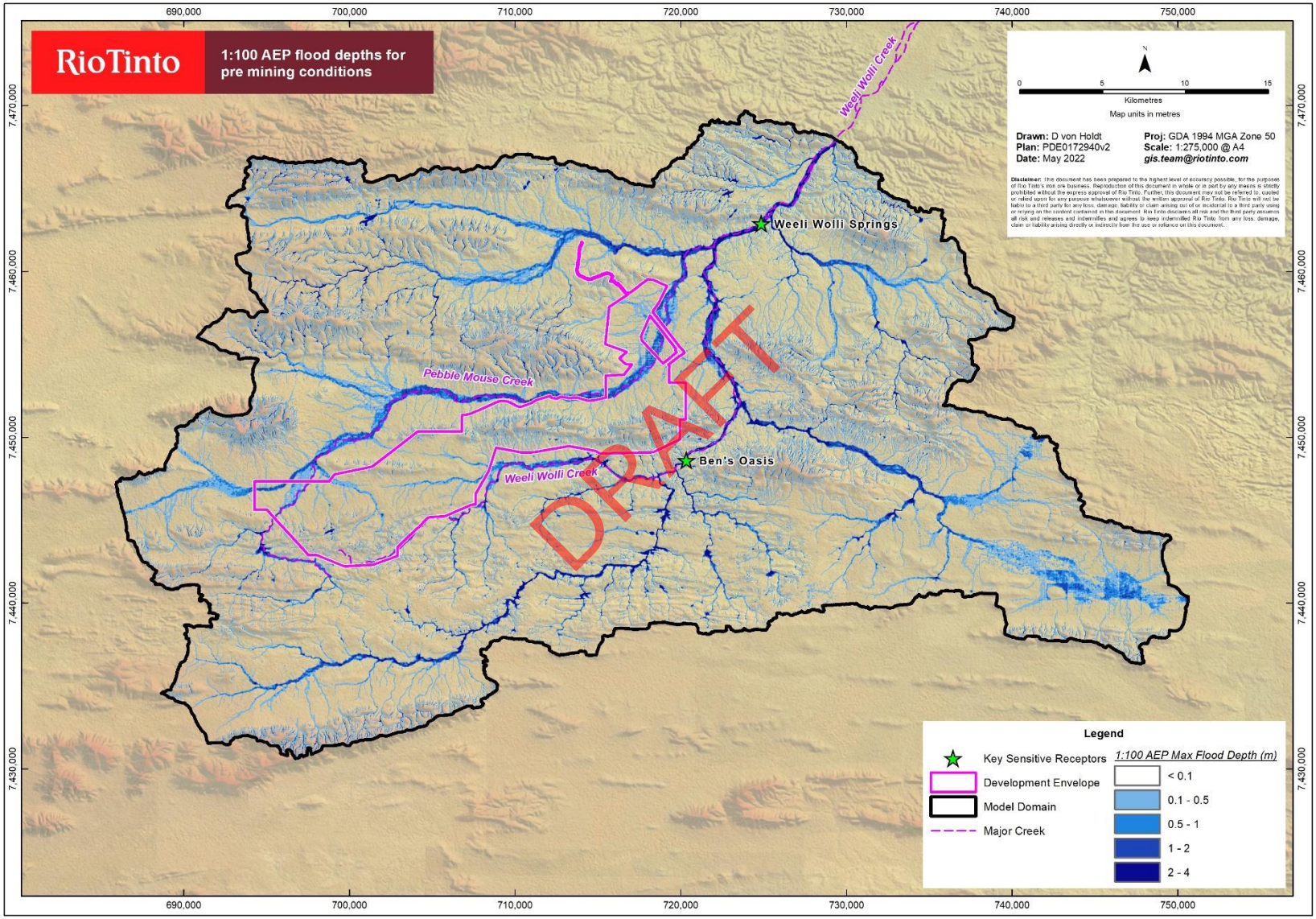

Figure 12: 1:100 AEP flood depths for pre mining conditions

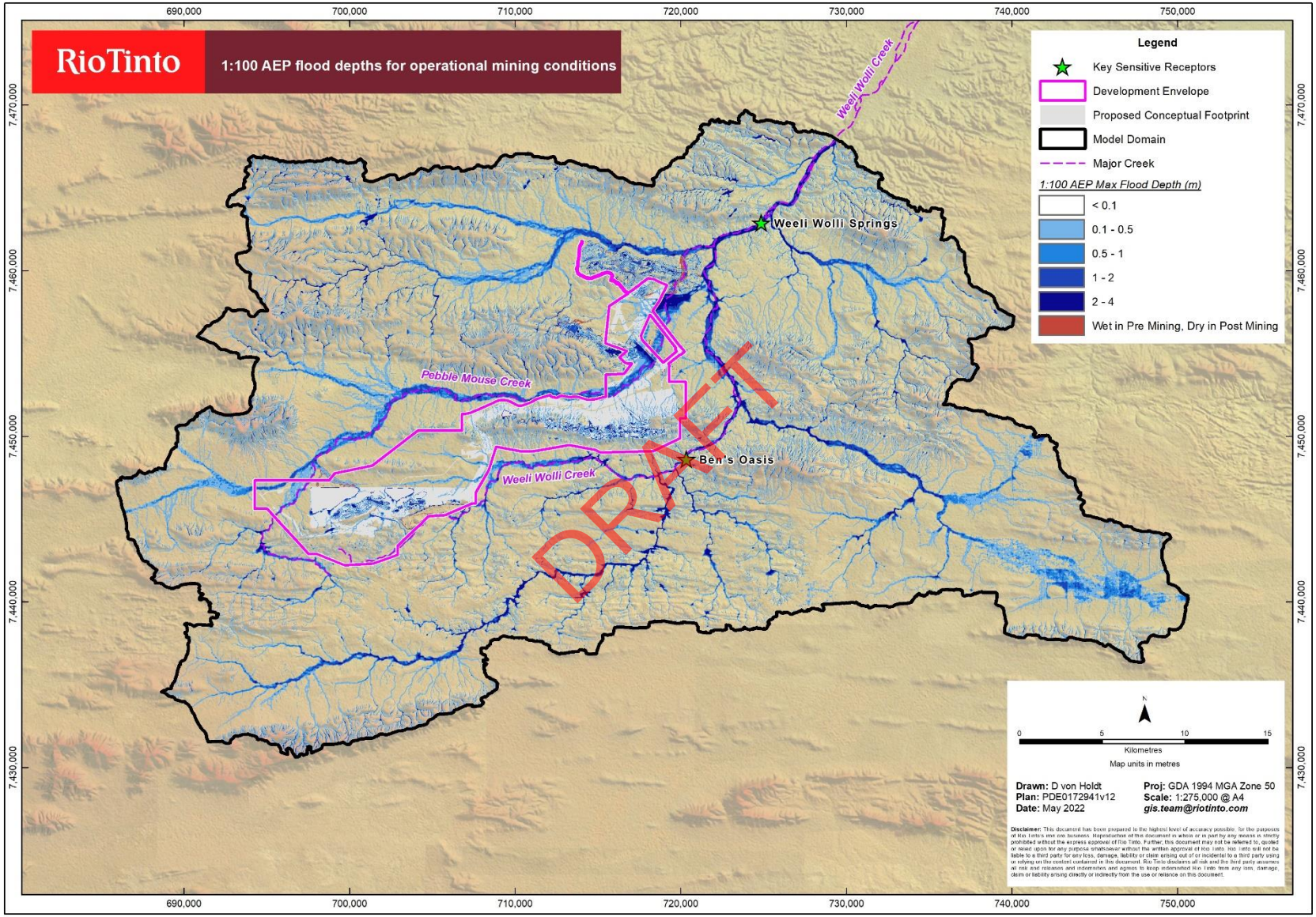

Figure 13: 1:100 AEP flood depths for operational mining conditions

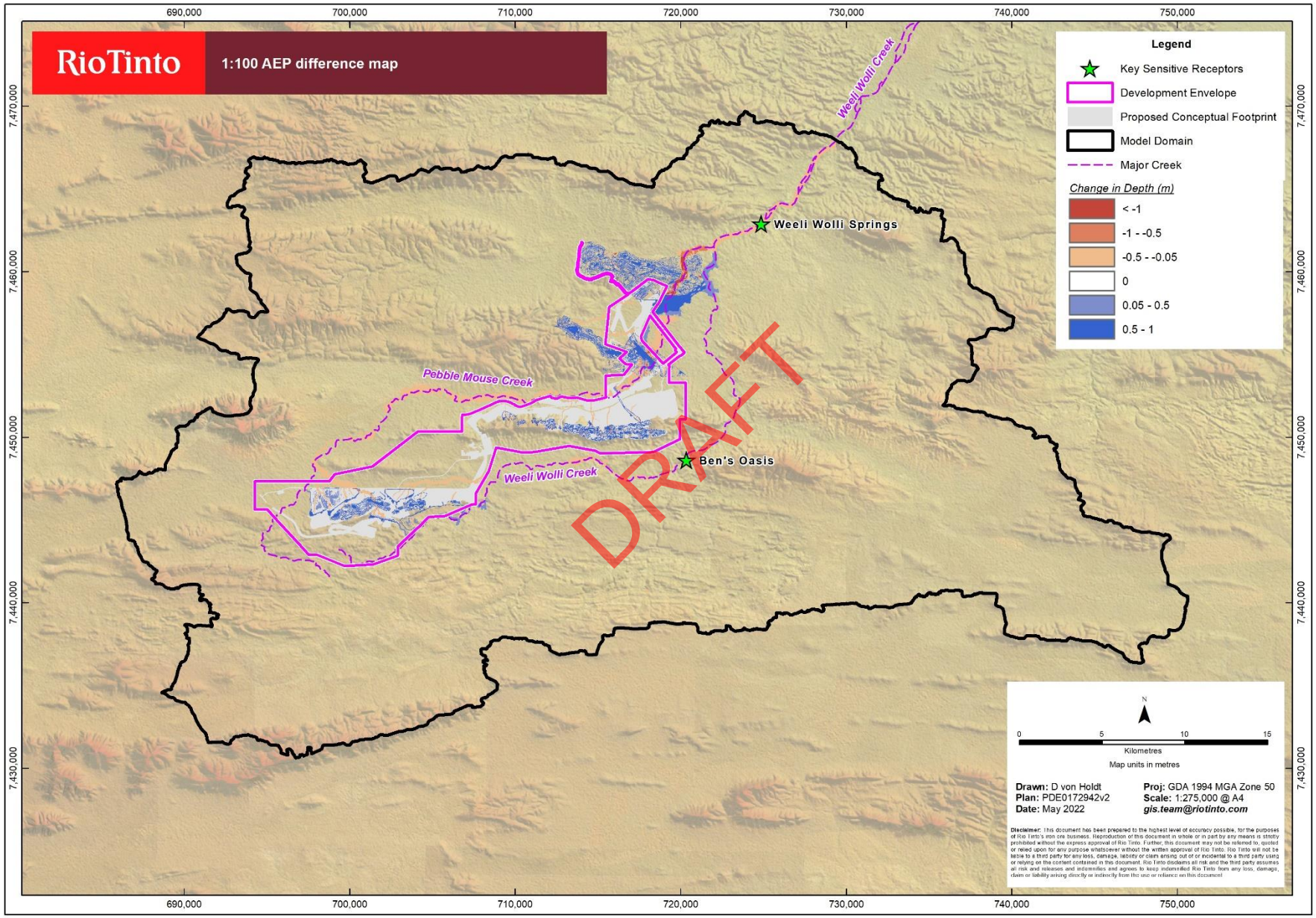

Figure 14: 1:100 AEP difference map

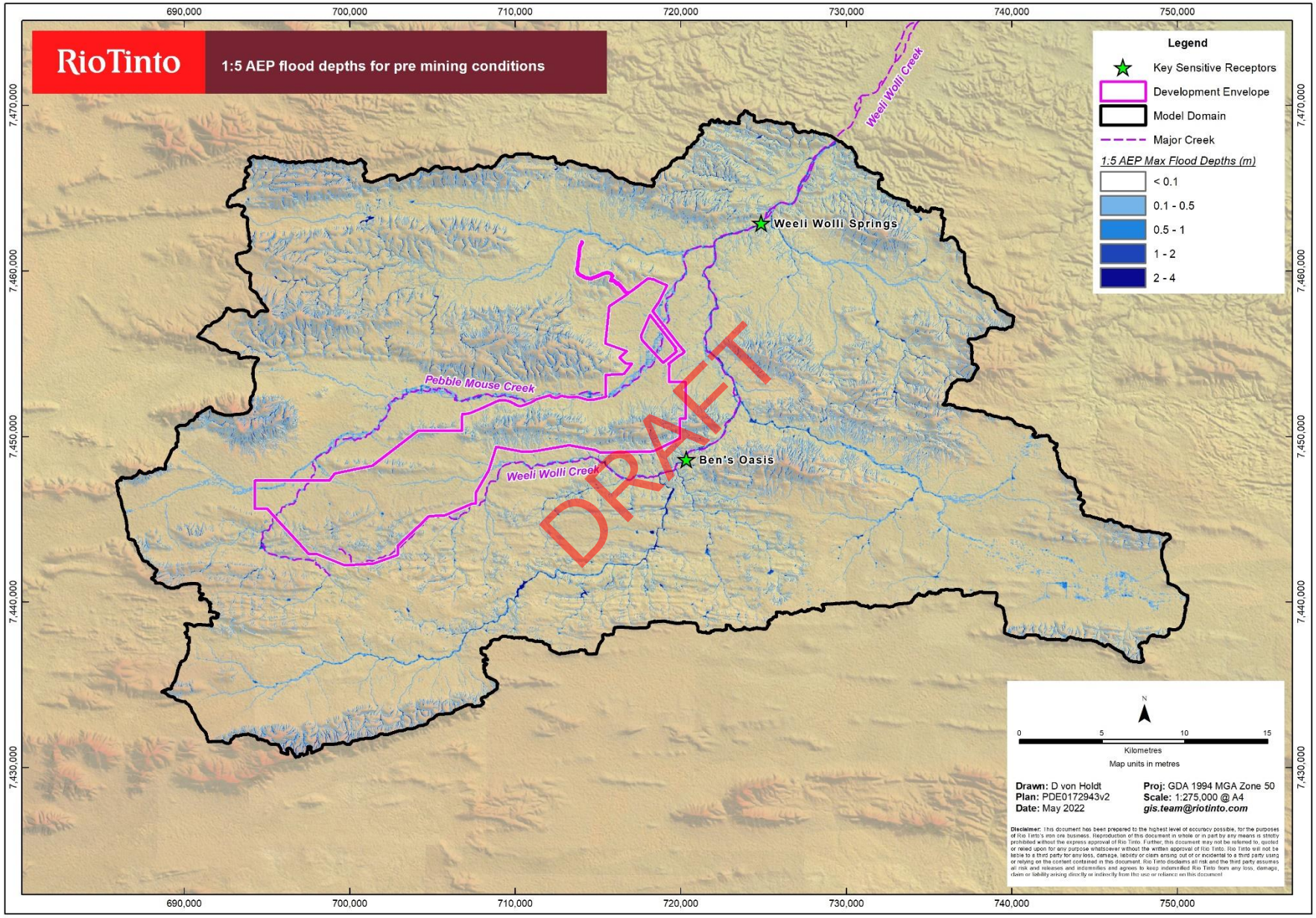

Figure 15: 1:5 AEP flood depths for pre mining conditions

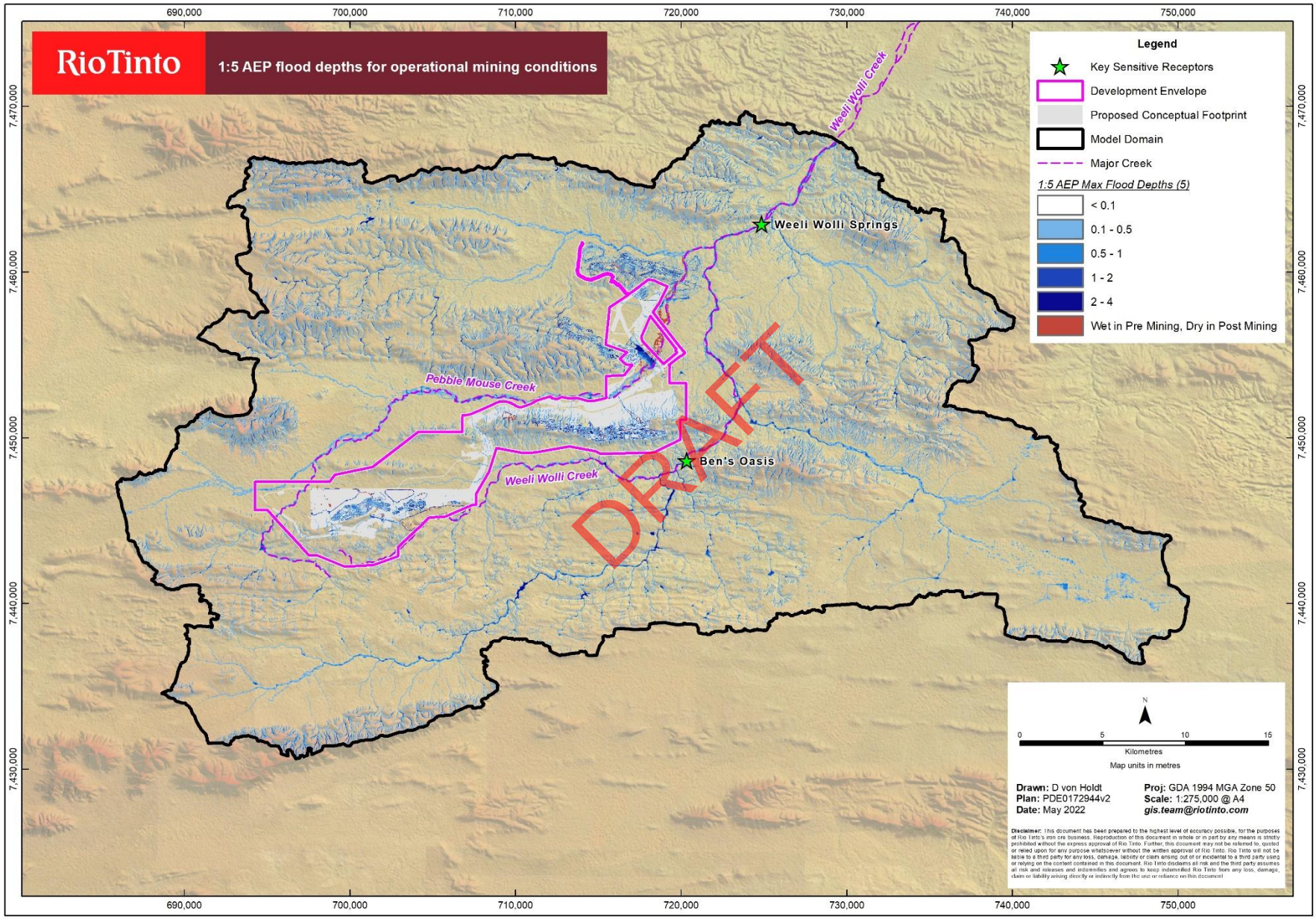

Figure 16: 1:5 AEP flood depths for operational mining conditions

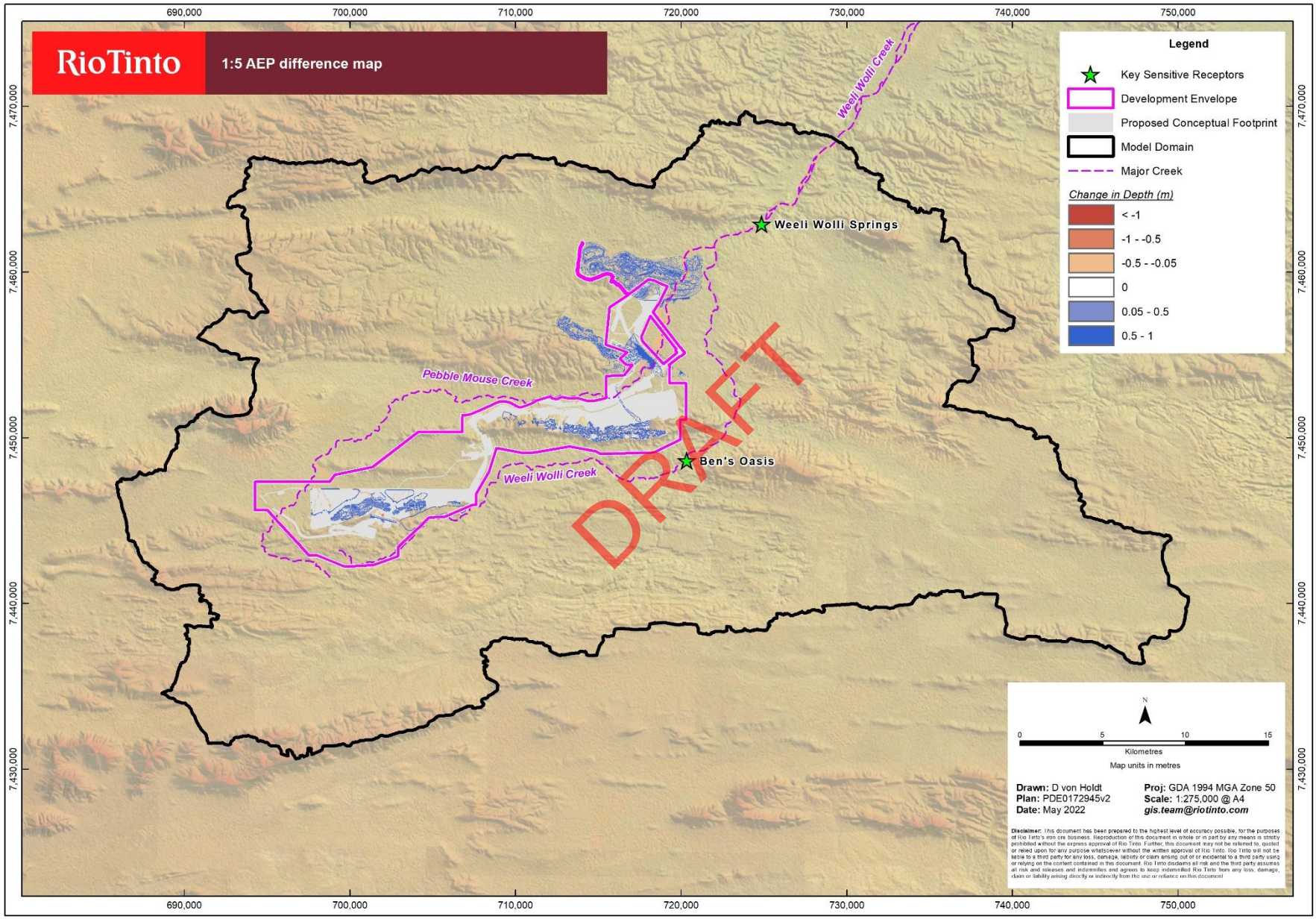

Figure 17: 1:5 AEP difference map

6. SURFACE WATER FLOW IMPACTS

6.1. Regional catchment

Difference mapping (discussed above) has highlighted the areas within Pebble Mouse Creek and Weeli Wolli Creek that are likely to experience a change in maximum surface water depths in the operational mining scenario. As expected, depths have increased at the location of HD2 diversion drains, which is predicted to result in a reduction to depths by less than 0.1 m in Pebble Mouse Creek directly north of the HD2 pits. The attenuation of surface water upstream of the Pebble Mouse Creek haul road crossing is predicted to result in an increase of depths in this area of up to 1 m. Depths downstream of the crossing appear to be impacted only slightly, with the difference map indicating a maximum decrease of 0.1 m for the 1:100 AEP.

6.2. Key sensitive receptors

A comparison of peak flows modelled, for critical duration storms at the key sensitive receptors for pre- and operational mining conditions. is provided in Table 5 and total volumes are compared in Table 6.

Table 5: Peak flows at the key sensitive receptors

Location	Event	Pre mining (m^3/s)	Operational mining (m^3/s)	Difference (m^3/s)	Difference (%)
Weeli Wolli Spring	1:100 AEP 24 hr	2,474	2,438	- 36	- 1.4
	1:5 AEP 12 hr	148	135	- 12	- 8.1
Ben's Oasis	1:100 AEP 24 hr	921	911	- 10	- 1.1
	1:5 AEP 12 hr	55	53	- 2	- 3.6

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Table 6: Total modelled volumes at the key sensitive receptors

Location	Event	Pre mining (GL)	Operational mining (GL)	Difference (GL)	Difference (%)
Weeli Wolli Spring	1:100 AEP 24 hr	25.2	24.7	- 0.5	- 2
	1:5 AEP 12 hr	0.8	0.6	- 0.2	- 25
Ben's Oasis	1:100 AEP 24 hr	7.1	7.0	- 0.1	- 2
	1:5 AEP 12 hr	0.33	0.31	- 0.02	- 7

As previously discussed in Section 4.1, mining operations at HD2 and BHT (including proposed dumps) will truncate approximate 45 km^2 of the total catchment reporting to Weeli Wolli Spring. This equates to a reduction of 3.5 % in the catchment reporting to Weeli Wolli Spring. Modelling has shown that the truncation will result in the loss of approximately 2 % of the total runoff volume at the spring for the 1:100 AEP 24 hour flow event of Weeli Wolli Creek. Peak flows at the spring for this event will decrease by 36 m^3/s, equivalent to a 1.4 % reduction. Modelled flow reductions for the 1:5 AEP event is slightly higher, with an

estimated 8.1 % reduction in flow. It should be noted that this reduction is not only the result of the changes due to the proposed HD2 mining activities but a cumulative impact from both HD1 and HD2 mining activities. Water levels (and therefore volumes) at Weeli Wolli Spring are supplemented by dewatering discharge from a series of spur lines running off the main discharge pipe to Weeli Wolli Creek. There are several monitoring locations in this area used to ensure water levels at the Spring are maintained. This discharge to the creek and the spur lines will continue for the operating life of HD2 therefore the modelled reduction to flows at the Spring is unlikely to be observed and the environmental and heritage values associated with the Spring are expected to be maintained.

Regarding Ben's Oasis, the total net change to the catchment reporting to this location is a reduction of approximately 1 km^2. Modelling indicates this will result in a reduction to the peak flow at Ben's Oasis by approximately 10 m^3/s or 1.1 % during a 1:100 AEP. Flow (volume) reduction observed for the 1:5 AEP is equivalent to a 3.6 % reduction. This limited loss of runoff is not expected to impact the environmental value of Ben's Oasis as the main source of water at this location is sustained by the groundwater aquifer.

6.3. Waterholes

Although the physical location of the HD2 waterhole (HD2_1404) will remain during the operational mining period, flows to this location will be impacted. The HD2 diversion levee is directly upstream of HD2_1404 and will reduce flow rates and volumes experienced at the waterhole. Modelling results indicate that during a 1:5 AEP rainfall event, maximum flows at the waterhole are reduced by 28 %. During a 1:100 AEP event, maximum flows are reduced by 59 %.

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Reductions to flow rates experienced at waterholes is not the only factor to consider when commenting on potential adverse impact. The capacity of the pool compared to the catchment yield volume is important to understand. Typically, waterholes of this size in the Pilbara will have relatively large upstream catchments contributing to the volume of water present in them. Direct rainfall onto the pool during heavy rainfall can have the ability to completely fill a small waterhole, with flow from the upstream catchment overtopping the pool and continuing to flow downstream. Analysis of multiple pools located in the Western Ranges, near Paraburdoo, using a long-term rainfall data set, demonstrated that, pending the size of catchment and capacity of waterhole, a pool can lose 80 – 85% of its upstream catchment and remain functioning in a wetting and drying cycle similar to historically cycles (undisturbed by mining activities). Therefore, similar modelling of HD2_1404 is recommended to understand the extent of impact it may experience due to the proposed HD2 mining activities. This worked is planned for the next study phase.

The BHT waterhole (GHD19-17-WS) will be directly impacted by proposed mining activities. The site is in the middle of a proposed waste dump; therefore, the waterhole will no longer exist.

Social, cultural and environmental values of both waterholes have been discussed with Traditional Owners through the Social Surroundings consultations. Significant work relating to pit and dump designs will be required if these sites are to remain unaffected by the proposed mining activities. These discussions are ongoing at the time of writing this report.

7. WATER QUALITY IMPACTS

Water quality in naturally occurring pools across the Pilbara can be highly variable due to the following factors: water supply (rainfall, creek flow, alluvial groundwater or groundwater structure); the preceding climate (drought/flood history, recent groundwater recharge); and interaction with livestock.

Furthermore, erosion is a naturally occurring process in Pilbara watercourses. This is indicated by the fact that the Pilbara ephemeral creeks typically have high sediment bed loads in their natural state and is further reflected by the range of turbidity values in water quality data collected in the region. Table 7 summarises the historic Department of Water and Regulation (DWER) water quality data collected across all Pilbara water courses. Figure 15 illustrates natural turbidity observed in Weeli Wolli Creek following rain event.

Table 7: Surface water quality values recorded across the Pilbara

	Pilbara Wide (DWER)	
	Minimum	Maximum
pH	5.2	9.4
EC (us/cm)	3	6090
Turbidity (NTU)	0.1	3200
TDS (mg/L)	22	3932

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Figure 18: Examples of natural turbidity within Weeli Wolli Creek

7.1. Water quality assessment

The primary source of potential water quality impact to the key sensitive receptors is liberation of additional sediment load to the watercourse. The biggest risk is associated with the proposed haul road crossing of Pebble Mouse Creek, given waste dumps are located further away from the main creeks. Liberation of sediment could occur in the unlikely event that a haul road crossing is washed out during a heavy rainfall event. The pathway from this source to the key receptors is a significant distance of ephemeral creek line – the proposed Pebble Mouse Creek haul road crossing is 14 km upstream of the Weeli Wolli Spring; the proposed road train crossing is 11 km upstream; and the proposed transfer pad and creek diversion levee is 7 km. These distances provide significant opportunity for sediments to be captured within creek and floodplain prior to reaching Weeli Wolli Spring, therefore reducing sediment load expected to reach the Spring.

It is considered unlikely that water quality at the key sensitive receptors identified in this study will be impacted by mining development at HD2 and BHT. To assess the credibility of this potential risk, a qualitative analysis of potential sediment transport from the Pebble Mouse Creek haul road and road train crossings to Weeli Wolli Spring is presented here.

7.2. Sediment transport in ephemeral creeks

Sediment transport in ephemeral creeks generally occurs as a pulse in response to runoff generated by the short duration, high intensity rainfall events (typically rare rainfall events) (Levick et al. 2008). Due to the common presence of bed armouring in ephemeral creeks, in particular channels formed in unconsolidated alluvium comprised of sands and gravel, the bulk of sediment transported generally comprise of the channel bed material (made available for transport once the armour layer has been mobilised) and sediments stored in alluvial plains and floodplains.

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Once the armour layer has been mobilised and bed flushing occurs, flows generated by high intensity rainfall events are more likely to contain heavy sediment loads with the potential to move large amounts of coarse sediment through the system. Two consequences of this occurring during such events include large transmission losses and decreasing discharge in the downstream direction, both of which promote the stepwise movement, deposition, and storage of sediment. The effect is a pulsing style of sediment movement that can be remobilised during the next flow (Levick et al. 2008).

This style of sediment movement is likely to be a characteristic of Pebble Mouse Creek in its pre mining condition. The application of this concept to the washout of an engineered crossing and mobilisation of significant loads, in addition to natural sediment loads, may be relevant due to the large amount of coarse material likely to be used in the construction of the crossing. However, it should be noted that rock armouring is likely to also feature in the construction of the crossing.

7.3. Factors affecting the Pebble Mouse Creek flow path

An important factor to consider when assessing the likelihood of sediment loading from the haul road and road train crossings impacting Weeli Wolli Spring is the flow path from the source to the receptor and existing infrastructure. The 14 km reach of Pebble Mouse Creek between the haul road crossing and Weeli Wolli Spring is intersected initially by the HD1 rail line; then the road train crossing directly downstream of the rail line; and then diverted by the HD1N levee (known as the “100 year levee”) before flowing to its confluence with Weeli Wolli Creek.

The HD1 rail line crossing is approximately 3 km downstream of the haul road crossing, consisting of 28 DN2700 culverts with projecting inlets. Experiments conducted by Faqiri (2014) found that, while projecting inlets typically provide a lower culvert capacity compared to winged wall or cut inlets, these culverts are

still capable of transporting sediment downstream. However, the inlet geometry is not the only factor affecting sediment transport through culverts. The flow condition directly upstream of the culvert (the area referred to as the expansion section) is also a determining factor. Low velocity, deeper flows were found to result in an increase of sediment deposition at the culvert expansion section compared to high velocity flows, mainly because of low velocities allowing sediments to drop out and settle. Hence, for sediment to be effectively transported through culvert barrels, flow regimes with high velocities and low depths are required. The HD1 rail line crossing is expected to reduce flow velocities, resulting in some sediment deposition upstream of and at the rail culverts, with reduced sediment loads carried downstream of the rail crossing.

The inclusion of the road train crossing (with culverts) directly downstream of the rail line presents an additional expansion section and compounds the effect of sediment deposition upstream of the culverts. Therefore, having a second set of culverts at this location would further reduce sediment loads carried downstream.

7.4. Hydraulic modelling

Hydraulic modelling has been used to assess the flow regime along Pebble Mouse Creek focussing on the characteristics of flow observed at the haul road crossing as well as the HD1 rail crossing. Using similar hydrological inputs to the regional model previously discussed, a refined model domain was adopted for this assessment as well as a higher resolution grid size (5 m). Pre and operational mining scenarios were run for the 1:5 and 1:100 AEP events.

Operational mining infrastructure included the Pebble Mouse Creek haul road crossing low flow design as this was considered the most credible scenario, compared to the other options, to release a source of increased sediment load to the creek system following a crossing failure.

A separate modelling scenario was run to assess the inclusion of the LTRT Option 3 alignment and its impact to flows in Pebble Mouse Creek.

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Figure 19 illustrates the model extent and downstream boundary location of the refined model domain.

7.5. Results

Results of the maximum depths and velocities modelled at the haul road crossing and HD1 rail crossing for the 1:100 AEP and 1:5 AEP are shown in Figure 20-21 and Figure 22-23, respectively.

Results of the maximum depths and velocities modelled at the LTRT Option 3 creek crossing and transfer pad (TP4) for the 1:100 AEP are shown in Figures 24 and 25.

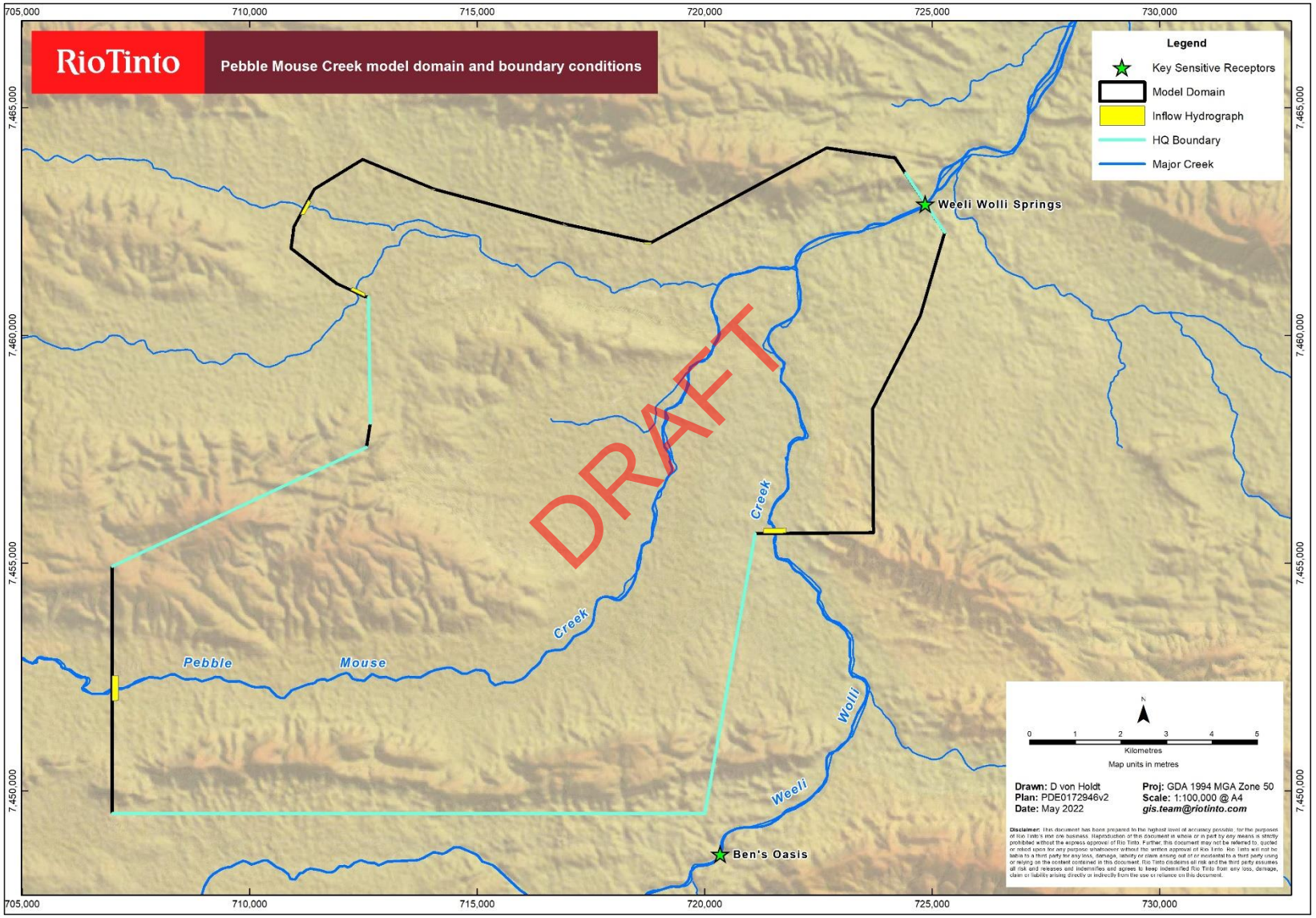

Figure 19: Pebble Mouse Creek model domain and boundary conditions

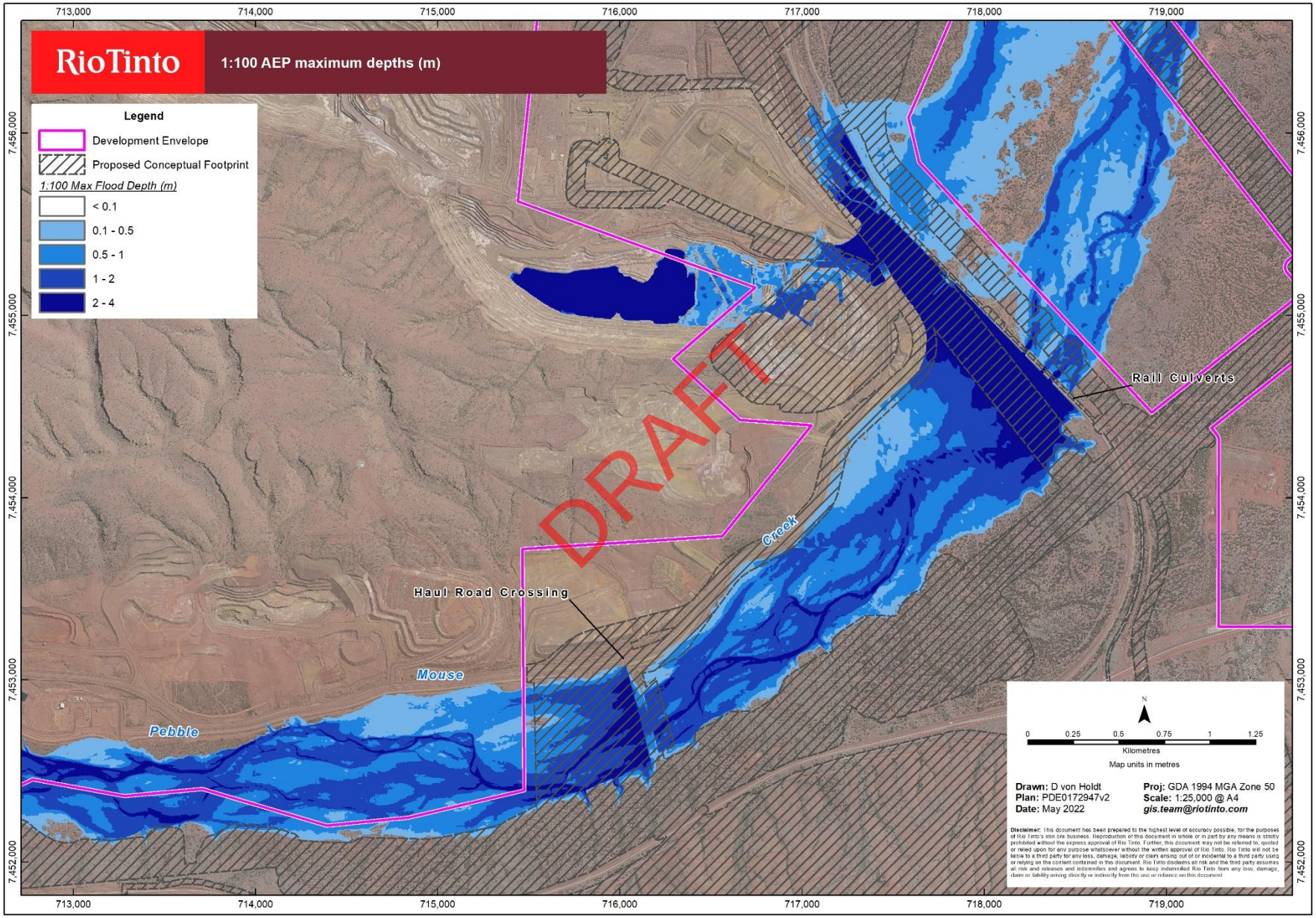

Figure 20: 1:100 AEP maximum depths (haul road crossing

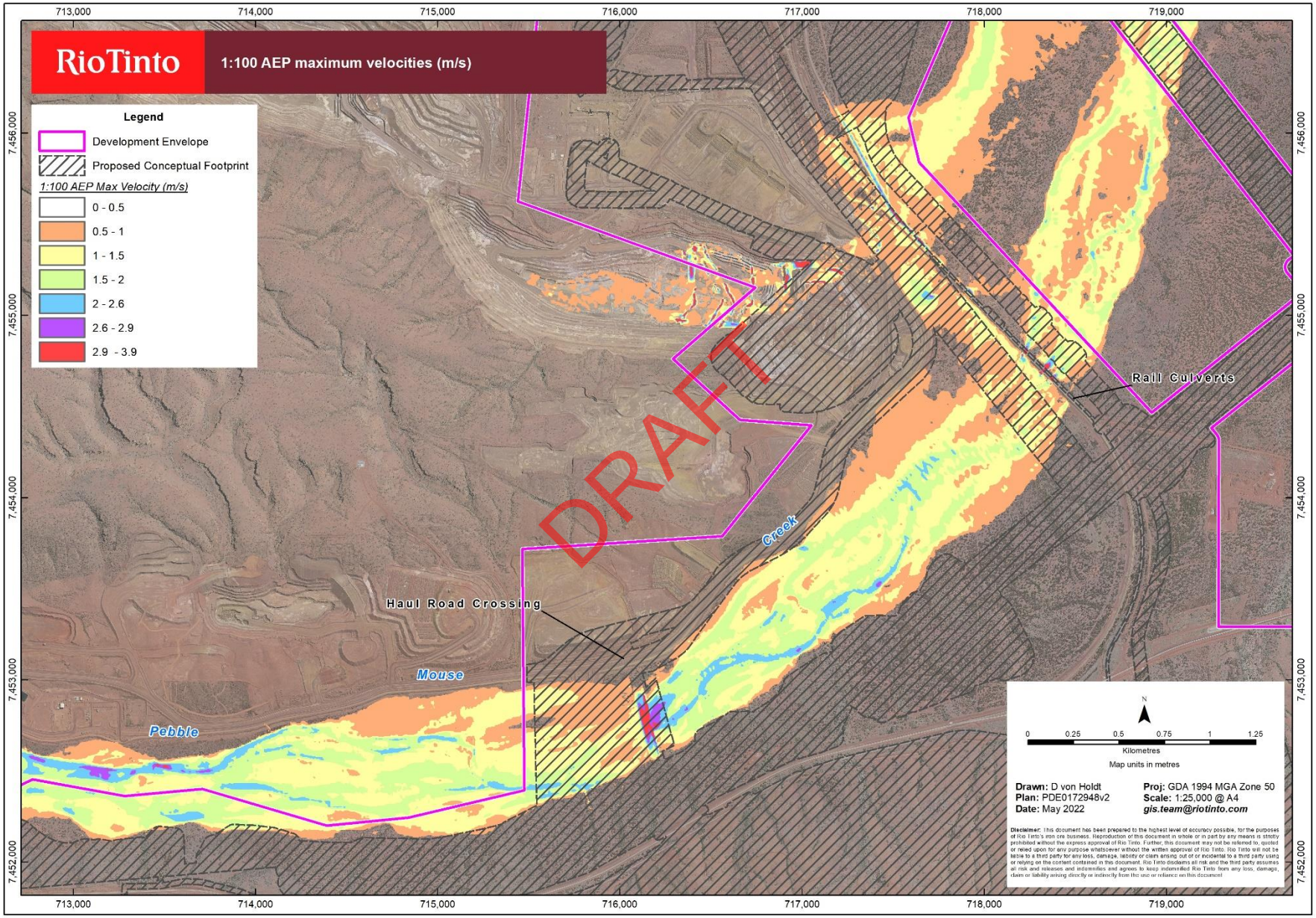

Figure 21: 1:100 AEP maximum velocities (haul road crossing)

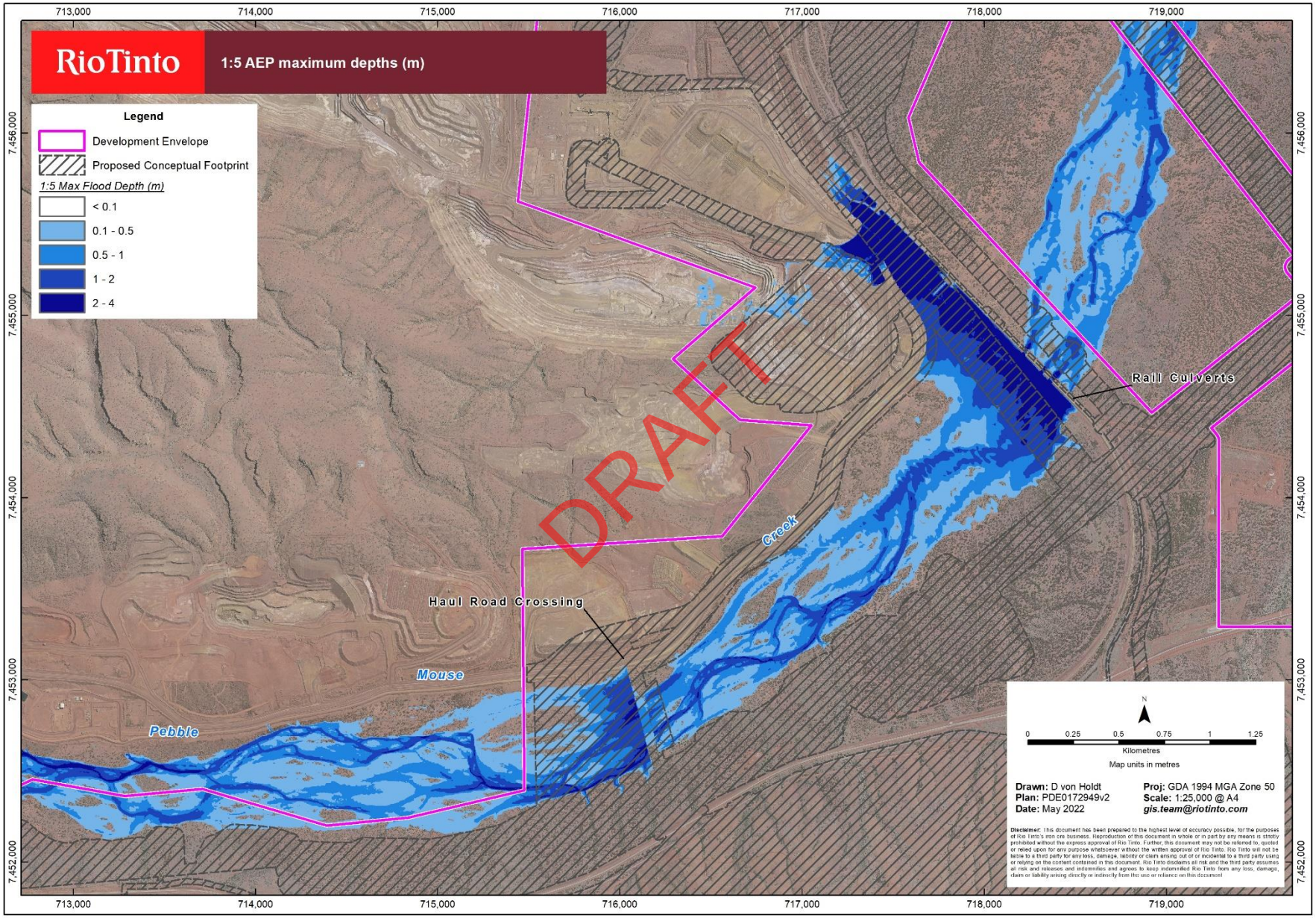

Figure 22: 1:5 AEP maximum flood depths (haul road crossing)

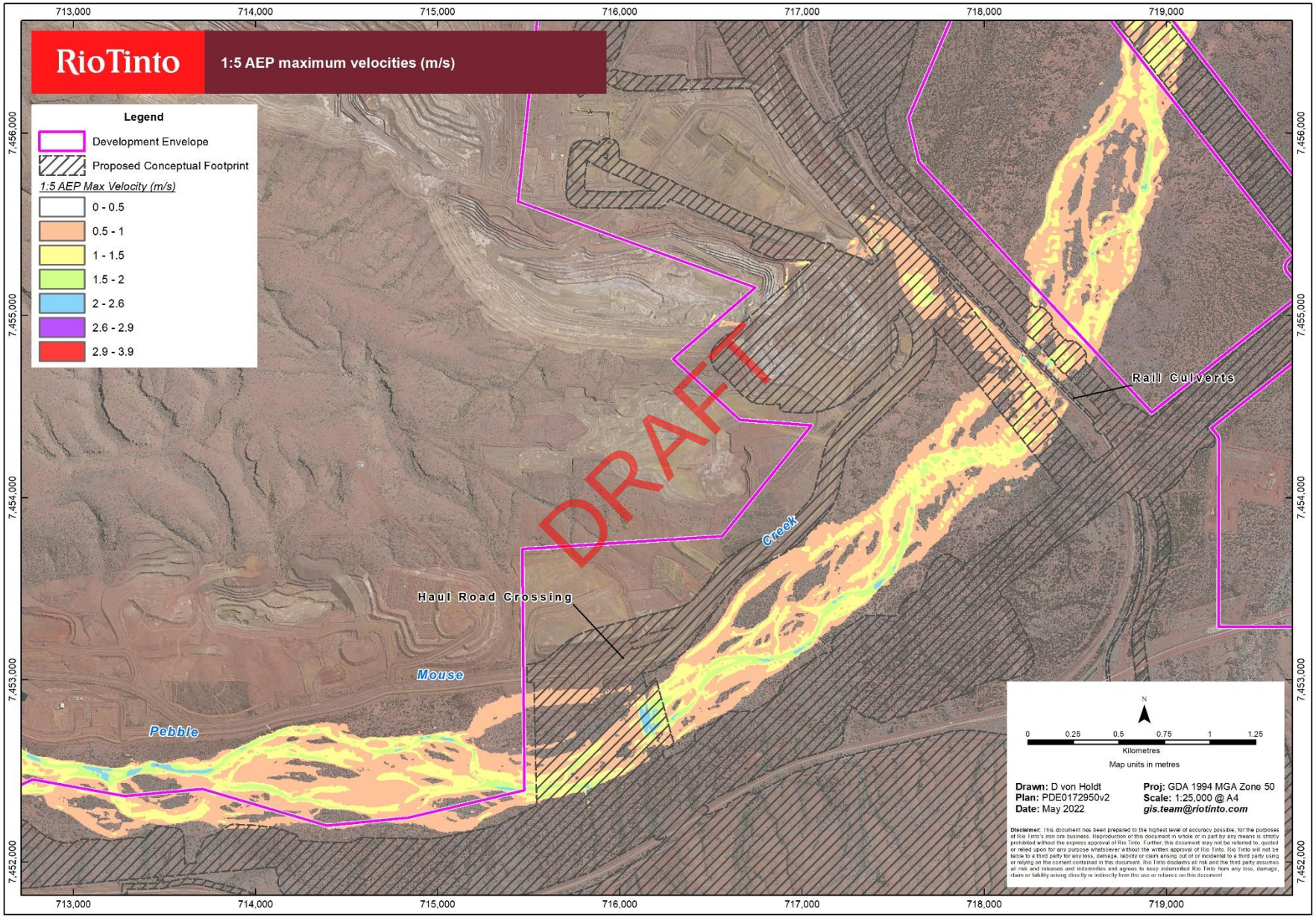

Figure 23: 1:5 AEP maximum velocities (haul road crossing)

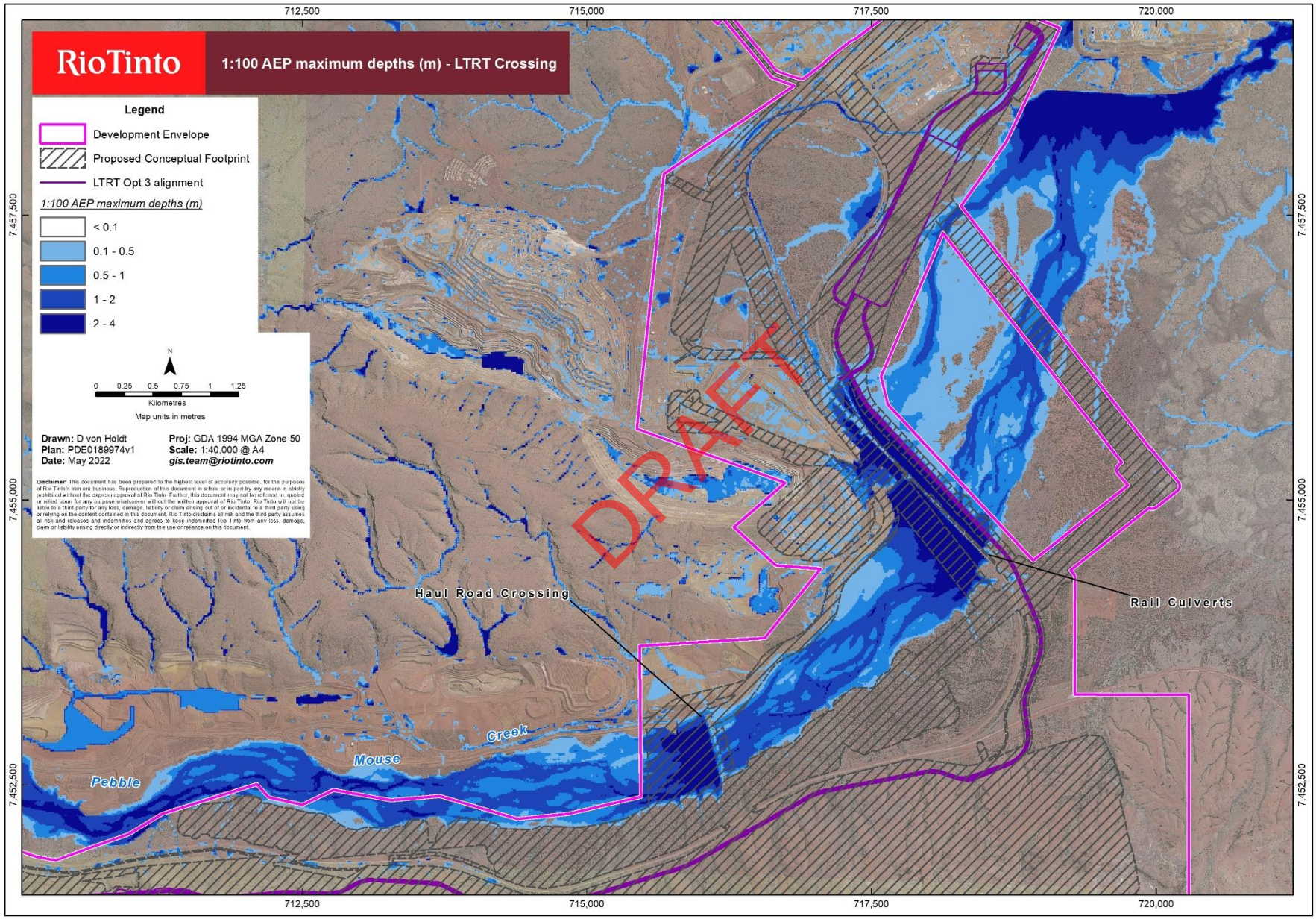

Figure 24: 1:100 AEP maximum depths (LTRT Crossing)

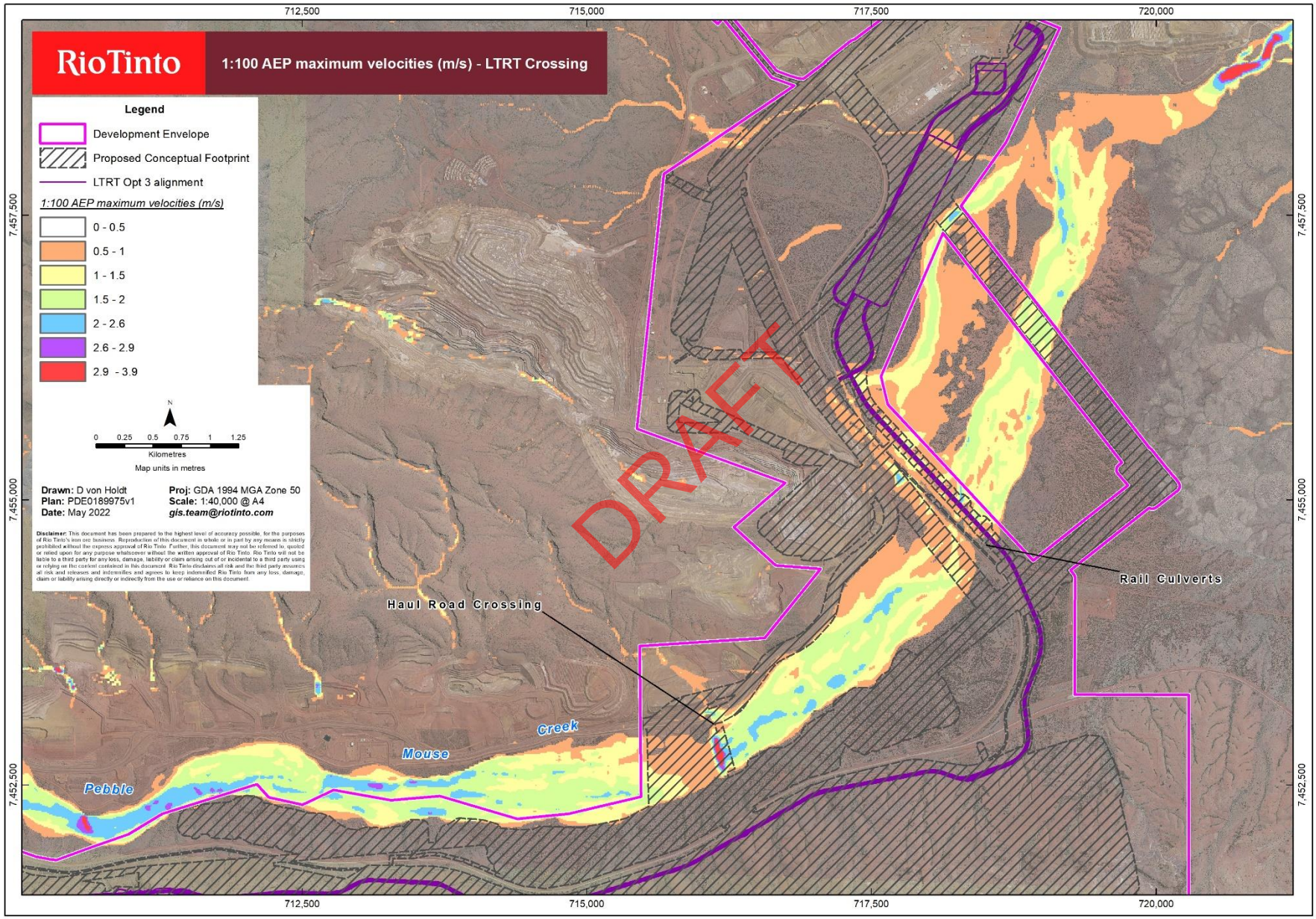

Figure 25: 1:100 AEP maximum velocities (LTRT Crossing)

7.6. Discussion

Hydraulic modelling indicates that during both frequent (1:5 AEP) and rare (1:100 AEP) events, maximum flow depths are observed upstream of the Pebble Mouse Creek haul road crossing as well as upstream of the rail line. This is expected due to the attenuation and backwater impacts of these structures. Velocity regimes at the crossing locations are typically characterised by a reduction in energy at the upstream side as flow is throttled by the crossing obstruction, with a distinct increase in the velocity at and immediately downstream of the crossing as flow is concentrated through the floodway or culvert.

Flow regimes at the crossing are likely to promote the mobilisation of sediment however it is difficult to comment on the extent of downstream sediment deposition without a detailed understanding of the crossing and bed load materials. Frequent event modelled velocities may have sufficient energy to overcome the shear stress of sediment directly at the crossing thus increasing erosion rates. Given the reduced flow velocities in the reach downstream of the crossing, the downstream flow regime is however unlikely to support the sediment loading for long distances, with sediment likely to start dropping out as flow velocities reduce. A crossing washout is more likely under a rare event, with increased velocities and higher energy potentially resulting in sediments transported over longer distances compared to frequent events.

The high flood depths and low velocities observed on the upstream side of the rail crossing supports the increased deposition of sediment at the culvert inlets and most likely poor transport of sediment through the culverts. Therefore, blockages are likely to occur at these culverts because of sediment transport from an upstream source thus reducing the culvert capacities and impacting downstream surface water flow regimes.

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Based on this assessment it can be assumed that sediment transported from a potential washout of the Pebble Mouse Creek haul road crossing will most likely be because of a rare rainfall event, with sediments more likely to be deposited at / upstream of the rail crossing, causing some blockage of the culverts at this location. It is therefore considered unlikely that this sediment would have any significant impact on the water quality of Weeli Wolli Spring which is located 14 km downstream of the crossing (and 10 km downstream of the rail culverts).

A similar conclusion can be drawn regarding the LTRT Option 3 creek crossing. With the alignment running parallel to the existing rail line crossing and the culverts being identical (or bigger) than the existing culverts, the flow regime is not expected to change much downstream of the crossing.

Therefore, it is considered unlikely the LTRT Option 3 infrastructure will adversely impact the water quality of Weeli Wolli Spring, located 11 km downstream from the creek crossing and 7 km downstream of TP4.

7.7. Frequency analysis of Pebble Mouse Creek rainfall data

To qualitatively assess the likelihood of frequent and rare rainfall events occurring during the operational life of the Pebble Mouse Creek haul road crossing, a frequency analysis was undertaken. The long term flow data recorded at the DWER Tarina gauging station (located on Weeli Wolli Creek downstream of Weeli Wolli Spring) was used for the analysis. The flow rates measured at Tarina station are based on the Weeli Wolli Creek catchment (1,530 km^2) however the rainfall patterns and streamflow responses observed within this catchment are considered like that observed within the Pebble Mouse Creek catchment. Therefore, the Tarina gauge dataset was scaled to apply to Pebble Mouse Creek using a scaling factor of

0.46. The scaling factor was calculated using the ratio of the two catchment areas to the power of 0.7 (Grayson et al, 2004).

Using peak design flow rates for various AEP events, previously calculated as part of the RORB hydrological modelling, the dataset was interrogated to identify periods of flow at Pebble Mouse Creek responding to frequent to rare rainfall events.

The frequency analysis identified 18 rainfall events characterised as equal to or greater than the 1:5 AEP event occurring over the 30-year period of the dataset. Majority of events were in the 1:5 to 1:10 AEP range, with two 1:20 AEP events and one event greater than the 1:100 AEP.

If mainly rare events have the potential to mobilise significant bed load in a creek and demonstrating that Pebble Mouse Creek has only experienced five rare events over 30 years, the risk of the haul road crossing impacting a key sensitive receptor 14 km downstream of the washout site is considered unlikely to occur.

7.8. Consideration of optional waterway crossings

Based on the alignment of the overland conveyor crossing, environmental flow volumes (lower magnitude than a 1:5 AEP event) in Pebble Mouse Creek will not be impeded. There is potential for flow regimes during the rare events (1:100 AEP event and above) to be altered at the crossing location. However, engineering design of the conveyor crossing will ensure full conveyance of design flows and provide the appropriate level of scour protection downstream. Typical design solutions under consideration, as described in Section 3.4, are expected to result in negligible change from the baseline depth and velocity values and any changes should be confined to those areas a short distance up and downstream of the crossings. Overall flow volume and flow rates are typically unchanged for at-grade crossings and culvert installations. Therefore, given that appropriate scour protection will be provided it is considered unlikely that any sediment movement associated with this crossing would have any significant impact on the water quality of Weeli Wolli Spring, which is located 14 km downstream.

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The bridges proposed at GNH and the alternative mine access road are approximately 34 km upstream of Weeli Wolli Springs. Modelling results presented in Section 7.5 indicated that a crossing 14 km upstream from the sensitive receptor would not significantly impact its water quality. Therefore, the addition of both these bridges will have no additional impact on Weeli Wolli Springs over and above those previously stated for the Pebble Mouse Creek haul road crossing.

8. CONCLUSIONS

Hydraulic modelling has shown that mining infrastructure related to the HD2 and BHT deposits will result in minor reductions to peak flows at the key sensitive receptors. The slight loss of runoff is expected to have little effect on the flow regime at Weeli Wolli Spring or Ben's Oasis and therefore is not expected to impact the environmental and heritage values of these areas.

A qualitative assessment of the potential for sediment transport from the Pebble Mouse Creek haul road crossing was undertaken to highlight the potential impacts on water quality at Weeli Wolli Spring. Hydraulic modelling demonstrated that velocities required to mobilise sediment load from the haul road crossing were more likely to be experienced during rare rainfall events. During the frequent events, sediment loading is unlikely to move far downstream due to the low energy estimated downstream of the haul road crossing. The significant distance between the sediment source and key sensitive receptor suggested it was unlikely that water quality would be impacted. This was further supported by the positioning of the HD1 rail line culvert crossing downstream of the haul road crossing through which sediment transport would be poor.

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9. References

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