This closure plan supersedes all previous closure, and decommissioning and rehabilitation plans for West Angelas.

2.1 Closure Planning Process

Closure planning is an iterative process that commences during the planning phase of the mine development and is regularly updated and refined during the operational phase (Figure 1). Closure plans are updated to account for changes resulting from:

- amendments to the mine plan;
- improvements of the site closure knowledge base (eg. through daily activities, technical studies and research actions, 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 closure plan is updated.

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

The detail of each closure plan increases as the knowledge base develops. When the site approaches scheduled closure, studies will be completed to define how infrastructure, decontamination, rehabilitation, the workforce and communications will be managed throughout the mine closure period (and beyond). Stakeholder engagement and endorsement of completion criteria is conducted at this time.

In the final closure plan, location specific management plans are 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 predict the post-closure outcomes are appended to the final closure plan.

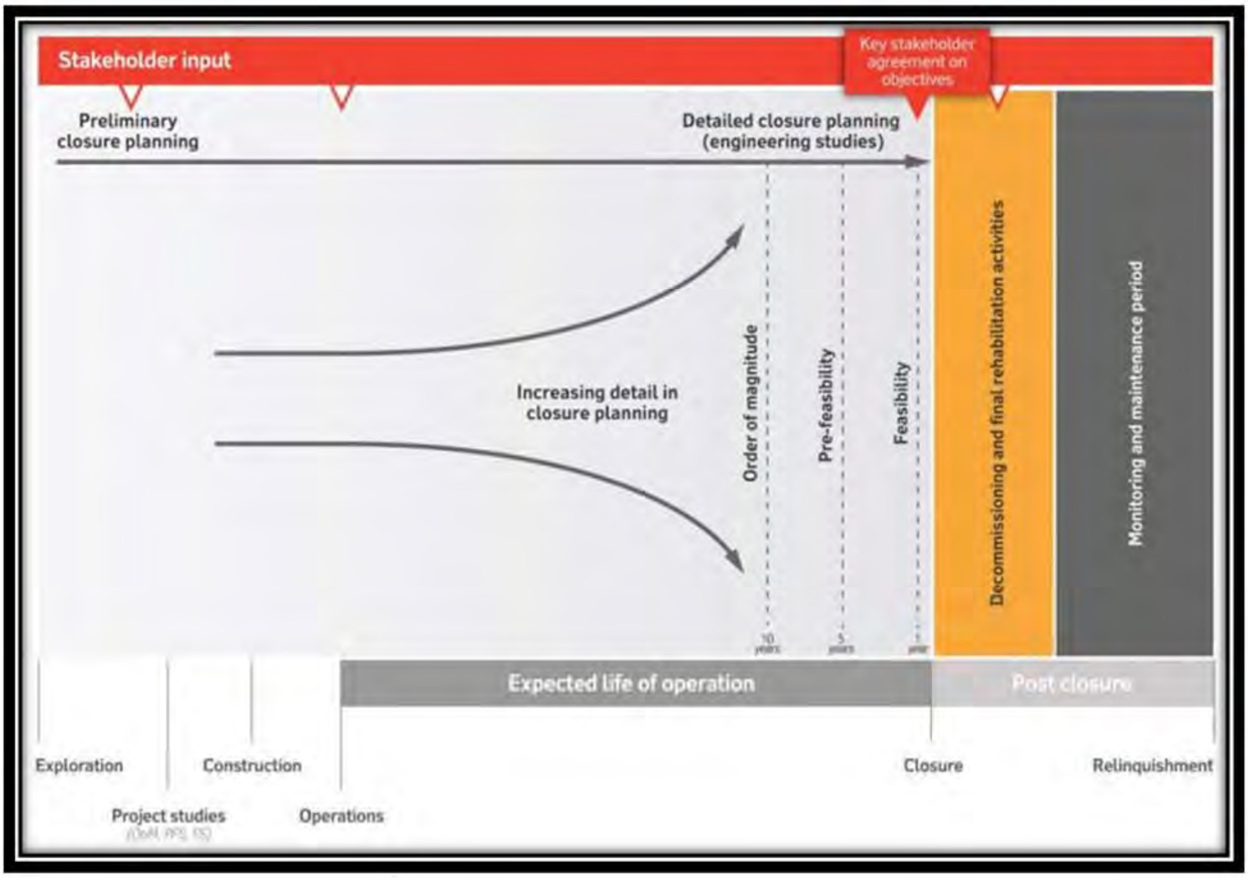

Figure 1: Progression of closure planning[2]

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[2] Rio Tinto Closure Guidance 2015 (Adapted from ICMM 2008)

PROJECT OVERVIEW

3. Description of the operation

3.1 Location

West Angelas is located in the Pilbara region of Western Australia, approximately 105km north-west of Newman, and falls within the local authority of the Shire of East Pilbara. It is in a relatively remote region of the State, with the closest town being Newman (Figure 2). There are no other communities in the immediate vicinity. Tenure associated with current and proposed mining activities is shown in Figure 3.

The mine is located predominantly on the traditional lands of the Yinhawangka people, with the eastern portion of Deposit F located on land held by the Ngarlawangga people (Figure 3). The nearest Aboriginal communities are Bellary and Wakathuni, which are both located on Yinhawangka land and are 80km and 100km respectively to the west.

The West Angelas mining lease has been issued on unallocated crown land. There is no pastoral activity in the immediate vicinity of the mine, with the nearest pastoral station lease (Juna Downs) approximately 20km to the north. Juna Downs is operated by Hamersley Iron Pty Ltd, which is wholly owned by Rio Tinto.

West Angelas mine is operated by the Rio Tinto iron ore group (Rio Tinto), on behalf of the Robe River Mining joint venture (JV) of whom Rio Tinto is the largest shareholder. The Robe River Mining JV comprises:

- Rio Tinto (53%);
- Mitsui Iron Ore Development Pty Ltd (33%);
- Pannawonica Iron Associates (10.5%); and
- Cape Lambert Iron Associates (3.5%).

3.2 Mine Operations

The West Angelas mine commenced operations in 2001. It is an open cut operation utilising conventional drill-and-blast and load and haul mining methods. The currently approved layout is presented in Figure 4, and consists of five deposits (A, A West, B, E and F). Approval is being sought for a further three deposits (C, D and G).

Mine planning schedules are currently being revised to incorporate the 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. The current central case scenario is presented in Table 1 below, but should be considered indicative only. The mine schedules and plans are subject to regular review to ensure optimised performance of the operations and are therefore subject to change.

It should be noted that there is the potential for further ongoing development of additional West Angelas deposits subject to future approval. Should these exploration areas eventually get developed, mining at West Angelas would continue longer than indicated in Table 1. The addition of new deposits may also impact the mining sequence and schedules for currently approved or proposed deposits.

The key landforms associated with the mine are shown in Table 2 below. The proposed construction and rehabilitation design criteria for these landforms are included in Appendix E.

Table 1 Indicative mining schedule (current central case, but only one of several development scenarios under evaluation)

Deposit	Pit	Commencement	Completion	Description	Regulatory Status
A	A	Commenced	2022	BWT	Approved
A West	3 pits anticipated	2027	2036	Mostly AWT	Approved
B	B	Commenced	2023	Mostly AWT	Approved
C	C1, C2 and C3	2020	2028	BWT	Proposed
D	D1, D2 and D3	2020	2030	BWT	Proposed
E	E	Commenced	2034	BWT	Approved
F	F1, F2 and F3	2016	2025	Mostly AWT	Approved
G	Multiple pits	2022	2027	Mostly AWT	Proposed

Table 2: Waste landform inventory

Landform	Type	Description	Status
Deposit A South WD	Waste Dump	Inert	Active / Partially Rehabilitated
Deposit A North WD	Waste Dump	Fibrous	Active / Partially Rehabilitated
Deposit A West Pit North Backfill	Backfilled pit area (treated as a waste dump)	Inert	Active
Deposit B East WD	Waste Dump	Fibrous	Active
Deposit B Low Grade	Low grade stockpile (treated as a waste dump)	Inert	Proposed
Deposit C&D WD1 West	Waste Dump	Inert	Conceptual
Deposit C&D WD1 East	Waste Dump	Inert	Conceptual
Deposit D WD	Waste Dump	Inert	Conceptual
Deposit E East WD	Waste Dump	Inert	Active (will be consumed by Deposit F West WD)
Deposit E South WD	Waste Dump	Inert	Active
Deposit E West WD	Waste Dump	Inert	Active
Deposit F West WD	Waste Dump	Inert	Proposed
Deposit F Low Grade	Low grade stockpile (treated as a waste dump)	Inert	Proposed
Deposit F East WD	Waste Dump	Inert	Proposed

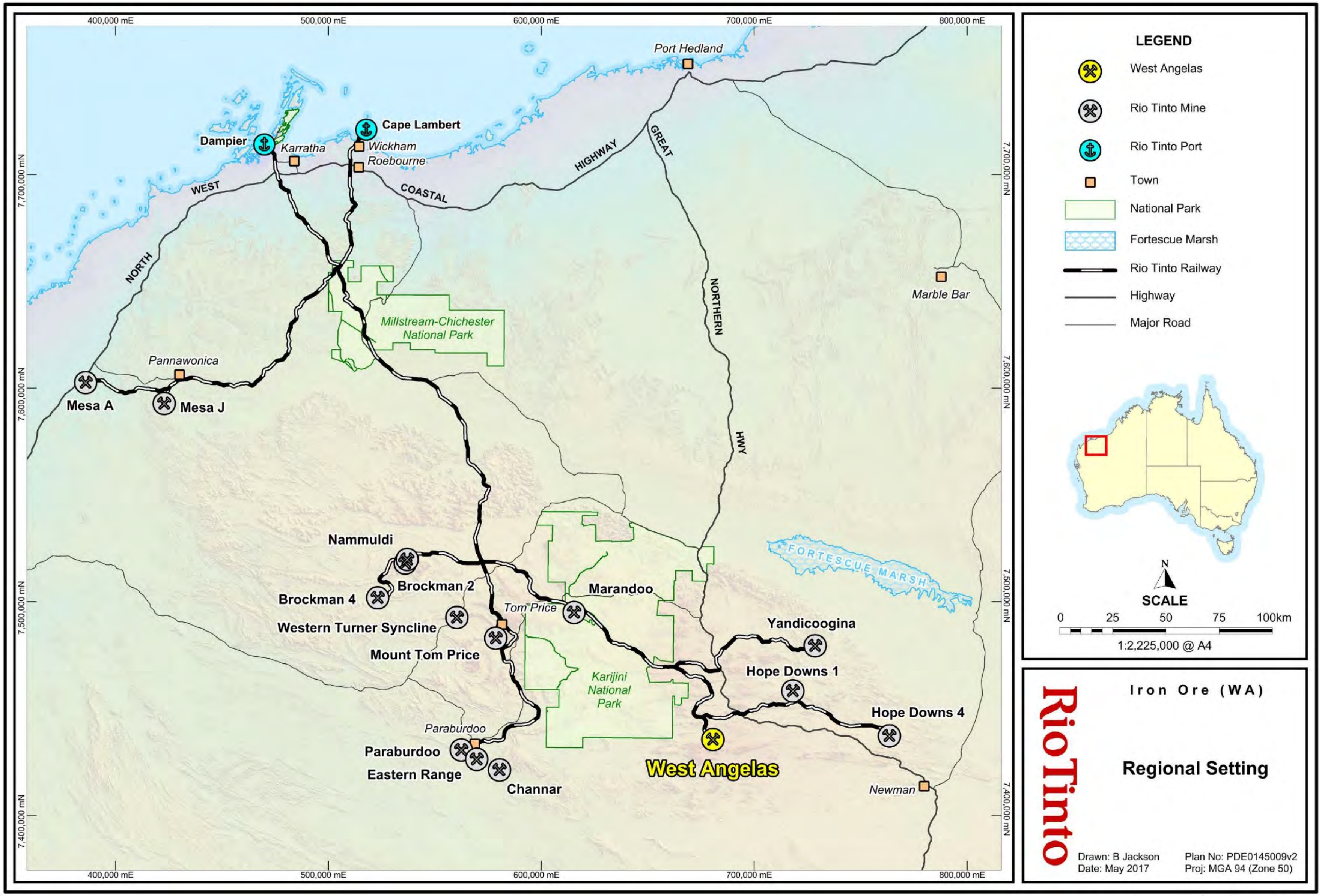

Figure 2: Regional setting

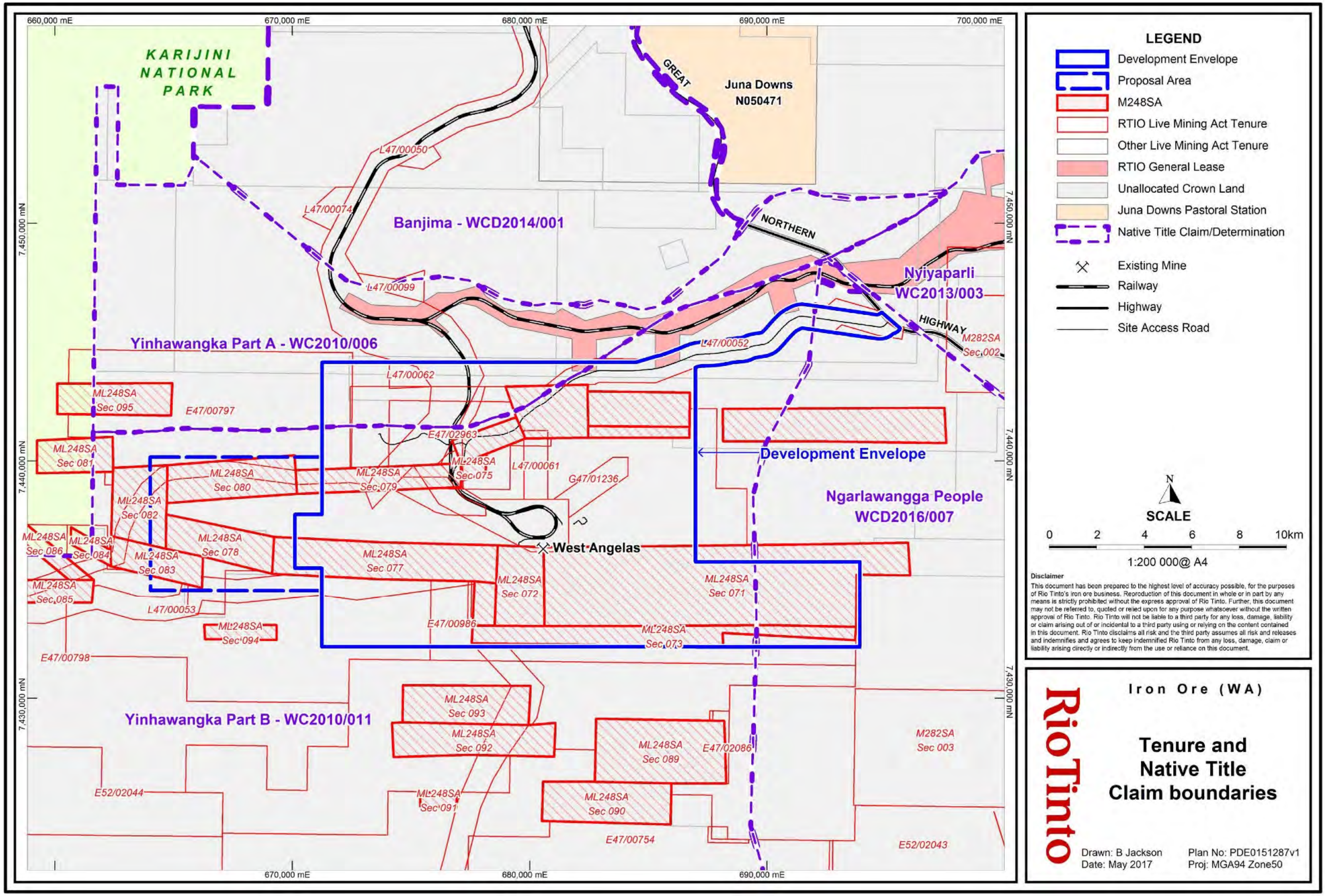

Figure 3: Tenure and Native Title claim boundaries

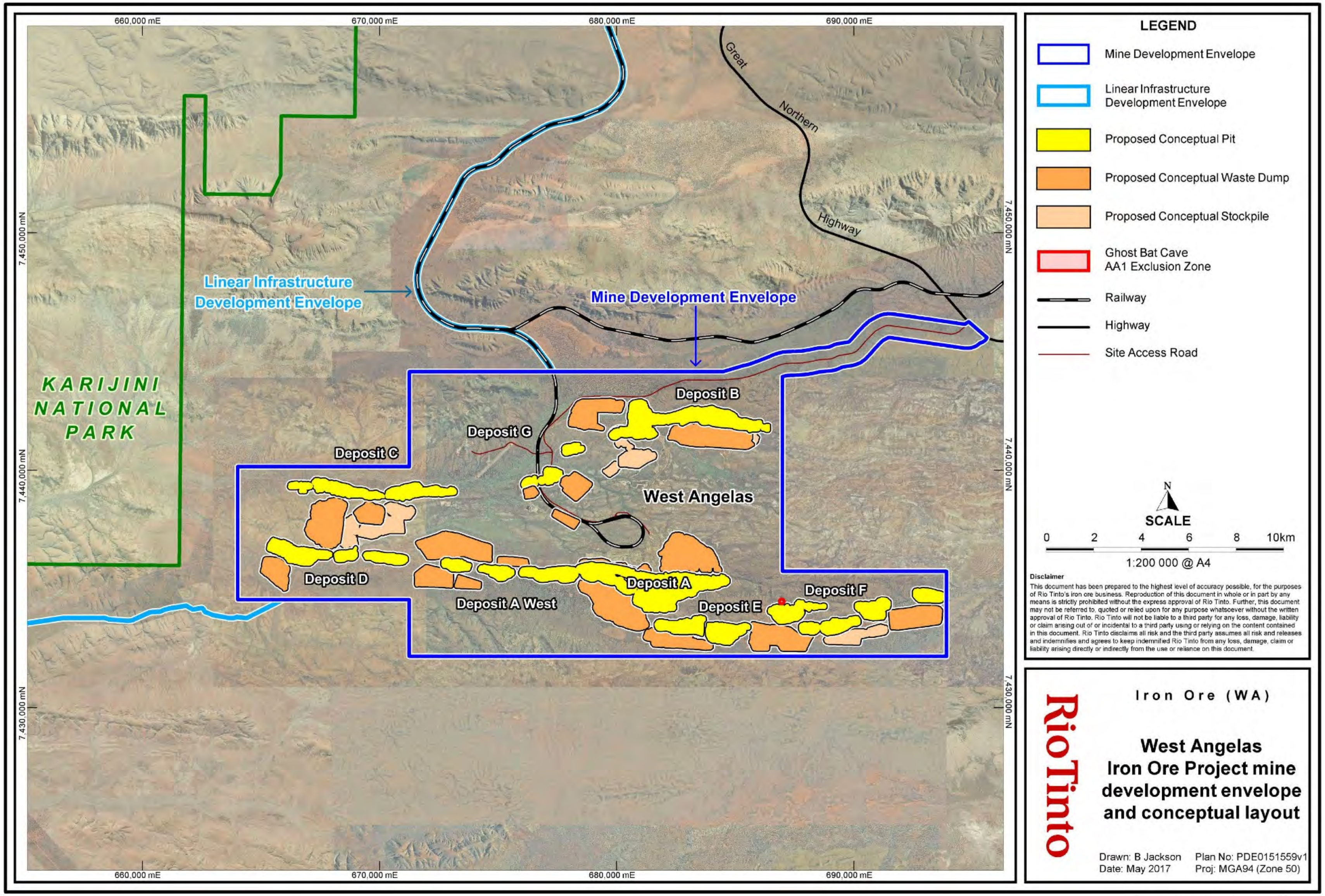

Figure 4: West Angelas Mine Layout

IDENTIFICATION OF CLOSURE OBLIGATIONS AND COMMITMENTS

4. Legal obligations

A closure obligations register is presented as Appendix A, It contains details of legal obligations from the following instruments:

- *Iron Ore (Robe River) Agreement Act 1964*;
- Ministerial Statement 970 (West Angelas Iron Ore Project)
- relevant Native Vegetation Clearing Permits (NCVP); and
- leases issued under the *Mining Act 1978*.

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

STAKEHOLDER ENGAGEMENT

5. Stakeholder engagement

5.1 Engagement process

Stakeholder engagement is a key part of mine closure planning as it ensures that the expectations of stakeholders are understood by the mine operator and these can be considered and managed during the planning and implementation phase of closure. Rio Tinto has established processes for consultation with stakeholders, and these are imbedded in both the Rio Tinto *Mine closure standard* (2015) 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 stakeholders that are relevant to the mining operations are identified and recorded in a register. This register is used to ensure relevant and timely communications are held with stakeholders across a broad range of issues, including closure. This register is regularly reviewed and updated to maintain currency. Regular consultation is conducted with a wide range of stakeholders via a variety of forums, for example various State and Local Government agency briefing meetings and Traditional Owner consultation forums established under Indigenous Land Use Agreements. Discussions regarding closure and related activities are included in these meetings as appropriate. The level of closure specific content and detail will increase as closure approaches.

A communications register specifically for closure of West Angelas is maintained and a copy as at the time of writing is included in Appendix B. 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.

POST-MINING LAND USE AND CLOSURE OBJECTIVES

6. Post-mining land use

6.1 Historical land use

Aside from mining activity and associated infrastructure, the West Angelas area is largely undeveloped. Pastoral activity in the region has historically been limited to grazing of cattle on Juna Downs Station to the north (the most southern boundary of which is located approximately 20 km to the north) and Rocklea Station (approximately 75 km to the west). There are no other mines currently operating in the immediate vicinity.

6.2 Proposed post-mining land use

Options for 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 West Angelas is underlain by Vacant Crown Land, and is located in close proximity to Karijini National Park, the return of a native ecosystem is considered to be the most appropriate final land use. This is consistent with advice provided by the OEPA in November 2014.

7. Closure objectives

7.1 Rio Tinto vision for closure in the Pilbara

Closure objectives 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 cultural heritage values of the area in cooperation with the Traditional Owners and other stakeholders.
- Develop and implement strategies for closure which consider the implications on local communities.
- Achieve completion criteria which have been developed with stakeholders and agreed with WA Government.
- Develop landforms that are safe and 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 which addresses the impacts of closure on employees and contractors.
- Achieve successful closure in a cost effective manner.

7.2 West Angelas closure objectives

The ultimate goal of mine closure at West Angelas is to relinquish the site to the Government. This goal 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 objectives reflect the aspects of the closure plan that the government and community agree are key to evaluating the site condition.

The approved February 2015 West Angelas closure plan included the objectives contained in Table 3. Whilst the intent of the February 2015 objectives remains current with the introduction of Deposits C, D and G into the closure plan scope, some revisions have been made to more explicitly address several key issues. The revised objectives are presented in Table 4.

Table 3: West Angelas closure objectives (February 2015 closure plan)

No.	February 2015 closure objective (now obsolete)
1	Rehabilitated landforms are stable
2	Final landforms are rehabilitated to be compatible with the final land use
3	Changes to surface water flows or groundwater quality are within acceptable limits
4	Public safety hazards have been addressed

Table 4: Revised West Angelas closure objectives (June 2017 closure plan)

No.	Revised (current) closure objective	Justification for change
1	Final landform is stable and considers ecological and hydrological issues	This new objective covers the issues addressed by previous objectives 1 and 3, and aligns with objectives for other Rio Tinto mines
2	Vegetation on rehabilitated land is self-sustaining and compatible with the final land use	Explicit recognition that rehabilitation areas need to be self-sustaining
3	Public safety hazards have been managed	It will not necessarily be possible to completely eliminate risk, but the company needs to demonstrate that risks have been effectively managed
4	Contamination risks have been appropriately managed	New objective to recognise this closure issue
5	Infrastructure has been appropriately managed	New objective to recognise this closure issue

Note that these objectives do not represent the full range of issues that need to be addressed upon closure of West Angelas: rather they represent the key objectives against which the ability to relinquish will be assessed.

Indicative completion criteria and measurement tools have been drafted for each of these objectives, and are discussed further in Section 8.

COMPLETION CRITERIA

8. Completion criteria

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

The completion criteria (Table 5) have been developed in consideration of the predicted closure outcomes. Measurement processes, and the associated supporting data (evidence and / or metrics), that could be used to evaluate the success of closure at West Angelas are also described in Table 5.

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 indicative only. As the site approaches scheduled closure the completion criteria will contain more measurable and time-bound parameters.

Table 5 Indicative completion criteria

Objective	Indicative completion criteria	Verification process or method	Evidence
Landform stability			
Final landform is stable and considers ecological and hydrological issues	1. There are no erosion features present that compromise landform integrity, and erosion features (if present) are stable 2. Unless otherwise approved, waste dumps are located outside of the zone of geotechnical instability around pits 3. The final landform has been constructed with consideration given to its stability during intense rainfall and large flood events 4. Erosion from landforms does not threaten the functionality of natural ecosystems 5. Landform design (including design of surface water diversions) and final landscaping considers local and off-site hydrological impacts	1. Visual assessment and monitoring including quantitative evaluation of rills and gullies, with evaluation of trends over time 2. Analysis of aerial imagery to provide qualitative/quantitative analysis of landform stability 3. Post-closure landform review to confirm that risks have been appropriately mitigated	1. Rehabilitation monitoring reports 2. Post-closure landform evaluation report 3. Survey data assessment
Biodiversity			
Vegetation on rehabilitated land is self-sustaining and compatible with the final land use	1. Seed used in rehabilitation works is of local provenance 2. Native plants within rehabilitated areas are observed to flower and/or fruit 3. Recruitment of native perennial plants is observed 4. Any weeds recorded within rehabilitation areas are consistent with those from the local area	1. Rehabilitation monitoring program 2. Analysis of historical monitoring data	1. Rehabilitation monitoring reports

Objective	Indicative completion criteria	Verification process or method	Evidence
	5. Species richness and diversity are indicative of a functional ecosystem		
Public safety			
Public safety hazards have been managed	1. Safety and health risks have been identified 2. Measures to mitigate the identified public safety and health hazards have been agreed with stakeholders, and have been implemented	1. Risk assessment conducted and mitigation actions implemented 2. Key stakeholders have been engaged and there is agreement on risk mitigation measures to be employed 3. Independent audit/review to confirm that agreed hazard mitigation measures have been implemented	1. Risk assessment report 2. Records of stakeholder engagement 3. Agreed risk mitigation actions 4. Audit/review report
Contamination risks			
Contamination risks have been appropriately managed	1. Requirements of the *Contaminated Sites Act 2003* have been met for the identification, remediation, management and transfer of any contaminated sites	1. The site has been appropriately assessed for the presence of suspected or known contaminated sites 2. Suspected or known contaminated sites have been appropriately reported under the requirements of the *Contaminated Sites Act 2003* 3. Appropriate management measures to address contamination have been implemented	1. Contaminated sites investigation reports 2. Reports on any ongoing monitoring, management and/or remediation of contaminated sites
Infrastructure			
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	1. Appropriate agreements and transfer processes are in place and communicated for any infrastructure remaining post-closure 2. Removal of all infrastructure that has not been agreed to remain	1. Agreements in place with party assuming liability for infrastructure 2. Decommissioning report 3. Visual inspection

8.1 Changes to completion criteria from the last closure plan

Rio Tinto has been continually refining its approach to establishing and presenting completion criteria for the past several years, and expects this process to continue in the future. In addition, the OEPA requested several specific changes to the completion criteria when it approved the February 2015 West Angelas closure plan in July 2106.

The completion criteria table has been substantively revised since February 2015.

8.1.1 Objective 1: Landform stability

The new objective has been redrafted so as to address issues relevant to the previous objectives 1 and 3. New criteria have been developed for the reasons stated in Table 6.

Table 6: Explanation for changes to criteria for Objective 1

Criterion in February 2015 closure plan (objectives 1 &3)	New criterion in June 2017 closure plan	Explanation for change
Demonstration that rills and gullies are stable	There are no erosion features present that compromise landform integrity, and erosion features (if present) are stable	The revised wording makes the intent of this criterion clearer
AMD risks are appropriately identified and managed	Removed	There is a low risk of AMD at West Angelas, and the issue is adequately addressed in the new objective on management of contamination risks
There are no unapproved changes to surface water flow regimes	Landform design (including design of surface water diversions) and final landscaping considers local and off-site hydrological impacts	The Pilbara is a dynamic environment and surface water flow regimes can change naturally following intense events. Furthermore, the old criterion required drainage changes to be approved, even though there are no approval mechanisms available for minor and trivial local changes.
-	Waste dumps are located outside of the zone of geotechnical instability around pits	New criterion to recognise this closure risk. Rio Tinto recognises that several West Angelas waste dumps are located in close proximity to pits and that any approval to retain them would require justification based on the geotechnical risk profile of each specific location.
-	The final landform has been constructed with consideration given to its stability during intense rainfall and large flood events	New criterion to recognise this closure risk
-	Erosion from landforms does not threaten the functionality of natural ecosystems	New criterion to recognise this closure risk

8.1.2 Objective 2: Biodiversity

Changes to criterion for this objective are explained in Table 7.

Table 7: Explanation for changes to criteria for Objective 2

Criterion in February 2015 closure plan	New criterion in June 2017 closure plan	Explanation for change
Vegetation is similar to the natural environment	Seed used in rehabilitation works is of local provenance	The previous criterion was not sufficiently specific.
Weed species are not unduly prevalent on rehabilitated areas	Any weeds recorded within rehabilitation areas are consistent with those from the local area	The criterion has been revised to recognise that it is unrealistic to expect rehabilitated areas to remain free of weed species if they are present in the surrounding landscape. The new criterion provides a more objective basis for determining whether weeds are unduly prevalent (i.e. comparison with the surrounding landscape)
Habitat is present for a variety of fauna species	Species richness and diversity are indicative of a functional ecosystem	The goal of rehabilitation will be to create functional ecosystems with a range of species present. Whilst there will be no guarantee of faunal colonisation, 'species richness and diversity' would include faunal species, and rehabilitation monitoring includes their identification (e.g. presence of tracks and scats, presence of ants).
-	Native plants within rehabilitated areas are observed to flower and/or fruit	This criterion has been drafted to address the requirement for vegetation communities on rehabilitated areas to be self-sustaining.
-	Recruitment of native perennial plants is observed	This criterion has been drafted to address the requirement for vegetation communities on rehabilitated areas to be self-sustaining.

8.1.3 Objective 3: Public safety

Changes to criterion for this objective are explained in Table 8.

Table 8: Explanation for changes to criteria for Objective 3

Criterion in February 2015 closure plan	New criterion in June 2017 closure plan	Explanation for change
-	Safety and health risks have been identified	New criterion to ensure that a risk identification process has been undertaken.
Public safety hazards have been addressed	Measures to mitigate the identified public safety and health hazards have been agreed with stakeholders, and have been implemented	The new criterion provides a more objective basis for determining that the outcome has been met. It is noted that it is unrealistic for associated risks to be completely eliminated. The new criterion allows for some level of residual risk, but ensures that this level is established through stakeholder negotiation.

8.1.4 Objectives 4 and 5: Contamination risks and infrastructure

Criteria have been set for these new objectives to align with closure plans of other Rio Tinto sites.

COLLECTION AND ANALYSIS OF CLOSURE DATA

The closure knowledge database (Appendix C) is a collection of baseline studies, models and interpretations, which are used to inform the closure planning process presented in this closure plan. 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).

9. Climate

The closest official Bureau of Meteorology weather recording station is at Newman Aerodrome (station 007176). Climatic information has been captured from this site since 1971. In addition, Rio Tinto maintains an automatic weather station at West Angelas itself. Information in this closure plan is sourced from both stations.

9.1 Climate and significant weather events

The climate in the area can be characterised as arid tropical with two distinct seasons, hot wet summers and cooler dry winters. Mean daily maxima temperatures range from 40°C in summer to 22°C in winter (Figure 5).

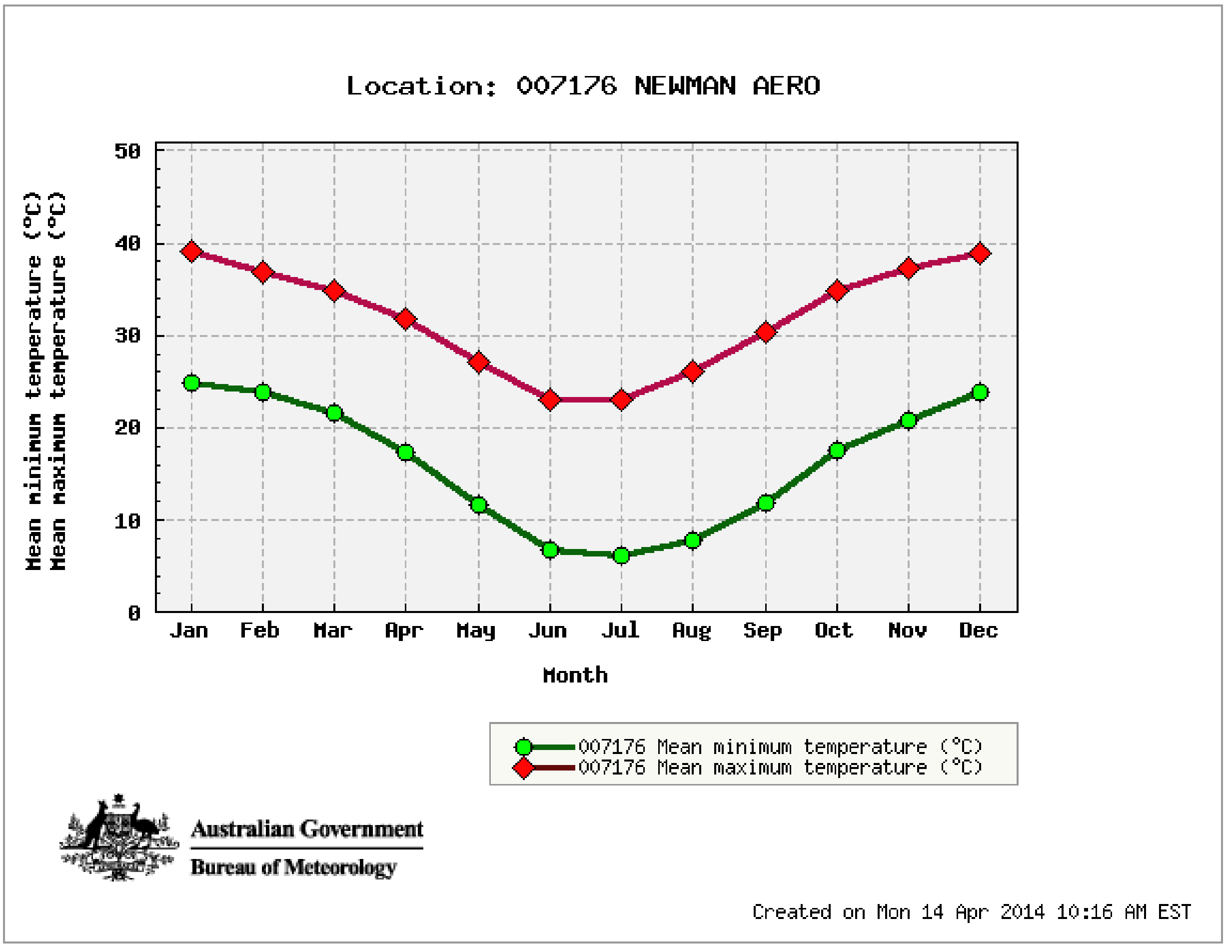

Figure 5: Mean monthly temperatures, Newman Airport 1996-2013.

The north/north-western coastline of Australia has experienced more tropical cyclones than anywhere else on mainland Australia. Most tropical cyclones are observed during the late summer, occurring between

November and May. Tropical cyclones can produce damaging wind gusts in excess of 150 km per hour, with heavy rains resulting in regional flooding. Five tropical cyclones are expected off the coast of the Pilbara each year, with two expected to make landfall.

Precipitation is driven by summer cyclonic activity, with the months of August, September and October have the lowest average rainfall, and December, January and February the highest average rainfall (Figure 6). Annual rainfall is also highly variable, (Figure 7).

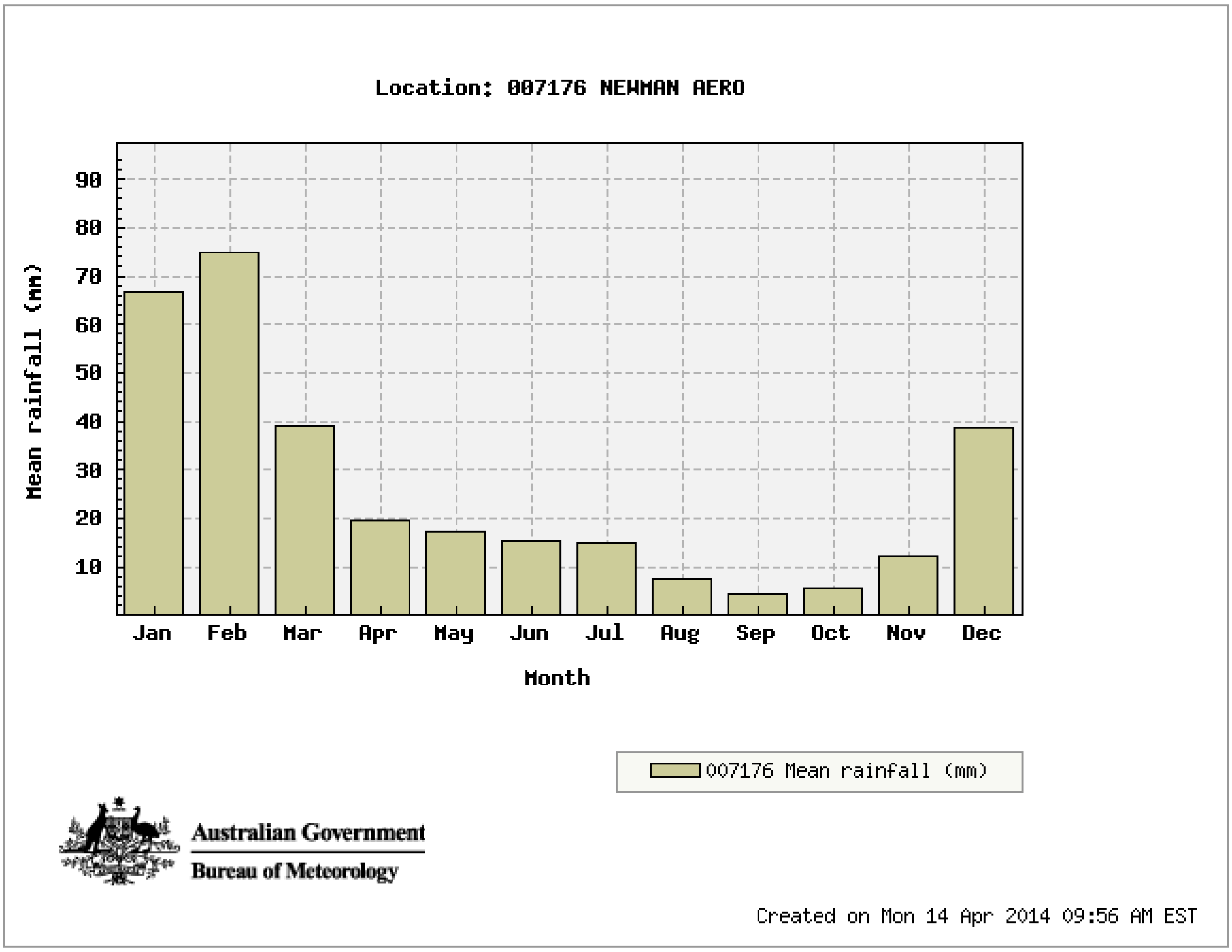

Figure 6: Mean monthly rainfall (1971 to 2013) at Newman Aerodrome

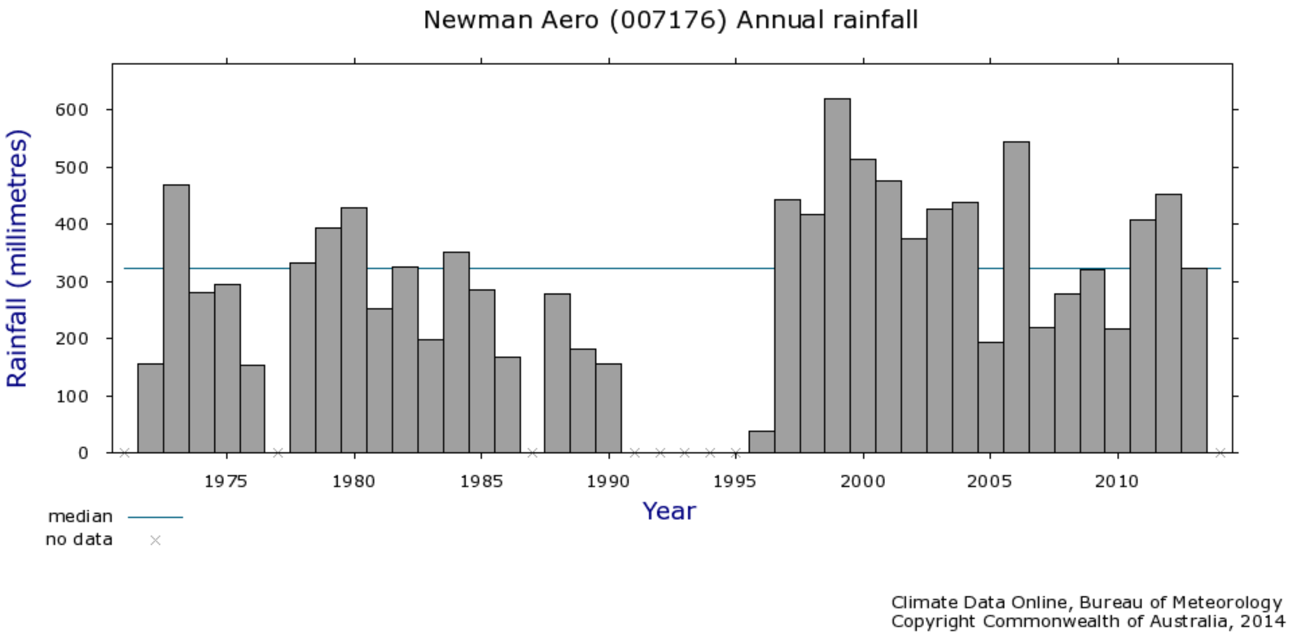

Figure 7: Historical annual rainfall (1971 - 2013) at Newman Aerodrome

9.2 Climate and landform stability

The heavy, intense rainfall experienced in the Pilbara makes rainfall the key climatic factor that influences surface stability. Rainfall erosivity (measured in megajoule millimetre per hectare per hour per year - MJ.mm/ha/hr/yr) is the term used to describe the erosive force of rain. For Pilbara sites, long-term annual erosivity values range from ~1,000-1,600 MJ.mm/ha/hr/yr. Rainfall in the Pilbara is typically more erosive than Perth's rainfall, even though it only receives on average half the rainfall that Perth receives on an annual basis. For comparison, average annual erosivity values for Perth are ~1000 MJ.mm/ha/hr/yr from an average of 780 mm of rain a year.

Rainfall erosivity is highly variable for each rainfall event. Studies of Pilbara rainfall concluded that at Tom Price, for example, erosivity for the period 1998 to 2009 ranged from 212 – 6,349 MJ.mm/ha/hr/yr. The most erosive year recorded was 2007 at Channar, where 421mm fell during February (704mm fell over the whole year). This singular rain period embodied 11,994 MJ.mm/ha/hr/yr of erosive force, or 89% of the entire erosivity of rain for that year. Given the pattern of intense and infrequent rainfall events in the Pilbara, it can be expected that only a few events every year (~1-3 events) will generate the majority of runoff and erosion of that occurs each year.

The studies showed a rapid decline in erosion or sediment yield occurs when annual rain decreases below about 300mm per year due to a corresponding decline in rainfall volumes and rainfall erosivity. However, when annual rainfall increases above ~300mm, vegetation growth increases and becomes increasingly effective in controlling soil erosion. Hence, there is a point of maximum erosion potential at an annual rainfall value of ~200-400 mm such that surface (vegetation) cover is low due to lack of rain and ineffective for controlling erosion, yet rainfall erosivity is sufficiently high to cause erosion, as observed in the Pilbara. Outcomes from these studies have informed development of the Rio Tinto Iron Ore (WA) Landform Design Guidelines for achieving stable waste dumps.

9.3 Climate and vegetation growth

Water is generally the limiting factor for plant growth in the Pilbara's arid environment. As a consequence of the hot temperatures, high evaporative demand and infrequent and irregular rainfall, much of the vegetation displays xeromorphic adaptations (plant structural adaptations for survival in dry conditions). These adaptations include the ability to regulate water loss from leaves, extract water from very dry soils and match reproductive strategies with wetter periods. Many species are ephemeral and persist in soil seed banks in between wetter periods.

The adaptive capacity of Pilbara species implies a degree of resilience to changes to hydrological regimes. However, the impacts to Pilbara vegetation as a consequence of climate change are not clear. Changes in vegetation density and water use will alter the amount of runoff that occurs after a rainfall event, which in turn will alter creek flows and groundwater recharge.

Some initial studies within the wider Pilbara are underway to understand how the presence and absence of water affects vegetation growth within riparian corridors. The outcomes from these studies and other evolving research on climate change will be monitored and integrated into future closure studies to inform assumptions on climate influences and impacts.

9.4 Climate change

The understanding of how climate will change in the future in the Pilbara is guided by the outcomes of climate modelling, commissioned privately by Rio Tinto and other Australian government agencies. The main climate drivers for the Pilbara are the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) ocean currents. However, these ocean currents are not well represented in most global climate models, and as a result climate predictions for the northwest of Western Australia vary significantly. Consequently the impact of climate change, the change in water availability and influence on ecosystems, in the Pilbara is still unclear.

The ENSO and IOD ocean currents are currently being researched by CSIRO. At the same time, modelling is being progressively improved by various Australian Government agencies to expand our understanding of the climate drivers in the southern hemisphere, to understand the associated impacts on water availability and to predict changes to existing ecosystems.

From the modelling completed to date, our understanding of Pilbara climate change suggests the region will experience the following climate trends:

- A shift in the historical tropical cyclone season, with an earlier start and potentially later finish.
  - For the period 2051 to 2099, compared to present day, tropical cyclone frequency could decrease by half, and the duration of a given tropical cyclone by 0.6 days on average. Projections also suggest that tropical cyclones could increase in size and intensity
- Continuation of the highly variable multi-decadal scale rainfall trends.
  - Projected rainfall reductions range from 1 to 24 percent for mid-century, and 9 to 24 percent for the end of the century
- A significant warming trend, influencing maximum temperatures, with the largest changes during the January to March period.
  - On average, maximum temperatures are expected to increase by 2.1 to 3.2 ˚C by mid-century and by a total range of 3.8 to 4.6 ˚C by the end of the century. For minimum temperatures the corresponding averaged increases are 1.9 to 2.4 ˚C (mid-century) and 4.1 to 4.6 ˚C (end of the century).

These changes, if realised as modelled, are likely to make successful rehabilitation in the Pilbara more challenging. Current landform designs are undertaken with inbuilt conservancy which allows for increased erosion factors, however lower average rainfall will impact ability to establish vegetative cover.

10. Land

10.1 Biogeographic overview

West Angelas 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. West Angelas is located in the Hamersley subregion which is described as a *"mountainous area of Proterozoic ranges and plateaus with low Mulga (Acacia aneura) woodland over bunch grasses on fine textured soils, and Snappy Gum (Eucalyptus leucophloia) over Triodia brizoides on the skeletal sandy soils of the ranges."*

10.2 Geological setting

The deposits at West Angelas lie within Archaean rocks of the Marra Mamba Iron Formation and the West Angelas Member of the Wittenoom Formation. The Marra Mamba Iron Formation has been subdivided into three members. From oldest to youngest these are:

- Nammuldi Member: overlies the Jeerinah Formation of the Fortescue Group and is characterised by poorly bedded yellow and brown chert and cherty banded iron formation (BIF) with occasional intercalated, generally thin, fissile shale partings and rare dolomite bands.
- MacLeod Member: a sequence of BIF, banded chert and chert, interbedded with a number of thick shale bands.
- Mount Newman Member: composed of alternating broad mesobands of iron oxides and white to yellow chert.

The West Angelas Member of the Wittenoom Formation overlies the Marra Mamba Iron Formation and consists predominantly of laminated pink, grey and khaki shales interbedded with lesser chert and minor BIF bands.

Tertiary and quaternary colluvium / alluvium (detritals) extend over much of the area, occasionally forming economic deposits when present in significant enough grades and volumes. Weathering has produced a widespread regolith profile over the iron rich bedrock. A significant hydrated zone or hardcap is present, commonly 20 - 50m thick but reaches to +100m in places.

Mineral waste generated at West Angelas is subsequently categorised with respect to the geological origins of the material, namely:

- detritals;
- hydrated;
- Nammuldi Member;
- MacLeod Member;
- Mt Newman Member;
- Wittenoom dolomite; and
- West Angelas shale.

10.3 Geotechnical stability of pit walls

Rio Tinto has committed to backfilling all pit voids at West Angelas to above the groundwater recovery level to avoid the formation of pit lakes, but significant voids will still remain after closure. There is no intent to reshape or rehabilitate these in-pit areas, and the remaining pit walls will be retained in the same configuration as when mining ceases. It is recognised that there will be some degree of geotechnical instability, and that walls will have the potential to collapse in some areas.

Preliminary zones of geotechnical instability have been identified around all pits covered within the scope of this closure plan, except for Deposit G which is yet to be sufficiently defined. Methodology is based on the angle method described in DMP abandonment bund guideline[3], using the conservative assumption that all pit walls are embedded into weathered rock (i.e. the polygons are lines drawn at a 25º angle from the base of the pit). Further geotechnical evaluation is being undertaken, and may result in a reduction of the current polygons. These are shown in Figure 8 – Figure 14.

The Deposit A South Dump and Deposit E South Dump intersect with the zones of instability for the adjacent pits.

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[3] Department of Industry and Resources (now DMP), *Safety Bund Walls Around Abandoned Open Pit Mines,* December 1997

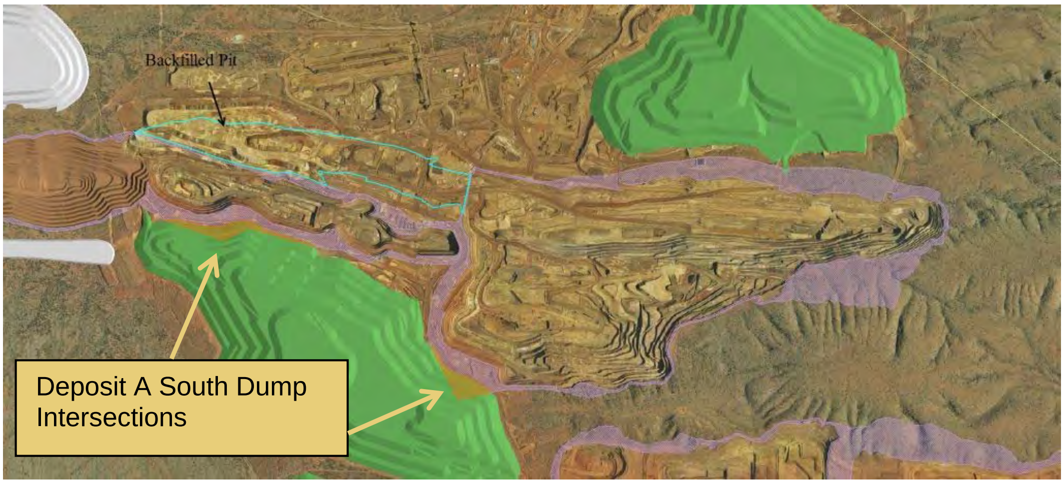

Figure 8: Zone of geotechnical instability around Deposit A

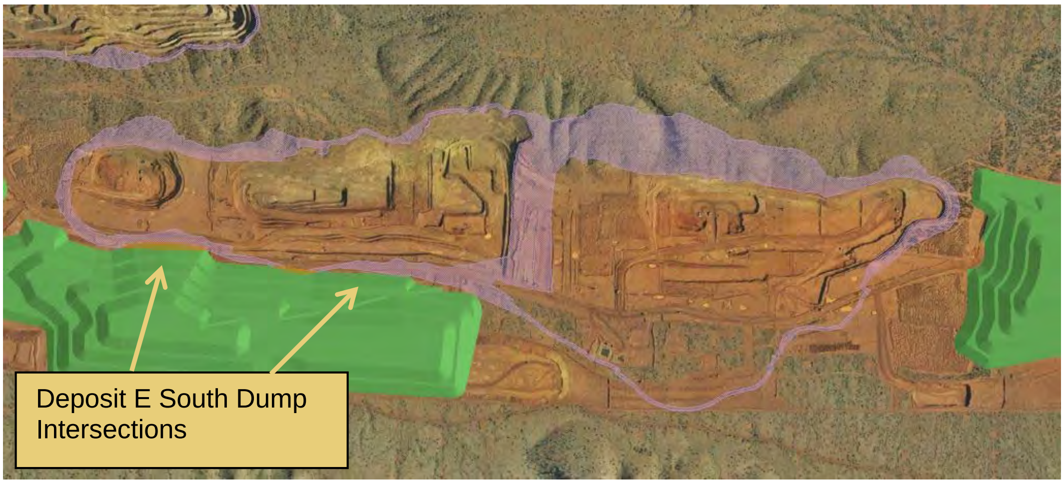

Figure 9: Zone of geotechnical instability around Deposit E

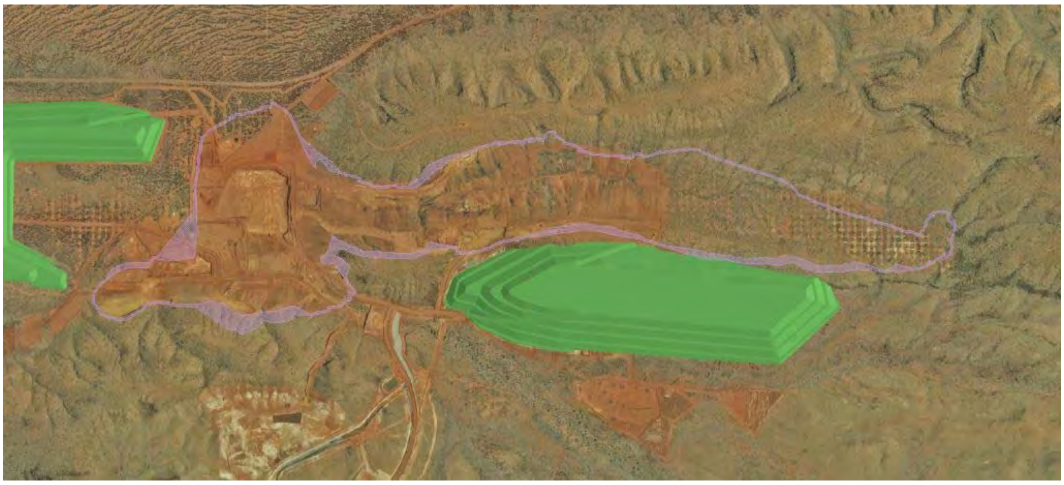

Figure 10: Zone of geotechnical instability around Deposit B

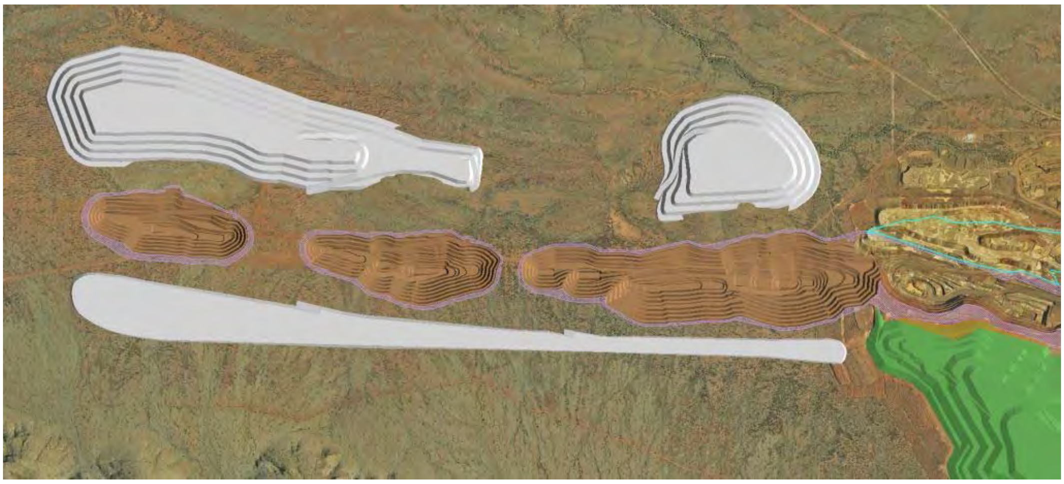

Figure 11: Zone of geotechnical instability around Deposit A West

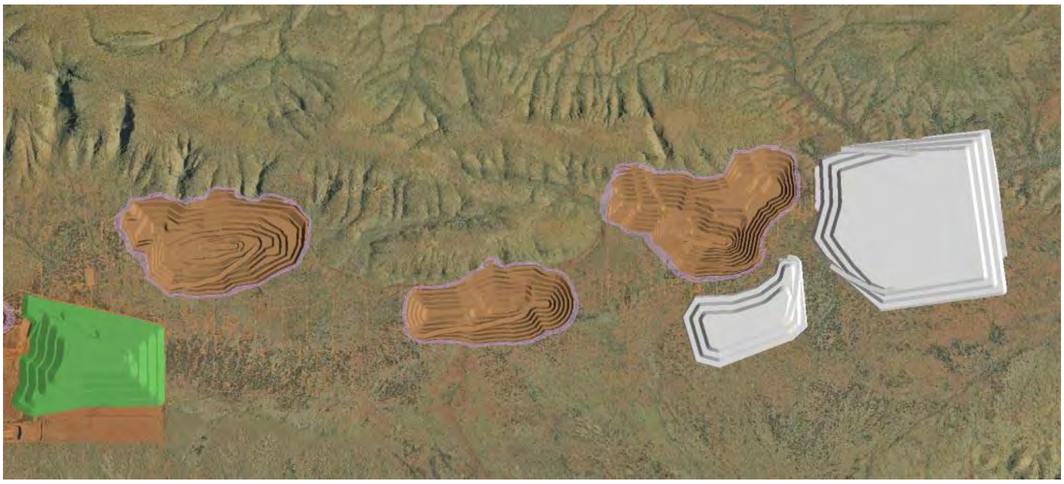

Figure 12: Zone of geotechnical instability around Deposit F

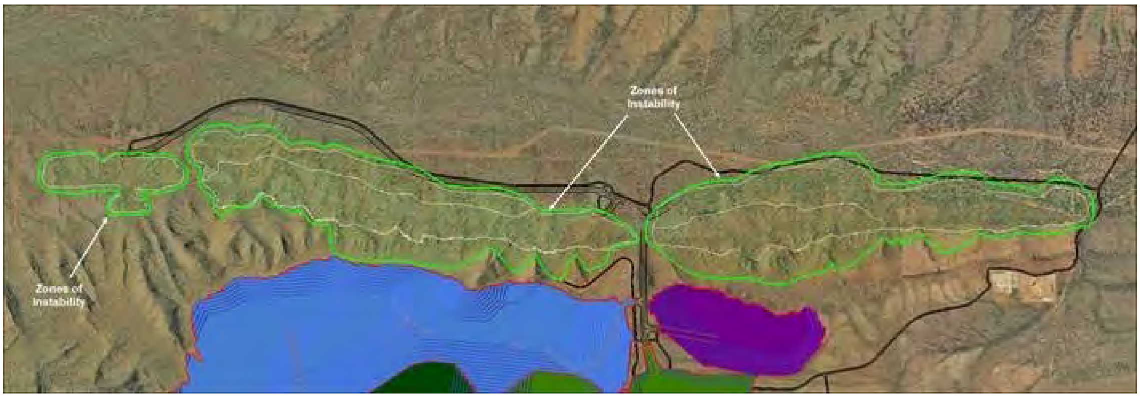

Figure 13: Zone of geotechnical instability around Deposit C

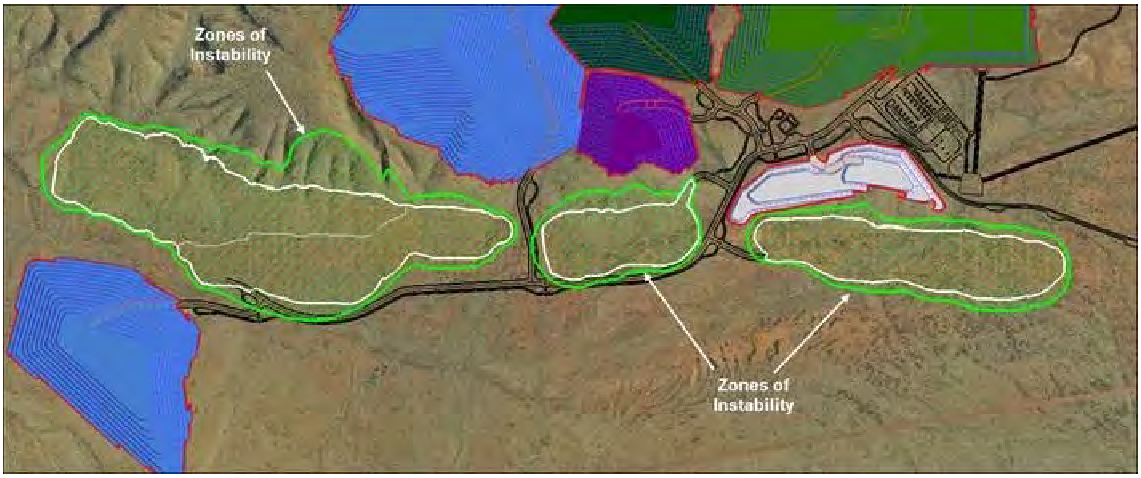

Figure 14: Zone of geotechnical instability around Deposit D

10.4 Waste characterisation and inventory

10.4.1 Physical characteristics

The erodibility potential of waste types at West Angelas was assessed using a combination of site-specific geophysical test work and extrapolation from equivalent material at similar sites. Table 9 lists the waste material types by erodibility class and percentage of total mineral waste predicted to be generated by closure.

Table 9: Waste material erodibility characterisation

Waste material type	Erodibility	Percent total waste (indicative)[4]
Detritals	High	48%
Hydrated	Low	16%
Mt Newman Member	Low	14%
Wittenoom dolomite	High	11%
West Angelas shale	High	7%
MacLeod Member	Low	3%
Nammuldi Member	Low	<1%

West Angelas mineral waste contains a significant proportion of material that is generally considered to be of high erodibility (e.g. detritals, shales), based on erodibility tests on mineral waste types undertaken by Rio Tinto across its Pilbara operations. However, there is some reason to believe that performance at West Angelas will be better than would be suggested from these erodibility tests:

- Observations made during a rainfall simulation field study at West Angelas materials in 2006[5] suggest lower erodibility than predicted by later laboratory tests on equivalent waste types; and
- Rehabilitated waste dump slopes at Deposit A are showing less signs of erosion that would be expected given the proportion of surface material that is classified as highly erodible.

[4] The proportion of waste present in individual dumps will vary, but conglomerate data is provided for the site to show the high proportion of erodible wastes.

[55] Landloch, Field Rainfall Simulator and Overland Flow Study of Waste and Topsoil Erodibility – Nammuldi and West Angelas Mines – Pilbara Iron, December 2006

The average bulk density of waste material is 2.5t/m^3 and loose material density of 2.02t/m^3 (Deposit A) to 2.06t/m^3 (Deposit B) with a physical swell factor (from in ground to on waste dump) of 1.25 used for volume calculations.

10.4.2 Geochemical characteristics

Rio Tinto has undertaken an extensive program of geochemical testing, over several years, to understand the potential for acidification and/ or metal enrichment to occur as a result of the various waste types common to mining operations in the Pilbara. The geochemical characterisation process aims to establish sulfur content, as an indicator of acid generation potential, and to undertake static (acid base accounting) and, if appropriate, kinetic testing of materials. This information is applied to the geological block model and subsequent mining model, to ensure materials with potential geochemical issues are identified prior to mining and managed, in accordance with the Rio Tinto Iron Ore (WA) Mineral Waste Management Work Practice and Spontaneous Combustion and Acid Rock Drainage (SCARD) Management Plan.

The most significant geochemical risk in Pilbara iron ore bodies is associated with sulfides, such as pyrite (FeS_2), which can form sulfuric acid when exposed to oxygen and water. Mt McRae Shale, the geological unit most commonly associated with pyrite and acid mine drainage in the Pilbara, is not present at West Angelas. However, pyrite can also occur in Banded Iron Formations. Other sulphate minerals present at the site, such as alunite and jarosite, can also pose a geochemical risk, albeit the risk is usually lower due to self-limiting chemical processes.

Over 150 samples from the Greater West Angelas deposits (ore and waste samples) have been submitted for Acid Base Accounting (ABA) and geochemical characterisation using methodology consistent with the Global Acid Rock Drainage (GARD) Guide. For lithologies such as banded iron formation (BIF) and detrital rock types, a value of 0.3% total sulfur concentration has been adopted as the boundary value to denote potentially acid forming (PAF) material from inert/non-acid forming (NAF) material. Samples associated with elevated-sulphate (where sulfur values may range from 0.1% to greater than 1%) have been classified as PAF-LC. A sulfur cut-off of both 0.1% and 0.3% are considered for the purpose of characterisation.

To date, approximately 82% of the samples submitted for ABA were classified as non-acid forming (NAF). Approximately seven percent of the samples submitted for ABA were classified as Uncertain and were expected to be NAF. The remaining 11% of samples were classified as potentially acid forming (PAF) or PAF in a low capacity (PAF-LC).

The potentially acid forming (PAF) samples are predominately from the Newman Member of the Marra Mamba Iron Formation. These samples are banded iron formation waste samples and the majority had visible pyrite logged. The PAF-LC samples are expected to have few sulfides present with the majority of the acid produced from the precipitation of metallic ions as hydroxides between pH 4.5 and 7.

Further analysis of sulfur values was undertaken on those rock types identified with acid-forming potential (and any related metalliferous drainage). The risk posed by the high sulfur values is determined by comparing the occurrence of sulfur levels greater than 0.1% and 0.3% against the total number of recorded drill samples for all in-pit (waste and ore) samples. These results, summarised in Table 10, suggest the risk of acid drainage being generated during the operation and / or from mineral waste materials from all deposits is low.

Table 10: Acid-forming potential risk based on sulfur values.

Deposit	Sulfur levels greater than 0.1%	Sulfur levels greater than 0.3 %	AMD Risk
Deposit A	2.9 %	0.3 %	Low
Deposit E	1.7 %	0.2 %	Low
Deposit B	7.0 %	0.2 %	Low
Deposit F	1.3 %	0.1 %	Low
Deposit A West	1.1 %	0.1 %	Low
Deposit C	0.9%	0.1%	Low
Deposit D	1.3%	0.3%	Low
Deposit G	0.8%	<0.1%	Low

A multi-element analysis has also been undertaken for drillhole samples across the site. Results showed that most rock types are either enriched or elevated in Fe, as correlated with the iron mineralisation associated with the ore body. Arsenic is enriched in most rock types while tin is either enriched or elevated. Other elements found to be enriched in select geological units included calcrete and dolerite from Deposit F with lead elevated, Wittenoom Formation from Deposit D with elevated levels of manganese, and waste from Deposit B, E and A West with elevated manganese, Nammuldi Waste from Deposit B with elevated manganese.

An analysis comparing the triggers against the medium concentration of select elements in each rock type indicates that:

- All rock types have average element values lower than DEC/EPA triggers for barium and phosphorus;
- The majority of rock types have elevated mean concentrations of manganese and vanadium;
- Lead levels are relatively high in Deposit E and F; and
- Zinc levels are relatively high in Deposit B.

In general, whilst concentrations of some trace elements of potential environmental concern (e.g. arsenic, lead) 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 arsenic. Groundwater contamination with arsenic is considered to be unlikely, based on historical groundwater assessments at West Angelas and experience from similar deposits in the Pilbara. Lead is similarly unlikely to mobilise into the groundwater and cause any environmental concern. These results suggest groundwater monitoring should initially include the following elements: Fe, As, Sn, Co, Cr, Cu, Mn, Ni, Pb and Zn.

10.4.3 Fibrous minerals

Fibrous minerals present a health hazard if fibres of a respirable size (approximately 6 microns) become airborne and are inhaled. The most common mineral associated with fibrous minerals encountered within the iron formations present at West Angelas is riebeckite. 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 to crocidolite, therefore, there is a higher probability of encountering crocidolite. If it is present, crocidolite seams occur primarily within the Newman Member close to, and often overlapping into the contact between the Newman Member and the underlying Macleod Member; although crocidolite can be found anywhere within the Marra Mamba Formation where iron ore mineralisation has not occurred.

Isolated occurrences of potentially hazardous fibrous material have been intersected during geological sampling and in the upper most benches of some deposits. The Rio Tinto Iron Ore (WA) Fibrous Minerals Management Plan and West Angelas Operations Fibrous Mineral Management Plan describe and provide guidelines for the management of fibrous minerals encountered during mine production, such as the encapsulation of intersected fibrous mineral waste in 2m thickness of non-fibrous mineral waste.

The small volume of potentially fibrous material that has been mined to date has been encapsulated in the Deposit A North waste dump. Similarly, fibrous material exposed in the WEPN final pit wall has since been backfilled, and poses no risk to closure. Similarly, fibrous materials excavated during the construction of the rail loop have been appropriately disposed within nominated fibrous materials burial areas.

No Potentially Hazardous or Designated Hazardous areas are demarcated in pit walls that will form the West Angelas post-mining landform and no geological units identified with a high risk of containing potentially fibrous materials are proposed to be mined in the future.

10.5 Local soils

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

The dominant soil types covering the project area are shallow coherent and porous loamy soils with weak pedologic development.

In the hills and rock ridges, which represent the surface expression of the Marra Mamba Iron Formation, extensive areas without soil cover occur. Those 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 as a result of 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. These soils are generally unfavourable for plant growth due to low moisture holding capacity and poor nutrient status.

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 carry a layer of small gravel, which is derived from the more resistant rocks in the area.

Typical Pilbara soil parameters are presented in Table 11.

Table 11: Typical Pilbara soil parameters[6]

Properties		Pilbara Soils
Physical Properties	Soil texture (<2mm soil fraction)	Sand – Clay Loam
	Coarse material content (%)	0 - 93.0
	Aggregate stability (Emerson Class[1])	2 - 6
	Soil Strength (Modules of Rupture (kPa))	0 - 267
	Plant available water holding capacity	-
	Hydraulic conductivity (Ksat(mm/h))	-
Chemical Properties	Soil pH	5.3 – 9.5
	Salinity (dS/m)	0.007 – 0.233
	Organic Carbon (%)	0.07 – 3.74
	Macro-nutrient status	-
	Micro-nutrient status	-
	Effective Cation Exchange Capacity (meq/100g)	1.9 – 16.8
	Exchangeable Sodium Percentage (%)	0.21 – 6.39
	Total metal concentrations	Low

10.6 Soil inventory

Topsoil is often a limited resource in the Pilbara with topsoil recovery often being restricted due to the nature and terrain of the landscape. The goal of soil management is to maximise the collection of topsoil and subsoil, and to store it to maximise its viability and productivity to ensure there is sufficient soil for subsequent use in rehabilitation.

[6] Note that the typical ranges above apply to topsoil and may not be representative of subsoil properties.

Where practical a minimum of 200mm of topsoil and 600mm of subsoil is collected when new areas are disturbed. Table 12 provides the current and projected soil inventory for West Angelas, and shows that there is a total soil surplus in current stockpiles of 1.3 Mm^3. However, it should be noted that a significant portion of this material is subsoil, which will be less favourable for vegetation growth than topsoil.

Table 12: Predicted LOM soil balances for West Angelas (as of December 2016)

Material	Current volume (Mm^3)	Predicted volume required for rehab (m^3) [Total volume required is 6.9 Mm^3][7]
Topsoil	5.4	5.4
Subsoil	4.5	1.5 (there is a current soil surplus of 3.0Mm^3)

11. Water

11.1 Surface water

Regionally, the majority of the West Angelas deposits (Deposits A, A west, B, C, D, E, G and the F1 and F2 orebodies of Deposit F) are located within the upper reaches of the Turee Creek Catchment, which forms part of the regional Ashburton River Catchment. The upper catchment has a complex drainage pattern characterised by intermittent flow and infrequent wide-spread flooding, depending on the occurrence of high intensity rainfall events.

The F3 orebody of Deposit F is located in the upper reaches of the Weeli Wolli Creek catchment, part of the regional Upper Fortescue River catchment, to the west of the regional Ashburton River catchment.

The east branch of Turee Creek (Turee Creek East) represents the most significant named watercourse in the area. Immediately upstream of the confluence with Turee Creek, Turee Creek East has a catchment area of approximately 2,050 km^2. This catchment has been progressively reduced due to existing mining operations. Existing operations have reduced the Turee Creek East catchment by approximately 85 km^2 (4%), which is expected to be reduced by a further 2% if Deposits C, D and G are approved and implemented.

Turee Creek East flows generally westward across the West Angelas operation, continuing west south-westerly through the Karijini National Park, before merging with Turee Creek. A number of operational deposits (including Deposits A, B, E and F) and proposed deposits (including Deposits C, D and G) are intersected by tributaries of Turee Creek East. Furthermore, Deposit C intersects the flood plain of Turee Creek East itself. Several diversions are in place at various locations across the site to keep direct surface water away from operational areas, and further diversions will be required to facilitate mining of Deposits C, D and G.

The proposal to mine Deposits C, D and G will result in additional dewatering water to be discharged, but the wetting front is not expected to reach the Karijini National Park boundary.

[7] Note that soil reconciliations and inventories do not yet take into account the Deposit C, D or G areas. It is anticipated that soil collected during development of these deposits will address closure inventory requirements

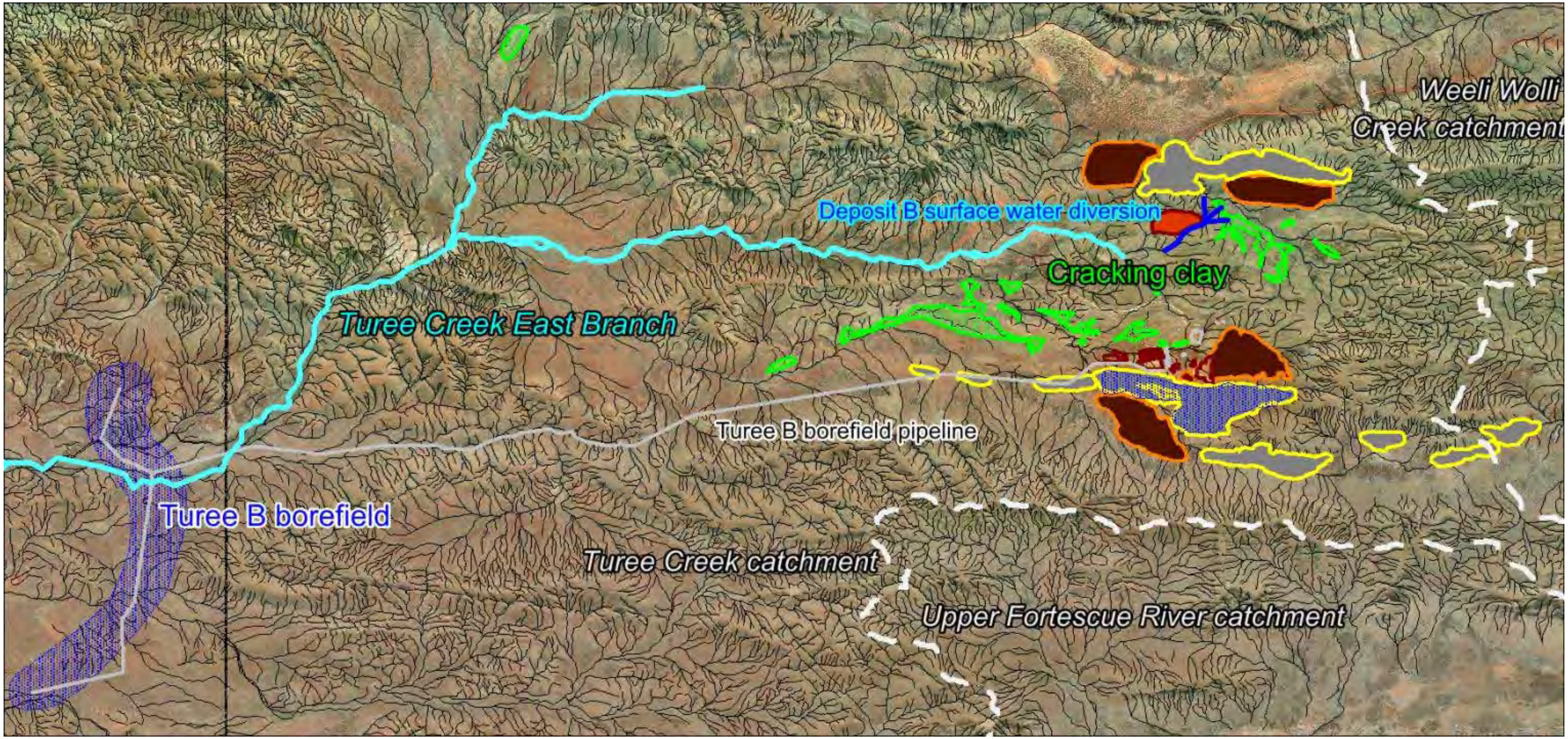

Figure 15: Surface hydrology surrounding West Angelas

11.2 Groundwater

The primary aquifer identified at West Angelas comprises the mineralised Mount Newman Member of the Marra Mamba Iron Formation (MMIF) and where mineralisation or weathering has occurred, the overlying Wittenoom Formation. The basal MMIF (MacLeod and Nammuldi Members) form an effective hydraulic barrier to groundwater flow. The depth to groundwater is relatively deep with groundwater flow from east to west for the majority of mining areas, with a relatively flat lying gradient. Based on a groundwater divide, possibly associated with a dolerite dyke between Deposit C2 and C3, the groundwater flow direction in the area of Deposit C3, G and B is reversed, from west to east, with a relatively flat lying gradient.

Groundwater quality at Deposit A is typically slightly alkaline to neutral with pH values ranging from 7.4 to 8.2 and salinity values ranging from 490 to 820 mg/l.

Recharge will be dominated by direct rainfall infiltration and, due to the naturally deep water table and low permeability Tertiary overburden, outside of the mine voids recharge is assumed to be very low. Ultimate recovery levels will vary depending on the level to which pits are backfilled. Recovery levels have been predicted for Deposits A, B and E under a ‘zero backfill’ scenario and a ‘backfill to AWT’ scenario (Table 13), with the difference between the two being accounted for by evaporation losses when the pit is not backfilled. Further modelling will be required to predict the intermediate scenario which minimises the amount of backfill required to reduce evaporation losses so as to prevent formation of permanent pit lakes.

Even if pits are backfilled to AWT, final water levels are expected to be lower than pre-mining levels in Deposit A, B and E. The catchment created by the mine void will serve to focus rainfall runoff and thus recharge, resulting in localised ponding at the base of the mine voids following heavy rainfall, which will dissipate via infiltration and evaporation shortly after the event. In the absence of further groundwater recovery modelling, it is conservatively assumed that pits will be backfilled to a level 2m above the recovery level predicted in the ‘backfill to AWT’ scenario.

Groundwater recovery modelling has not been undertaken for Deposits C, D, F and G. In the absence of such information it would be conservatively assumed for determining an appropriate backfill level that the water table would rebound to pre-mining levels.

Table 13: Predicted groundwater recovery levels

Deposit	Water level (mAHD) [and time taken to achieve a stable recovery level]		
	Pre-mining	Recovery assuming zero backfill	Recovery assuming backfill to AWT
Deposit A CEPN	640	574 [40 years]	610 [>100 years]
Deposit A CEPS	640	574 [65 years]	630 [30 years]
Deposit B B2 & B3	630	618 [20-30 years]	626 [20 years]
Deposit B B1	630	576 [40 years]	607 [>100 years]
Deposit E	668	586[8]	650 [>100 years]

Given that a portion of the West Angelas ore bodies are below the water table, a dewatering program is required. The potential impact of groundwater drawdown is considered to be relatively minor for currently approved deposits, but the development of Deposits C and D may result in groundwater drawdown of between 3m and 8m beneath an area of Karijini National Park with a potentially groundwater dependent ecosystem. An evaluation of biological survey data suggests that approximately 4.8ha of such vegetation may be at ‘low to moderate’ risk of impact as a result of this magnitude of groundwater drawdown. However, this is considered a worst case scenario as drawdown will happen over a period of time that should allow vegetation to adapt to the changing conditions and the conservative nature of the modelling undertaken did not allow for localized recharge during the wet season. Groundwater drawdown is not expected to have any impact on the inherent values of the Karijini National Park.

[8] Groundwater recovery time has not been modelled for the Deposit E zero backfill scenario.

12. Biodiversity

12.1 Terrestrial habitat

Eight broad habitat types were mapped at West Angelas prior to mining (Table 14), all of which are expected to be represented in undisturbed areas after closure.

Plain, hilltop and acacia woodland are the dominant habitat types in the area.

Hilltop, gully, cracking clay and creek habitats are of high value due to the diversity of microhabitats and potential to support conservation significant fauna species. Mesa top, mulga woodland and acacia woodland habitat is considered to have moderate habitat value due to the specialty habitat or number of fauna that may utilise the area, while plains habitat has lower value. In contrast, cleared habitat, created through mine disturbance, provides little food, shelter, water or any other life essential and is considered to have little to no habitat value.

Re-introduction of fauna is not considered as part of this closure plan. 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.

Table 14: Description of pre-mining habitats identified at West Angelas

Type	Basic description
Hilltop	Hills, ridges, plateaux remnants, gorges and breakaways of varied geological origin. Soil is generally skeletal sandy clay loams with greater than 80% stony detrital material. Under natural conditions this habitat zone is characterised by a scattered overstorey of Snappy gum *Eucalyptus leucophloia* and mulga (Acacia aneura complex) isolated trees over sparse shrubland of a combination or selection of *Senna artemisioides subsp. artemisioides, S. artemisioides subsp. filifolia, Ptilotus rotundifolius, Tribulus suberosus, Eremophila fraseri* and *Acacia ancistrocarpa* sparse shrubland to isolated shrubs over *Triodia pungens* hummock grassland. Rocky, sheltered ridges and breakaways provide a suite of specialist plants or species more typical of lowlands. This habitat creates a diverse array of microhabitats and refugia. The habitat often contains rock shelters in the form of overhangs, cracks, crevices, caves and areas for water to pool during the wet season. Vegetation provides microhabitats in the form of logs, debris and hollows. This habitat zone will be present in undisturbed areas of the mine and may evolve around the edge of the disturbed mine area especially where the pit shell intersects local hills after erosion processes occur. However the characteristics of this habitat are not compatible with the closure landform is unlikely to be restored or introduced as part of the rehabilitation activities.
Mesa top	Mesa top habitat is distinguished by its elevated plateau topography. This habitat is characterised by *Eucalyptus leucophloia*, *E. gamophylla, Acacia pruinocarpa* and mulga (*A. aneura complex*) open woodland to sparse trees, over *A. maitlandii, A. hamersleyensis, Keraudrenia velutina* and *Senna glutinosa subsp. glutinosa* open shrubland, over *Triodia pungens, T. longifolia* and/or *T. wiseana* open hummock grassland This habitat is characterised by a low diversity due to the elevation and therefore the isolation from accessible surrounding habitats. However, invertebrate fauna can be quite diverse and specialised as a result of this isolation. This habitat zone will not be substantially disturbed by mining activities and will be present in undisturbed areas to the east of Deposit B. The characteristics of this habitat are not compatible with the closure landform is unlikely to be restored or rehabilitated as part of the rehabilitation activities.

Type	Basic description
Major gorge	Very steep topography with an irregular surface with little exposed soil. The soil, when available, is sandy to sandy-clay. This habitat commonly includes *Acacia aptaneura* open woodland over *Ptilotus obovatus* isolated shrubs over *Themeda triandra* and *Eriachne* sp. open tussock grassland and *Triodia pungens* isolated hummock grasses. *Astrotricha hamptonii, Ficus brachyopoda* and *Cyperus cunninghamii* are species found only in the major gorge are considered descriptive of this habitat type, although not dominant. This habitat creates a diverse array of microhabitats and refugia. The habitat often contains rock shelters in the form of overhangs, cracks, crevices, caves and areas for water to pool during the wet season. Vegetation provides microhabitats in the form of logs, debris and hollows. This habitat zone will be present in undisturbed areas of the mine. The characteristics of this habitat are not compatible with the closure landform is unlikely to be restored or rehabilitated as part of the rehabilitation activities.
Plains	Low and occasionally slightly undulating alluvial plains including outwash areas and broad drainage basins. Under natural conditions soils often consisting of sandy-clay soils covered by rocky lag gravel. The habitat is characterised by *Eucalyptus leucophloia, E. gamophylla, Corymbia hamersleyana, A. pruinocarpa, A inaequilatera* and species in the *A. aneura* complex open woodland to sparse trees over *Acacia spp., Eremophila spp., Ptilotus spp., Senna spp.* and *Solanum lasiophyllum* open shrubland over Triodia spp. open hummock grassland. The habitat includes minor drainage lines, where *T. longifolia, Gossypium robinsonii and Acacia ancistrocarpa* are characteristic. This habitat type contains limited microhabitats with the dominant Acacia species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. SRE invertebrate species usually comprise mygalomorph (trapdoor) spiders, scorpions, pseudoscorpions and isopods. Most SRE invertebrates prefer the southern footslopes where sun exposure is reduced and the level of moisture under shrubs and trees is increased. This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be suitable for rehabilitation planning and could be considered where there is the opportunity for deep soils to develop, i.e. on waste dumps.
Acacia woodland	Flat with no or very small drainage channels, under natural conditions soils often consist of a clay loam with continuous layers of small ironstone pebbles on the surface. The habitat is characterised by open to medium dense woodland with a tree stratum of mulga (*Acacia aneura* complex) and scattered *Acacia pruinocarpa*, over *Acacia maitlandii* and *Ptilotus* sp. sparse shrubland, over *Triodia wiseana* and *T. pungens* open hummock grassland dominated the mixed *Acacia* woodland habitat. Similar to the plains habitat, this habitat type contains limited microhabitats with the dominant Acacia species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. However, avifauna is most diverse after significant rainfall, and when acacia shrubs and trees are flowering. This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be suitable for rehabilitation planning and could be considered on flat areas that sustained mixed acacia woodland vegetation prior to disturbance.

Type	Basic description
Mulga woodland	Flat areas dominated by overland surface water flows, rather than concentrated flow along drainage lines, following very heavy rainfall. Soils are typically comprised of sandy-clay with no rocks. This habitat consists of both groved and banded mulga, where different species of the *Acacia aneura* complex were present in a closed woodland, over *Ptilotus obovatus* and juvenile mulga trees sparse shrubland, over *Maireana* sp. and *Salsola australis* isolated herbs and *Aristida* sp. and *Cymbopogon obtectus* isolated tussock grasses creating distinct micro-habitats that include dense leaf litter and shaded zones. Similar to the acacia woodlands habitat, this habitat type contains limited microhabitats with the dominant Acacia species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. Avifauna is most diverse after significant rainfall, and when acacia shrubs and trees are flowering. This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be suitable for rehabilitation planning and could be considered on flat areas that sustained mulga woodland vegetation prior to disturbance.
Cracking clay	Characterised by sand-clay to clay soils with an undulating surface caused by crabholes and gilgai. Rocks and pebbles were very rare and when present, the rock type was consistently ironstone. This habitat supports very few trees or tall shrubs and is characterised by open and sparse low vegetation with approximately half of its area being bare ground. Isolated shrubs of *Salsola australis, Boerhavia paludosa* and *Ptilotus nobilis* subsp. *nobilis* were present over open tussock grassland of *Aristida* sp., *Brachyachne* sp. and *Astrebla pectinata.* This habitat is identified as Priority 1 ecological community due to its restricted distribution across the Pilbara, and contains species which are both rare and edaphically restricted (i.e. distribution is influenced by the soil rather than by the climate). This habitat zone will be protected as far as practicable during mining activities and will be present in undisturbed areas to the north of Deposit A West and south of Deposit B. The soil profile required to restore this habitat is not compatible with the closure landform; although, following further investigation, opportunities may exist to establish a community in an appropriate locations by relocating habitat scheduled to be destroyed (e.g. areas under Deposit B waste dumps).
Creek	A linear habitat characterised by regular surface water flows, defined banks and associated riparian vegetation corridor. The creek habitat includes areas that are periodically flooded due to high surface water flow volumes (floodplains). Vegetation is characterised by open woodland of *Eucalyptus victrix, Acacia citrinoviridis* and *Acacia aptaneura*, over S*enna artemisioides subsp. oligophylla, Rhagodia eremaea, Ptilotus obovatus, Tephrosia rosea* and *Malvaceae spp. shrubland* over *Themeda triandra* and Bothriochloa sp. sparse tussock grasses and/or *Triodia pungens* sparse hummock grasses. Creek habitats act as wildlife corridors that help flora and fauna disperse across the landscape. There is a high diversity of microhabitats including logs, debris, tree hollows and soft soils, as well as temporary and permanent pools. This habitat zone will be present in undisturbed areas outside of the mine. Disturbed creek habitat, i.e. access roads that cross creeks and discharge related infrastructure, will be rehabilitated with the aim of returning the land to functional creek habitat.

12.2 Conservation significant flora and communities

Table 15 describes the Threatened and Priority flora that have been identified at or near the West Angelas operations and have biodiversity value because of their rare and/or threatened status.

Table 15: Conservation significant flora identified near or at West Angelas.

Flora taxon	Conservation status WA	Habitat comments
Eragrostis sp. Mt Robinson (S. van Leeuwen 4109)	1	Red brown skeletal soils, ironstone. Steep slopes, summits
Eremophila sp. Hamersley Range (K. Walker KW 136) PN	1	Summit of hill, high in landscape, steep rock slopes and scree, skeletal brown-red soil over massive banded ironstone of the Brockman Iron Formation
Eremophila sp. West Angelas (S. van Leeuwen 4068)	1	High in landscape, summit of hill, gently undulating to steep terrain, skeletal red gritty soil over massive banded iron of the Brockman Iron Formation
Josephinia sp. Marandoo (M.E. Trudgen 1554)	1	Outer edge of creek vegetation. Soil: Orange-brown (terracotta) coloured clay-loam
Rhodanthe ascendens	1	Clay
Tetratheca fordiana	1	Shale pocket amongst ironstone
Vittadinia sp. Coondewanna Flats (S. van Leeuwen 4684)	1	Flat plain. Red sandy clay loam.
Aristida lazaridis	2	Sand or loam
Eremophila pusilliflora	2	Flat terrain, low in landscape, base of broad valley, stony gibber plain above shallow drainage line, red clay loam
Euphorbia clementii	2	Sandplains, gravelly hillsides, stony grounds
Hibiscus sp. Gurinbiddy Range (M.E. Trudgen MET 15708) PN	2	Near summit of hill, high in landscape, skeletal red brown stony soil over massive ironstone of the Brockman Iron Formation
Oxalis sp. Pilbara (M.E. Trudgen 12725)	2	Gully. Brown red loam, cobbles and pebbles
Teucrium pilbaranum	2	Crab hole plain in a river flood plain, margin of calcrete table
Acacia effusa	3	Stony red loam. Scree slopes of low ranges
Acacia aff. *subtiliformis*	3	Rocky calcrete plateaux
Dampiera metallorum	3	Rocky ledges and breakaways with loose scree material in lower section of plot.
Goodenia sp. East Pilbara (A.A. Mitchell PRP 727)	3	Red brown clay soil, calcrete pebbles. Low undulating plain, swampy plains
Grevillea saxicola	3	Breakaways and scree slopes, orange-brown loam soils
Indigofera gilesii	3	Pebbly loam amongst boulders and outcrops. Hills.
Oldenlandia sp. Hamersley Station (A.A. Mitchell PRP 1479)	3	Cracking clay, basalt. Gently undulating plain with large surface rocks, flat crabholed plain
Olearia mucronata	3	Schistose hills, along drainage channels
Pilbara trudgenii	3	Skeletal, red stony soil over ironstone. Hill summits, steep slopes, screes, cliff faces
Rhagodia sp. Hamersley (M. Trudgen 17794)	3	Broad plain at the base of hills (enclosed on all sides). Red brown clay/loam. Ironstone pebbles
Rostellularia adscendens var. *latifolia*	3	Ironstone soils. Near creeks, rocky hills

Flora taxon	Conservation status WA	Habitat comments
Sida sp. Barlee Range (S. van Leeuwen 1642)	3	Skeletal red soil pockets. Steep slopes
Themeda sp. Hamersley Station (M.E. Trudgen 11431)	3	Red clay. Clay pan, grass plain
Triodia sp. Mt Ella (M.E. Trudgen 12739)	3	Light orange brown, pebbly loam. Amongst rocks and outcrops, gully slopes
Acacia bromilowiana	4	High in landscape, summit of hill and on steep slope, skeletal red gritty soil over massive basalt type rock
Goodenia nuda	4	Wide alluvial plain or creek beds. Red brown clay loam, ironstone.
Lepidium catapycnon	4	Skeletal hills, hillsides

12.3 Priority and/or Threatened Ecological Communities

There are no Threatened Ecological Communities in the West Angelas region. However, the West Angelas Cracking Clay Priority Ecological Community (PEC) is listed in Western Australia as a Priority 1 community. It's considered significant because it is relatively uncommon in the Pilbara and because it is in very good condition, attributed to the absence of historic cattle grazing in the region. Notwithstanding this, cracking clay communities at West Angelas (and other areas in the Pilbara) appear to be predominantly sustained by surface water (sheet) flows generated by incident rainfall, and its condition in recent years has been described as poor following a number of years of below average rainfall.

The PEC is described as open tussock grasslands of *Astrebla pectinata, A. elymoides, Aristida latifolia,* in combination with *Astrebla squarrosa* and low scattered shrubs of *Sida fibulifera,* on basalt derived cracking clay loam depressions and flow lines.

The PEC footprint is treated as an exclusion zone and direct disturbance is avoided during mine construction and operations, although approximately 15.5 ha is proposed for clearing to facilitate mining of Deposit D. This may provide an opportunity to undertake a translocation trial (see Section 19.6) to determine the viability of reconstructing cracking clay habitats at this and other locations across the Pilbara.

12.4 Seed provenance and selection

Locally collected seed is needed to assist in revegetation and the creation of a self-sustaining ecosystem. Over time the viability of seeds in stockpiled topsoil decreases, and thus the quality of the topsoil deteriorates. In addition the topsoil that was salvaged prior to disturbance may not contain seeds of all the target species of its new location / habitat.

Seed mixes for rehabilitation are of local provenance. Specific seed mixes are selected to provide a range of species appropriate to the desired habitat, 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 Iron Ore purchases seeds from commercial seed suppliers, with emphasis on ensuring that there are appropriate local provenance seeds available for rehabilitation of each of its sites. Seeds are stored in purpose-built, climate controlled storage facilities to maximise long term viability.

The inclusion of rare and threatened species in rehabilitation programmes is limited by:

- 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;
- availability of seed at the time when rehabilitation occurs; and/or
- seed dormancy.

Given these issues, the main focus of rehabilitation programs is to restore vegetation complexes that include the more common species present in the particular 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.

12.5 Invasive flora

Flora and vegetation surveys have recorded eight species (Table 16) on the Department of Parks and Wildlife Impacts and Invasiveness Ratings list for the Pilbara.

Table 16: Weed species recorded at West Angelas

Scientific Name	Common Name	Ecological Impact	Invasiveness
Acetosa vesicaria (L.) A.Love	Ruby Dock	High	Rapid
Cenchrus setiger Vahl	Birdwood Grass	High	Rapid
Cenchrus ciliaris	Buffel grass	High	Rapid
Malvastrum americanum	Spiked Malvastrum	High	Rapid
Sigesbeckia orientalis	Indian Weed	Unknown	Rapid
Sonchus oleraceus	Common Sowthistle	Low	Rapid
Setaria verticillata	Whorled Pigeon grass	High	Rapid
Bidens bipinnata	Beggars Tick	Unknown	Rapid

12.6 Conservation significant fauna

Conservation significant species have been identified as present at or near the site and/or may be present at the site due to the presence of appropriate habitat within their known range, are listed in Table 17.

Table 17: Species of conservation significance and associated habitats at West Angelas

Fauna species	Conservation status WA	EPBC Act status	Habitat occurrence
Dasyurus hallucatus (northern quoll)	Schedule 2	Endangered	Gullies Disturbed
Rhinonicteris aurantia (Pilbara leaf-nosed bat)	Schedule 3	Vulnerable	Gullies Hilltop
Liasis olivaceus barroni (olive python)	Schedule 3	Vulnerable	All hill habitats
Falco hypoleucos (grey falcon)	Schedule 3	Vulnerable	Acacia woodland Mulga woodland All drainage habitats
Macroderma gigas (ghost bat)	Schedule 3	Vulnerable	Gullies Hilltop
Apus pacificus (fork-tailed swift)	Schedule 5	Migratory	All drainage habitats

Fauna species	Conservation status WA	EPBC Act status	Habitat occurrence
Merops ornatus (rainbow bee eater)	Schedule 7	Migratory	All valley habitats
Falco peregrinus (peregrine falcon)	Schedule 7	-	All habitats
Ramphotyphlops ganei	Priority 1	-	All habitats
Underwoodisaurus seorsus (Pilbara barking gecko)	Priority 2	-	All hill habitats
Pseudomys chapmani (western pebblemound mouse)	Priority 4	-	All hill habitats
Leggadina lakedownensis (short-tailed mouse)	Priority 4	-	All

13. Progressive rehabilitation

Regular reviews of the mine plan are used to identify disturbed areas of the site where mining activity has been completed. These areas are then reviewed for potential to undertake progressive rehabilitation works. Lessons learnt during these activities and from subsequent monitoring campaigns are used to inform and update our standard management practices and provide input into suitability of final closure criteria for the site.

13.1 Borrow pits and rail loops

Rehabilitation at most of the West Angelas borrow pits and rail loop sites was undertaken between 2000 and 2003. Established monitoring transects include:

- Five borrow pits at the highway end of access road (Highway 1-5);
- Four rail loop rehabilitation areas (Rail Loop 1a, 1b, 2 and 3);
- Three borrow pits adjacent to the airstrip (Airstrip 1-3); and
- Three reference transects C7, C8 and C9.

The vegetation is well established (Figure 16), and in most cases sites compare favourably with one or more of the reference sites. Over half the species present in the rehabilitation sites were recorded in three reference sites. They include a range of perennial shrub and grass species. The absence of some species from rehabilitation may reflect pre-mining site differences as well as rehabilitation establishment and survival.

Other species were present in rehabilitation but not in reference sites. Likely reasons are the greater sampling effort in rehabilitation (i.e. more sites) and the increased presence of early colonizing species. The number of species in the rehabilitated sites is expected to increase with time through natural re-colonisation from surrounding areas.

All sites appear stable; and some sites may be nearing a stage where signoff could be considered.

Figure 16: Rehabilitation progress at Highway 3.

13.1.1 Waste dumps

Two waste dumps areas at Deposit A South waste dump and North (also known as East) waste dump were rehabilitated in 2012. The South waste dump (Figure 17) area is a 6 ha portion of the lower lift, and North waste dump (Figure 18) area is a 1.5 ha section of the lower lift. Reference sites have been established in unmined areas that consist of similar vegetation, soil and terrain characteristics of the area to be rehabilitated.

Monitoring undertaken in 2015 indicates that both rehabilitation areas are performing very well, with values for all parameters (e.g. plant density, plant cover, species richness, diversity, weed count) similar to, or in many cases better than those in reference sites. Spinifex density was within the range recorded in reference sites, but numbers were lower than had been recorded in 2014. This is not unexpected, and probably reflects the loss of some seedlings due to environmental factors.

Both rehabilitation areas are also performing well with respect to erosion. The North Dump has few gullies, and those that are present appear to be stable. There are two obvious gullies on the South Dump, although one of these appears to be stable. There is one significant gully on a corner of the dump which appears to be increasing. Monitoring will continue, and corrective works undertaken if it appears to threaten dump stability.

The generally good performance with respect to erosion is of particular significance because the final rehabilitation design specifications are less conservative than would applied based on the large proportion of detritals and shales which are currently classified as being highly erodible based on recent laboratory testwork. However, this performance is consistent with the results of 2006 field simulations of the material, and further work is proposed to confirm an appropriate design specification. It should be noted that less conservative design specifications (e.g. higher lifts, higher slope angles) are advantageous with respect to reducing the overall footprint and/or reducing the number of berms on the rehabilitated surface, and would accordingly be adopted where appropriate.

Figure 17: Rehabilitation progress at Deposit A South waste dump (2015) 3 years after seeding.

Figure 18: Rehabilitation progress at Deposit A North (East) waste dump (2015) 3 years after seeding.

14. Contaminated sites

Rio Tinto Iron Ore maintains registers for potentially contaminating activities and known and suspected contaminated sites which have been formally reported under s11 of the *Contaminated Sites Act 2003* (WA). The registers are informed by regular preliminary site investigations to identify such activities and sites. Currently no locations at West Angelas have been reported under the *Contaminated Sites Act 2003* (WA). Potentially contaminating activities and land uses as described in the guideline '*Assessment and management of contaminated sites'* (DER, 2014), are however performed onsite and include amongst others things:

- Airport facilities;
- Automotive repair workshops (light and heavy machinery);
- Substations and transformers;
- Explosives storage;
- Putrescible landfill sites;
- Mineral processing, mining, screening and crushing facilities;
- Rail transport corridors;
- Hydrocarbon storage, handling and dispensing facilities;
- Sewage waste water treatment plants and irrigation areas; and
- Disturbance of potentially acid forming materials during the course of mining.

A contaminated sites assessment will be undertaken prior to closure as part of the decommissioning process. Specific plans will be developed to remediate or manage contamination, where required, to support the final land use.

15. Cultural heritage

Rio Tinto Iron Ore 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 we operate. Extensive archaeological and ethnographic surveys have been undertaken in the West Angelas area, and these surveys help to inform the heritage values of the area. We take all reasonable and practicable measures to prevent harm to cultural heritage sites, this includes during works associated with rehabilitation and closure. Where this is not possible, steps are taken to minimise or mitigate impacts and ensure required statutory approvals are obtained. Closure works consider issues such as post closure access requirements to culturally significant sites and appropriate return of any materials salvaged during mining operations.

15.1 Relevant Aboriginal groups

The Yinhawangka and Ngarlawangga Peoples are the traditional custodians of the land identified within this closure plan.

Yinhawangka is represented by Yinhawangka Aboriginal Corporation (YAC) and Ngarlawangga is represented by Ngarlawangga Aboriginal Corporation assisted by Ngurra Barna Aboriginal Corporate Services. Yamatji Marlpa Aboriginal Corporation (YMAC) currently act as Ngarlawangga's heritage body. Members of these corporations are geographically dispersed with key locations being Wakathuni and Bellary near Tom Price, Onslow, Roebourne, Karratha and Port Hedland.

Consultation with regards to closure has been limited to date. Topics that require consultation include the on-going access to heritage sites post closure and the ultimate resting place of any artefacts salvaged.

15.2 Ethnographic and archaeological values

In line with statutory requirements and internal heritage management standards, archaeological and ethnographic surveys have identified a rich and diverse region of material culture that includes an abundance of artefact scatters, rockshelters, scarred trees and rock art, in part due to the proximity to Turee Creek East and its tributaries and the presence of readily accessible naturally formed shelters. The large concentration and close proximity of artefact scatters and scarred trees to rockshelters seemingly demonstrates the adaptation to the local environment and the story of subsistence of people moving through this part of the country.

Several sites of high archaeological and/or ethnographic significance to the Yinhawangka People have been identified in the region and works have been modified to mitigate direct impacts to these sites outlined in Management Plans drafted in consultation with the Yinhawangka.

Whilst this closure plan does not include strategies for maintaining or restoring cultural values, it does recognise that post-closure access to some of these sites may be required and that the area will need to be made safe for this purpose.

16. Regional Community

The area surrounding the mine is unallocated crown land with no homesteads or Aboriginal communities in close proximity. The nearest town, Newman, is located approximately 120km south-east of West Angelas.

West Angelas operates solely as a Fly-In Fly-Out (FIFO) operation. The majority of the workforce flies in and out of the privately owned airstrip adjacent to the mine village. As a result, there is little direct social interaction between the workforce and any surrounding local communities.

17. Workforce

West Angelas is operated wholly as FIFO operations, with no personnel residing in the Pilbara. The majority of staff is flown directly from Perth to the site operated airport, with small numbers also flying directly from Busselton and Broome. Personnel are housed on site, in a fully serviced accommodation facility that will be decommissioned as part of this closure plan.

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

IDENTIFICATION AND MANAGEMENT OF CLOSURE ISSUES

18. Risk evaluation process

A closure risk assessment was completed to identify and assess closure issues for West Angelas. The risk assessment is included in Appendix D. The assessment was completed by an internal panel of multi-disciplinary subject matter experts with the aim of:

- identifying hazards, aspects and opportunities that could influence the successful closure of the site;
- evaluating the resulting risks to people, property and the environment; and
- defining the actions required to reduce the risk to below the risk acceptance threshold.

Risk was evaluated on the basis of the maximum reasonable outcome consequence and the likelihood of that consequence occurring. Risks were evaluated inclusive of current management and commitments, and represent current residual risk.

Issues are assessed against the following consequence criteria:

- **Health**: reversible health effects of little concern (very low) to multiple fatalities (very high);
- **Personal safety**: inconvenient first aid treatments (very low) to multiple fatalities (very high);
- **Environment**: reversible impact (very low) to widespread, long-term impacts (very high). As some environmental impacts can escalate if immediate identification and remediation is not possible, environmental consequences are also evaluated by:
  - **On-site**: referring to impacts that occur during the pre-closure and decommissioning phases, when staff are able to utilise site equipment and quickly react to remediate impacts; and
  - **Off-site**: referring to impacts that occur during the post-closure phase, when remediation may not immediately follow impact identification, due to a need to bring equipment and experts back to site to remediate.
- **Community trust**: mistrust amongst a small section of the wider community (very low) to widespread mistrust with key stakeholders (very high); and
- **Compliance**: non-conformance to internal requirements (very low) to prosecution for breach of regulatory licence(s) (very high).

Risks are classified as follows:

- **Low** (Class I): Risks that are below the risk acceptance threshold and do not require further management.
- **Moderate** (Class II): Risks that lie on the risk acceptance threshold and require regular review to ensure management remains adequate and fit-for-purpose.
- **High** (Class III): Risks that, based on the current level of knowledge, could exceed the risk acceptance threshold and require proactive management and / or resolution of knowledge gaps.
- **Critical** (Class IV): Risks that, based on the current level of knowledge, will exceed the risk acceptance threshold and need urgent and immediate attention to develop an alternative approach.

Actions are assigned to risks that exceeded the risk acceptance threshold and therefore require additional control measures to reduce the risk to an acceptable level. Actions are also assigned to address knowledge gaps where it is assessed that further information is required to better understand and/or adequately assess the risk presented by an issue. This would typically be the case in the early stages of closure where the detailed knowledge of the issues may be low.

19. Management of key issues

The DMP/EPA *Guidelines for Preparing Mine Closure Plans* lists a number of rehabilitation and closure issues that may be relevant for mine sites, including five that are identified as key issues. An evaluation of the relevance of each of these issues to West Angelas mine is presented in Table 18. The information in this table is intended to compliment that contained in the risk assessment presented as Attachment D.

Table 18: Relevance of potential closure and rehabilitation issues to West Angelas

Issue	Evaluation of relevance to West Angelas	Further discussion
Acid and metalliferous drainage	Geochemical studies have identified a low AMD risk for West Angelas.	Not addressed further in this chapter
Challenges associated with rehabilitation and revegetation	Rehabilitation conducted to date, which includes trial rehabilitation areas on two waste dumps, appears to have resulted in good outcomes.	Not addressed further in this chapter
Dispersive, sodic and erosive materials	West Angelas mineral waste contains a high fraction of material that is classified as highly erodible	Section 19.1
Radioactivity	Not a significant issue for this site	Not addressed further in this chapter
Mine pit lakes	The current closure strategy involves backfill to a level that prevents the formation of pit lakes	Not addressed further in this chapter
Geotechnical instability	Several waste dumps intersect zones of instability around pit walls	Section 19.2
Inadvertent public access	Abandonment bunds will be required to restrict inadvertent public access	Section 19.3
Hazardous materials	Hazardous materials (e.g. hydrocarbons, ammonium nitrate) will be removed prior to, or during, decommissioning	Not addressed further in this chapter
Hazardous and unsafe facilities	All infrastructure will either be demolished during decommissioning, or handed to the State in accordance with State Agreement requirements	Not addressed further in this chapter
Contaminated sites	There are no reportable contaminated sites	Not addressed further in this chapter
Fibrous materials	Fibrous mineral wastes are present	Section 19.4
Non-target metals and target metal residues in mine wastes	No chemical processing occurs at the site	Not addressed further in this chapter
Adverse impacts on surface and groundwater quality	There is not predicted to be any significant surface or groundwater impacts	Not addressed further in this chapter
Design and management of surface water structures	Surface water diversions are present	Section 19.5
Dust emissions	This is not considered to be a significant closure issue for the site due to its remote location	Not addressed further in this chapter
Flora and fauna diversity/threatened species	Cracking clay Priority Ecological Communities are located in close proximity to the mining footprint	Section 19.6
Visual amenity	This is not considered to be a significant closure issue for the site due to its remote location	Not addressed further in this chapter
Heritage issues	Management of cultural heritage values is conducted through processes established under the Indigenous Land Use Agreement, and strategies incorporated into Cultural Heritage Management Plans.	Not addressed further in this chapter

Issue	Evaluation of relevance to West Angelas	Further discussion
Alteration of the direction of groundwater flow	Alteration of groundwater flows is not expected to be significant	Not addressed further in this chapter
Alteration of the depth to water table of the local aquifer	Groundwater is not expected to recover to pre-mining levels, and there will be a long-term groundwater drawdown footprint.	Section 19.7
Alteration of the hydrology and flow of surface waters	Alterations to the hydrology and flow of surface waters are expected to be localised and not significant.	Not addressed further in this chapter

19.1 Management of erodible mineral waste

19.1.1 Principles of waste dump design

Waste dumps located on mine sites that are operated by Rio Tinto are designed and rehabilitated in accordance with internal Landform Design Guidelines[9]. This document provides guidance on:

- the objectives of waste dump design, which is to achieve dumps that are:
  - safe;
  - stable;
  - aesthetically compatible with the surrounding landscape;
  - vegetated;
  - non-polluting;
  - compatible with the agreed post-mining land use; and
  - progressively rehabilitated;
- selection of appropriate locations for the siting of waste dumps;
- appropriate shapes and designs of waste dumps;
- appropriate surface treatments; and
- links to other relevant internal and external guidance material.

These Guidelines are updated on a regular basis to incorporate learnings from research, studies and rehabilitation implementation projects. The most significant recent update occurred in 2012 to provide designs for waste dumps 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 including those at West Angelas, with design recommendations based on the assumption that an average erosion rate of 5/ha/year (with a maximum of 10/ha/year) will be acceptable. Further studies have since been undertaken on additional waste types, and this resulted in another update in 2014.

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, further reducing the erosion potential.

19.1.2 West Angelas erosion risk

A significant fraction of the West Angelas mineral waste is comprised of geological units that are generally classified as being of high or moderate erodibility (e.g. detrital material, shales) with the more competent Banded Iron Formation geology that is common elsewhere in the Pilbara present in significantly lower

[9] Rio Tinto Iron Ore (WA), *Landform Design Guidelines,* July 2014, RTIO-HSE-0015708

proportions. However, there is a significant proportion of hydrated material, which is classified as having low erodibility.

West Angelas waste dump rehabilitation designs are therefore considered as conservative, adopting one or more of the following approaches:

- Construction of 'berm and batter' slopes to prevent excessive surface water flows down the slope;
- Reduction of slope angles from angle of repose (~37 degrees) to 18-20 degrees;
- Restriction of individual lift heights (i.e. the vertical distance between berms) in some cases to 5m, which is the height recommended for slopes of this angle based on laboratory testing of the dominant material types at West Angelas and subsequent landform evolution modelling;
- Stockpiling of hydrated material to apply to the surface of waste dumps prior to rehabilitation, to enable a greater lift height of up to 20m; and/or
- Selective dumping of material during operations to ensure that more competent waste types are concentrated on the surface of the dump.

Trials to date appear to illustrate that West Angelas waste dumps may be less susceptible to erosion than is predicted through the landform evolution modelling based on laboratory tests.

A field trial was conducted in 2006 to measure erosion rates simulating rain and overland flows applied to experimental plots, and measurements made of runoff and sediment. This information was then used to provide input data for landform evolution modelling. Recommendations arising from this work suggest that more typical rehabilitation '20/20/10' designs applied elsewhere in the Pilbara (20m lift height, 20 degree slope, 10m berms) could also be appropriate for this site. These specifications are less conservative than those arising from laboratory testing but may account for processes such as self-armouring of surface materials that are not as effectively measured in the laboratory.

Progressive rehabilitation trials have been conducted on Deposit A South and North (East) waste dumps in 2011/2, with a single batter rehabilitated on one section of each dump. The South WD batter ranged in height from 14-21m, and had an average gradient of 16 degrees. The North WD had maximum batter heights of 10-12m. Both slopes are performing much better than expected from an erosion perspective, with few gullies evident. With the exception of one gully at South Dump (Figure 19), they appear to now be stable and supporting good vegetation growth.

The performance of these rehabilitation trial areas was evaluated in 2016. Findings and recommendations included:

- The unstable gully in South Dump is currently eroding at a rate of approximately 25 t/ha/y, which is well in excess of the target maximum 5 t/ha/y erosion rate, and is possibly explained by a number of factors including high average gradient (17-19 degrees) in this area, a complex S-shaped profile rather than a linear slope, and topsoil potentially applied too thickly;
- All other sections of the rehabilitated slopes are exhibiting erosion rates lower than the target maximum erosion rate;
- Further erodibility testing is warranted on West Angelas waste materials;
- The recommendations arising from the 2006 study were based on achieving different erosion thresholds than are targeted today, and should therefore be considered obsolete; and
- Lift heights of ~12-15m and gradients of <16 degrees appear to produce sufficiently stable batter profiles.

Based on the results of these field trials, rehabilitation design specifications are currently being reviewed.

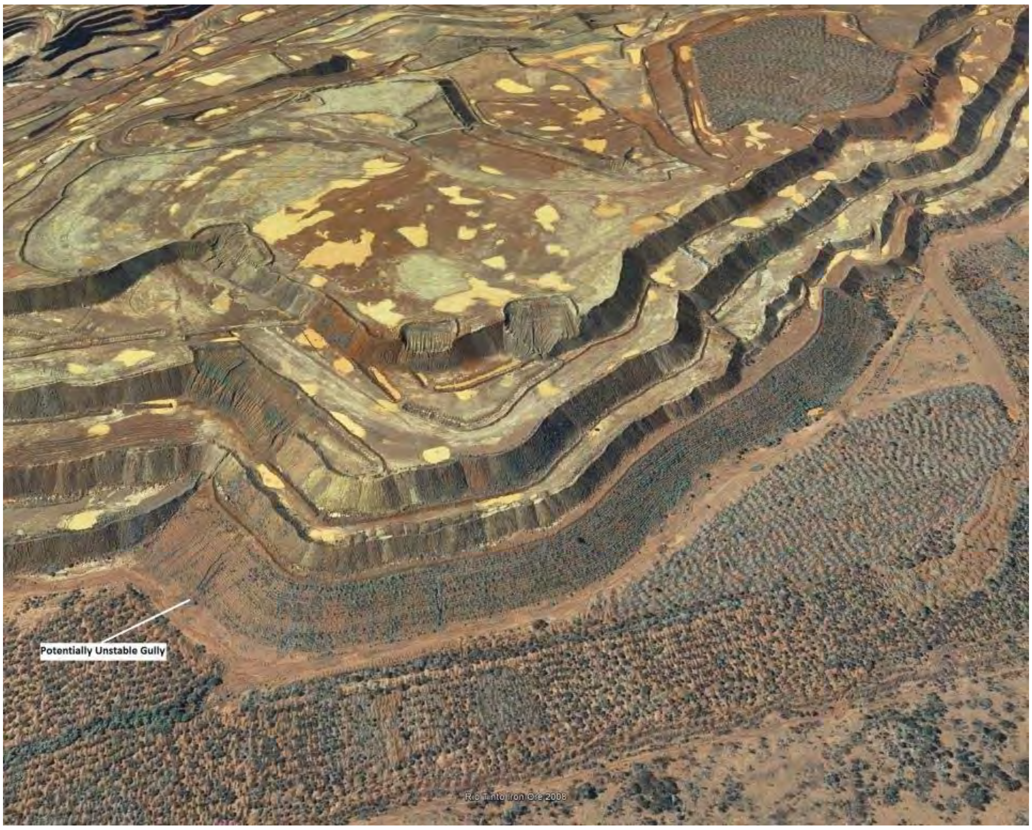

Figure 19: Aerial view of West Angelas Deposit A South Waste Dump

19.2 Management of waste dumps within zones of geotechnical instability

The Deposit A South Dump (Figure 8) and Deposit E South Dump (Figure 9) have minor intersections with the preliminary zone of instability defined by the default method prescribed by the DMP. However, it should be noted that:

- The zone of instability polygons may reduce in size following the outcomes of geotechnical evaluation as the current polygons are derived from default methodology documented in DMP guidelines; and
- Waste material that is stored within these dumps will be utilized to backfill pits to a level that prevents the formation of pit lakes, and the dumps can therefore be reshaped if required to ensure that they are fully outside of the defined zone.
- In addition to these free-standing waste dumps, the Deposit A West Pit North backfill area is effectively a waste dump that has been constructed so as to straddle the pit edge so that half the dump is inside the pit and half is outside of it. The dump itself will therefore provide sufficient buttressing to the pit wall that geotechnical stability in this area is not a significant risk. The area will be rehabilitated as if it were a free-standing waste dump.
- No other current or proposed waste dumps intersect zones of instability around pits, and significant stand-offs have been adopted for recent and future mining areas (Deposits C, D, F and G).
- There is potential for a cutback to occur in the Deposit A pit, which may result the pit moving closer to the South Dump (indeed it is possible that the cutback will extend the pit edge into the current dump footprint). Should this occur then the situation will be re-evaluated and portions of the waste dump removed and returned into the pit if required.

19.3 Management of inadvertent public access

The likelihood of inadvertent public access to the mining area is considered to be low for several reasons:

- West Angelas is situated in a remote location, with no population centres or public roads in the immediate vicinity;
- There are no adjacent pastoral stations or Aboriginal communities;
- The final landform will not contain any features such as pit lakes that would attract visitors;
- All infrastructure is proposed to be removed; and
- Regional topography is rugged from most directions to the site (although less rugged to the west in the direction of Great Northern Highway).

However, it is recognised that there is a possibility of public access if:

- Local cultural heritage sites need to be made accessible to Traditional Owners;
- Roads and tracks to the site are not properly closed; and/or
- Off-road vehicles travel to the site from the west (i.e. from the direction of Great Northern Highway)

Vehicular access to the site is currently via the private West Angelas Access Road, which comes off the public Great Northern Highway and enters the site from a north/northeast direction. The road is approximately 30km in total length, but passes relatively close to Deposit B pits approximately 15km off the public highway. In addition, there is a significant unsealed road leading into the site from the north and numerous tracks in the area.

Although there are currently no significant access routes entering the site from the south or west, several tracks have been installed in these areas to facilitate exploration activities. Terrain is rugged to the south and west of the site, and the potential for alternative vehicular access routes (including off-road vehicles) is limited to current tracks.

In order to mitigate the risk of inadvertent public access, the following conceptual measures are proposed, with details to be agreed with the Department of Mines and Petroleum Resources Safety Division as the site approaches closure:

- Rehabilitation of tracks that are not required for monitoring and/or maintenance post-closure, and installation of physical barriers (e.g. earthen bunds) 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), unless the State wishes the roads to remain accessible for whatever reason; and
- A review of the potential for visitors to inadvertently access the site, and installation of additional control measures, including abandonment bunding around pits, where appropriate.

At this stage there is uncertainty about the precise location of final pit shells for current deposits, and the potential for further unapproved deposits to be developed around those that currently exist. Precise abandonment bund locations have therefore not been proposed, but they will:

- be designed in accordance with the DMP guideline *Safety Bund Walls Around Abandoned Open Pit Mines* unless an alternative design is approved by the DMP;
- be placed outside of the zone of instability around pit walls;
- be constructed with consideration of the implications for local site drainage, and particularly giving consideration to associated impacts to cracking clay ecological communities; and

- be constructed fully around pit edges unless agreement is reached with the DMP that the risk of inadvertent access is sufficiently low in specific areas (e.g. due to natural topography, or due to the presence of barriers in other locations).

Abandonment bunds will be incorporated into the construction design for Deposits C and D, with a view to potentially installing them prior to the commencement of operations. If construction is delayed for whatever reason, their construction will be scheduled in the mine plan.

19.4 Management of fibrous mineral waste

Some isolated occurrences of fibrous material have been intersected at West Angelas, and a larger volume of material has been classified as 'potentially fibrous' based on conservative geological interpretation rather than confirmed occurrence. Control measures are employed during operations to reduce the potential health risk posed by exposure to this material in line with the Iron Ore (WA) Fibrous Minerals Management Plan. Material that is classified as 'designated fibrous' or 'potentially fibrous' is stored preferentially in-pit, but otherwise in ex-pit waste dumps and encapsulated with a minimum of 2m non-fibrous material. It should also be noted that the likelihood of public exposure to fibrous minerals will be further reduced at West Angelas due to its remote location, and the installation of abandonment bunds to prevent inadvertent public access.

No Potentially Hazardous or Designated Hazardous areas are demarcated in pit walls that will form the West Angelas post-mining landform and no geological units identified with a high risk of containing potentially fibrous materials are proposed to be mined in the future.

Potentially fibrous material has been stored in Deposit A North Waste Dump (Figure 20). Detailed rehabilitation designs are currently being developed to support progressive rehabilitation of several faces of the dump in the near future, and will take into account that potentially fibrous material needs to remain encapsulated in the final design.

Deposit B East Waste Dump has also been designated as a storage location for potentially fibrous material in the future, but specific storage locations within the dump are yet to be determined.

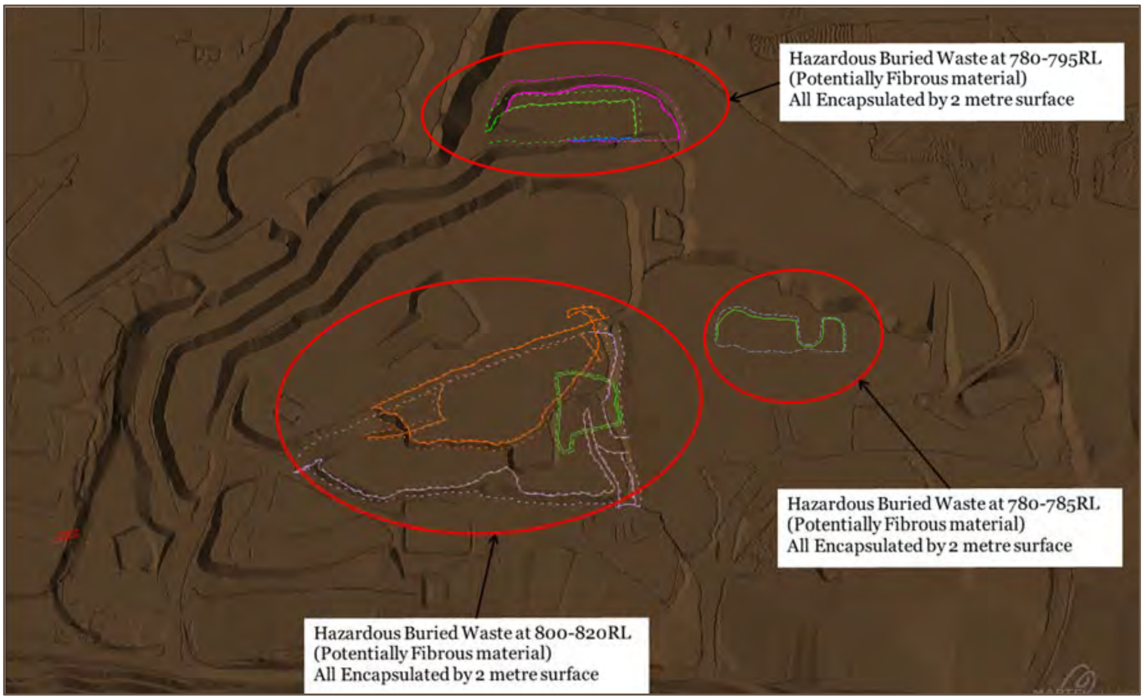

Figure 20: Potentially Fibrous Material Storage at Deposit A North Waste Dump

19.5 Drainage diversion design and management

There are two drainage diversions constructed at the site (Deposit B and Deposit F), and diversions will also be constructed to facilitate mining at Deposit C and D.

19.5.1 Deposit B Diversion

A diversion has been construction for an unnamed ephemeral creek in order to facilitate mining of Deposit B. The original creek location is shown in Figure 21.

In order to avoid capture of flows into the Deposit B pit, a diversion berm has been constructed which directs flows to a diversion channel (Figure 22). The berm and diversion are intended to be permanent structures.

The diversion berm is approximately 320m in length, 200m wide, and has a maximum height of 8.5m. Since the berm is intended to be a permanent structure, and has been designed to contain events up to the 2000 year ARI event. Modelling suggests that the berm would be overtopped during a PMF event, and would need to be raised an additional 3.1m in order to contain such an event. The value of raising the berm to this level will be assessed as the site approaches closure, by which time there should be improved validation of model parameters.

The diversion channel has a base width of 18m, which increases to 23m at the top, and runs for a total length of 2.1km. The channel is relatively wide, which is intended to reduce flow velocities and associated scouring. The channel flows under a haul road, and two 1200mm culverts have been constructed to facilitate this. The haul road and culverts will be removed at closure, but no further closure works are currently proposed. The diversion channel is rock-lined, and rehabilitation is not proposed.

The performance of the channel will be evaluated during operations, and the closure strategy will be reassessed as the site approaches closure.

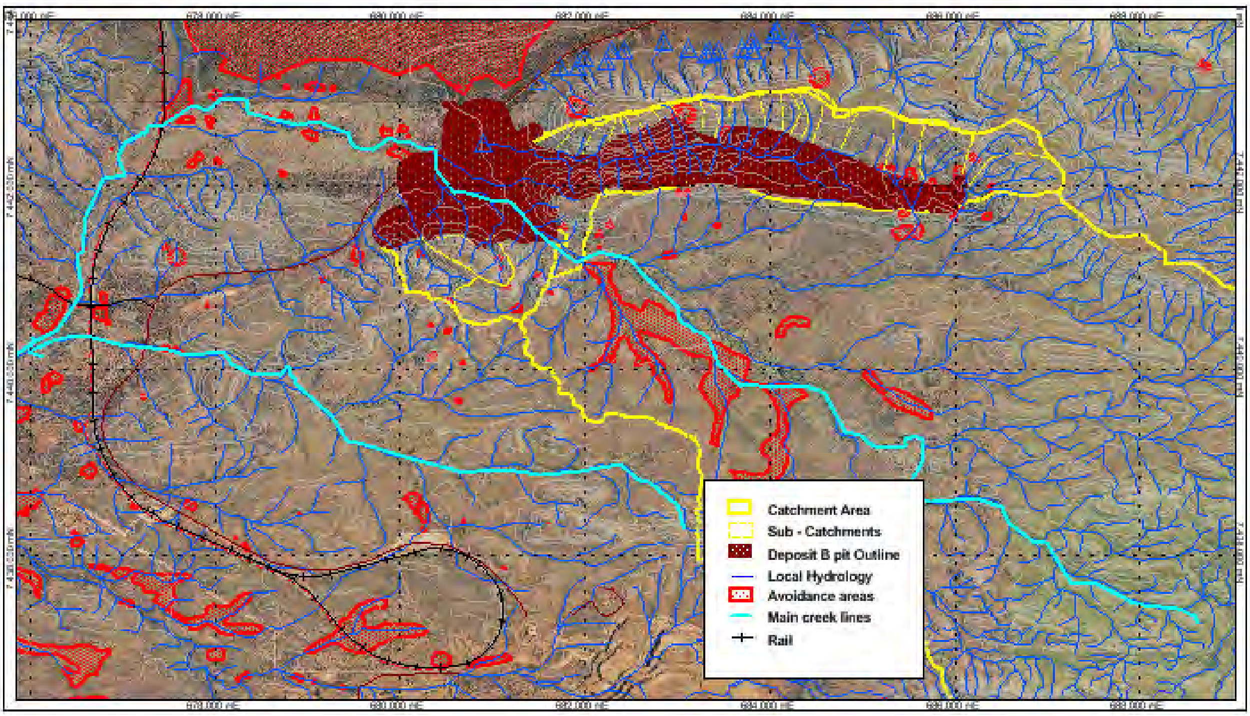

Figure 21: Original location of ephemeral creek impacted by Deposit B development

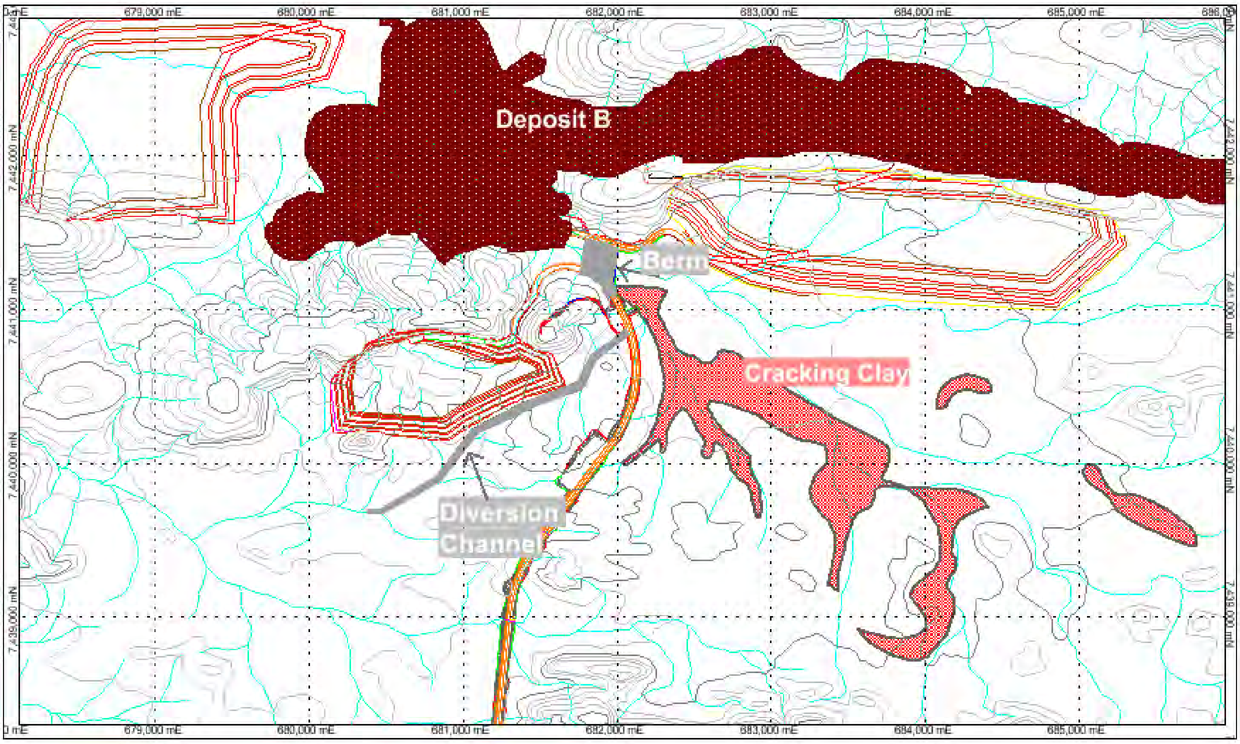

Figure 22: Deposit B diversion berm and channel

19.5.2 Deposit F Diversion

One of the Deposit F pits (F2 pit) intercepts an unnamed ephemeral creek. In order to manage flows, a diversion and levee has been placed upstream of the pit to direct flows eastwards into the Weeli Wolli Creek catchment, as shown on Figure 23.

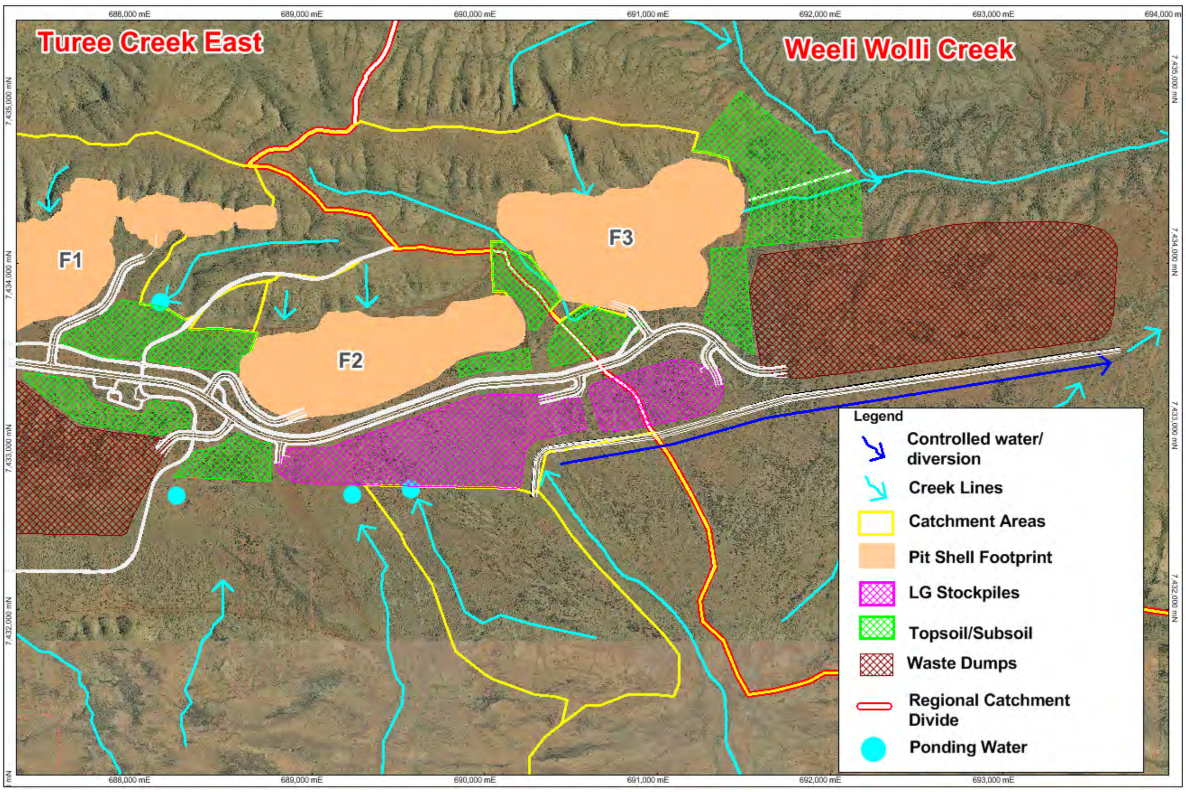

Figure 23: Deposit F diversion

The diversion and levee is 3.4km in length and ranges in height from 3.5m to 5.6m. It is 15m wide at the base, tapering to 3m wide at the top.

Hydraulic modelling indicates that flow velocities in this region are relatively low, not exceeding 2m/s during a 2% AEP flood event. On this basis, the risk of scour and sediment transportation along the alignment is considered low. However, scour protection has been incorporated into the design to provide additional protection to the structure.

The diversion and channel are planned to be retained post-closure.

19.5.3 Deposit C and D Diversion

The Deposit C and D resources have several hydrological risk locations as shown in Figure 24 and Figure 25. Options for managing these risks are still being evaluated, but one or more diversions are expected. Future updates of the closure plan will document final designs and closure strategies.

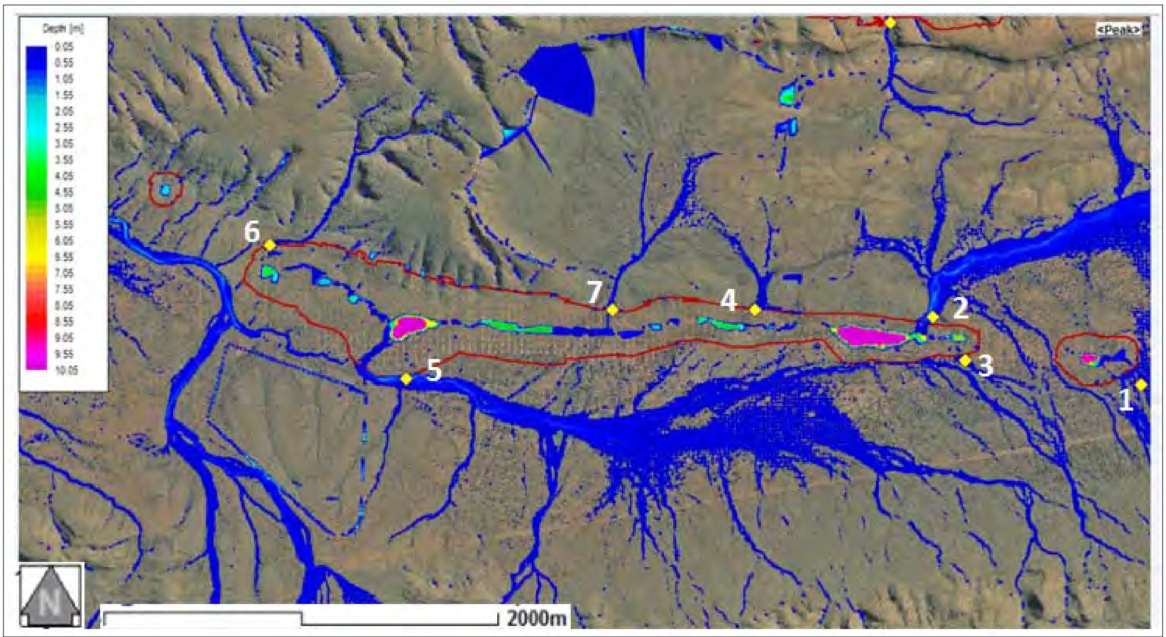

Figure 24: Deposit D hydrological risk locations in a 2% AEP event with no surface water infrastructure.

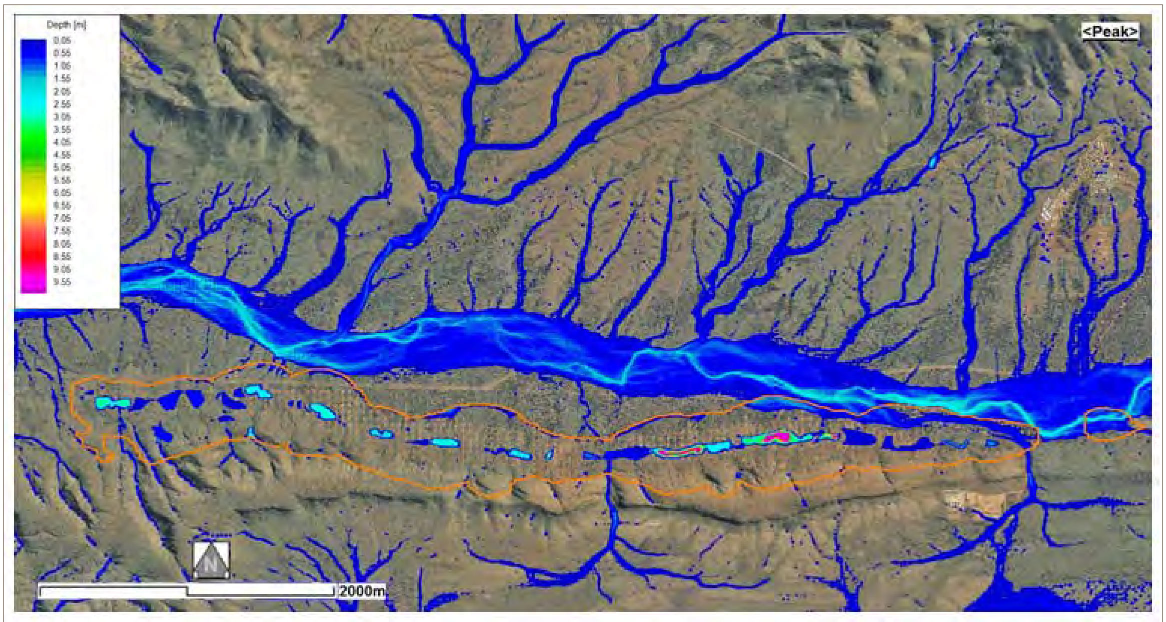

Figure 25: 1% AEP flood extents at Deposit C

19.6 Maintenance of Cracking Clay ecological community values

There are numerous areas of *Themeda* grassland cracking clay Priority Ecological Communities (PEC) at the West Angelas site (Figure 26), in addition to several other cracking clay communities with different vegetation assemblages that have not been listed as PEC.

The PEC areas have been identified as exclusion zones and controls are in place to prevent unapproved direct disturbance during operations and closure. This includes direct disturbance that could occur as waste dump footprints are expanded during rehabilitation in order to create stable landforms.

Notwithstanding controls against direct disturbance of PEC areas, there is the potential for indirect impacts resulting from changes to surface water flow regimes caused through the altered landform. This is a risk that will need to be evaluated when final landscaping profiles have been developed, and passive mitigation measures adopted where appropriate.

Non-PEC cracking clay communities are identified internally as 'restricted' access zones which limits the potential for disturbance, but disturbance is possible from time to time. Preliminary studies have been undertaken to assess the potential for translocating one of these communities to a new location with appropriate drainage characteristics, potentially adjacent to an existing PEC cracking clay area to extend its size.

Studies of the soil profile[10] have shown that there are two clay layers: an upper vertosol cracking clay which overlays a red kandasol structureless clay. Vegetation roots do not appear to be capable of penetrating the kandasol clay layer, and translocation would therefore appear to require collection of the vertosol layer and respreading it onto an impermeable clay layer in the new location (potentially a compacted clay sourced from a different location). Based on the chemical and physical analysis of the vertosol, there are indications that short-term stockpiling of the material should not affect its viability.

A translocation trial will be considered if source material becomes available (i.e. if a new cracking clay area requires disturbance) and an appropriate trial location can be found.

[10] Astron, West Angelas Cracking Clay Study, February 2015

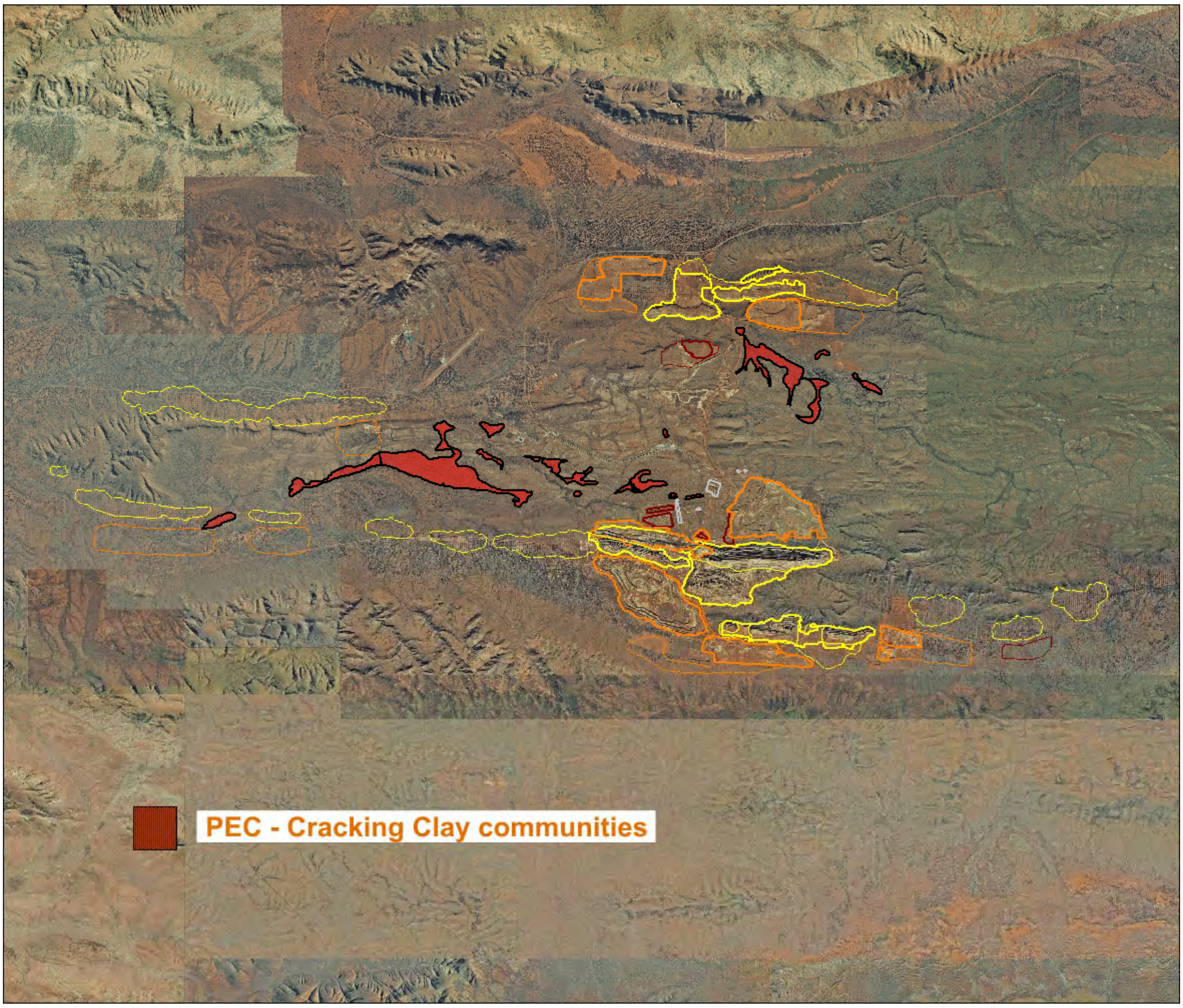

Figure 26: West Angelas Cracking Clay Community Locations

19.7 Groundwater drawdown

Numerical groundwater recovery modelling has been undertaken for Deposits A, B and E. The modelling indicates that recovery will be slow, and that levels will not rebound to pre-mining levels in all locations.

Data presented in previous versions of the closure have assumed that pits will be backfilled to above pre-mining water table levels, as per the key characteristics of the original West Angelas proposal. This was adjusted by the Deposit F and A West expansion proposal, which was assessed on the basis that pits would be backfilled to a level that prevents the formation of a permanent pit lake.

The minimum backfill level that would be required to avoid the formation of a permanent pit lake has not yet been determined, but is expected be a lower elevation than the pre-mining water table as losses of water through evaporation and infiltration are taken into account. There would be some degree of permanent groundwater drawdown around the pit in this scenario, but the spatial extent has not been defined.

The proposed Deposits C and D are closer to Karijini National Park than current mining areas. The results of conservative modelling suggests that the groundwater table may be lowered between 3 to 8m over 100 years post-mining under sections of the Park which contain potentially groundwater dependent ecosystems. However, environmental impact assessment concluded that groundwater would remain accessible to vegetation, and that the change is likely to occur over a significantly long time frame to enable individual plants to successfully adapt. In addition, the conservative nature of the modelling did not allow for localised recharge during the wet season which would mitigate drawdown in the area.

As groundwater in the West Angelas region has limited alternative beneficial use, and significant vegetation in the area (e.g. the Cracking Clay PEC) is not reliant on groundwater, a permanent localised lowering of the groundwater table is not considered to be significant, and closure strategies have not been developed to manage the issue.

If new information arises to elevate the predicted consequence of groundwater drawdown, closure strategies will be explored to actively manage this risk.

20. Actions to address issues and risks

A West Angelas closure risk assessment has been undertaken (Appendix D), resulting in the development of actions to mitigate risk (Table 19).

The risk assessment was conducted using a framework consistent with that provided in the Leading Practice Sustainable Development in Mining Handbook on *Risk Assessment and Management.*[11] A list of threats was compiled with consideration given to all of the potential issues identified in this chapter, and the most serious credible threat scenarios for each issue was identified. Risk assessment assumed that mine operations and closure are implemented in accordance with current strategies, and taking into account the controls already in place to mitigate risk. These were then evaluated using a standard likelihood and consequence matrix, and classified according to the following scale:

- Class IV – the most serious threats that require action
- Class III – serious threats that require active mitigation
- Class II – threats that require monitoring, but not necessarily action
- Class I – threats that do not require action

[11] Department of Industry Tourism and Resources, *Leading Practice Sustainable Development in Mining Handbook: Risk Assessment and Management,* 2008

Table 19: Actions identified to address issues and risks

Risk scenario	Identified mitigation actions	Indicative timing
Fibrous materials are re-exposed post-closure, creating a public health risk	1. Evaluate closure landform designs with respect to managing the potential for exposure/re-exposure of fibrous materials, and incorporate design changes where required.	1. Report progress in next closure plan update
A permanent pit lake forms at the base of a mine void, due to inaccurate groundwater recovery information and/or high surface water flow contribution, and leads to an increase of invasive species	1. Undertake groundwater recovery modelling for all pits	1. Report progress in next closure plan update
Geotechnical failure of a pit wall causes a waste dump to collapse into a pit void, requiring rehabilitation rework after the active post-closure maintenance period	1. Develop rehabilitation designs for waste dumps that are currently located within zones of instability (Deposit A South Dump and Deposit E South Dump) that ensure these dumps are outside the zone of instability	1. Report progress in next closure plan update
Excessive erosion of waste dumps resulting in rehabilitation failure and downstream sediment impacts	1. Develop new rehabilitation designs for existing waste dumps (e.g. Deposit A) that may not have been constructed to readily facilitate stable rehabilitation slopes 2. Undertake further site specific waste characterisation to better define dump erosion potential	1. Report progress in next closure plan update 2. Report progress in next closure plan update
Post-closure access of the mine area leads to a third party injury or fatality	1. Confirm abandonment bund locations and timing of construction	1. Report progress in next closure plan update
Grading of the landscape around cracking clay communities changes surface water flow paths or sedimentation, resulting in impacts to ecosystem health	1. Evaluate the final landform design with respect to the potential for impacts to cracking clay communities 2. Undertake trials to evaluate the potential to translocate cracking clay communities that may be disturbed during operations or post-closure -	1. Defer until the site is approaching closure 2. Undertake when opportunities arise
Landscape and ecosystem changes impact cultural heritage values in the area	1. Investigate the potential for cultural heritage values to be impacted post-closure, and evaluate the implications of impacts if they arise. 2. Develop closure strategies to maintain cultural heritage values 3. Ensure consistency between Cultural Heritage Management Plan and Closure Plan	1. Managed and reported internally through Cultural Heritage Management Plan 2. Managed and reported internally through Cultural Heritage Management Plan 3. Internal action – closure plan will be updated as required

CLOSURE IMPLEMENTATION

Rio Tinto uses closure domains to group areas with common features, 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 as the site approaches closure. The closure measures identified below consider the methods used to manage key risk as discussed in the previous section.

21. Closure domains

Closure domains are used to group areas with common features, rehabilitation and decommissioning requirements. Figure 27 illustrates the closure domains that have been established for West Angelas (noting that Deposit A West and G are conceptual at this stage, and therefore only indicative pit locations are shown). Also note that the current Deposit E East waste dump has not been identified as a closure domain on the basis that it will be consumed by Deposit F West waste dump. West Angelas domains include:

- **Pits**: Includes currently operating, developing or proposed pits associated with Deposits A, A West, B, C, D, E, F and G;
- **Inert waste dumps**: Includes inert external waste dumps and long term low grade material stockpiles that are not currently planned to be utilised in processing;
- **Fibrous waste dumps**: Includes external waste dumps that contain designated or potentially fibrous mineral waste;
- **Landfill**: Refers to site putrescible landfill including general waste;
- **Diversions**: Refers to surface water diversions that have been constructed to facilitate mining;
- **Infrastructure:** Refers to areas where items of infrastructure are located (not shown in Figure 27);
- **Disturbed areas**: All areas of disturbance that are not categorised by any of the above landform domain categories (not shown in the Figure 27). This domain has been broken down into ‘high disturbance’, ‘moderate disturbance’ and ‘low disturbance’ sub-domains, based on the amount of earthworks that will be required during final landscaping, to allow for more accurate closure cost estimation.

22. Closure implementation strategies

Proposed closure strategies for each of the closure domains are included in Table 20.

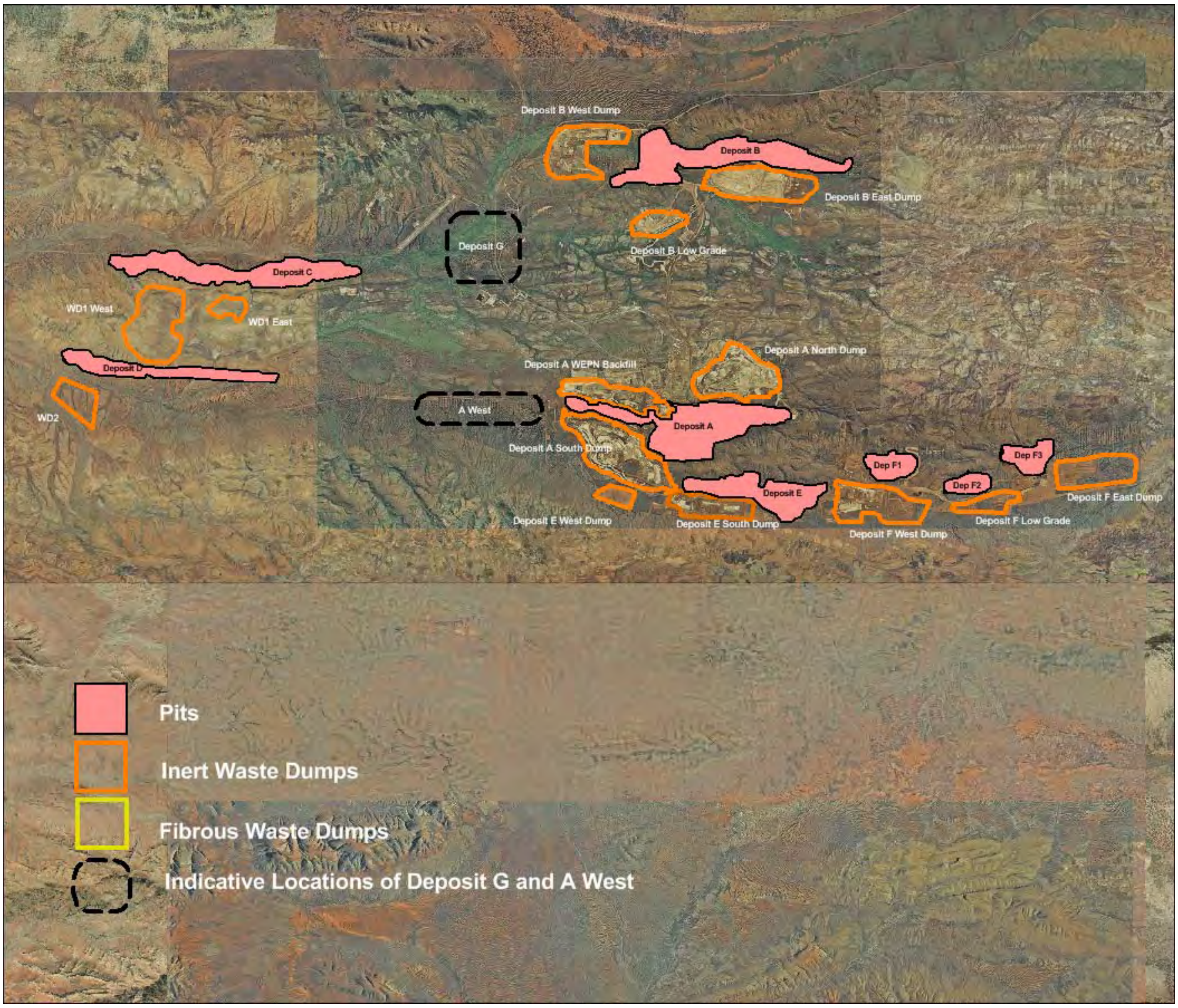

Figure 27: West Angelas closure domains (pits and waste dumps only)

Table 20: West Angelas general area implementation strategies by closure domain.

Domain	Area	Closure measures
Pits	All deposits and internal backfill areas, with the exception of Deposit A West Pit North backfill	1. Backfill pit to at least 2m above the long-term predicted groundwater recovery level. Minimum backfill levels for Deposits A, B and E are presented below (although these levels may be reduced depending on the outcomes of refined groundwater recovery modelling), with other pits to be ascertained once groundwater recovery modelling is complete: • Deposit A CEPN: 612 mRL • Deposit A CEPS: 632 mRL • Deposit B1: 609 mRL • Deposit B2 and B3: 628 mRL • Deposit E: 652 mRL • Backfill level in other pits yet to be confirmed 2. Install abandonment bunds around pit perimeters if this is recommended following a review of public safety risks. 3. No further rehabilitation will be conducted within pit voids unless the backfill level is within 10m of the ground surface.
Free standing inert waste dumps	Deposit A South WD Deposit A West Pit North backfill Deposit B Low Grade Deposit C&D WD Deposit D WD Deposit E South WD Deposit E West WD Deposit F West WD Deposit F Low Grade Deposit F East WD	1. Waste dump construction and rehabilitation design specifications are presented in Appendix E, noting that design specifications are currently under review. 2. Hydrated material, which is known to be a low erodibility material, is being stockpiled for use as a capping layer on waste dump slopes where required. 3. Apply a 200mm layer of topsoil (or subsoil where topsoil is unavailable). 4. Deep rip the surface on the contour and seed using appropriate native species.
Fibrous waste dumps	Deposit A North WD Deposit B East WD	1. Segregation and encapsulation of fibrous material 2. Reshaping outer slopes to appropriate angles/profiles based on design criteria suitable for waste type 3. Application of subsoil/topsoil 4. Rip and seed using appropriate native species.
Landfill	Landfill	1. Cap landfill with a layer of inert material to a minimum thickness of 2 metres 2. Rehabilitate final surface in accordance with standard procedures (as per infrastructure areas)
Diversions	Deposit B diversion Deposit F diversion Deposit C diversions Deposit D diversions	1. As a general rule, where a drainage line has been diverted to facilitate mining activity, no attempt will be made to restore the original drainage configuration. Rehabilitation will be in accordance with the information presented in Section 19.5.

Domain	Area	Closure measures
Other areas of disturbance	Areas of disturbance that are not captured by any of the above domain classifications, including infrastructure areas	1. Retain or remove infrastructure in accordance with State Agreement requirements 2. Undertake contaminated sites evaluation and clean up if required 3. Where infrastructure requires removal, remove all structures and footings that is above surface or within 1m of the final land surface 4. Drain pipelines and remove hazardous materials (from pipelines and elsewhere across the site) in accordance with Controlled Waste Regulations 5. Actively seek reuse and recycling opportunities for decommissioned infrastructure 6. Dispose of inert materials are not retained, reused or recycled in an inert landfill area (may be a used pit area) and then cap with at least 2 metres of inert material 7. Where linear infrastructure is removed, reinstate drainage lines where appropriate 8. Rehabilitate final surface in accordance with standard procedures, which includes: o add a layer of topsoil where available and appropriate o deep rip the surface where required to address compaction o revegetate with an appropriate mix of species of local provenance

23. Unexpected closure

The closure implementation schedule may be influenced by factors outside of the current mine plan. These factors include:

- suspension of operations under care and maintenance; this could occur if production costs exceed product value e.g. due to commodity price changes;
- unexpected closure; this could occur if there was major change in global demand for iron ore; and
- future proposals; these could occur if iron ore deposits of appropriate quality are identified adjacent to the existing deposits.

23.1 Temporary care and maintenance

In the event of temporary closure, measures will be undertaken to transfer the site from operations into a care and maintenance regime and relevant authorities notified. A care and maintenance plan will be developed prior to the care and maintenance period which demonstrates how on-going environmental obligations associated with the site will continue to be met during the period of care and maintenance.

23.2 Early permanent closure

Whilst Robe considers the risk of unexpected closure to be minimal, there are numerous factors that could force early closure of one or several sites. Even if some level of contraction were to occur, it is reasonable to assume that the company would continue to operate in the Pilbara and that it could continue to manage closure of its sites. It should be noted that Robe is one group within the global Rio Tinto group of companies, which further mitigates this risk.

The West Angelas closure plan will naturally become more detailed as time progresses, but may not be of sufficient detail to facilitate closure implementation if the site closes unexpectedly. This would be the case particularly if the proposed closure strategies rely on the full mining sequence, and need to be revised accordingly. If sudden and unexpected closure occurs, the site would effectively be placed on a period of care and maintenance whilst studies and plans are developed to facilitate effective closure implementation. Final completion criteria would also be agreed with stakeholders during this period. Closure could be expected to be delayed by several years if production ceases unexpectedly.

Notwithstanding this, the most likely early closure scenario would involve a decision to cease production made several years in advance of the event, which would provide time for the closure plan to be updated sufficiently to facilitate more timely closure implementation.

CLOSURE MONITORING AND MAINTENANCE

24. Closure monitoring program

The primary purpose of closure monitoring is to assess whether closure objectives have been met for West Angelas. 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.

24.1 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 until either:
    - o There is a demonstration that closure objectives have been met and that the site is able to be relinquished; or
    - o Parameters being monitored reach a steady state.

This plan considers pre-closure, closure and post-closure monitoring.

24.2 Indicative monitoring program

The monitoring program will be finalised during development of a Final Decommissioning Plan as the site approaches closure. Specific and appropriate monitoring will be conducted to ensure data is obtained to allow assessment of performance against completion criteria (Section 8).

The monitoring programme is likely to contain specific monitoring of the following key areas, as a minimum.

24.2.1 Rehabilitation monitoring

The purpose of the rehabilitation monitoring program is to evaluate successional development of rehabilitation areas and thereby provide useful feedback for the improvement of rehabilitation techniques, and to help assess progress towards long term rehabilitation objectives.

Rehabilitation monitoring also provides vital information which can be used to set realistic and achievable completion criteria. This can be achieved by examining changes in key parameters over time, and by comparing results from the rehabilitation with those from corresponding reference sites. Reference sites, also known as Controls or Analogues, are positioned within local areas of uncleared native vegetation.

Rehabilitation monitoring occurs on a scheduled basis, aimed at establishing trends for the locations return to self-sustaining status. The rehabilitation development is compared to the reference site values. Data analysis is undertaken to assess progress towards an acceptable outcome and a report produced to document findings.

24.2.2 Water monitoring

Water monitoring during closure will focus on confirming groundwater recovery and pit lake modelling predictions, and identification of any AMD issues. A specific program of monitoring will be developed prior to decommissioning.

24.3 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.

25. Post-closure maintenance

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

FINANCIAL PROVISION 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.

26. 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:

- a 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; and
- a 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[12]:

- decommissioning (ie removal of infrastructure)[13];
- final landform construction;
- rehabilitation and biodiversity management;
- heritage management;
- workforce management (ie training costs and redundancy payments)[14];
- monitoring costs;
- costs associated with updating the closure plan to facilitate effective closure implementation;
- costs associated with undertaking a final shutdown of operations;
- 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.

27. 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[15]. 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 each site is revised on an annual basis to account for incremental mine development during the year. The TPC estimate is revised whenever a formal closure plan review is conducted (usually 3-yearly) to capture

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

[13] 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.

[14] Workforce management costs have only been included in the TPC.

[15] The level of accuracy applied to Rio Tinto iron ore 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%.

any changes to life of mine design. As part of Rio Tinto assurance processes these costs are audited by external financial auditors annually to ensure adequate closure provisions are maintained.

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

MANAGEMENT OF INFORMATION AND DATA

28. Data and information management

28.1 Iron Ore Document Management System (IODMS)

Rio Tinto operates a comprehensive document management system, with electronic records of all key information and data. The document system, known as Iron Ore Document Management System (**IODMS**) 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 IODMS to ensure that it is appropriately retained post-closure.

28.2 Closure knowledge base

The closure knowledge database 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.

28.3 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;
- 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.

28.4 Legal and other requirements system

The Legal and Other Requirements System (LAORS) is used by Rio Tinto to manage the following:

- Approval and Legislation Reports which provide a high level snapshot of approvals and legislation and is used to check the status and expiry dates of approvals.
- Approval and Legislative Requirements Reports which lists
    - accountabilities for specific conditions within approvals and clauses within legislation;
    - required actions to comply with approvals and or legislation; and
    - due dates for specific requirements.
- Statutory Position Appointed Persons reports which list individuals appointed to a statutory position.

- Statutory Position Accountabilities Reports which identify clauses of legislation that the statutory position is accountable for.

This information is used to track legal requirements associated with closure and will be maintained during closure activities to ensure all requirements and obligations are met.

APPENDIX A – REGISTER OF KEY CLOSURE OBLIGATIONS

WEST ANGELAS CLOSURE OBLIGATIONS REGISTER

Legal Obligations

Ministerial Statement 970	
Condition No.	**Closure conditions**
9-1	The proponent shall ensure that the mine is closed, decommissioned and rehabilitated in an ecologically sustainable manner, consistent with agreed post-mining outcomes and land uses, and without unacceptable liability to the State of Western Australia.
9-2	The proponent shall prepare a Mine Closure Plan for the West Angelas Iron Ore Project
9-3	The Mine Closure Plan required by condition 9-2 shall: (1) when implemented, manage the implementation of the proposal to meet the requirements of condition 9-1; (2) be prepared in accordance with the *Guidelines for Preparing Mine Closure Plans, June 2011* (Department of Mines and Petroleum and Environmental Proection Authority) or its revisions; and (3) be to the requirements of the CEO on advice from the Department of Mines and Petroleum.
9-4	Within 12 months of commissioning of additional mine pits or as otherwise agreed by the CEO the proponent shall implement the approved Mine Closure Plan and continue implementation until otherwise agreed by the CEO.
9-5	Revisions to the Mine Closure Plan may be approved by the CEO on the advice of the Department of Mines and Petroleum.
9-6	The proponent shall implement revisions of the Mine Closure Plan required by condition 9-5.

Mining Act 1978	
Tenement No. G47/1235	
Condition No.	**Closure conditions**
12	(The lease is issued subject to) 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	(The lease is issued subject to) at the completion of operations or progressively where possible, all access roads and other disturbed areas to be covered with topsoil, deep ripped and revegetated with local native grasses, shrubs and trees to the satisfaction of the Executive Director, Environment Division, DMP.

Tenement No. G47/1236

Condition No.	Closure conditions
13	(The lease is issued subject to) 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.
16	(The lease is issued subject to) at the completion of operations or progressively where possible, all access roads and other disturbed areas to be covered with topsoil, deep ripped and revegetated with local native grasses, shrubs and trees to the satisfaction of the Executive Director, Environment Division, DMP.

Tenement No. L47/41	
Condition No.	**Closure conditions**
13	On the completion of the life of mining operations in relation to Miscellaneous Licence 47/71 the holder shall: - remove all installations constructed pursuant to this licence; - cover over all wells and holes in the ground to such degree of safety as shall be determined by the Inspector; and - on such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Inspector and properly maintain same until the Inspector advises regrowth is self supporting. Unless the Mining Registrar/Warden or Minister for Mines orders or consents otherwise.

Tenement No. L47/52	
Condition No.	**Closure conditions**
11	(The lease is issued subject to) 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 where 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 outcome agreed to the satisfaction of the Executive Director, Environment Division, DMP.

Tenement No. L47/53	
Condition No.	**Closure conditions**

Iron Ore (Robe River) Agreement Act 1964	
Clause No.	**Closure obligations**
10 (e)	The parties agree with each other as follows: that on the cessation or determination of any lease license or easement granted hereunder by the State to the Company… the improvements and things erected on the relevant land and provided for in connection therewith other than plant and equipment shall remain or become the absolute property of the State without compensation and freed and discharged from all mortgages and encumbrances and the Company will do and execute such documents and things (including surrenders) as the State may reasonably require to give effect to this projection. In the event of the Company immediately prior to such expiration or determination or subsequent thereto deciding to remove its locomotives rolling stock plant and equipment or any of them from any land it shall not do so without first notifying the State in writing of its decision and thereby granting to the State the right or option exercisable within three months thereafter to purchase at valuation in situ the said plant and equipment or any of them. Such valuation shall be mutually agreed or in default of agreement shall be made by such competent valuer as the parties may appoint or failing agreement as to such appointment then by two competent valuers one to be appointed by each party or by an umpire appointed by such valuers should they fail to agree.

Relevant Legislation

Closure planning and implementation requires consideration of general legislative requirements beyond those that apply to a specific site. A list of potentially relevant legislation is provided below, but is not necessarily exhaustive. A comprehensive legal review will be required as closure approaches to ensure that all relevant legislative requirements are identified.

Australian Commonwealth Legislation

Environmental Protection and Biodiversity Conservation Act 1999
Native Title Act 1993
Aboriginal and Torres Strait Islander Heritage Protection Act 1984
Workplace Relations Act 1996

Western Australian State Legislation

Environmental Protection Act 1986
Environmental Protection Regulations 1987
Environmental Protection (Controlled Waste) Regulations 2004
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

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 (2015)	Western Australian Department of Mines and Petroleum and Environmental Protection Authority
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

APPENDIX B – COMMUNICATIONS REGISTER

West Angelas Closure Plan
Consultation Register

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
West Angelas Deposits A and B Environmental Review and Management Program	Summary of consultation outcomes arising from the ERMP (1999)	EPA advice provided for the Deposit A and B referral (relevant to closure) requested: - location and design of waste dumps have no impact on vegetation with high conservation value or cracking clay areas; - original drainage patterns be restored; and - supports the commitment to pit infilling required to prevent evaporation of groundwater bround to the surface by capillary rise in the soil cover.	Robe integrated these requests into its (then) Decommissioning and Rehabilitation Plan, which has since been superseded by this document.
West Angelas Deposit E development proposal	Summary of consultation outcomes arising from the proposal (which was not formally assessed by the EPA)	CALM avised that the mulga in the Deposit E area is significant	Internal approval processes are required for each parcel of new footprint disturbed, and impacts to areas of environmental significance (e.g. mulga communities) are considered in this process.
Update of MS514	EPA (October 2013)	EPA proposed the addition of a condition on MS514 requiring submission of a closure plan, and requested removal of Section 8.9 (Closure and Rehabilitation Mgt Plan) from the EMP to avoid duplication	The EMP no longer contains a section on Closure and Rehabilitation, as this is now addressed by this document.

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
West Angelas Deposit F and A West Referral	DMP (July 2014)	RTIO met with the DMP to discuss various aspects of the proposal to develop Deposits F and A West (which had already been submitted to the OEPA Compliance and Assessment Division to comply with Condition 9 of Ministerial Statement 970). Concerns raised by the DMP included: 1. Erosion of the toe of surface water diversion structures resulting in design failures 2. Questions about whether the Deposit A South waste dump was located within the geotechnical zone of instability 3. Abandonment bunds will be required outside the zone of instability 4. The whole site would need to comply with current standards rather than the standards that may have applied at the time that the site commenced operation 5. Any pit lakes would need to be conisdered in light of the minimum expectation of landforms being safe and stable - given that there would be increased access to a pit lake, expectations are likley to be higher than for a dry pit void. Furthermore, safe egress would need to be considered. 6. Safe access to heritage sites that have the potential to be accessed post-closure would need to be considered.	1. Not considered in this update of the closure plan, but diversion designs (when developed) will consider erosion controls and be presented in future updates of the closure plan. 2. Addressed in this closure plan 3. Noted. The precise location of abandonment bunds will be determined in consultation with the DMP, and be presented in future updates of the closure plan. 4. Noted. 5. Noted. Pit lakes are not currently planned. 6. Not considered in this update of the closure plan, but plans to provide safe access to heritage sites (where appropriate) will be presented in future updates of the closure plan.

West Angelas Closure Plan
Consultation Register

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
OEPA Response to July 2014 closure plan	OEPA (November 2014)	The OEPA advised that it had sought advice on the July 2014 closure plan from the DMP, and that it could not be approved until nine comments had been addressed: 1. Demonstration of a risk analysis process 2. Specificity of management controls 3. Inclusions of rehabilitation designs for the Deposit B long term low grade stockpile 4. Consultation with the DMP 5. Given that the site is on vacant crown land close to Karajini National Park, the return of a native ecosystem would be supported, and acceptance of pastoralism as a final land use would require consultation with relevant stakeholders. 6. Closure objectives do not encompass all aspects of the site. 7. Waste dumps appear to be within the zone of instability around pits 8. Consultation with the DoW 9. Completion criteria do not address all aspects of the site. A compliance date of December 2015 was provided to address these concerns.	Consultation was conducted on 11 February 2015 (see record below) to discuss these issues.

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
Discussion of OEPA Response to July 2014 Closure Plan	DMP (11 February 2015)	A meeting was held with the DMP to discuss the points raised in the November 2014 OEPA correspondence (see above). As a general comment, the DMP advised that it had not recommended for the closure plan to not be approved, but had advised that there were several improvements that should be addressed in the next closure update. With respect to each of the nine concerns raised: 1. Risk assessment: accepted by Rio Tinto with no further discussion 2. Management controls: DMP indicated that this concern related specifically to the absence of specific waste dump rehabilitation design information in the Implementation section of the closure plan, and reliance of adherence to Landform Design Guidelines without explanation of how these would be specifically applied. 3. Long Term low grade stockpiles: accepted by Rio Tinto 4. DMP consultation: DMP indicated that it was generally comfortable with the level of consultation undertaken by Rio Tinto in relation to closure planning. 5. Final land use: accepted by Rio Tinto 6. Closure objectives: DMP indicated that this concern related specifically to a failure to clearly articulate in the closure objectives that the site would meet the Department's minimum expectation of safe, stable and non-polluting landforms. 7. Zones of instability: accepted by Rio Tinto. The DMP inidicated that it may accept waste dumps within the zone of instability of a pit, but that this would need to be approved on a case by case basis. 8. Consultation with the DoW: accepted by Rio Tinto.	1. A risk assessment has been conducted and is appended to this closure plan. 2. Waste dump construction, design and rehabilitation implementation information is presented in the Implementation section 3. Waste dump data sheets, including low grade stockpiles, are appended to this closure plan. 4. DMP consultation has been undertaken and is discussed in this register. 5. Pastoral activity is no longer discussed as a potential final land use. 6. Rio Tinto has re-evaluated its approach to objectives and criteria over the past several years, and the outcomes are presented in this closure plan. 7. Zones of instablity are discussed in the Identification and Management of Closure Issues section of this closure plan. 8. DoW consultation has been undertaken and is discussed in this register. 9. Rio Tinto has re-evaluated its approach to objectives and criteria over the past several years, and the outcomes are presented in this closure plan.

West Angelas Closure Plan

Consultation Register

Consultation Stage	Stakeholder & Date	Summary of discussion relevant to closure	Response
DMP Environment Division Inspection	DMP (14 July 2015)	DMP Environment Division undertook an inspection of the West Angelas mine on 14 July 2015. The following points relevant to closure were raised in the corresponding inspection report: 1. The backfilled portion of open cut pits such as Deposit A requires progressive rehabilitation. This is to enable the land to become a self sustaining ecosystem therefore meeting closure objectives of safe stable and non-polluting landform. 2. The establishment of abandonment and pit safety bunds is recommended to be installed in early stages of pit development as it will be easier to implement in regards to gaining access. 3. Rehabilitation of south west dump bottom lift trial was progressing well, and it appears that species diversity and cover is abundant. Rehabilitation of East Dump also appeared to be progressing well with abundant native plant diversity.	The EMP no longer contains a section on Closure and Rehabilitation, as this is now addressed by this document.
Pre-referral consultation regarding the Deposit CDG proposal	DoW (15 November 2016)	Various stakeholders were consulted prior to submission of environmental referral. Whilst a number of issues were raised, the only issues with direct relevance to closure were raised by the DoW. 1. Concern was raised about the ability to restore the natural groundwater regime at closure, particularly with removal of the dolerite dyke structure through Deposit C. 2. The DoW sought to understand the closure strategy for the proposed diversion of Turee Creek East tributary.	1. The water level at Deposit C3 is higher (~636mRL) than that observed at Deposit C2 to the west (~624mRL). The dyke is assumed to form a groundwater divide between Deposits C2 and C3 and its removal is expected to result in level equilibrating, with a permanent reduction at C3. Groundwater level reductions may extend for an undetermined distance to the east. The impact of this is not expected to be significant and no attempt to restore levels will be made. The proposal is based on the assumption that there may be a long term reduction in groundwater levels of up to 8m at a location within Karijini National Park which hosts a potential groundwater dependent ecosystem. Studies suggest this will not be environmentally significant. 2. Specific designs are yet to be finalised, but the diversion is intended to be permanent.

APPENDIX C – CLOSURE KNOWLEDGE DATABASE

Rio Tinto West Angelas 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).

CONFIDENTIAL

Geochemical characterisation

Acid Generating Potential, Selected Core Samples Mt Newman Member BIF, West Angeles Deposit A Open Pit — **1988**

A preliminary assessment of the potential for the generation of acid drainage was undertaken on banded iron formation samples from West Angeles Deposit A open pit.

Internal reference: RTIO-PDE-0030854

Only one of the five samples was determine to have acid generating potential. Three of the samples tested contained reactive carbonates.

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

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.

Internal reference: RTIO-PDE-0021130

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.

Geochemical Characterisation of Paraburdoo Lens 2, Tom Price North Deposit Dales Gorge and West Angelas Samples — **2008**

A geochemical assessment was undertaken on samples from Paraburdoo, Dales Gorge and West Angelas to determine acid generating potential, oxidation rates and leachable contaminants.

Internal reference: RTIO-PDE-0034616

Seven of eight West Angelas (Deposit A) samples studied were classified as potentially acid forming. In samples of banded iron formation and/or shale lithologies from the three mine sites C, S, As, Au, Bi, Mo, Sb, Se, Sn were enriched. Only Mo and Se were readily leachable.

Mineralogical Analysis of Potentially Acid Forming Materials — **2008**

Quantitative mineralogy (QEM-Scan) for samples of rock collected from Tom Price, Channar, West Angelas, Brockman, Paraburdoo, 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.

Internal reference: RTIO-PDE-0053725

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.

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

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

Internal reference: RTIO-PDE-0051613

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.

West Angelas ARD and Geochemical Risk Assessment **2010**

Risk associated with acid rock drainage in the current, possible and future deposits at the West Angelas project area have been investigated.

Internal reference: RTIO-PDE-0052917

Deposit C and G pose low-nil risk of acid and metalliferous drainage. Deposit A, E and F poses a low risk. Deposit D a moderate to low risk and Deposit B a moderate risk. High risks have been classified for WA6 Area (southern West Angelas project area) WA7 Area (northwest of West Angelas project area), WA8 Area (west of Deposit A), WA9 Area (west of Deposit A) and Angelo River.

Contaminant Leaching from Non-Sulfidic Waste Material **2011**

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.

Internal reference: RTIO-HSE-0145041

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**

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

Internal reference: RTIO-PDE-0103857

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**

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.

Internal reference: RTIO-PDE-0090689

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.

West Angelas Deposit B AMD Risk Ranking July 2012 **2012**

Memo regarding review and update of the 2008 West Angelas deposit B AMD risk assessment and ranking.

Internal reference:

The risk assessment (Terrusi 2008) indicated that the rocks from Deposit B were enriched in As and Fe and elevated in Sn for most strand-tag groups, with Cr, Mn and Pb elevated in some others. It is unlikely that these elements will mobilise under neutral conditions as demonstrated by Brown (2012). The overall AMD hazard score for West Angelas Deposit B is Moderate. One of the largest contributors to the Moderate risk rating is around surface water management. Currently there is a significant creek line that is located where the proposed Deposit B pit is located. Diversions are recommended to control the surface water from entering the pit or mobilising salts from the pit wall that would reduce the chance of contaminants from polluting the surrounding environment. If the diversion is implemented the AMD risk rating for the deposit would become low.

Geochemical Assessment of Samples from West Angelas Deposits, B, D and A West **2013**

Internal reference: RTIO-PDE-0120532

Report summarising geochemical testing of samples from West Angelas deposits B, D and A west for the purpose of; determining acid forming characteristics of waste rock, provide a preliminary assessment of the likelihood of occurrence of potentially acid forming rock types, assess the reactivity of any sulphide mineralisation to provide estimates of geochemical behaviour and lag times for acidification, identify element enrichments that could be environmentally significant and assess mobilisation of elements, provide recommendation for kinetic testing.

Testing has been conducted on seven different waste rock types from two deposits of the West Angelas Mine and indicates that 79% of the samples have a low total S content and 71% have a low acid neutralising capacity (ANC). About two thirds of the samples (66%) were NAPP negative and one third (34%) were NAPP positive.Sulphur speciation testing indicated that for all but one of the samples selected, the majority of the sulphur occurs in non-acid generating forms. Results suggested that the total S content of samples from West Angela Mine cannot be used reliably as criteria for identifying PAF material types at the West Angela Mine. Materials represented by the samples may have elevated concentrations of As, Be, Fe, S, Tl and V, however, the solubility of most of these elements at circum-neutral pH was low for the samples that were tested. Overall, 92% of the samples are classified as barren or non-acid forming (NAF) and 8% potentially acid forming (PAF or PAF-LC).

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.

Greater West Angelas AMD Risk Assessment **2014**

Internal reference: RTIO-PDE-0120775

The acid and metalliferous drainage (AMD) risk assessment for the West Angelas deposits has been updated from an assessment completed in June 2008. This current assessment takes into account total sulfur concentrations within rock types, considering recent drillhole data associated with the greater West Angelas area and individually within the currently available final pit shells. Logging data and the samples location with respect to the water table was used to indicate whether sulfur is in the form of sulfide or sulfate minerals. Geochemical data is also assessed to identify enriched elemental concentrations which may pose an environmental risk. This data, along with site specific baseline information, can be used to generate a conceptual site model to describe mechanisms by which acid and metals/metalloids may mobilise and interact with environmental receptors.

AMD risks for all deposits are low, based on the current pit designs. Although pyrite has been visually identified in drillhole samples, no pyrite samples are located within the current proposed pit shells. The sulfur associated with elevated-sulfur samples are likely to be associated with sulfate minerals including gypsum which will not generate acid, or alunite which has the potential for relavitely low levels of acid release from elevated-sulfate samples. The low solubility of alunite means that only a low flux of acid (and contaminant) release. Fe, As and Sn, as well as Co, Cr, Cu, Mn, Ni, Pb and Zn have been identified as being enriched in West Angelas deposits and should be monitored in groundwater.

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.

Greater West Angelas Risk Assessment **2016**

Internal reference: RTIO-PDE-0120775

The West Angelas AMD risk assessment was updated to incorporate proposed Deposits C, D and G and Angelo River

Deposits C, D and G were assessed to have a low AMD risk. The Angelo River deposit was assessed to be a low-moderate AMD risk, based largely on the size of the deposit. <1% of samples in all deposits had sulfur concentrations about 0.3%, and those above this threshold are assumed to result from sulfates.

Physical characterisation

Field rainfall simulator and overland flow study of waste and topsoil erodibility - Nammuldi and West Angelas Mines - Pilbara Iron

2006

This study was carried out to assess the erodibility of dominat wastes and topsoils on Nammuldi and West Angelas mine sites, to provide a basis for the design of stable landforms for rehabilitation. To determine the erodiblity of materials, simulated rain and overland flows were applied to experimental plots, and measurements made of runoff and sediment in runoff. Erodibility parameters for the WEPP runoff/erosion model were derived from the data, and the model was run using 100-year climate files.

Internal reference:
RTIO-HSE-0036709

Several of the West Angelas materials (two wastes, one topsoil) showed a degree of similarity. For those three materials, it appears that - if linear batter slopes are constructed - the maximum landform height likely to be stable is 20 m. If it is essential that waste dumps be constructed to a greater height, then concave profiles and rock armouring could enable a significant increase in landform height. If such options are likely to be requried, forward planning (including sourcing and stockpiling competent rock) would be advisable. The other material studied at West Angelas (low grade fines from the Roche crushing plant) would only give a 10 m high linear batter slope of acceptable stability, and will clearly need to be covered with more erosion-resistant material if batter slopes higher than 10 m are to be rehabilitated.

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

2014

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.

Internal reference:
RTIO-PDE-0128431

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.

Growth Media Characterisation

2016

This study was undertaken to interpret material characterisation data from 53 samples and their review their potentials as growth mediums.

Internal reference:
RTIO-HSE-0298702

53 samples were assessed has been classified as ‘suitable’ or ‘not suitable’ for use as a growth medium. This report should be used as a guide to assist in selecting materials that can be considered for use in rehabilitation activities, provide that these other factors are also included as part of the rehabilitation plan. Several materials have properties that were invariably suitable. In some cases, materials have some properties that are suitable and others unsuitable. In others, serval 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.

Groundwater

West Angelas Deposit D Hydrogeological Conceptual Model Report

2015

This report describes a conceptual hydrogoeological model for West Angelas Deposit D.

Internal reference:
RTIO-PDE-0135949

The aquifer at Deposit C is principally associated with the mineralised section of the Mount Newman Member of the Marra Mamba Iron Formation as well as the overlying Wittenoom Formation. The groundwater gradient is relatively flat across the area, with the groundwater flow direction to the west. Due to the depth to groundwater, as well as the thickness of clayey detritals, it is expected that rainfall recharge will be low.

West Angelas Deposit C Hydrogeological Conceptual Model Report

2015

This report describes a conceptual hydrogoeological model for West Angelas Deposit C.

Internal reference:
RTIO-PDE-0135550

The aquifer at Deposit C is principally associated with the mineralised section of the Mount Newman Member of the Marra Mamba Iron Formation as well as the overlying Wittenoom Formation. Evidence for a groundwater divide exists in the centre of the site, in an area of a dyke, possibly forming a barrier to groundwater flow. Due to the depth to groundwater, as well as the thickness of clayey detritals, it is expected that rainfall recharge will be low.

Water interactions and pit lakes

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

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.

Internal reference: RTIO-HSE-0198428

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.

Flora

Flora & Vegetation Survey of Orebody A & B West Angela Hill and Rail Route Options March 1998 **1998**

Report defines premining flora and vegetation communities for West Angelas Deposits A and B as well as the access road and proposed rail alignment options.

Internal reference: RTIO-HSE-0202800

There are two vegetation types of conservation signficance in the West Angelas Deposit A and B and access road study areas. These consist of Cracking Clays and Mulga stands. Cracking clays found both to the west of Deposit A and south of Deposit B are locally signficant as the contain species which are both rare and edaphically restricted. There are two signficant stands of Mulga in the West Angelas area. The first of which is west of Deposit A on a broad alluvial fan. This area is of conservation signficance not because of its regional restriction as it is found elsewhere but beceause of the condition of the stand as it has had little to no impact from grazing. The Mulga stand north of Deposit B and the mine access road is of high conservation value (vegetation type (6adb231)) due to the unique species assemblage where Acacia aneura var. (green, flat; MET 15, 946) is dominant.

Flora & Vegetation Survey of Orebody A & B West Angela Hill and Rail Route Options March 1998 **1998**

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Robe River Mining Southern Spur rail route Mulga monitoring programme – December 2004 **2004**

Results of 2004 Mulga monitoring programme for the Southern Spur of the West Angelas Rail.

Internal reference:

The results suggest that there has been no decline in the health of perennial emergent and perennial grasses along the southern spur rail route, with no overall increase in the cover of perennial grasses and health of perennial emergent at the control and experimental sites.

Vegetation and Flora Survey of Deposit E and F **2006**

Internal reference:

Biota Environmental Sciences (Biota) was commissioned to undertake a flora and vegetation survey of Robe River Mining's (Robe's) Deposits E/F study area at West Angelas in May 2004. This report describes the results of this study, and also integrates data previously collected from the area.

Twelve vegetation types were identified within the Deposits E/F study area. The following vegetation types within the study area are considered to have moderate conservation significance: • Mulga vegetation types M1-M5: which was considered to be relatively restricted in the area, and also comprise ecosystems at risk in the form of grove/intergrove and valley floor mulga; • Vegetation types Hi and H3 of stony hills and gorges respectively: these comprised the main mapping units from which the undescribed spinifex species Triodia sp. Mt Ella was recorded. This Priority 3 taxon is known only from the vicinity of West Angelas, and is apparently uncommon and restricted in distribution. It can therefore be surmised that any vegetation type in which this species is a significant component will also be uncommon and restricted. The remainder of the vegetation types are considered to be of low conservation significance, representing units that are likely to be widely distributed and relatively well represented in the Hamersley Range subregion. None of the vegetation types within the Deposits E/F study area are considered to be sufficiently rare or restricted at a subregional level to warrant designating them as being of high conservation significance. No Declared Rare Flora have been recorded within the Deposits E/F study area. Eight Priority flora have been recorded from the Deposits E/F study area. There were also five records of the Priority 2 Acacia effusa from south of the main study area.

West Angelas Coondewanna Mulga Monitoring 2008-2009 **2009**

Internal reference: RTIO-HSE-0145907

Results of 2009-2009 Mulga monitoring programme for the Southern Spur of the West Angelas Rail.

The majority of perennial grass test site were moderately to heavily burnt in 2006, and the data from these sites clearly demonstrates that fire is still the dominant influence on the extent of perennial grass cover at these sites, although a partial recovery is now evident. The influence of fire on these sites is so great as to mask any other effects which may or may not be present due to change in surface hydrology. Comparison of the mulga health status 2008 data relative to 2002 indicated only six of the 51 transects tested were significantly different, of which three sites declined and three sites improved. As with the perennial grass data, the equal proportion of declining and improving sites suggests that, at least at a broad scale, the rail infrastructure is not resulting in deterioration in mulga health status.

UWA West Angelas Mulga Report - February2010 **2010**

Internal reference:

Review of long term mulga vegetation monitoring that has been conducted for Rio Tinto ore iron. The review measured any potential impacts of slatered surface hydrology that maybe attributed to rail infrastructure, provide a combined monitroing data set and re-analyse each data set and combine to provide new insight to whether changes in vegetation condition could be attributed to rail infrastructure for the three long term monitoring site of Yandicogina, Marandoo and Coondewanna flats (West Angelas southern rail spur).

Review, comtination and re-analyse of the three long term data sets found that there were no trends in the combined dataset that indicated that the Central Pilbara Railway has had a negative effect on the density of mulga on either side of the rail line. It was also found that fire is the most significant factor in mulga density and it could not be estiblished if a drainage shadow effect has occured as not soil moisture analyse has been complete upslope or downslope of the rail.

West Angelas Coondewana Mulga Monitoring 2011 **2012**

Internal reference:

Results of 2011 Mulga monitoring programme for the Southern Spur of the West Angelas Rail.

No clear trends in changes to total cover of perennial grasses at unburnt or lightly burnt test sites relative to the baseline survey were detected, suggesting that, at least at a broad scale and within this time frame, the rail infrastructure has not resulted in deterioration in the health of these species. Similarly the lack of any clear trend in unburnt or lightly burnt control sites relative to 2001 suggests that seasonal differences between surveys periods have not contributed significantly to the changes in total cover. Data from transects burnt moderately or severely clearly demonstrates that fire remains the major influence on the extent of perennial grass cover. The influence of fire on these transects is likely to mask any other effects which may or may not be present due to change in surface hydrology. There appears to have been a decline in seedling numbers at test sites, and a concurrent increase in shrub numbers, suggesting that some seedlings have grown to the extent that they are now classified as shrubs. The number of trees has increased marginally from the significant decline observed in 2006 post burning, but remains significantly lower that in the baseline survey of 2001. In contrast the cover of perennial grasses at burnt sites is generally now increasing, though still lower then pre-fire levels. Consideration of the location of each transect in the landscape has shown no trend in mulga health status. As with the perennial grass data, an equal proportion of declining and improving sites suggests that, at least at a broad scale, the rail infrastructure is not resulting in deterioration in mulga health status.

West Angelas Rehabilitation Record
South and East Waste Dumps **2012**

Internal reference: Rehab close out rep

Two separate waste dump berms on the West Angelas South waste dump and East waste dump were rehabilitated in 2012.

The waste material on the berm was highly erodible West Angelas shale material, such that slope angles up to 17 degrees were required. The slopes were dressed with 200mm topsoil, deep ripped and seeded.

Greater West Angelas Vegetation and Flora Assessment, ecologia, April 2013 **2013**

Rio Tinto (RT) commisioned ecologia Environment (ecologia) to undertake a two phase assessment of the Greater West Angelas Study Area (Deposits C, D, D extension, G, F, H and Mt Ella were surveyed).

Internal reference: RTIO-HSE-0185831

Overall the vegetation condition was found to be excellent. 22 vegetation communities were described. One Priority 1 PEC, West Angelas Cracking-Clays, occurs extensively within the Study Area. This community is further defined as open tussock, on derived cracking-clay loam depressions and flowlines. Local vegetation communities considered to be of conservation significance are detailed including vegetation located in; rocky midslopes, gullies, sandy undulating plains and rocky hilltops.

West Angelas - Rehabilitation Monitoring Report 2013 **2013**

This report contains the analysis and summary of results from the 2013 West Angelas rehabilitation monitoring program. This report describes the findings from 2013 monitoring of two transects at the West Angelas east waste dump (WD1 T1 and WD1 T2), and two transects at the south waste dump (WD2 T1 and WD2 T2). For comparison, three reference sites were monitored, viz. C3 and C4 (both located on slopes) and C8 (located on a flatter area).

Internal reference:

As the rehabilitation was monitored when it was only 9 months old, any conclusions regarding whether it has been successful or not will be preliminary, and further monitoring will be required to determine any likely trends over time. Several erosion gullys were recorded in WD1T2, and these may be related to the generally lower cover values recorded compared to WD1 T1. Apart from these, the site appears stable. It is apparent that, despite the two rehabilitated areas being given apparently similar rehabilitation treatments, the developing vegetation in the four transects is quite variable. It can be concluded that rehabilitation at some sites (particularly WD1 T1 and WD2 T2) has begun to develop well, while that at WD2 T1 has not yet developed as well. The vegetation, fauna habitat and erosion data provide a useful baseline for future comparison.

West Angelas Rights Reserved Site - Biological Assessment **2015**

A biological assessment was conducted of the Rights Reserved Site YINHARR-20 to determine the signficance of vegetation present, and its potential groundwater dependence.

Internal reference: RTIO-HSE-0289259

Vegetation at the site was described as low open woodland and is consistent with that of other minor drainage lines within the West Angelas area and more broadly the Hamersley subregion. Groundwater at the site is estimated to be approximately 40-50m below ground level, and would not be accessible to the species present at the site. The vegetation is therefore more likely to be dependent on surface water flows including runoff from the surrounding hills.

West Angelas Deposit C and D Groundwater Dependent Vegetation Assessment **2017**

The objective of this study was to evaluate the potential for a potentially groundwater dependent ecosystem (GDE) in Karijini National Park may be impacted by groundwater drawdown

Internal reference: RTIO-HSE-0310114

Modelling suggests that the groundwater table below a potential GDE in Karijini National Park may be lowered by 3-8m as a result of Deposit C and D dewatering, with maximum drawdown soon after closure, but this is considered to be a worst case scenario as the model did not account for natural recharge. The impact assessment conservatively assumed a long-term 8m drawdown and concluded that this would not lead to signficant impacts. Whilst some loss of health may occur, vegetation would have time to adapt to groundwater level changes

Fauna

West Aneglas Vertebrate fauna assessment study April 1998 **1998**

Report documenting the findings of a vertebrate fauna assessment survey completed between June and October 1997. This report identifies vertebrate fauna species found, fauna habitats and their conservation significance in the West Angelas mine area.

Internal reference: RTIO-HSE-0016008

Six fauna habitats were identified as being representative of both the landform features and vegetation associations of the mine area; mulga woodland, rocky gullies, cracking clay, creeklines, hilltop and spinifex plain. The ghost Bat Macroderma gigas was recorded in the mine area as well as several other priority and scheduled species were found. Significant habitats have been identified as the Cracking Clay habitat and Mulga woodland.

West Angelas Stygofauna assessment survey Nov 1998 **1998**

The report summarises the findings of the preliminary stygofauna survey for the West Angelas mine and Turee Creek B borefield. The aim of the study was to determine if stygofauna are present in the mine and borefield areas, identify key habitat features and assess potential environmental impacts from water abstraction and detail management options. The study was commissioned to support the Part IV approval for West Angelas.

Internal reference: RTIO-HSE-0016004

Of the 44 bores sampled in the area 6 bores contained stygofauna. Five specimens were collected in mine area and one specimen in the Turee Creek B borefield area. Species have not been identified as little was known at the time of taxonomy of Australian stygofauna. It was determined that most influencing factor for stygofauna habitat is dolerite and to a lesser degree black shale. It is thought that the presence of fractures and weathered zones in these two non-permeable substrates are utilised as habitat in the absence of more suitable habitat. Potential environmental impacts from mine are summarised as arising from mine dewatering and potential groundwater contamination

West Angelas Minesite - Ghost Bat Monitoring Survey **2001**

Report documenting surveys were undertaken of known Ghost Bat roosting sites to determine the distribution and abundance of Ghost Bats within the caves located within the mine area. Caves surveyed were located within Deposit B and F as well as the eastern side of West Angelas Hill. A search for potential bat habitats was also conducted on the southern boundary of Deposit B and in a small gully between Deposit B and G that had not previously been investigated.

Internal reference: RTIO-HSE-0014000

Recent activity of Ghost Bats were recorded in three out of five caves. No Ghosts Bats were present in any caves searched. Summary of completed manangement actions in regards to the Ghost Bat management plan and planned future actions.

West Angelas Stygofauna Assessment Survey **2002**

A re-survey of stygofauna in the Turee Creek borefields and the Jeerinah Formation, within the West Angelas lease area. A total of 20 bores were investigated for their sampling potential. Of the 20 bores investigated only 12 were successfully sampled.

Internal reference: RTIO-HSE-0016003

Stygofauna were found in five bores. Up to five major groups were recognised from a single bore location. Bore WB51 revelased representative Amphipods, Copepods, Syncarids, Tubellarians and possibly Isopods. Bore WB54 contained potentially two species of Amphipod, one Copepod species and one species of Tubellarian worm. Copepods were the most commonly recorded stygofaunal group with 40 individuals collected from WB54 and 225 individuals observed in bore WB51. WB51 also revealed a large number of Tubellarian worms with 35 individuals recorded.

West Angelas expansion deposits E & F subterranean fauna survey May 2004 **2004**

Report summarises findings of targeted stygofauna survey for E and F deposits of the West Angelas mining operation.

Internal reference: RTIO-HSE-0015937

A review of the geological units present in the valley system containing these deposits suggests that the area is not overly prospective for stygofauna. This is largely because the unit with greatest potential to provide habitat for stygofauna of those present, the superficial alluvials, is situated above the water table. There are also no significant calcrete systems present, which constitute core habitat for stygofauna in other parts of the Pilbara (Humphreys 1999). The deeper geological units that are saturated do not generally support stygal communities in most situations.

Fauna habitats and fauna assembalges of deposit E and F at West Angelas June 2005 **2005**

Robe River Iron Associates commissioned Biota Environmental Sciences to conduct a fauna survey of their Deposit E/F study area, adjacent to the existing operations at West Angelas. The survey was conducted over a 9-day period between the 4/5/2004 and 12/5/2004.

Internal reference: RTIO-HSE-018209

Four primary habitats were identified within the project area: broad colluvial valleys, lower stony footslopes, stony hilltops, incised gullies and creeks. One fauna habitat is considered to have moderate conservation significance within the study area, based on the vegetation types. Broad colluvial valleys dominated by Acacia aneura (Mulga vegetation types M1-M5) comprise ecosystems at risk in the form of grove/intergrove and valley floor mulga. Two priority listed species were identified and one short range endemic (trapdoor spiders).

Greater West Angelas Terrestrial Fauna Assessment, ecologia, January 2014 **2014**

This report details a baseline fauna survey of the Greater West Angelas study area deposits C, D, D extention, G, F, H and Mt Ella.

Internal reference: RTIO-HSE-0215896

Six mammal species (including Pilbara leaf nose bat), 12 bird species and three reptile species are listed as conservation significant. The literature review also identified 32 SRE species that have been previously recorded in the region surrounding the study area. A total of nine broad-scale habitat types have been identified within the study area; ‘footslope or plain’, ‘hilltop, hillslope, ridge or cliff’, ‘mixed Acacia woodland’, ‘mesa top’, ‘cracking clay’, ‘major gorge and gully’, ‘major drainage’, ‘mulga woodland’ and ‘cleared area’. No habitats recorded were regarded as rare or unique to the study area.

Biodiversity improvement studies

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

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.

Internal reference: RTIO-HSE-0109961

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.

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

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.

Internal reference: RTIO-HSE-0108843

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**

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.

Internal reference: RTIO-HSE-0119260

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**

This study examined partial root zone drying (PRD) responses of Melaleuca argentea.

Internal reference: RTIO-HSE-0252171

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**

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.

Internal reference: RTIO-HSE-0134168

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.

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.

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.

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.

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.

West Angelas Cracking Clay Study **2015**

Internal reference: RTIO-HSE-0253397

Cracking clay community soil samples were collected prior to clearing for constrution of the Deposit B waste dump. The objective was to better understand system functionality with a view to evaluating whether translocation or recreation of similar habitat might be viable.

Two distinct clay layers were observed across the study area. An upper vertosol (cracking clay) layer was found to overlay a red kandasol (structureless clay) layer. All plant growth was observed in the upper vertosol layer, with no roots penetrating the kandasol layer. Physical and chemical properties of the vertosol were assessed as being conducive to plant growth, and the material is expected to be relatively stable if stockpiled. The study concluded that translocation may be viable, and that only the vertosol layer would need to be stockpiled and replaced. However, the kandasol layer (or an alternative clay liner) may be required to replicate its role in hydrological function.

Progressive rehabilitation

West Angelas Rehabilitation Trial - Landform Design Performance

2017

Internal reference: RTIO-HSE-0310927

Two rehabilitation trials were conducted at West Angelas Deposit A South and North dumps in 2012. Their performance was evaluated in this study.

The rehabilitation specifications for both trial sites did not conform to current specifications. However, with the exception of one unstable gully in Deposit A South dump, erosion was generally within target parameters. There are several factors that may have caused the unstable gully. A relaxation of design parameters to 12-15m lift heights (assuming a gradient of 17 degrees) appears to be supported, but further testing is required to confirm that this is appropriate.

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.

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

West Angelas Preliminary Site Investigation Report

2008

Internal reference: RTIO-HSE-0058441

The purpose of this preliminary site investigation was to identify areas of potential environmental concern associated with current and historical activities at the site.

Results from the risk ranking analysis show that in terms of overall risk factor, no "high risk" areas were identified at the site. The rail refuelling area, the diesel pipeline, the former landfill and the vehicle wash-down facilities were assessed to be of "moderate high" to "moderate low" risk. No previous environmental investigations have been undertaken at any of the facilities, these areas are potential areas of concern and have yet to be quantified. In all cases visual and/or anecdotal evidence suggested that potential adverse impacts to soil, groundwater or surface water, be it fuel spills, leaks or ongoing run-off/infiltration has historically occurred at these locations. For each of these areas of concern, a soil and groundwater sampling and analysis plan should be developed.

Control Measures for Potentially Acid Forming Pit Wall Rocks **2010**

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.

Internal reference: RTIO-PDE-0079541

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**

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.

Internal reference: RTIO-PDE-0101903

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.

Contaminated Site Investigation - Soil and Liquid Waste Dumping Area at West Angeles **2012**

This report investigats the recent increase in contaminated material placed in storage ponds and potential for infiltration to occur through soil stockpiles to groundwater.

Internal reference: RTIO-HSE-0142463

Results of the sampling concluded that there is minimal risk present at the area where the former contaminated stockpile was located. The remaining hydrocarbon concentrations are compliant with the ecological guidelines, with a few areas of elevated concentrations. Concentrations are expected to degrade over time, further reducing the potential for environmental impacts. A new bunded and graded cell has been created at the land farm. The area is expected to be suitable for rehabilitation.

Updated Preliminary Site Investigation and Sampling and Analysis Plan for West Angelas Final **2012**

The objectives of the project was to update existing information relating to known or suspected contamination at West Angelas and to subsequently develop a sampling and analysis plan in order to further characterise identified areas of interest.

Internal reference: RTIO-HSE-0148156

The review of the Preliminary Site Investigation found that, in general, the existing findings are accurate and have been carried out and presented in a manner consistent with the Department of Environment and Conservation Contaminated Sites Management Series. Additional areas of environmental concern were identified during the review. Areas of further interest presented in the sample and analysis plan are: 1) Mine Area - Rail refuelling area, former landfill, fire training ground, contaminated soils stockpile area, crusher area and the current mine landfill; and 2) Workshop / Administration Area - Light vehicle refuelling area, heavy vehicle refuelling area, heavy and light vehicle workshop area, heavy vehicle workshop area, light vehicle workshop areas, heavy and light vehicle wash-down facilities, bulk oils store, bulk fuels store, intermediate lube store, emergency power plant, recycling yard and the ammonium nitrate / fuel oil shed.

Development of a conceptual model: Sulfate accumulation as a consequence of pit dewatering activities, memo **2012**

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.

Internal reference: RTIO-PDE-0101903

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**

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.

Internal reference: RTIO-HSE-0218222

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.

APPENDIX D – CLOSURE RISK ASSESSMENT

Ref. Risk Type (T=T	Category	Subcategory	Item	Risk Description Evaluated 21 of 21 risks Threat Title	Potential causes (Triggers / Indicators)	Existing Controls and Commitments	Site specific overview	Evaluation Rationale (Maximum reasonable consequence)	Risk Evaluation Likelihood	Health	Safety	Environment On-site	Environment Off-site	Community Trust	Compliance	Risk Management	Detailed Action Descriptions
T	A			**Planning and knowledge**													
T	A	01		**Contaminated sites**													
T	A	01	01	Under-estimated general contaminant clean up requirements	• Use of chemicals and hydrocarbons during operations • Housekeeping practice and maintenance of work areas and equipment	• Regular maintenance / inspection / audit of work place procedures • Spill management kits readily available • Contaminated sites register maintained across life of operation • Contaminated soils treated at landfarm facility	• Regular maintenance / inspection / audit of work place procedures • Detailed site investigation to be undertaken prior to closure • Preliminary site investigations have been undertaken - no reportable sites have been identified, but housekeeping issues have been identified from time to time • Original landfarm was not constructed to specifications - has now been replaced	Hydrocarbon contamination identified during pre-closure DSI results in unexpected clean-up costs	P						L	II	
T	A	01	02	Under-estimated acid and / or metalliferous drainage management requirements during operations (pre-closure) & decommissioning phase	• Potential for acid / alkaline / metalliferous / neutral / saline drainage generation during operation of mine • Water management, storage and monitoring practices • Water quality prior to return to environment e.g. via infiltration or discharge	• Geochemical characterisation of waste material • Mineral Waste Management Work Practice • SCARD management plan • PAF waste stored in cells within waste dumps • Wet season management plans used to control run off. • Groundwater operating management plan to monitor groundwater quality • Water Discharge Monitoring and Management Plan	• Low AMD risk assumed across the site	Unexpected PAF is identified and requires management	R			L				I	
T	A	01	03	Acid and / or metalliferous drainage generation (after closure) creates a contaminated site	• Interaction of water and mineral waste could generate acid / alkaline levels that leach metals / salts from the mineral waste or local environment • Presence of temporary or permanent open water bodies, enabling evapoconcentration to occur with creation of alkaline / hypersaline water quality • Ability of metals / salts to move through environment to impact a sensitive receptor, to meet definitions in Contaminated Sites Act 2003	• Geochemical characterisation of waste material • SCARD management plan provides specifications for PAF cover • Waste dump design specficiations based on material erodibility parameters • Pits will be backfilled to AWT	• Low AMD risk assumed across the site • No PAF material present behind pit walls	Metalliferous salts build up in the soil profile at the base of pits	U				M			II	
T	A	01	04	Human health impacts from in situ fibrous material exposures	• Hazardous fibres exposed in situ by mining, mined and moved to encapsulated areas or naturally present in soils disturbed by mining / rehabilitation activities • Erosion of materials containing hazardous fibres post-closure	• Physical materials characterisation, some fibres present in mineral waste materials, surface alluvials and associated with infrastructure installation (cuts through non-mined geology) • Fibrous materials management plan enacted	• Fibrous material has been encountered • Fibrous material has been encapsulated in Deposit A North waste dump • Pit wall exposures on WEPN north wall have been covered with backfill material • Assume that current procedures may result in some fibrous material being present on pit walls in some areas - additional management may be required	Fibrous materials are re-exposed post-closure, creating to a public health risk (NB - risk evaluated on the basis of minimal potential for long-term public exposure)	U	H						III	1. Evaluate closure landform desgins with respect to managing the potential for exposure/re-exposure of fibrous materials, and incorporate design changes where required.
T	A	02		**Void management**													
T	A	02	01	Lake and / or lake fringe habitat has undesirable impacts on general ecosystem function.	• Open water bodies in Pilbara naturally attract fauna (feral and native species) for food/ water/ refuge, safe access to water required • Concentration of natural groundwater or mineral waste derived salts through evapoconcentration in open water bodies • Release of metals from natural geology or mineral waste into water (infiltration or groundwater flow) • Water provides opportunity for plant /weed growth, good and bad (toxic algal blooms, noxious weeds) • Certain plant / animal species bio-accumulate / magnify toxic metals • Instability associated with saturated, unconsolidated ground, can be increased by high trafficability	• Void closure management guidance • At this stage, all pits will be backfilled to a level that prevents formation of a permanent pit lake	• No permanent pit lakes - currently committing to backfill to pre-mining water table level • Considering amending this commitment to backfill to prevent formation of permanent pit lake - this would result in a high incidence of ephemeral water in the base of pits • May be an opportunity to challenge this commitment in the future, but would need to undertake sufficient studies to support that the outcome is acceptable - for the purposes of this risk assessment, assume that this opportunity will not be realised • May have temporary/ephemoral pit lakes	A permanent pit lake forms at the base of a mine void, due to inaccurate groundwater recovery information and/or high surface water flow contribution, and leads to an increase of invasive species. (NB: Risk evaluated on the basis that commitments are amended to only require backfill to a level that prevents permanent pit lakes from forming, and that any lake would be a sink)	U				M		M	II	1. Undertake groundwater recovery modeling to determine backfill levels for all pits.
T	A	02	02	Lake poses public liability and / or health risk	• Lake(s) in a location that is easily accessible by the general public e.g. near or visible from a public road • Lake(s) is near an existing attraction e.g. area of cultural significance or tourist attraction • Access to the lake edge is not via a dedicated, safe path • Contaminants well above recreational guidelines • Strongly acidic or alkaline lake water, or releases noxious gases • Toxic algal blooms and / or noxious weeds • Waterborne pests and disease e.g. mosquitos	• Void closure management guidance • At this stage, all pits will be backfilled to a level that prevents formation of a permanent pit lake • Abandonment bunding around pits to prevent inadvertant access	• No permanent pit lakes • May have temporary/ephemeral pit lakes, generally shallow water expected • In-pit ramps will form an egress route, but not designed to be stable post-closure • Will be installing abandonment bunds in appropriate and agreed locations	A temporary/ephemeral pit lake forms at the base of a mine void, and egress routes have collapsed - people and/or stock that enter the pit are unable to exit. (NB: Risk evaluated on the basis commitments are changed to only require backfill to prevent formation of a permanent pit lake)	U		VL					I	
T	A	02	03	Degradation of regional groundwater quality or levels	• Concentration of natural groundwater or mineral waste derived salts through evapoconcentration in open water bodies • Groundwater flow through pit lake or mineral waste with connection to regional aquifer • Density driven saline groundwater flow from groundwater sink-style pit lakes • Downstream groundwater users (people, plants or animals)	• Void closure management guidance • Environmental surveys include regional groundwater dependent ecosystem • Geochemical waste characterisation and column leach tests • Preliminary integrated ground-surface water modelling (with recovery) completed • Management of mineral waste to minimise surface water area exposed to evapotranspiration, to minimise salinity	• Pits will be backfilled to a level that prevents formation of permanent pit lakes and groundwater recovery levels predicted to be up to 70m lower than pre-mining levels, and may take more than 100 years to stabilise • The environmental impact of a permanent reduction in groundwater levels has been assessed to be low. The nearest signficant groundater dependent ecosystems are within Karijini National Park where it has been assumed that there could be a permenant reduction of groundwater levels up to 5m - the vegetation is assumed to be able to successfully adapt to this scenario. • No permanent pit lakes (i.e. limited water losses from the system due to evaporation) • Low AMD risk • Assume environmental systems are sufficient to prevent formation of contaminated sites with the potential for groundwater impacts • There may be a permanent reduction in stygofauna habitat, but stygofauna species do not appear to be environmentally significant, and there are no local groundwater users. • Local aquifers are minor contributors to the regional system	Permanent reduction of local groundwater levels leads to a loss of environmental values.	P			L	L			II	
T	A	02	04	Geotechnical zone of instability compromises closure outcomes	• Influence of erosion, subsidence, seismicity, wall slip • Influence of groundwater recovery and surface water flow on stability. • Creek system neighbouring or within zone of instability, potential stream capture • Ecosystem downstream of void dependent on surface water flows • Poor communication of zone of instability to facilitate identification of important features	• Geotechnical assessments for wall stability and zone of collapse as part of mine design reviews, as required • Pit walls design factor of safety 1.3, geotechnical assessment show zone of collapse for high risk locations (near creeks, infrastructure etc.) • Conceptual location for abandonment bunds established	• This has been raised as a specific issue for the site by the OEPA in its response to the 2014 closure plan, and by the DMP in its 2015 environment inspection (waste dumps located within the zone of instability) • Zones of instability are considered when siting new waste dumps, but existing waste dumps need to be verified as outside the polygon • Deposit A south waste dump and Deposit E South dump are located within the zone of instability (as calculated using methodology in DMP guidelines) • Also need to consider the potential for pit wall collapse to affect other environmental (creek lines and diversions, bat roosts) and heritage (rock shelter and associated access routes) impacts. • Numerous sites to consider across the site • Additional backfill in Deposit A will occur - can be undertaken so as to effectively buttress the wall if required, but further evaluation is needed to determine whether this is required.	Geotechnical failure of a pit wall causes a waste dump to collapse into a pit void, requiring rehabilitation rework after the active post-closure maintenance period	L		H		L		M	IV	1. Develop rehabilitation designs for waste dumps that are currently located within zones of instability (Deposit A South dump and Deposit E South dump) that ensure these dumps are outside the zone of instability.
T	A	03		**Closure landforms**													

Risk Type (T=T	Category	Subcategory	Item	Risk Description Evaluated 21 of 21 risks Threat Title	Potential causes (Triggers / Indicators)	Existing Controls and Commitments	Site specific overview	Evaluation Rationale (Maximum reasonable consequence)	Risk Evaluation Likelihood	Health	Safety	On-site Environment	Off-site Environment	Community Trust	Compliance	Risk Management	Detailed Action Descriptions
T	A	03	01	Built landforms (excluding mine void areas) erode and / or collapse	• Physical material properties considered in design • Drainage and erosion management • Construction of landforms / waste dumps to design requirements • Sensitive receptors identified downstream	• Physical materials characterisation completed • RTIO Rehabilitation handbook used for general rehabilitation activities • Rehabilitation designed to be stable without vegetation • Invasive species management plan will be developed as part of decommissioning activities	• Significant proportion of high erodibilty material in some waste dumps (detritals, shales) • Strategies for managing high erodibilty varies, with some dumps constructed to a flatter angle, selective dumping of some dumps and capping of others. Some of these options will require a higher level of operational control than is typical for waste dumping in the Pilbara. • Some waste dumps (e.g. Deposit A South dump) have not been constructed to readily facilitate a stable closure design. • Multi-disciplinary pit and waste dump design sign-off processes, considers landform design guidelines and provides rehabilitation designs where appropriate • Need to consider abandonment bund placement - needs to account for hydrological regime • Deposit A South dump was not constructed and rehabbed to current design standards, but appears to be performing satisfactorily (confirmed during DMP inspection in 2015) with the exception of one unstable gully • A number of site features are within PMF flood extent - this needs to be assessed with respect to impacting landform stability, particularly waste dumps • Abandonment bunds will need to be constructed for perpetuity - need to confirm that sufficient inventory of competent rock is available. • Need to consider access roads	Excessive erosion of waste dumps resulting in rehabilitation failure and downstream sediment impacts.	P				M			III	1. Develop new rehabilitation designs for existing waste dumps (e.g. Deposit A) that may not have not be constructed to readily facilitate stable rehabiltiation slopes. 2. Undertake further site specific waste characterisation to better define dump erosion potential.
T	A	03	02	Surface treatment on landforms limits vegetation growth	• Availability of top soil stockpile soil / poor stockpile management e.g. soil washed away • 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	• Physical and geochemical materials characterisation complete. Material is inert and general expected to be acceptable growth media. • Rehabilitation handbook provides direction on surface treatment options • Annual stockpile reconciliation of top soil and sub soil stockpiles, return of 200mm to create quality surface growth media • Wetland rehabilitation trial established, will provide feedback on general waste erosion performance, will look at value of adding mulch	• Soil and mineral waste is typical of the Pilbara, and should be conducive to native plant growth • The currently predicted topsoil deficit should be addressed following expansions • Rehabilitation to date is performing well • Current RTIO practice does not include the use of soil ameliorants to assist plant growth • There are a variety of habitat types within the West Angelas area	Rehabilitation success is compromised by the absence of suitable topsoil stockpiles, resulting in a requirement to reseed some areas	U			L				I	
T	A	03	03	Vegetation is not self-sustaining	• 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 etc	• Rehabilitation handbook provides guidance on seed selection for appropriate diversity • Top soil stockpiles provide seed bank • Wetland rehabilitation trial established to assist in appropriate species selection for post-closure soil water conditions • Invasive species management plan will be developed as part of decommissioning activities	• Remote location not affected by pastoral activity - should not be significant pressures from stock trampling, however there are a lot of camels present in the Angelo area. There are no pit lakes proposed, which reduces the risk of them migrating to the West Angelas area • Detailed site investigation to be undertaken prior to closure • Responses to fire are not fully understood, but indications from sites elsewhere in the Pilbara suggest that recovery after fire could be expected as long as the rehabilitation has reached a reasonable level of maturity. • Rehabilitation utilises a range of species	Rehabilitation areas do not show signs of recruitment, requiring rework to occur	R				L			I	
T	A	03	04	Access through area post-closure poses public liability risk	• Post-closure access / land-use requirements, e.g. for stock, people, heritage, environmental monitoring, adjacent mining activities etc. • Potential for general public to create their own access if appropriate access not provided.	• Regular review and integration of stakeholder feedback into closure plan updates.	• Abandonment bunds to be constructed, but locations not confirmed • May be post-closure access to rock shelters and bat caves (monitoring, etc.) • TO access requirements yet to be determined, but historically there has been a lot of TO movement through the area. Assume that there will be TO's accessing the site for hunting and ceremonial purposes. Need to construct safe access routes.	Post-closure access of the mine area leads to a third-party injury or fatality	P		M					III	1. Confirm abandonment bund locations
T	**A**	**04**		**Other regional considerations**													
T	A	04	01	Environmental outcomes outside of disturbance areas do not align with approved environmental impacts	• New (previously unidentified) environmental sites, not considered in existing environmental impact assessment • Changes to environmental conditions due to cessation of artificial support / mitigation activities, e.g. water supplementation • Change to drainage patterns on closure e.g. removal of temporary diversions, drains etc.	• Internal ground disturbance approval request system to prevent inadvertent disturbance • Baseline biological / ecosystem health surveys and existing monitoring to define post-mining status • GIS system includes results from all flora, fauna, vegetation surveys • Operational management plan for discharge includes actions relating to water quality and discharge extent targets, to ensure environmental issues are managed during operations • Significant species management plan implemented during operation to minimise impact to select species • Vegetation management plan implemented during operations to monitor and manage impacts to vegetation (riparian, understorey and weeds) • Water Discharge Monitoirng and Management plan	• Hydrological regime will be permanently impacted • Deposit D rights reserved area is thought to be surface water fed - disturbance may impact values of this site, and needs to be considered in closure designs • No known surface water dependent ecosystems in the area • Diversions will need to last for perpetuity where appropriate (e.g. Deposit C and B depending on the outcomes of studies and approvals) • EPA has expressed a concern about the impacts CDG expansion with respect to environmental values of Karajini NP - the proposal assumes that a permanent lowering of the water table by 5m in this area will not lead to unacceptable impacts • Assuming that permanent diversions are in place, abandonment bunds should not affect (or be affected by) surface water flows.	A permanent reduction of water table levels in Karajini National Park causes signifcìant impact to groundwater dependent ecosystems	P				L			II	1. Develop designs for permanent diversions where required.
T	A	04	02	Adverse impact to flora or fauna with conservation status or wider regional impact to high value environment	• Scheduled, listed or declared rare and / or threatened species of flora or fauna present in/adjacent to site • Downstream regional area of high value • Environmental conditions post-closure differ significantly from pre-mining conditions • Post-mining land use differs from pre-mining land use	• Internal ground disturbance approval request system to prevent inadvertent disturbance • Baseline biological / ecosystem health surveys and existing monitoring to define post-mining status • GIS system includes results from all flora, fauna, vegetation surveys • Operational management plan for discharge includes actions relating to water quality and discharge extent targets (proximity to Fortescue Marsh), to ensure environmental issues are managed during operations • Significant species management plan implemented during operation to minimise impact to select species • Vegetation management plan implemented during operations to monitor and manage impacts to vegetation (riparian, understorey and weeds)	• Project footprint is surrounded by PEC cracking clay communities • Several priority flora and fauna in the area, but conservation status is not expected to be impacted by mining or closure • Cracking clay translocation trials proposed - if successful, these may enable greater disturbance of cracking clay habitat, but afford greater levels of protection to the overall environmental value • Communities appear to be mainly dependent on incident rainfall and cutting overland flows to them may not be significant	Grading of the landscape around cracking clay communities changes surface water flow paths or sedimentation, resulting in impacts to ecosystem health	U			H				III	1. Evaluate the final landform design with respect to the potential for impacts to cracking clay communities 2. Undertake trials to evaluate the potential to translocate cracking clay communities that may be disturbed during operations or post-closure.
T	A	04	03	Heritage site condition / cultural value is degraded as a result of implementing the closure plan	• New (previously unidentified) heritage sites, not considered in existing assessment, discussions, agreements or with authority to disturb • Changes to landforms on closure have potential to alter conditions at downstream sites, e.g. consider drainage, landform footprint, erosion implications • Cessation of maintenance of / to heritage site	• Internal ground disturbance approval request system • GIS system includes results from heritage surveys • Heritage sites within mine area, S18 application etc. prior to disturbance • Ongoing consultation with Traditional Owners	• Several rights reserved areas are present, including a significant site at Deposit E that is likely to be impacted during mining. Also sites at Deposit F and D • Deposit E site is currently planned to be protected during operations by retaining a 'pillar' - closure strategies will need to ensure that this is a permanent solution (e.g. buttressing may be required) • Other sites will also need to be considered, but are not considered to be as significant a risk of failure as Deposit E • Deposit CD waste dumps have been redesigned to avoid disturbance of a signficant heritage site.	Landscape and ecosystem changes impact cultural heritage values in the area (Threat is evaluated on the values of a rights reserved area, such as at Deposit E, to be impacted throguh poor closure design)	P					H		IV	1. Investigate the potential for cultural heritage values to be impacted post-closure, and evaluate the implications of impacts if they arise 2. Develop closure strategies to maintain cultural heritage values (e.g. buttressing of Deposit E 'pillar' to maintain its integrity post-closure) 3. Ensure consistency between Cultural Heritage Management Plan and Closure Management Plan with respect to strategies for maintaining cultural heritage values.

APPENDIX E - LANDFORM DESIGN CRITERIA

Deposit A South Dump

Erodibility Ranking	Moderate to High
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	318
Overall height (RL/m)	105

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	Range 10-20	12-15 (under review)
Berm width (m)	Range 34-68	10
Berm slope (degrees)	0	-10

Comments

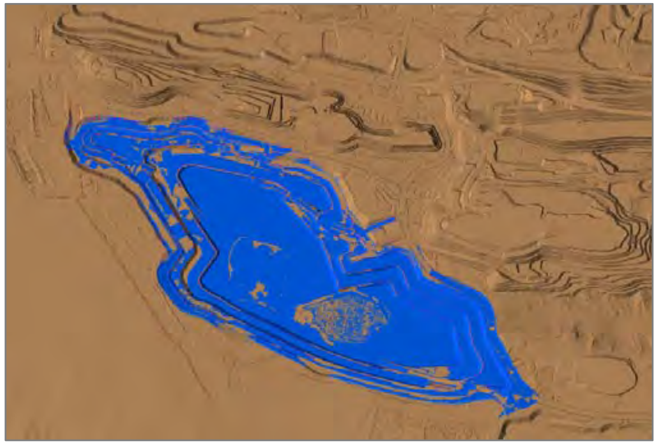
A section of the waste dump was rehabilitated in 2012.

Rehabilitation designs have been developed for the dump, but will require substantive modification to address the following issues:

1. The dump is situated within the assumed zone of instability around the Deposit A pit, and a proposed cutback within the pit would magnify this issue. Material will need to be removed from the northern side of the dump to ensure that the final rehabilitation slope is outside of this zone.
2. The dump was originally constructed to achieve rehabilitation slopes with lift heights of up to 20m, as was typical at the time. Subsequent material characterisation has highlighted a predominance of erodible detrital and shale material, which would require much smaller lift heights. Based on evaluation of the 2012 rehabilitated slope, the rehabilitation specifications presented in the table above would be sufficiently stable, but further testing is required to confirm this.
3. The dump has been over-tipped beyond the target construction specifications.

The rehabilitation strategy and designs presented in the previous version of the closure plan are now considered obsolete for the reasons stated above, and are currently being re-evaluated. Revised designs will be presented in the next closure plan update.

Construction Design



Rehabilitation Design

To be presented in the next closure plan update

Deposit A North Dump (incorporating previous 'East Dump')

Erodibility Ranking	Moderate to High
Classification	Inert ☐ PAF ☐ Fibrous minerals ☒
Footprint (ha)	237
Overall height (RL/m)	90

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	20	12-15 (under review)
Berm width (m)	68	10
Berm slope (degrees)	0	-10

Comments

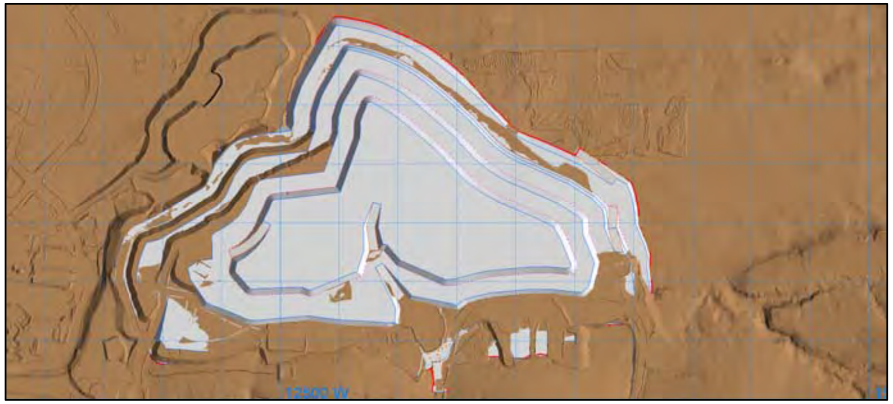
A section of the waste dump was rehabilitated in 2012.

Rehabilitation designs have been developed for the dump, but will require substantive modification to address the following issues:

1. The dump was originally constructed to achieve rehabilitation slopes with lift heights of up to 20m, as was typical at the time. Subsequent material characterisation has highlighted a predominance of erodible detrital and shale material, which would require much smaller lift heights. Based on evaluation of the 2012 rehabilitated slope, the rehabilitation specifications presented in the table above would be sufficiently stable, but further testing is required to confirm this.
2. The dump has been over-tipped beyond the target construction specifications.
3. A cell of fibrous minerals is present relatively close to the surface, and rehabilitation designs will need to ensure that it remains sufficiently encapsulated with inert material.

The rehabilitation strategy and designs presented in the previous version of the closure plan are now considered obsolete for the reasons stated above, and are currently being re-evaluated. Revised designs will be presented in the next closure plan update.

Construction Design



Rehabilitation Design

To be presented in the next closure plan update

Deposit A West Pit North backfill

Erodibility Ranking	Moderate to High
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	146
Overall height (RL/m)	40

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	20	12-15 (under review)
Berm width (m)	45-68	10
Berm slope (degrees)	0	-10

Comments

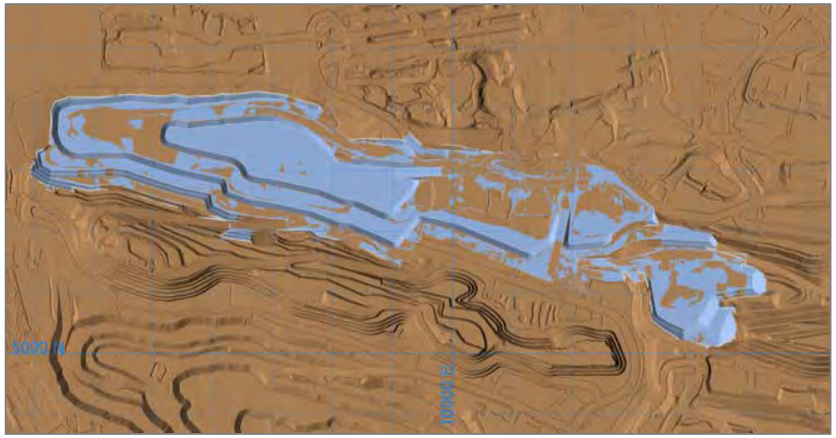
This waste dump is a section of the Deposit A pit which has been backfilled to above the natural topography level.

Rehabilitation designs have been developed for the dump, but will require substantive modification to address the following issues:

1. Additional waste will be required to be placed into Deposit A pit to prevent the formation of a permanent pit lake. The strategy for achieving this is currently being developed, and will influence the rehabilitation design of this dump.

The rehabilitation strategy and designs presented in the previous version of the closure plan are now considered obsolete for the reasons stated above, and are currently being re-evaluated. Revised designs will be presented in the next closure plan update.

Construction Design



Rehabilitation Design

To be presented in the next closure plan update

Deposit B East Dump

Erodibility Ranking	Moderate to High
Classification	Inert ☐ PAF ☐ Fibrous minerals ☒
Footprint (ha)	209
Overall height (RL/m)	75

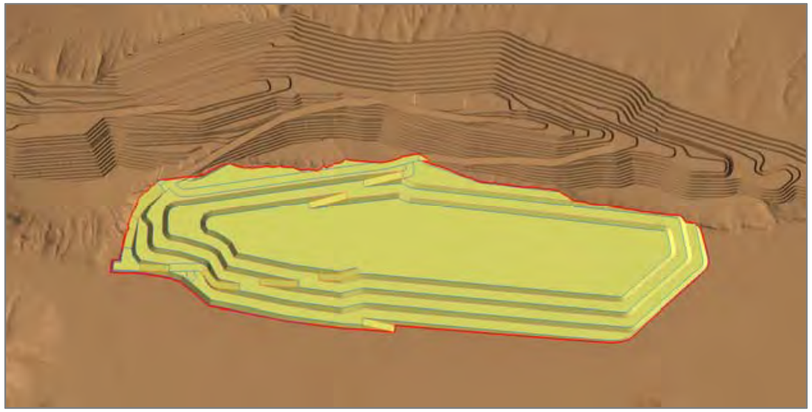
	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

Comments

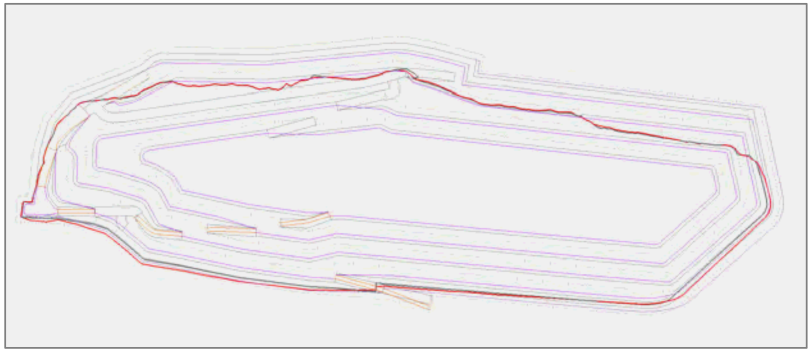
There is a lower proportion of erodible wastes present at Deposit B than in other West Angelas deposits, and selective dumping is proposed to ensure that competent materials (e.g. BIF) are located on the outer surface of the dump.

The dump will contain material that is classified as potentially fibrous –this material will be encapsulated with inert material if fibres are encountered.

Construction Design



Rehabilitation Design



Deposit B West Dump

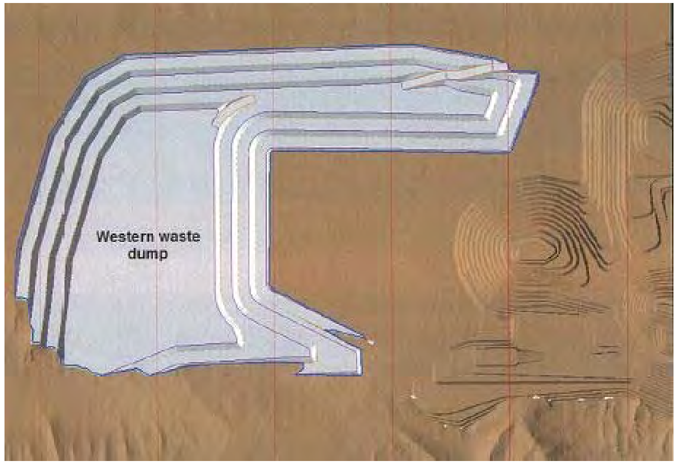
Erodibility Ranking	Moderate to High
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	209
Overall height (RL/m)	75

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

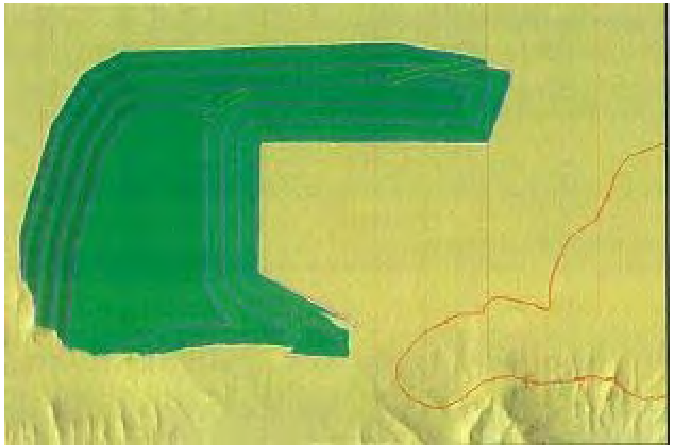
Comments

There is a lower proportion of erodible wastes present at Deposit B than in other West Angelas deposits, and selective dumping is proposed to ensure that competent materials (e.g. BIF) are located on the outer surface of the dump.

Construction Design



Rehabilitation Design



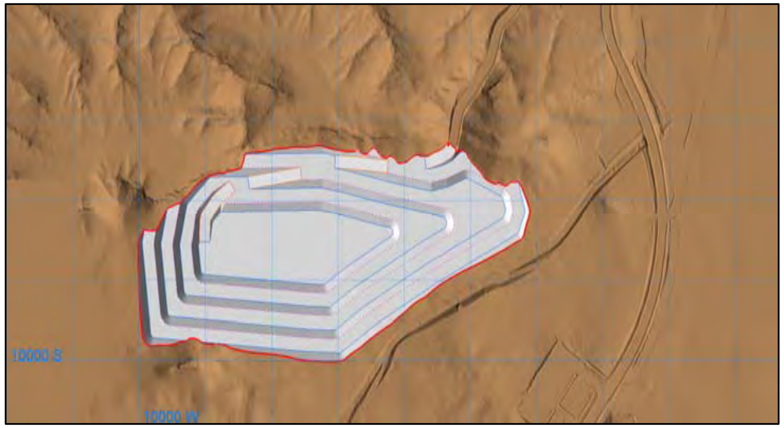
Deposit B Low Grade Dump

Erodibility Ranking	Low
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	75
Overall height (RL/m)	80

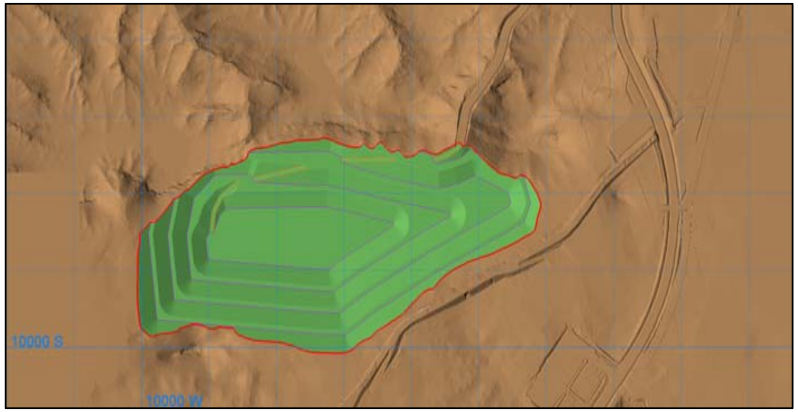
	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

Comments

Construction Design



Rehabilitation Design



Deposit C and D waste dumps (conceptual)

Erodibility Ranking	Moderate to High
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	-
Overall height (RL/m)	-

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	17 (under review)
Lift Height (m)	20	12-15 (under review)
Berm width (m)	34-68	10
Berm slope (degrees)	0	-10

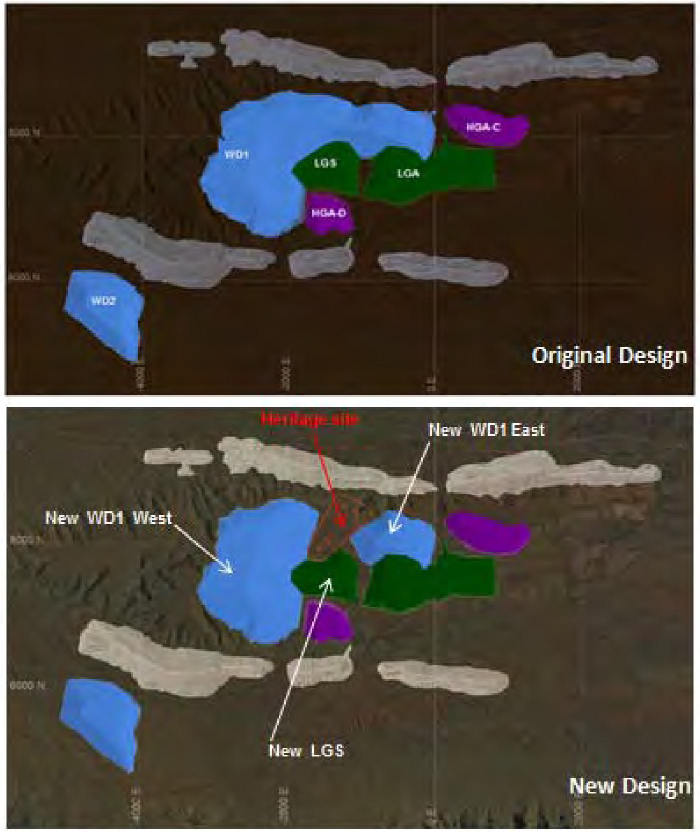
Comments

Deposit C and D mineral wastes are expected to perform similarly to those at Deposit A, and similar rehabilitation strategies are expected. Further testing will be required to confirm material characteristics.

Waste dump designs are still at a conceptual stage. Original designs have recently been modified to avoid disturbance of a significant heritage site, and further design adjustments may be required as new knowledge arises. Rehabilitation designs will be developed following confirmation of the construction design.

In addition to external waste dumps, waste will be deposited directly into pit voids when areas become available. Rehabilitation of these areas may be required if backfill extends to (or near to) the ground surface.

Conceptual Construction Design



Deposit E South waste dump

Erodibility Ranking	Moderate to High (Low when capped)
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	125
Overall height (RL/m)	80

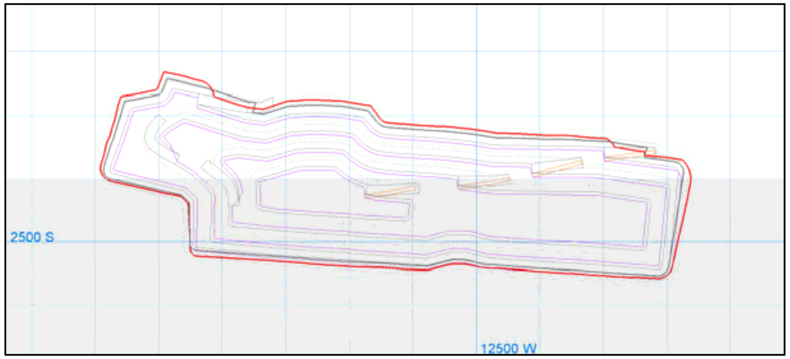
	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	43	15
Berm slope (degrees)	0	-10

Comments

Material emanating from Deposit E is of generally of moderate to high erodibility. However, there is a significant proportion of hydrated material which is sufficiently competent to be used as a capping layer to protect the surface of the dump from erosion. Stockpiles of the material will be used to cap the dump prior to rehabilitation, and this will allow less conservative design specifications to be applied than elsewhere at the site.

Construction Design

Rehabilitation Design



Deposit E West waste dump

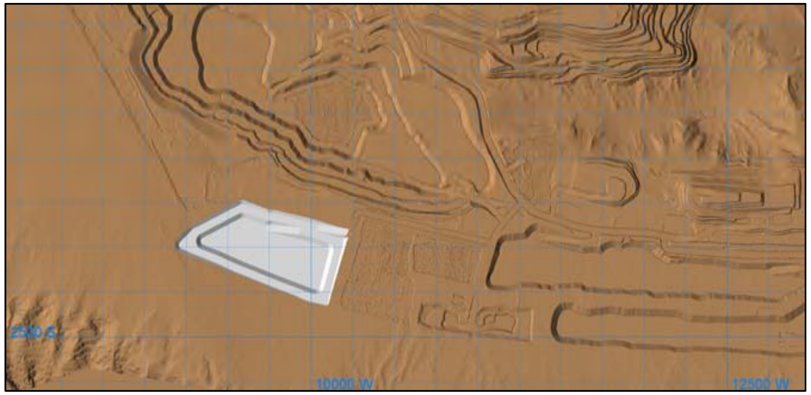
Erodibility Ranking	Moderate to High (Low when capped)
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	35
Overall height (RL/m)	43

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	43	15
Berm slope (degrees)	0	-10

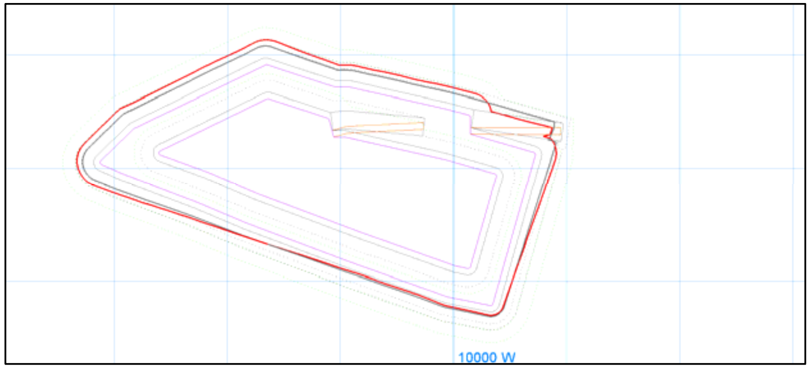
Comments

Material emanating from Deposit E is generally of moderate to high erodibility. However, there is a significant proportion of hydrated material which is sufficiently competent to be used as a capping layer to protect the surface of the dump from erosion. Stockpiles of the material will be used to cap the dump prior to rehabilitation, and this will allow less conservative design specifications to be applied than elsewhere at the site.

Construction Design



Rehabilitation Design



Deposit F waste dumps (West Dump, East Dump, Low Grade Dump)

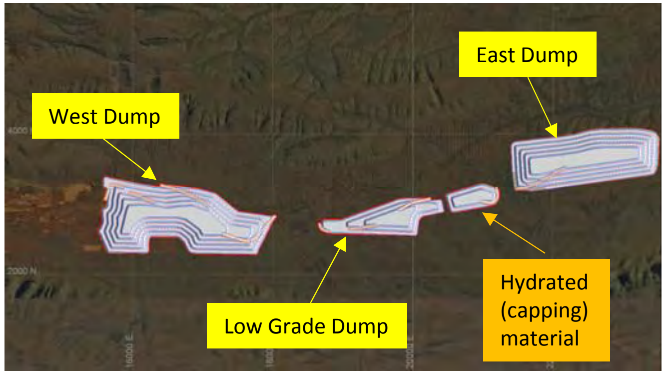
Erodibility Ranking	Moderate to High (Low when capped)
Classification	Inert ☒ PAF ☐ Fibrous minerals ☐
Footprint (ha)	35
Overall height (RL/m)	43

	Construction Specifications	Rehabilitation Specifications
Slope angle (degrees)	37	20
Lift Height (m)	20	20
Berm width (m)	43	15
Berm slope (degrees)	0	-10

Comments

Material emanating from Deposit F is generally of moderate to high erodibility. However, there is a significant proportion of hydrated material which is sufficiently competent to be used as a capping layer to protect the surface of the dump from erosion. Stockpiles of the material will be used to cap the dump prior to rehabilitation, and this will allow less conservative design specifications to be applied than elsewhere at the site.

Construction Design



Rehabilitation Design

WEST ANGELAS DUST DISPERSION MODELLING – DEPOSITS A, B, E, F, AWEST, C, D AND G

Prepared for

RioTinto

Rio Tinto Pty Ltd

by

ENVALL

Environmental Alliances Pty Ltd

November 2016

Disclaimer and Limitation

Environmental Alliances Pty Ltd (ENVALL) will act in all professional matters as a faithful adviser to the Client and exercise all reasonable skill and care in the provision of its professional services.

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Client: Rio Tinto Pty Ltd

Job No: L5103/L6294	**Version**	**Prepared by**	**Reviewed by**	**Submitted to Client**	
Status				**Copies**	**Date**
Draft Report	2c	DP	-	*.pdf	22/9/2015
Draft Report	3a	DP	-	*.pdf	16/10/2015
Final Report	3c	DP	KP	*.pdf	22/10/2015
Revised Draft[a]	4a	DP	-	*.pdf	10/11/2016
Revised Final	4b	DP	-	*.pdf	14/11/2016

[a] Revised with updated blast fuel increase from 1200 kg to 4500 kg.

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1. INTRODUCTION

ENVALL has been engaged by Rio Tinto Iron Ore (RTIO) to model dust emissions in association with mining deposits A, B, E, F, Awest, C, D and G at West Angelas as they are developed over the years from 2016 to 2032. This assessment is intended to support applications for environmental approvals under Part V of the *Environmental Protection Act 1986*.

Previous assessments of the West Angelas dust impacts are described in:

- Environmental Alliances Pty Ltd (ENVALL), 2007, “Preliminary Air Quality Assessment Report West Angelas Operations”, May 2007;
- Environmental Alliances Pty Ltd (ENVALL), 2010, “West Angelas Iron Ore Operation Deposit E Project - Dust Impact Assessment”, January 2010;
- Environmental Alliances Pty Ltd (ENVALL), 2013, “Validation of Dust Dispersion Modelling For West Angelas Iron Ore Mining Operations”, January 2013;
- Environmental Alliances Pty Ltd (ENVALL), 2013, “Dust Impact Assessment for Development of Deposit B -West Angelas Iron Ore Mining Operations”, June 2013.

A report titled “West Angelas Dust Dispersion Modelling – Deposits A, B, E, F, Awest, C, D and G” was prepared in 2015 (ENVALL 2015). This report is a revised version of the afore-mentioned to account for a change in the blast size from 1,200 kg to 4,500 kg[1].

2. LOCATION

The West Angelas mine operation is located in the Eastern Pilbara region of Western Australia approximately 130 kms west of Newman (see Figure 1). The deposits are located within the Mining Lease Number AML70/00248 within the Shire of East Pilbara.

[1] References to changes in dust levels throughout this report can be found by searching for “4,500 kg”.

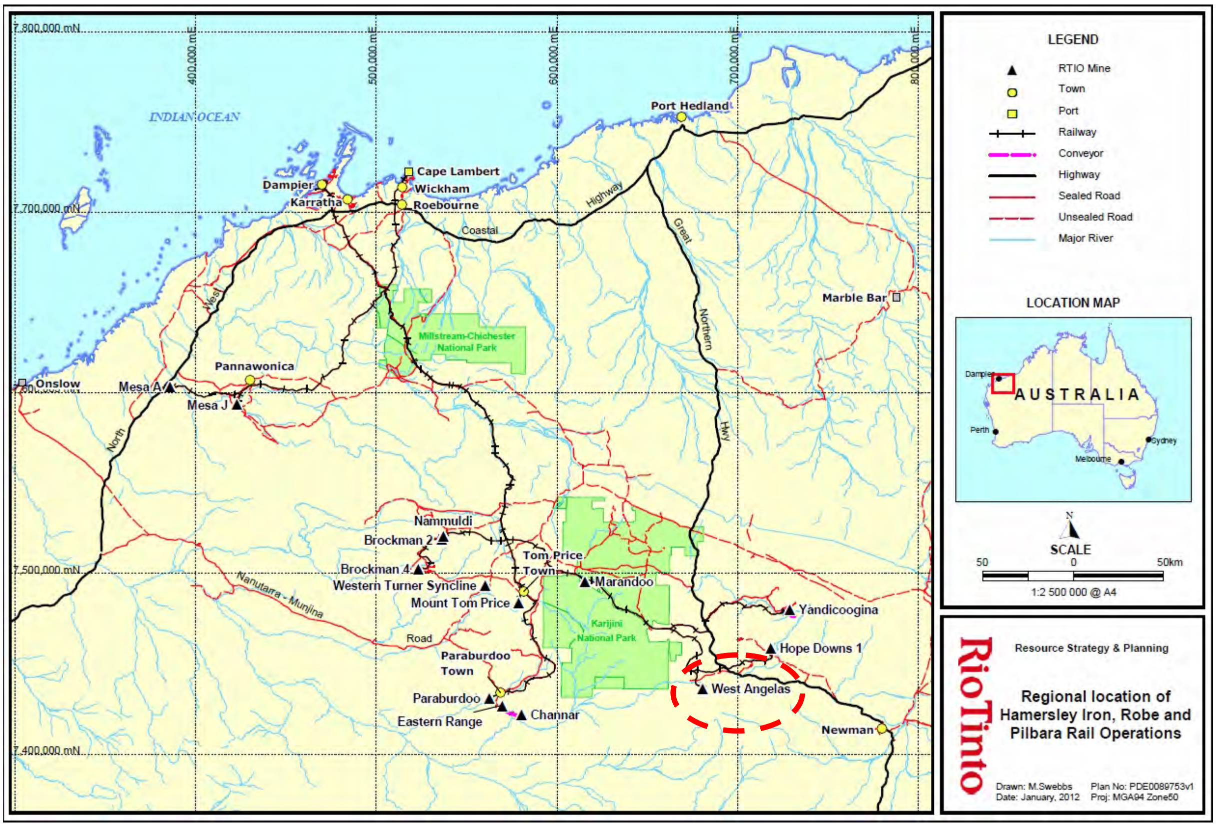

Figure 1 Regional location of West Angelas operation

3. ASSESSMENT CRITERIA

3.1 NATURE OF DUST

Particulates, alternatively referred to as particulate matter (PM), aerosols or fine particles, are tiny particles of solid (a smoke) or liquid (an aerosol) suspended in a gas. They range in size from less than 10 nanometers to more than 100 micrometers (µm) in diameter. "Dust" is a more common name for particulate matter and is generally defined as particles that can remain suspended in the air by turbulence for an appreciable length of time. Dust can consist of crustal material, pollens, sea salts and smoke from combustion products.

Typically, particulate matter is characterised by its size, as measured by collection devices specified by regulatory agencies. The particulate size ranges specified in ambient air guidelines are:

- Total suspended particulate (TSP);
- Particulate matter measured with a sampler with 50% cut point at 10 µm (PM10); and
- Particulate matter measured with a sampler with 50% cut point at 2.5 µm (PM2.5).

TSP refers to particulates that can remain suspended in the air or can be measured though a TSP sampler. The particle size is not a fixed physical size, but varies, as the size of particle that can remain suspended in the air is a function of air turbulence. TSP is associated with nuisance impacts such as a reduction in visibility. PM10 is inhalable; PM2.5 is more associated with health impacts. In addition such impacts are dependent on the actual particulate type / content, as some are more likely to have health implications than others.

This report addresses TSP, PM10 and dust deposition impacts. PM2.5 is not assessed, as health impacts from crustal sources are considered to be less than from urban sources and therefore no applicable criterion has been adopted by environmental regulators[2].

3.2 DUST CRITERIA

3.2.1 Dust in the Pilbara

The regulatory management of dust from industrial sources in the Pilbara is complicated by the ubiquitous nature of other dust sources which can, for example, take the form of vehicle-generated dust from unpaved roads and wind erosion of unpaved roads, non-vegetated and disturbed areas. The Pilbara environment is also characterised by periodic “dust storms” caused by large scale wind erosion of inland areas that have been denuded of vegetation by recent wildfires or following a prolonged dry period.

This is illustrated by ambient dust monitoring data from Boodarie (near Port Hedland), considered to be a “background site”, in the 2007 State of the Environment Report (Table A.3.1 EPA, 2007). This showed that over 1996 to 2001, there were up to 22 exceedences of the NEPM 24-hour average PM10 standard in some years, and zero exceedences for other years. For the six years of data reported, there was on average 8.5 exceedences of the PM10 standard per year.

The Western Australian Department of Environmental Regulation (DER) and Environmental Protection Authority (EPA) do not have generic dust criteria applicable to remote mining operations. The criteria used here are from other references as an indication of what might be considered acceptable.

3.2.2 Airborne concentrations for human health and amenity

The RTIO E2 Air Quality Standard requires the development of ambient air quality criteria in the absence of specific government regulations. Dust criteria for inland Pilbara mining operations adopted by RTIO are described in “Iron Ore (WA) Cleaner Air Management Plan” (February 2011). RTIO’s airborne dust concentration criteria for human health and amenity are shown in Table 1.

[2] Note that the National Environmental Protection Measure for Ambient Air Quality was amended in 2003 to include an “advisory reporting standard” for PM2.5. This is intended to “provide a tool for communicating information to the community on air quality related to PM2.5, and enable the effectiveness of air quality management programs that are designed to manage PM2.5 emissions to be assessed” (NEPC 2003). Consequently, the modelling for this work can provide PM2.5 predictions if subsequently required.

Table 1 RTIO internal dust concentration criteria – inland mining operations

Parameter/ Particle size	Averaging time	Concentration	Frequency	Location	Relevant Sites
PM10	24 hours	70 μg/m^3 [(a)]	Not more than 10 days a year	Nearest sensitive receptor to operations (eg. camp, towns, nearest residence)	Tom Price, Greater Paraburdoo, Marandoo, Brockman 2, Brockman Syncline 4, Nammuldi, West Angelas, Hope Downs, Yandi, Robe Valley mines
	Annual[(b)]	70 μg/m^3	Annual average	Nearest sensitive receptor to operations (eg. camp, towns, nearest residence)	Tom Price, Greater Paraburdoo, Marandoo, Brockman 2, Brockman Syncline 4, Nammuldi, West Angelas, Hope Downs, Yandi, Robe Valley mines

From RTIO (2011) Table 5.

(a) From the Port Hedland Air Quality and Noise Management Plan for managing air quality impacts from Port Hedland port operations on nearby residential and commercial areas (see http://www.dsd.wa.gov.au/7899.aspx). The dust criterion is defined as *a maximum allowable level for Port Hedland dust (PM10) of 70 μg/m^3 (micrograms per cubic metre) over 24 hours with not more than 10 exceedances per year.* The criterion was based on the recommendations of a report commissioned by the Department of Health (Lung Institute of Western Australia Inc and Institute of Occupational Medicine 2007). The Western Australian Government has adopted the Plan.

(b) The basis of this is not known, however it is considered to be too high relative to the 24-hour guideline.

Other criteria used for regulatory assessments of dust impacts in populated/urban areas in Western Australia, are:

- For PM10, the National Environmental Protection Measure for Ambient Air Quality ("Air NEPM") Standard of 50 μg/m^3, 24-hour average (NEPC 2003); and
- For TSP, the Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992, collectively referred to as the "Kwinana EPP".

These are summarised in Table 2. In the past, the DER has accepted that the PM10 Standard specified in the Air NEPM cannot be met in the inland Pilbara[3].

[3] See the Environmental Assessment Report in the Mesa A licence - http://portal.environment.wa.gov.au/pls/portal/docs/PAGE/ADMIN_LICENSING/LICENCES/2006/TAB8118754/8388ROBEMESA_3.PDF

Table 2 Other Western Australian criteria for airborne dust concentrations in populated areas

Parameter	Value	Units	Averaging time[c]	Frequency	Reference
PM10 concentration	50	µg/m³	1 day	Not more than 5 days per year	Air NEPM (NEPC 2003)
TSP concentration	90	µg/m³	1 day	"Desirable not to be exceeded" [b]	Kwinana EPP, Area C (residential) [a]

[a] Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992.

[b] This has been interpreted as the 5th highest 24-hour average in a year for the purposes of environmental impact assessments of Dampier Port upgrades (EA 2005). This is approximately the 99th percentile and is also consistent with the NEPM PM10 Standard which is referenced to the 5th highest 24-hour average in a year. This means that if the 6th highest predicted PM10 or TSP concentrations exceed the relevant concentration limit, the guideline is predicted to be exceeded.

[c] Averaging times defined as calendar periods.

3.2.3 Dust deposition

Deposited dust is that defined by the sampling method in Australian Standard AS 3580.10.1-2003. Particles that settle from the air are collected in a vessel. The sample is then sieved, filtered and the mass of remaining insoluble solids weighed. RTIO's dust deposition criterion is shown in Table 3.

Table 3 RTIO internal dust deposition criterion – inland mining operations

Parameter/ Particle size	Averaging time	Concentration	Frequency	Location	Relevant Sites
Deposited Dust	Annual[a]	4 g/m²/month as total maximum from all sources; equivalent to - 2 g/m²/month as additional maximum from mining operations for 2 g/m²/month background; or - 3 g/m²/month as additional maximum from mining operations for 1 g/m²/month background.	Monthly	Mining lease boundary/nearest sensitive receptor	Tom Price, Greater Paraburdoo, Marandoo, Brockman 2, Brockman Syncline 4, Nammuldi, West Angelas, Hope Downs, Yandi, Robe Valley mines

From RTIO (2011), Table 5.

[a] The criterion is an annual average but expressed on a "monthly" basis where the averaging period of a month is classified as a 30-day period.

This criterion is from the New South Wales (NSW) "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales" (2005). The NSW dust deposition criterion is based on nuisance effects to humans and applies at sensitive human receptors. Table 7.1 of the NSW document clarifies that the criterion is actually one part of a dual-part criteria. The 4 g/m²/month[4] refers to total deposited dust, while the adjacent specification of 2 g/m²/month is the additional

[4] A dust deposition rate of 4g/m²/month equates to a visible layer of dust on outdoor furniture or on a clean car deposited each month.

deposition attributable to the (industrial) source. Consequently, it has therefore also been assumed that background dust deposition around population centres in the Pilbara is 2 g/m^2/month. Away from population centres, the background dust deposition in the Pilbara is considered to be around 1 g/m^2/month[5].

With respect to vegetation health, research on the effects of dust deposition has been undertaken in Australia by Doley (2006). Doley concluded that “critical dust loads that result in significant alterations in the most sensitive plant functions vary with the particle size distribution and colour of the dust, from about 1 g/m^2 for carbon black with a median diameter of about 0.15 µm to about 8 g/m^2 for coarse road or limestone dusts with median diameters greater than about 50 µm. The critical loads vary with the plant function and it is not possible to predict precisely the nature of one plant response from the knowledge of another”. For mineral dust, “Farmer (1993) showed that direct physical effects of mineral dusts on vegetation became apparent only at relatively high surface loads (e.g. >7 g/m^2)”.

The Pilbara environment is naturally dusty, hence native vegetation is expected to be reasonably tolerant to dust deposition. Internal studies undertaken for Rio Tinto (Butler 2009) suggest that the potential for adverse dust deposition effects on plants is seasonally related. This is consistent with the results from other studies on the effects of air pollutants on vegetation, which indicate that adverse effects are usually related to the growing season.

The Butler (2009) study failed to identify any significant loss of plant function for exposures of Pilbara species to deposited crustal dust loadings on plant leaves of up to a very high level of 7,500 g/m^2 (Butler 2009). This level should not strictly be compared to dust deposition predictions from modelling. Dust deposition predictions from modelling are effectively from vertical settling only. Plant leaves tend to trap dust irrespective of whether the dust is deposited from vertical settling or impacted horizontally from the wind. Therefore a plant leaf dust loading of 7,500 g/m^2 would correspond to a predicted deposition of somewhat less than this.

For this study, 7 g/m^2/month is used as an indicative criterion for potential effects on vegetation, however the Butler (2009) work shows that this is probably very conservative.

3.2.4 Aerodrome

There is no specific criterion for the operation of the aerodrome and residential criteria are not relevant in this case. Occupational hygiene should be considered in a separate study. Aerodrome Management Services (AMS) is assisting RTIO in aerodrome management.

3.2.5 Fauna habitat

Whilst there is no established criterion for Ghost Bats, the species has a conservation status of Priority 4 as listed by the Department of Parks and Wildlife. In addition, the West Angelas Operational Environmental Management Plan (Ministerial Statement 970) specifies the requirement to protect Ghost Bat habitat in close proximity to deposits. For this reason, RTIO have Blast Management Plans in place for Deposits E and B, and further plans will be developed specific to each deposit (i.e. Deposit F), as required. The Management Plans cover aspects such as monitoring, blast prediction and utilisation of sonic fencing for protection against noise and dust from blasting.

[5] O. Pitts pers com from greenfields monitoring data.

3.3 SUMMARY OF GUIDELINES

The dust guidelines considered applicable in remote areas of the Pilbara and used in this report are summarised in Table 4.

Table 4 Guidelines for airborne dust concentrations

Parameter	Averaging time[b]	Value	Frequency	Location	Reference(s)
PM10 concentration	1 day	70 μg/m^3	Not more than 10 days a year	Nearest sensitive receptor to operations (eg. camp, towns, nearest residence)	PHNDMP (Government of WA 2010) "Iron Ore (WA) Cleaner Air Management Plan" (Rio Tinto 2011)
TSP concentration	1 day	90 μg/m^3	"Desirable not to exceed" - Not more than 5 days a year		Kwinana EPP, Area C (residential) [a]
Deposited Dust[c]	Annual	4 g/m^2/month as total maximum from all sources; equivalent to - 2 g/m^2/month as additional maximum from mining operations for 2 g/m^2/month background; or - 3 g/m^2/month as additional maximum from mining operations for 1 g/m^2/month background.		Mining lease boundary/nearest sensitive receptor	NSW (2005) "Iron Ore (WA) Cleaner Air Management Plan" (Rio Tinto 2011)

(a) Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992.

(b) Averaging times defined as calendar periods.

(c) Deposited dust is determined as the insoluble solids as defined by AS 3580.10.1-2003.

4. BACKGROUND AIRBORNE CONCENTRATIONS ASSUMED FOR MODELLING

In previous Pilbara mining assessments, ENVALL has assumed a "clean" regional background PM10 concentration of 11 µg/m^3, which was based on the average concentration from ambient monitoring during offshore winds at Dampier where the upwind fetch was undisturbed land.

Background levels can, however, be higher than this if there are other local human activities (e.g. towns, public roads and pastoral) in the region that cause dust emissions. In such cases, background levels are subject to higher variability.

RTIO have previously provided ambient PM10 data for the period July 2011 to June 2012 from an E-Sampler dust monitor, located 500 m east of the on-site Village (data described in detail in ENVALL (2013)).

This report has assumed 18 µg/m^3 as representative of local background PM10 concentrations. This was determined from the 70th percentile of 24-hour average PM10 concentrations from the monitor. The use of the 70th percentile of measured concentrations as an estimate of background levels for modelling is recommended in the Victoria Government Gazette (2001).

For TSP, ENVIRON (2004) reported a 70th percentile 24-hour average TSP concentrations from monitoring at Port Hedland of 33 µg/m^3. In that study, the daily background was determined as the minimum from all the Port Hedland monitoring sites for that day.

It is assumed that background levels of TSP in the West Angelas Village should be similar to those in Port Hedland and hence a background level of 33 µg/m^3 has been used in this study, noting that this is really only applicable to predicted TSP at the Village.

5. SENSITIVE RECEPTOR LOCATIONS

5.1 IMPACTS TO HUMANS

The nearest sensitive receptors to the West Angelas operation, where impacts to humans are relevant, are the mine village and the aerodrome, which are approximately 6 kms west of Deposit B (see Figure 3).

Table 5 Locations of dust-sensitive receptors for impact to humans

Location	GDA94E (Km)	GDA94N (Km)
Mine village (south side)	673.660	7,440.730
Aerodrome	675.441	7441.096
	675.552	7440.985
	674.072	7439.585
	673.969	7439.686
	674.559	7440.248
	674.500	7440.311

5.2 BAT LOCATIONS

Rio Tinto personnel have also provided locations of local ghost bat caves for which dust level predictions are required. The locations of these are shown in Table 6.

Table 6 Locations of bat caves

Location	GDA94E (Km)	GDA94N (Km)
Caves A1 & A2	681.780	7442.620
Caves L2 & L3	682.928	7442.614
Cave AA1	686.953	7434.461

6. MODELLING METHODOLOGY

6.1 DISPERSION MODEL

The United States Environmental Protection Agency's (US EPA's) CALPUFF version 6 model was used to predict dust impacts from the West Angelas operation. This model has been adopted by the US EPA in its "Guideline of Air Quality Models" as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas, and on a case-by-case basis for certain near-field applications involving complex meteorological conditions.

More specifically to this study, the US EPA Guideline provides for the use of CALPUFF on a case-by-case basis for air quality estimates involving complex meteorological flow conditions, where steady-state straight-line transport assumptions are inappropriate. The hilly terrain around the Pilbara mine-sites and the relatively large distances between sources and areas of interest necessitates the use of this type of model for realistic predictions of dispersion and deposition.

The CALPUFF modelling system consists of three main components; CALMET - a diagnostic 3-dimensional meteorological model, CALPUFF - an air quality dispersion model, and CALPOST - a post-processing package.

An example of the input parameters used for the CALPUFF model is provided in Appendix 6.

The following is a summary of key model set-ups:

- meteorological modelling grid resolution used of 1 km with a pollution grid resolution of 500 m used to improve predictions closer to sources[6];
- terrain height data was sourced from the United States Geological Survey (USGS) Shuttle Radar Topography Mission (SRTM) archive (see http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/). These data were obtained from the STS-99 mission of the Space Shuttle Endeavour during February 2000. For Australia, these data are available at a resolution of 3 arc-seconds (referred to as SRTM3) or approximately 90 m with elevated features removed;
- a land use category of 30 – "Rangeland" was defined for modelling domain. The CALMET defaults were used for this category except for a slightly increased roughness length of 0.25 m;
- terrain effects on dispersion taken into account using plume partial height adjustment scheme; and
- particle settling[7] and deposition taken into account.

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6 It was originally intended to use a 250 m resolution for the pollution grid, however the computational requirements across the domain for the number of sources used became excessive.

7 Note that this requires the setting of the MTILT=1 option outside the CALPUFF GUI and each particle size to be modelled separately

6.2 METEOROLOGICAL DATA

Surface meteorological data for the modelling period 1/7/2011 to 30/6/2012, was derived from the RTIO West Angelas anemometer, with missing data from the Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) The Air Pollution Model (TAPM) prognostic model (see Appendix 1). An annual wind speed and direction frequency rose from these data is shown in Figure 2 This shows that winds from the north-north-east to east are dominant. The average wind speed of 3.0 m/s is fairly typical of Pilbara inland locations.

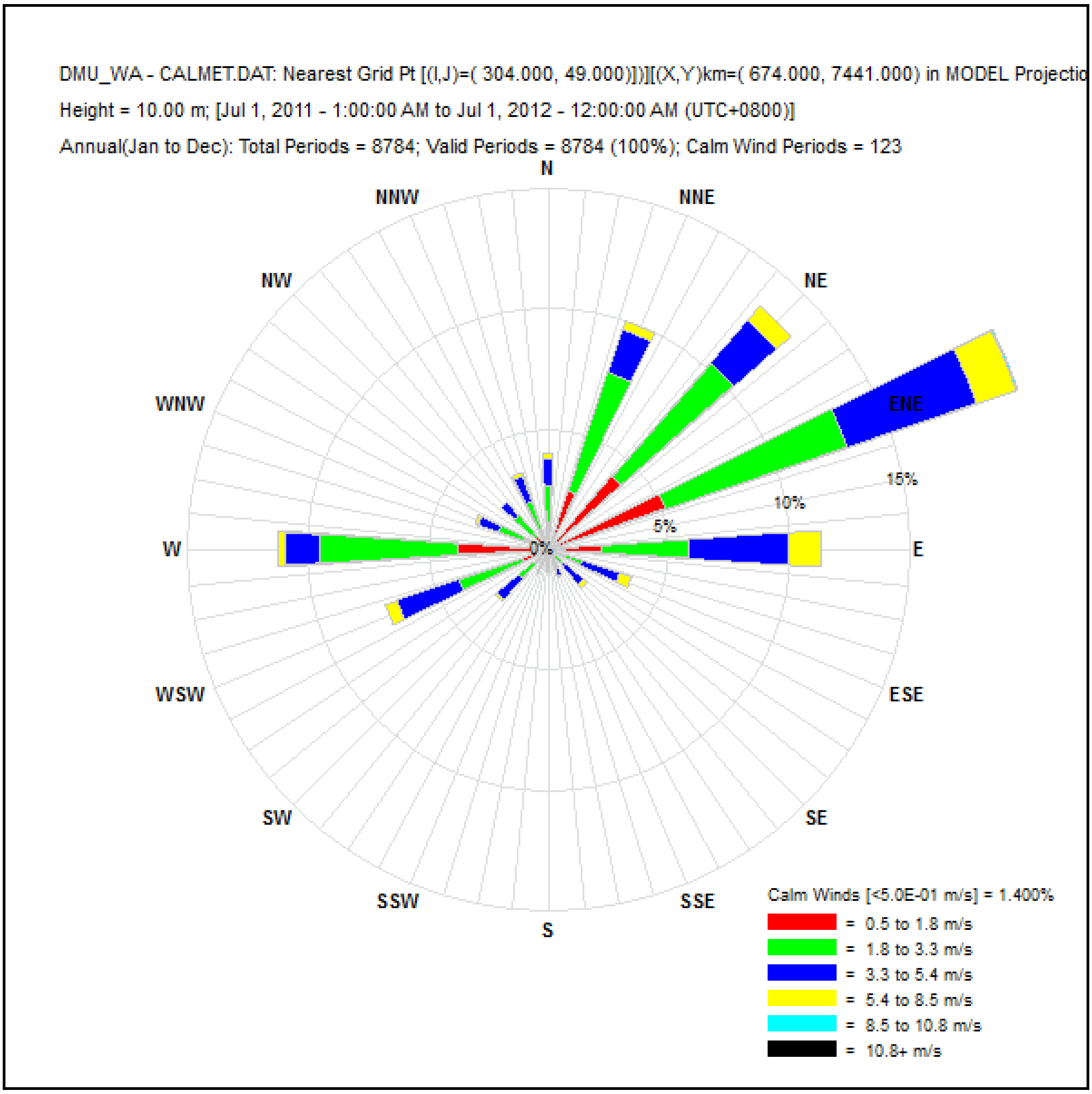

Figure 2 Wind speed and direction frequency matrix and rose for West Angelas 1/7/2011 to 30/6/2012

Seasonal and diurnal roses are shown in Appendix 1. The diurnal regime is for strong east winds from the early morning, becoming lighter during the day and swinging to west to north-west in the late evening.

An upper air profile for CALMET was also generated using TAPM (see Appendix 1).

7. DUST EMISSIONS

Dust emissions estimates were based on PM10 emissions for the 2013-14 year for the existing operation reported by RTIO pursuant to the National Pollutant Inventory (NPI) requirements. It is noted that dust emissions from mining operations are difficult to determine accurately using generalised emissions estimation techniques (EETs)[8].

Four broad categories of sources were defined for modelling purposes:

- active pits;
- active waste dumps;
- stockpiles; and
- plant/process areas.

In most cases, the general physical locations of the emissions sources are apparent from the NPI spreadsheets (eg wind erosion from pits), however in some cases, assumptions are required for the physical location of the sources (eg truck dumping, dozing etc).

The assumed distribution of PM10 emissions sources from the source groups for the existing operation are summarised in Table 7.

[8] As stated on the NPI EET web page "It should be emphasised that the emissions data derived using any EET will have a degree of uncertainty associated with it"[8].

Table 7 Dust emissions apportionment by source for 2013-14

Source	Dust emissions apportionment by source (%)				
	Total	Pits	Waste dumps	Ore Stockpiles/ Outloading	Process Area
Drilling	1.3	1.3			
Blasting	1.5	1.5			
Excavator	0.9	0.9			
Dozers	13.2	7.8	5.4		
Unloading Haul trucks	1.3	0.8	0.5		
Haul truck wheels in pits/dumps	52.4	22.3	30.1		
Graders	0.1	0.1	0.1		
Wind erosion	6.5	1.2	4.3	0.1	0.9
Primary Crushing	1.6				1.6
Loading Haul trucks	0.4	0.3	0.2		
Transfers/Stackers/Train Load Out/Locos	20.8			20.8	
Total/Sub-totals	**100.0**	**36.1**	**40.5**	**20.9**	**2.5**

7.1 DEVELOPMENT OF WEST ANGELAS

The layout and mining stages of the West Angelas deposits relevant to this study are shown in Figure 3 and Table 8 respectively.

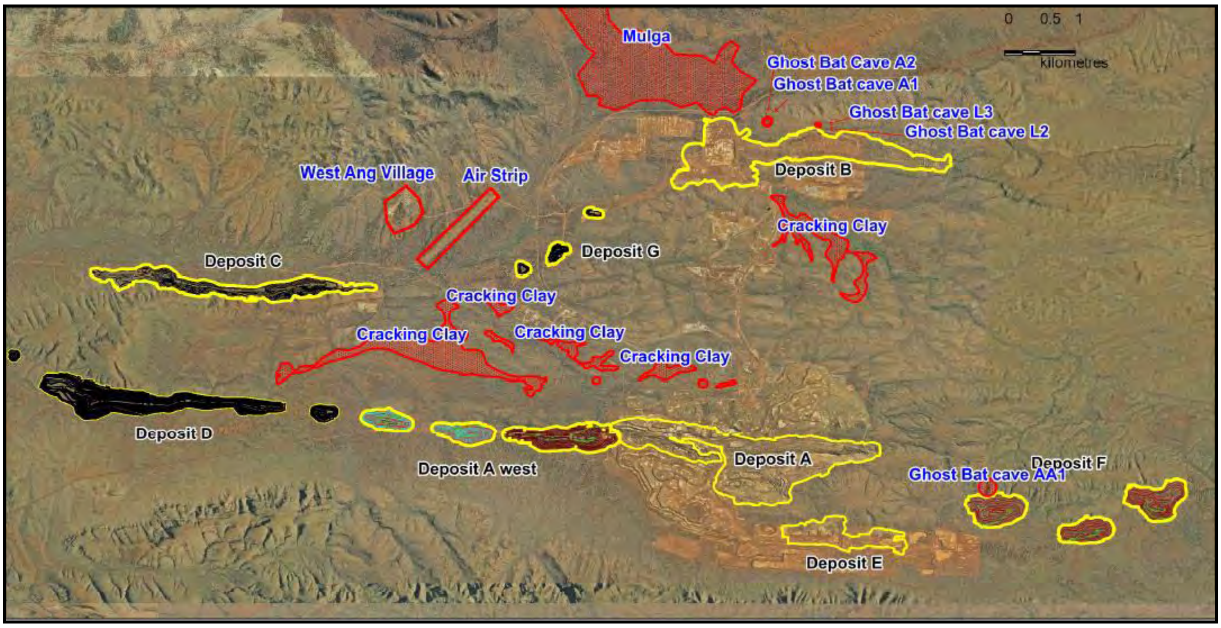

Figure 3 West Angelas current and future deposits

The estimated dust (as PM10) emissions are shown in Table 9. Emissions for hauls roads external to pits and dumps were considered as additional sources. The derivation of these emissions is discussed in Appendix 3, as these are very uncertain and have a large impact on predicted ambient dust levels. The years modelled – 2017, 2019, 2021, 2022, 2023, 2025, 2027 and 2029, were selected to indicate likely worst-case impacts through the project at various different locations closest to the maximum producing pits.

Table 8 Summary of West Angelas production 2016 to 2032 (000's tonnes)

Year	2013-14	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Pits																		
Awest		0	0	0	0	0	0	0	0	0	538	4,840	1,959	8,576	11,056	3,211	0	0
DepA		7,485	8,837	4,053	774	0	0	0	0	0	0	0	0	0	0	0	0	0
DepB		22,398	22,228	25,709	19,438	7,997	8,856	2,191	5,003	8,204	1,172	0	0	0	0	0	0	0
DepC		0	0	0	232	10,100	16,173	16,395	12,210	7,044	3,448	618	1,635	0	0	28	0	0
DepD		0	0	0	0	1,018	3,650	11,304	12,596	7,424	9,046	2,417	1,979	1	369	2,256	3,695	950
DepE		4,987	0	0	0	62	168	156	1,590	5,802	5,865	1,576	3,376	2,691	0	3,997	0	0
DepF		38	3,392	4,698	13,799	15,070	5,650	4,443	1,093	243	0	0	0	0	0	0	0	0
DepG		0	0	0	0	0	0	0	1,975	2,564	1,803	418	580	0	0	0	0	0
DepH	36,975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-Totals		34,908	34,456	34,460	34,243	34,247	34,496	34,488	34,467	31,282	21,873	9,871	9,529	11,268	11,425	9,492	3,695	950
Dumps																		
Awest		0	0	0	0	0	0	0	0	32,899	45,836	55,481	45,015	46,223	25,861	3,265	0	0
DepA		26,793	13,163	5,947	137	0	0	0	0	0	0	0	0	0	0	0	0	0
DepB		62,386	61,627	50,522	29,506	35,782	28,844	28,847	34,997	13,038	815	0	0	0	0	0	0	0
DepC		0	0	0	968	28,094	36,577	40,680	19,309	17,468	11,552	877	1,710	0	0	186	0	0
DepD		0	0	0	0	6,982	50,786	60,610	52,716	24,518	17,070	2,302	1,530	7,513	27,969	14,707	7,113	646
DepE		10,486	0	11,454	24,155	23,797	15,099	22,602	31,206	28,822	12,934	4,138	11,504	8,327	0	6,612	0	0
DepF		762	39,156	40,812	42,933	38,077	24,323	13,395	1,641	59	0	0	0	0	0	0	0	0
DepG		0	0	0	0	0	0	0	16,358	5,487	1,187	60	904	0	0	0	0	0
DepH	82,130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-Totals		100,427	113,946	108,735	97,699	132,732	155,628	166,134	156,226	122,290	89,394	62,859	60,663	62,063	53,830	24,771	7,113	646

Note: As provided by RTIO "WA_CDG_OoM_report_03_basecase_MM_25AL_FINAL" spreadsheet date Tuesday 16 June 2015. Beige shaded years are those modelled.

Table 9 Estimates PM10 emissions per year over duration of West Angelas project

Year	PM10 Emissions (kg/year)										
	Operations areas [(a)]				Haul Roads (outside pits/dumps)[(b)]						
	Pits[(c)]	Waste dumps	Ore Stockpiles/ Outloading	Process Area	Deposit Awest	Deposit B	Deposit C	Deposit D	Deposit E	Deposit F	Deposit G
2016	1,146,981	1,667,943	663,260	79,276	0	5,359,856	0	0	1,240,419	65,163	0
2017	1,132,129	1,892,474	654,672	78,249	0	5,750,893	0	0	0	3,520,665	0
2018	1,132,261	1,805,927	654,748	78,258	0	5,656,769	0	0	639,344	3,980,009	0
2019	1,125,131	1,622,635	650,625	77,766	0	3,800,215	65,534	0	1,470,409	5,762,929	0
2020	1,125,262	2,204,481	650,701	77,775	0	2,783,593	2,776,956	427,393	1,860,723	6,023,356	0
2021	1,133,443	2,584,750	655,432	78,340	0	2,630,315	4,066,790	3,293,226	1,269,097	2,918,336	0
2022	1,133,181	2,759,239	655,280	78,322	0	1,608,520	4,232,270	5,170,906	2,025,120	2,139,857	0
2023	1,132,491	2,594,681	654,881	78,274	0	2,894,553	2,790,707	4,952,197	3,141,665	412,715	976,298
2024	1,027,840	2,031,055	594,365	71,041	3,544,312	1,545,629	1,809,996	2,806,345	3,622,568	68,930	482,133
2025	718,686	1,484,701	415,592	49,673	5,077,335	182,811	957,873	2,638,968	2,241,765	0	216,883
2026	324,334	1,043,994	187,551	22,417	7,147,671	0	125,409	576,920	566,963	0	41,214
2027	313,097	1,007,522	181,053	21,640	5,162,309	0	312,106	478,861	1,679,152	0	108,279
2028	370,235	1,030,774	214,094	25,590	6,719,387	0	0	346,152	1,438,200	0	0
2029	375,394	894,036	217,078	25,946	4,916,072	0	0	1,631,590	0	0	0
2030	311,881	411,409	180,350	21,556	906,998	0	13,332	1,247,154	1,566,345	0	0
2031	121,408	118,136	70,206	8,391	0	0	0	1,148,229	0	0	0
2032	31,214	10,729	18,050	2,157	0	0	0	223,710	0	0	0

(a) All emissions scaled by 1.24 based on the results of previous modelling validation exercises for RTIO iron ore mining operations (see Appendix 4).

It is assumed that there are no wind-generated dust emissions from operational areas once activity has ceased. This is considered reasonable on the basis that erodible dust from exposed areas is depleted in the absence of continuing activity, the crusting of erodible areas following rain periods and assuming that waste dumps are progressively rehabilitated.

It was assumed that all equipment would be operating continuously during the operational hours.

(b) Deposit A haul roads considered within pits/dumps.

(c) The increase in blast size to 4,500 kg increases dust emissions from the pits by 21%, however only increases all sources dust emissions by 0.7 to 2.4% depending on the year.

7.2 PARTICLE SIZE DISTRIBUTION

Since dust is subject to gravitation settling and deposition, assumptions need to be made regarding particle sizes. A particle size distribution for modelling dust dispersion was therefore estimated using composite data from the US EPA size distributions and the National Energy Research, Development and Demonstration Council (NERDDC) (1988) study, as summarised in Table 10 (from Air Assessments 2011).

Table 10 Airborne particle size distributions

Source/ Aerodynamic particle diameter range (µm)	<2.5	2.5-5.0	5.0-10.0	10-15	15-30	30-50	50-90	90-150
Percentage of PM30								
USEPA (2006) wind erosion	7.5	42.5		10	40	NA	NA	NA
USEPA (2006) unpaved road	3.1	27.6		69.4		NA	NA	NA
Percentage of TSP								
USEPA aggregate handling (Nov 2006)	5.3	14.7	15	13	26	26		
NERDDC (1988) operations iso-kinetic sampler	4	9	17	11	22	17	13	7
Composite fraction of TSP (%)	5	12	16	12	25	15	10	5
Used in this assessment								
Aerodynamic particle diameter range (µm)	**<2.5**	**2.5-5.0**	**5.0-10.0**	**10-15**	**15-30**	**>30**		
Fraction of TSP (%)	**5**	**12**	**16**	**12**	**25**	**30**		
Assumed aerodynamic particle diameter (µm)	**1.8**	**3.8**	**7.5**	**12**	**22**	**40**		

Notes

1) USEPA TSP percentages were estimated from the PM_{30} based on 74% of wind erosion material and 76% of batch drop dust is below PM_{30}.

2) Mass in size fraction as a percentage of PM10 adopted this study TSP/PM10 =3.03; PM2.5/PM10 = 0.16.

The above distribution indicates that the fraction of PM10 in TSP is 0.33. Therefore, the modelled TSP emission rates are 3.03 times the PM10 emission rates.

8. MODEL PREDICTIONS

8.1 MODEL UNCERTAINTY

Atmospheric dispersion models represent a simplification of the many complex processes involved in determining ground level concentrations of pollutants. Model uncertainty is composed of model chemistry/physics uncertainties, data uncertainties, and stochastic uncertainties. Models predict 'ensemble mean' concentrations for any specific set of input data (for example, 1-hourly over a year), that is, they predict the mean concentrations that would result from a large set of observations under the specific conditions being modelled. However, for any specific hour with those exact mean hourly conditions, the predicted ground level concentrations will never exactly match the actual pattern of ground level concentrations, due to the effects of random turbulent motions and random fluctuations in other factors such as temperature.

As described in US EPA (2005), from the results of numerous studies of model accuracy:

- models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and
- models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ± 10 to 40 percent are found to be typical i.e., certainly well within the often quoted "factor-of-two" accuracy that has long been recognized for models. However, estimates of concentrations that occur at a specific time and location are poorly correlated with actually observed concentrations and are much less reliable.

For this study, a somewhat coarse pollution grid interval of 500 m was used to reduce computational requirements. This means that predictions close to sources will be less reliable within this distance.

8.2 PREDICTED DUST LEVELS FOR EACH YEAR

The predicted dust levels at each discrete receptor are shown in Table 11 to Table 14. Time series plot of predicted dust levels at each discrete receptor are shown in Figure 4 to Figure 8. In these figures, the change resulting from the blast size increase to 4,500 kg is shown above the previous values and labelled with a "-Rev" in the Legend. It should also be noted that the background contributions are relatively large.

From these, in general, the prediction in relation to the criterion for TSP is a little more stringent than for PM10. This could be because the TSP criterion was derived for urban residential areas where the ambient environment has low background dust, whereas the PM10 criterion has been derived for the dustier Pilbara conditions.

Some general observations from the tables and figures are:

- the maximum predicted dust levels at the Village for all parameters are for 2022; and
- the maximum predicted dust levels at the most impacted area of the aerodrome are also at 2022.

The reasons the highest dust levels occur at the Village and aerodrome during 2022 are:

- over the year 2022, the TMM, and therefore dust emissions, peak for Deposit C;
- the peak annual TMM from Deposit C is reasonably high (approximately 57 Mtpa);
- Deposit C is relatively close to the Village and aerodrome (approximately 1 -2 kms to the west-south-west);
- winds from the west-south-west, are reasonably frequent at approximately 7 – 8% of the time. Furthermore, winds from the due west, which would also cause dust from the western end of Deposit C to impact the Village and aerodrome, are even more frequent at approximately 11% of the time; and
- the dimensions of Deposit C are largest along the east-west axis, which means that dust emissions result in a narrow, more concentrated plume for winds near westerly.

In relation to the ghost bat caves:

- the maximum predicted dust levels at the ghost bat caves A1 and A2 are at 2017 after which they decrease;
- the maximum predicted dust levels at the ghost bat caves L2 and L3 are at 2017 after which they decrease; and

- the maximum predicted dust levels at the ghost bat caves AA1 are at 2019 after which they decrease.

The dust impacts at the ghost bat caves are simply coincidental to the year that the highest TMM occurs from the adjacent deposit.

Table 11 Predicted 11th highest 24-hour PM10 concentrations at Village and aerodrome each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion ($\mu g/m^3$)	70	70	70	70	70	70	70	70
Background ($\mu g/m^3$)	18	18	18	18	18	18	18	18
Predicted from operation ($\mu g/m^3$)								
Mine village	49	37	58	67	62	52	33	32
Aerodrome	52	40	53	63	65	54	36	34
	56	41	57	65	69	56	38	36
	39	32	104	117	84	62	43	39
	38	31	96	110	81	59	41	38
	41	32	67	78	68	52	37	34
	40	31	65	76	67	51	36	32
Aerodrome maximum	56	41	104	117	84	62	43	39
Cumulative (operation + background) ($\mu g/m^3$)								
Mine village	67	55	76	85	80	70	51	50
Aerodrome maximum	74	59	122	135	102	80	61	57
Percent of criterion (%)								
Mine village	96%	79%	109%	122%	115%	100%	74%	71%

Table 12 Predicted 6th highest 24-hour TSP concentrations at Village and aerodrome each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion (µg/m³)	90	90	90	90	90	90	90	90
Background (µg/m³)	33	33	33	33	33	33	33	33
Predicted from operation (µg/m³)								
Mine village	76	57	90	104	96	78	49	46
Aerodrome	89	67	82	93	102	78	53	51
	96	68	87	97	107	82	56	54
	67	51	174	200	143	99	71	63
	67	49	165	190	138	96	68	60
	70	53	107	125	107	83	59	53
	69	53	103	119	105	82	57	51
Aerodrome maximum	96	68	174	200	143	99	71	63
Cumulative (operation + background) (µg/m³)								
Mine village	109	90	123	137	129	111	82	79
Aerodrome maximum	129	101	207	233	176	132	104	96
Percent of criterion (%)								
Mine village	122%	100%	136%	152%	144%	123%	91%	87%

Table 13 Predicted annual average dust deposition addition at Village and Aerodrome each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion (g/m^2/month)	4	4	4	4	4	4	4	4
Background (g/m^2/month)	2	2	2	2	2	2	2	2
Predicted from operation (g/m^2/month)								
Mine village	1.0	0.7	2.0	2.3	1.8	0.8	0.5	0.4
Aerodrome	1.7	1.1	1.6	1.8	1.5	0.8	0.4	0.4
	1.2	0.8	3.7	4.2	3.2	1.5	0.8	0.7
	1.4	0.9	2.7	3.0	2.4	1.1	0.6	0.6
Aerodrome maximum	1.7	1.1	3.7	4.2	3.2	1.5	0.8	0.7
Cumulative (operation + background) (g/m^2/month)								
Mine village	3.0	2.7	4.0	4.3	3.8	2.8	2.5	2.4
Aerodrome maximum	3.7	3.1	5.7	6.2	5.2	3.5	2.8	2.7
Percent of criterion (%)								
Mine village	76%	67%	101%	108%	95%	70%	62%	61%

Table 14 Predicted annual average dust deposition addition at ghost bat caves each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion ($g/m^2/month$)	4	4	4	4	4	4	4	4
Background ($g/m^2/month$)	1	1	1	1	1	1	1	1
Predicted from operation ($g/m^2/month$)								
Caves A1 & A2	7.4	6.0	3.3	1.6	2.7	0.9	0.3	0.3
Caves L2 & L3	9.5	8.1	4.2	1.8	3.3	1.0	0.3	0.3
Cave AA1	2.7	6.1	2.9	2.2	1.3	0.9	0.7	0.1
Cumulative (operation + background) ($g/m^2/month$)								
Caves A1 & A2	9.4	8.0	5.3	3.6	4.7	2.9	2.3	2.3
Caves L2 & L3	11.5	10.1	6.2	3.8	5.3	3.0	2.3	2.3
Cave AA1	4.7	8.1	4.9	4.2	3.3	2.9	2.7	2.1

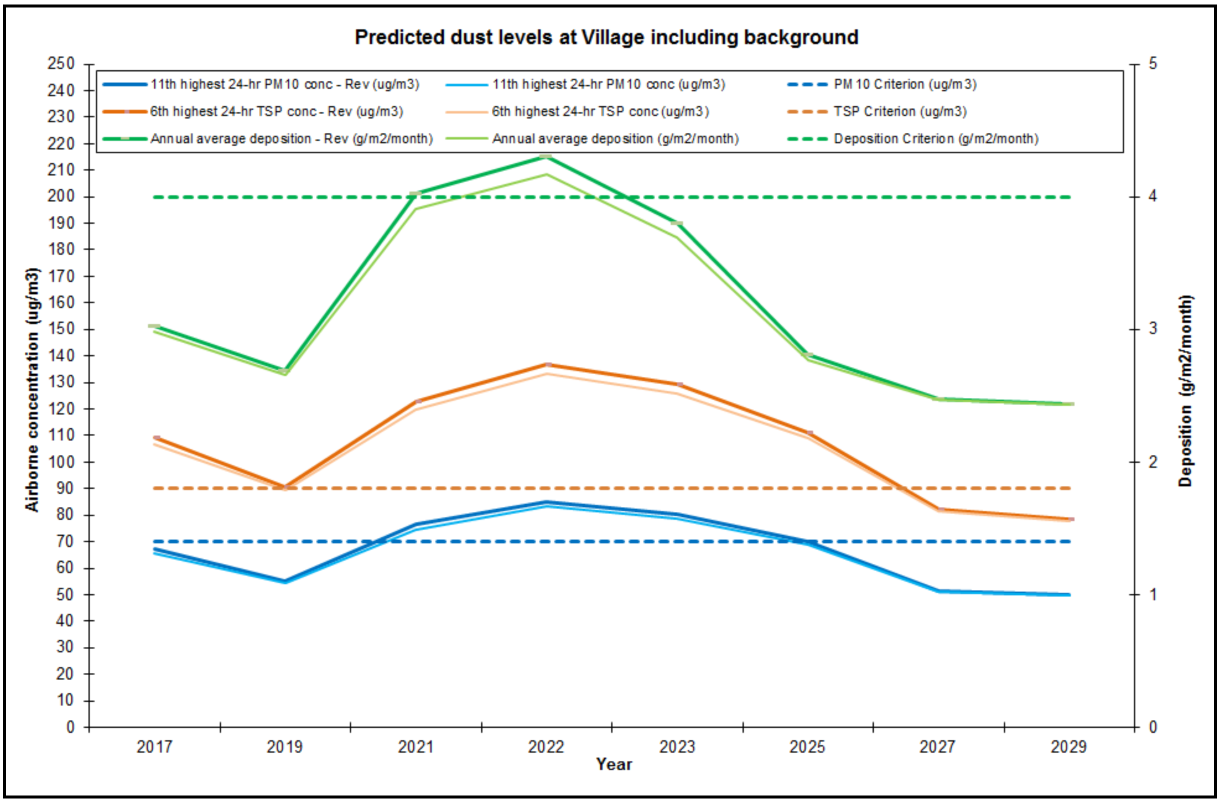

Figure 4 Predicted dust levels at Village including background each year

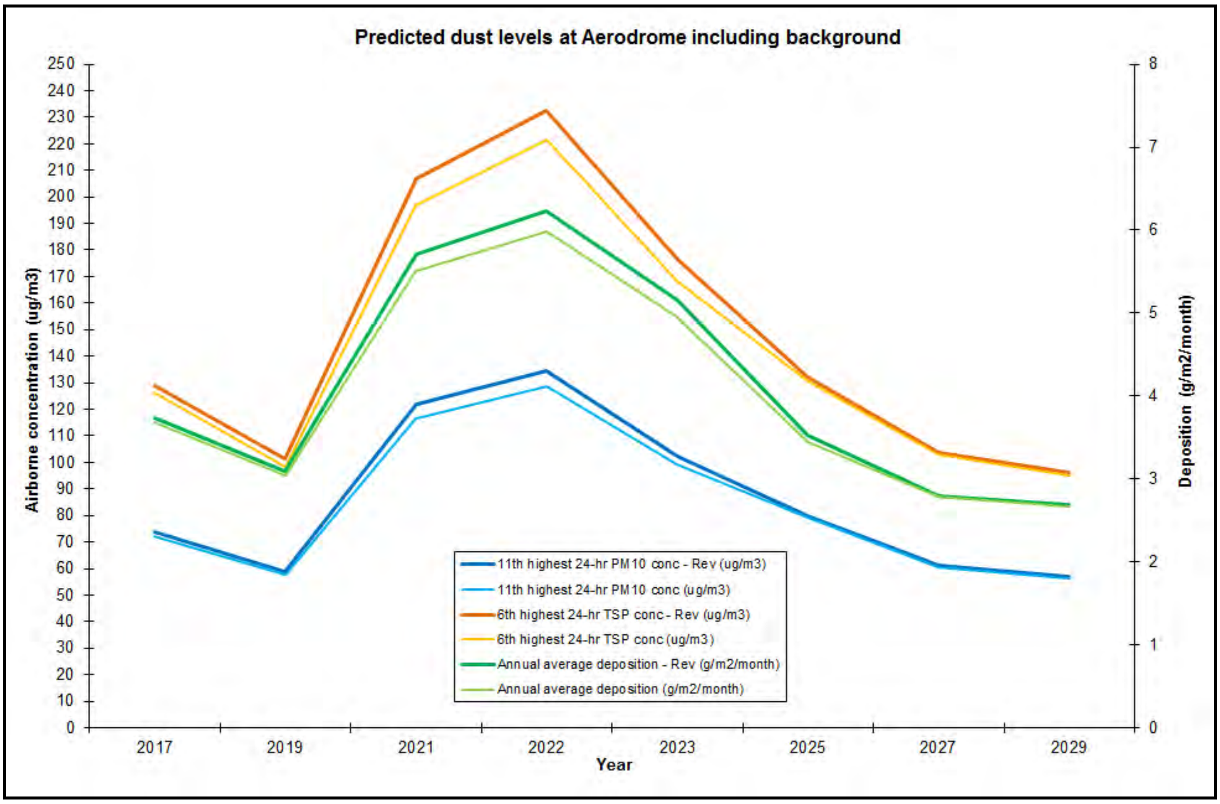

Figure 5 Predicted dust levels at Aerodrome including background each year

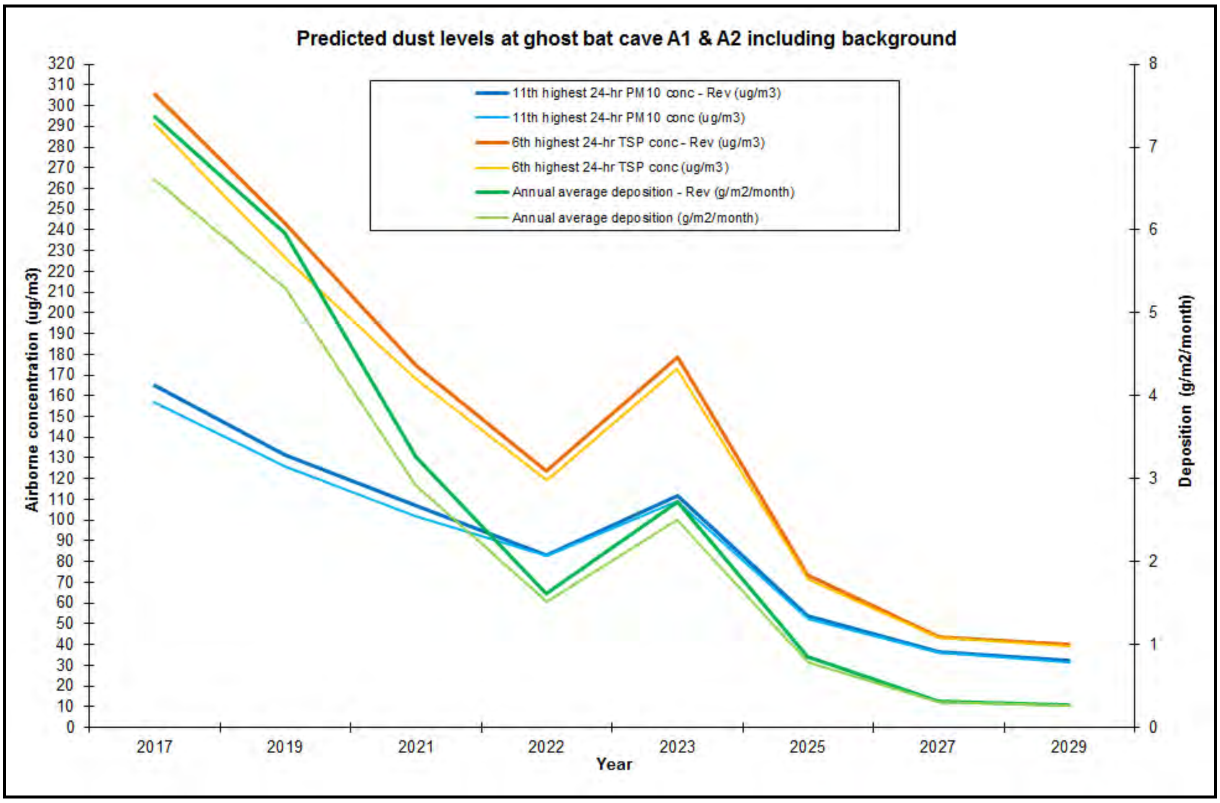

Figure 6 Predicted dust levels at ghost bat caves A1 & A2 including background each year

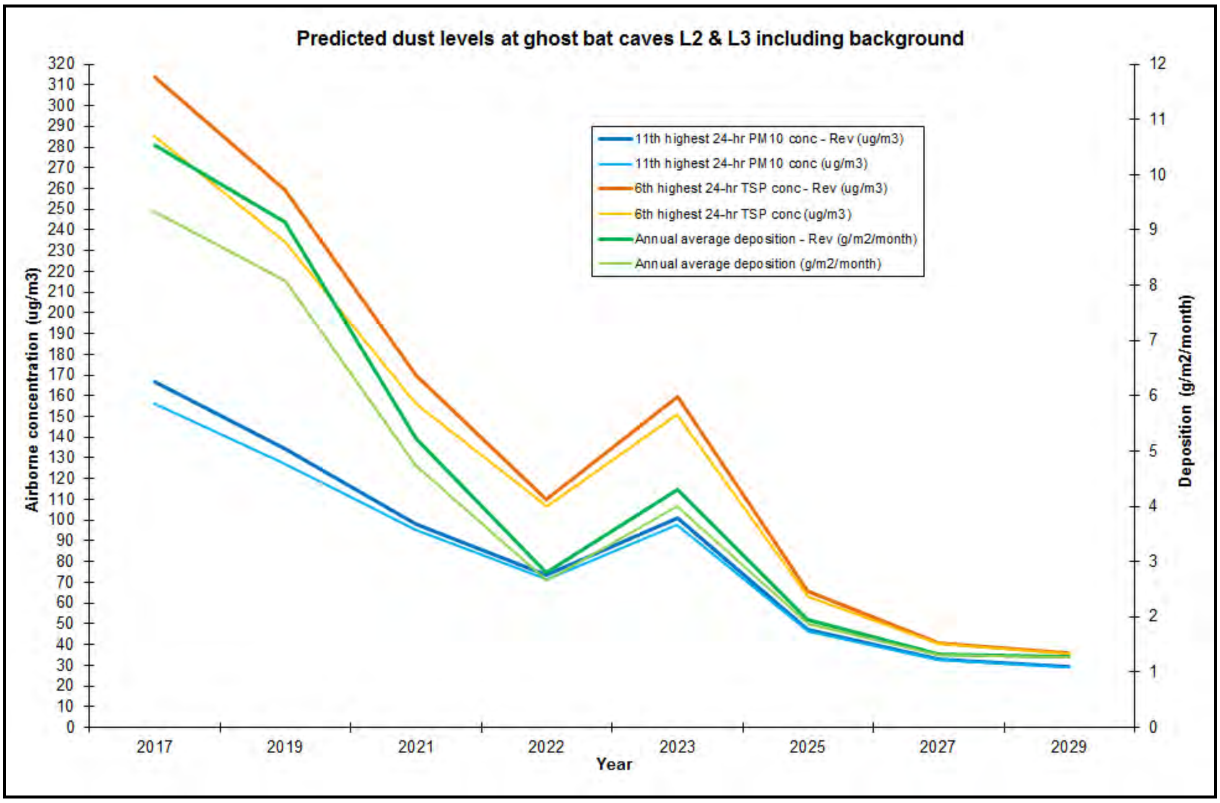

Figure 7 Predicted dust levels at ghost bat caves L2 & L3 including background each year

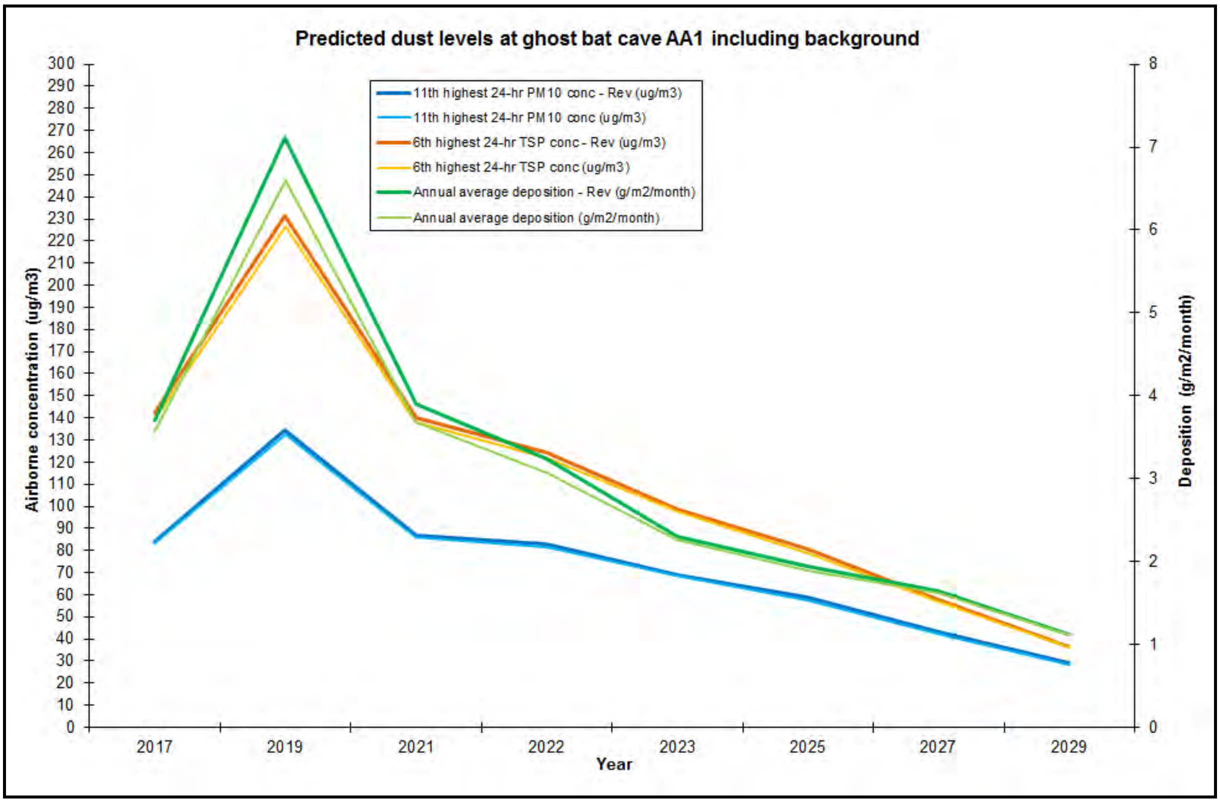

Figure 8 Predicted dust levels at ghost bat cave AA1 including background each year

8.3 CONTOUR PLOTS

Contour plots are a visual representation of the spatial extent of dust levels. Predicted dust level contours for each year are illustrated for each criterion in the following figures. Contours plots are shown for:

- predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations each year in Figure 9 to Figure 16;
- predicted 6th highest 24-hour average TSP concentrations from West Angelas operations each year in Figure 17 to Figure 24; and
- predicted annual average dust deposition from West Angelas operations each year in Figure 25 to Figure 32.

The contour figures for PM10 and TSP include the additional of background levels to enable a direct comparison with the criteria, which include background levels. The contour figures for dust deposition do not include background levels because the derivation of the criterion is actually based on the additional deposition attributable to the operation.

It is notable that dust deposition decreases with distance from the source more rapidly than airborne dust concentrations.

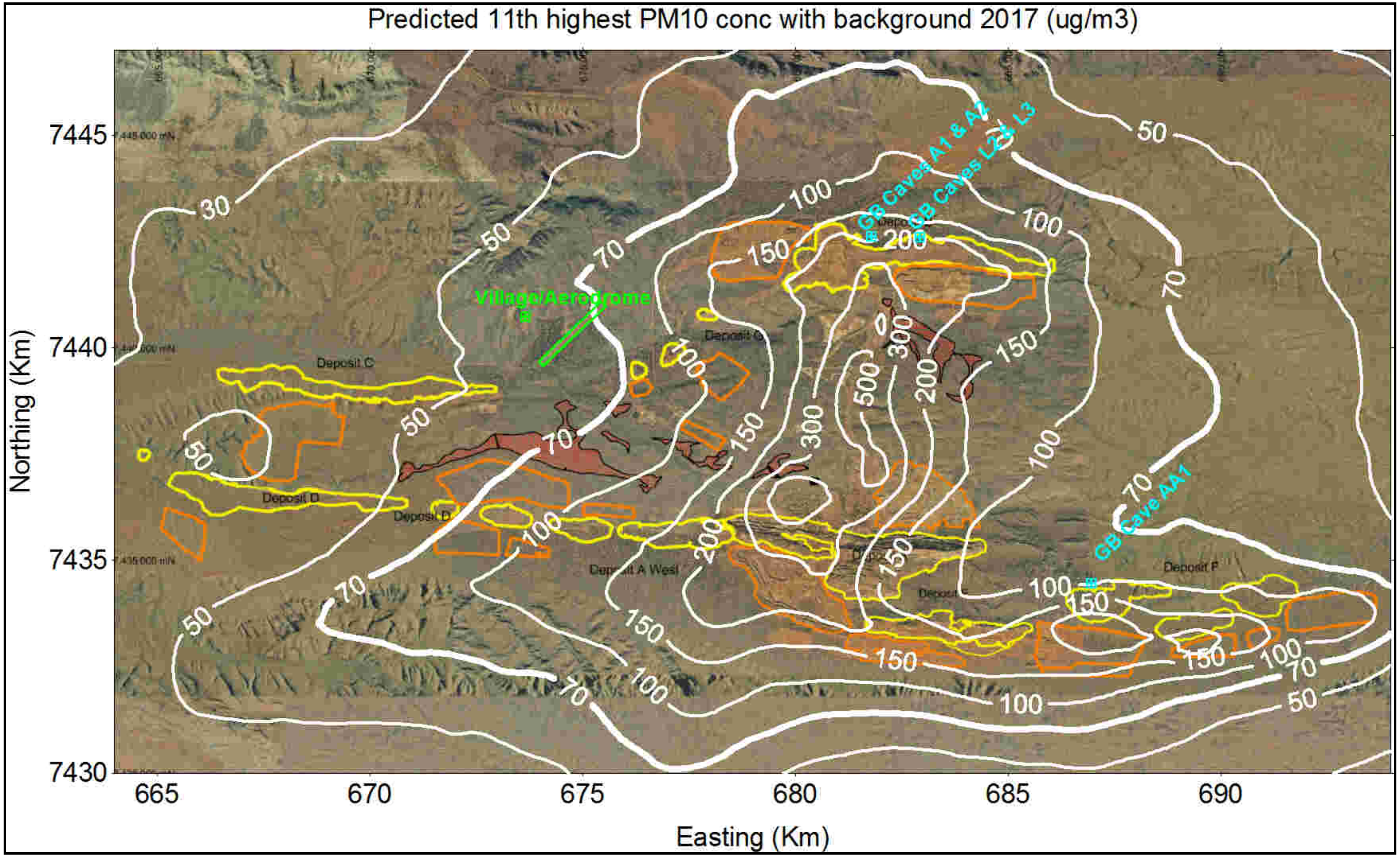

Figure 9 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2017

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

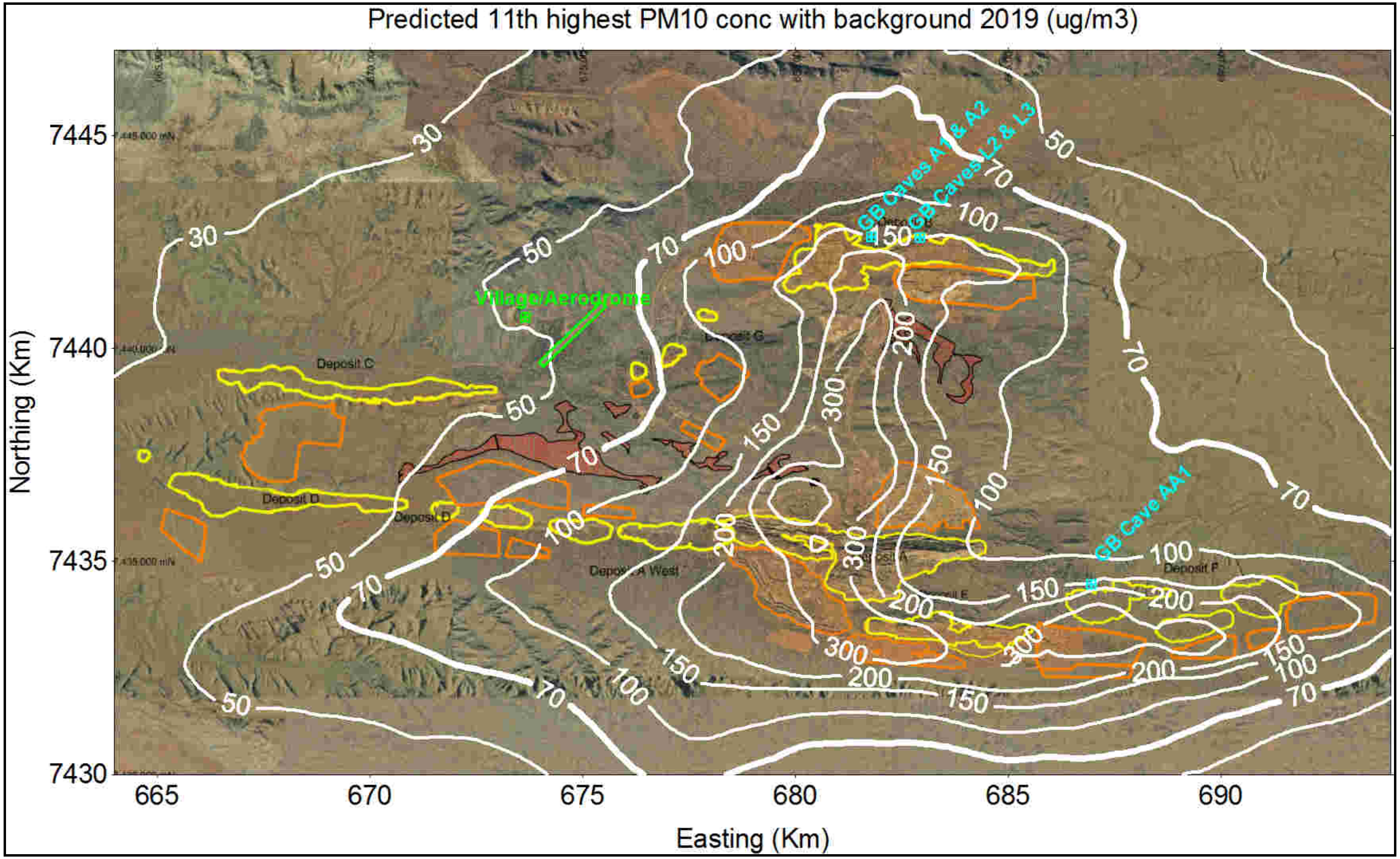

Figure 10 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2019

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

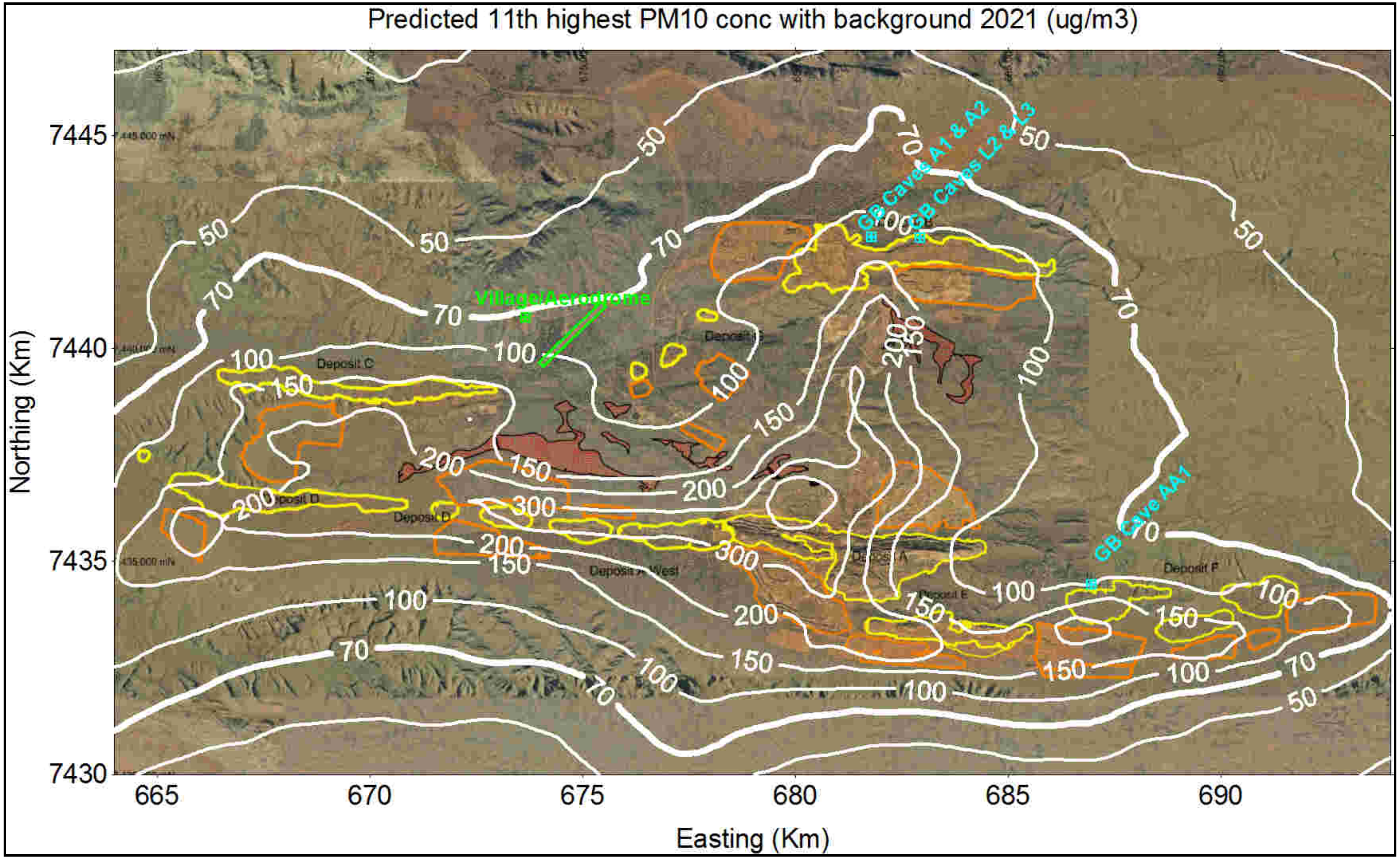

Figure 11 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2021

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

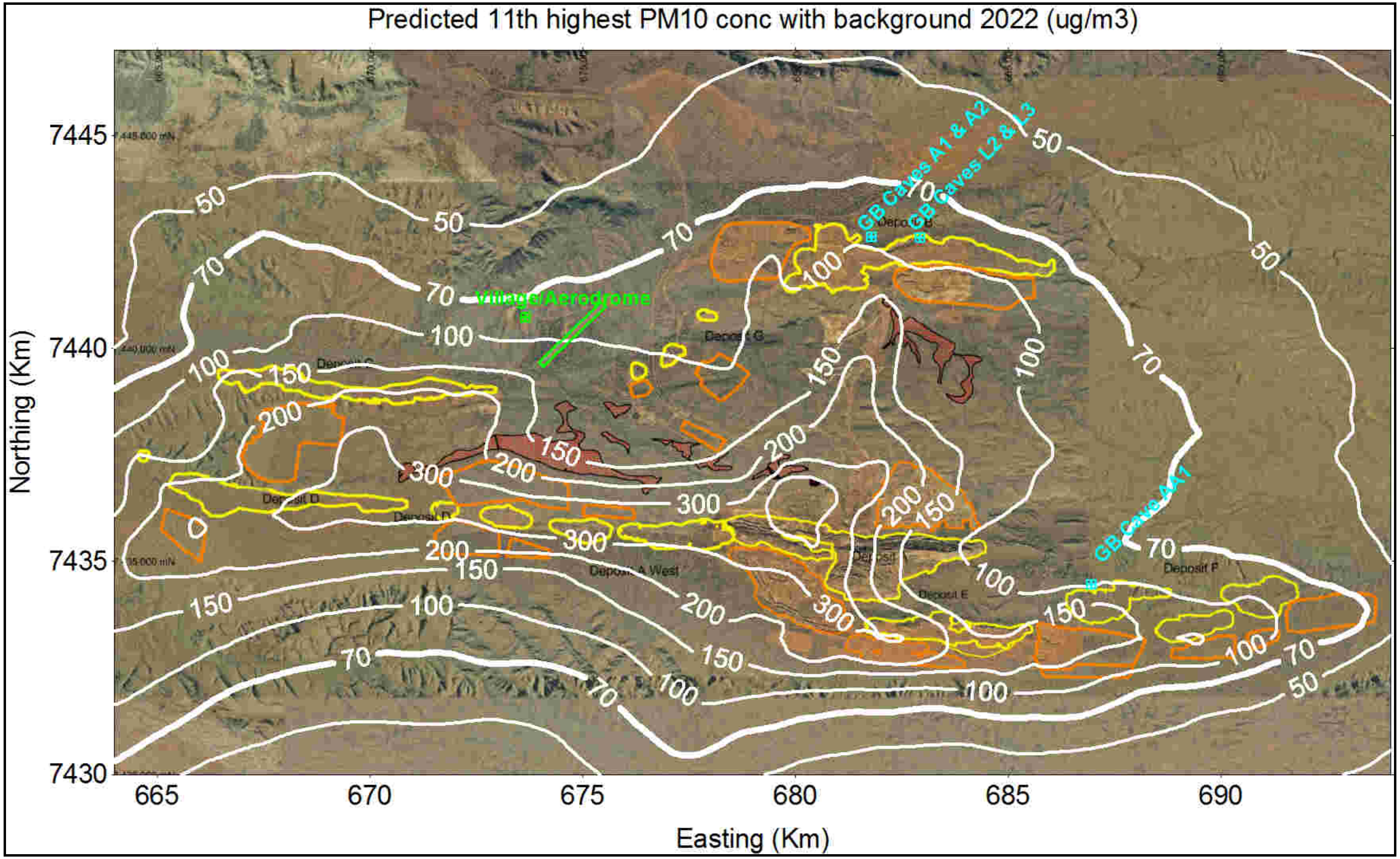

Figure 12 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2022

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

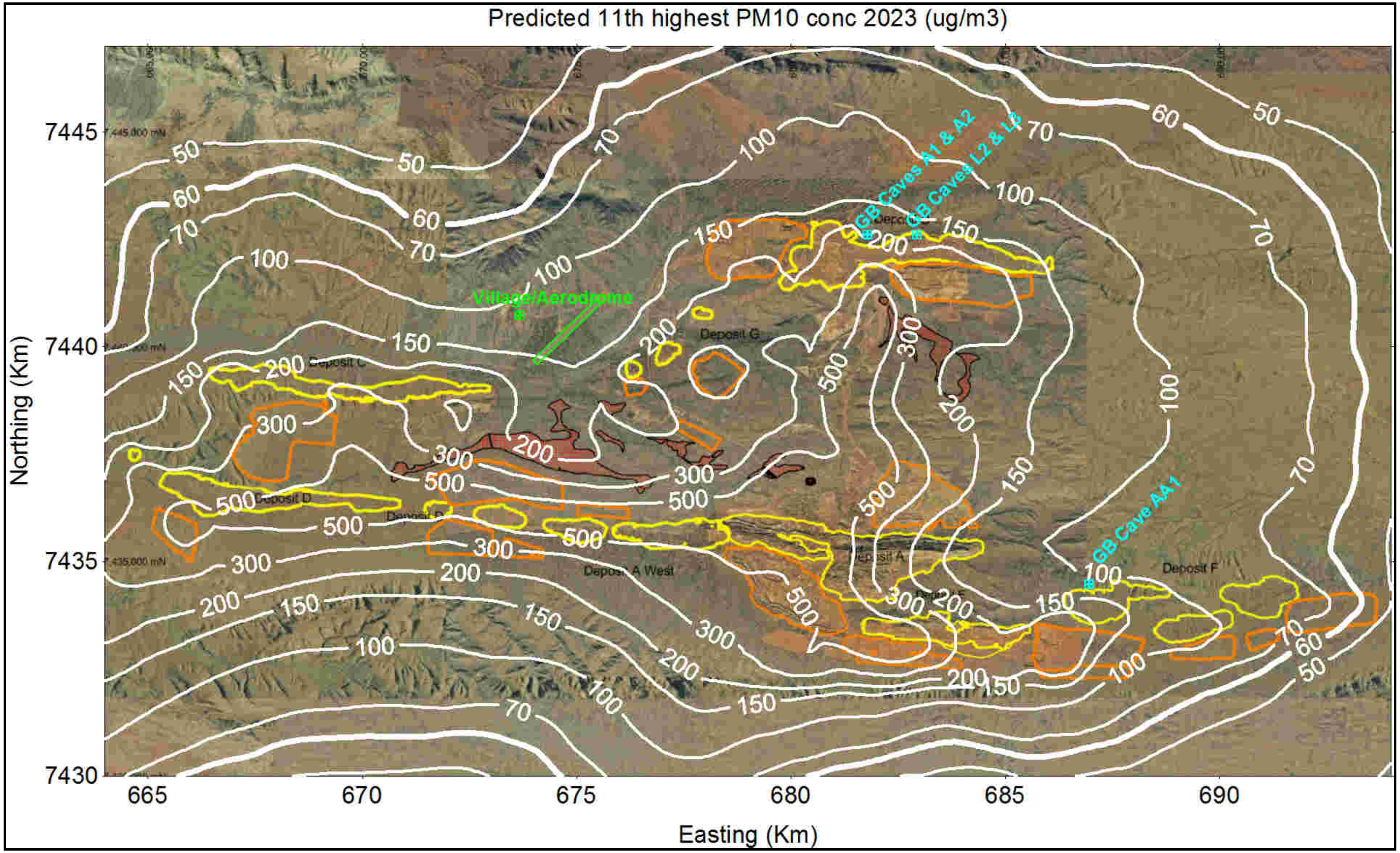

Figure 13 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2023

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

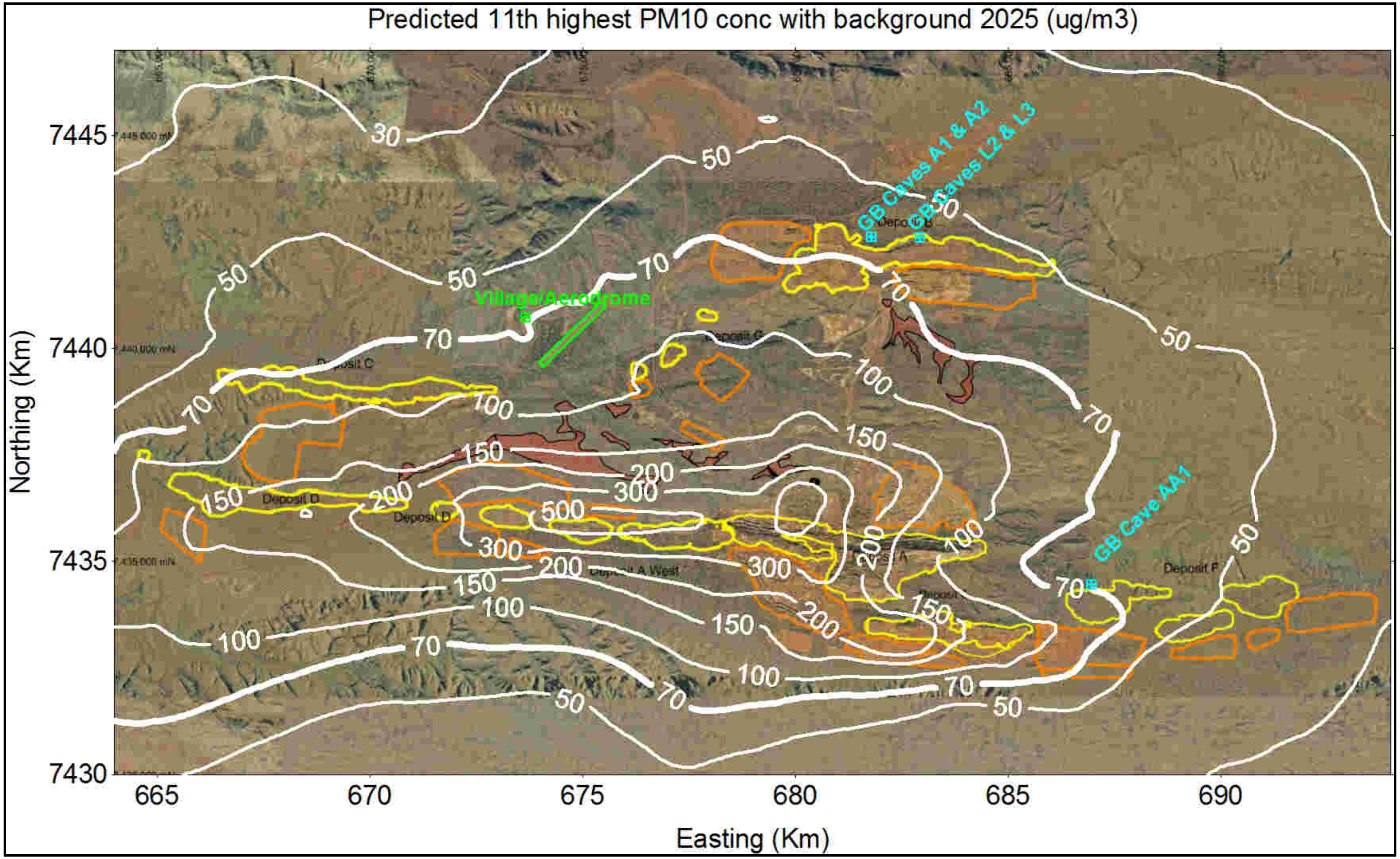

Figure 14 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2025

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

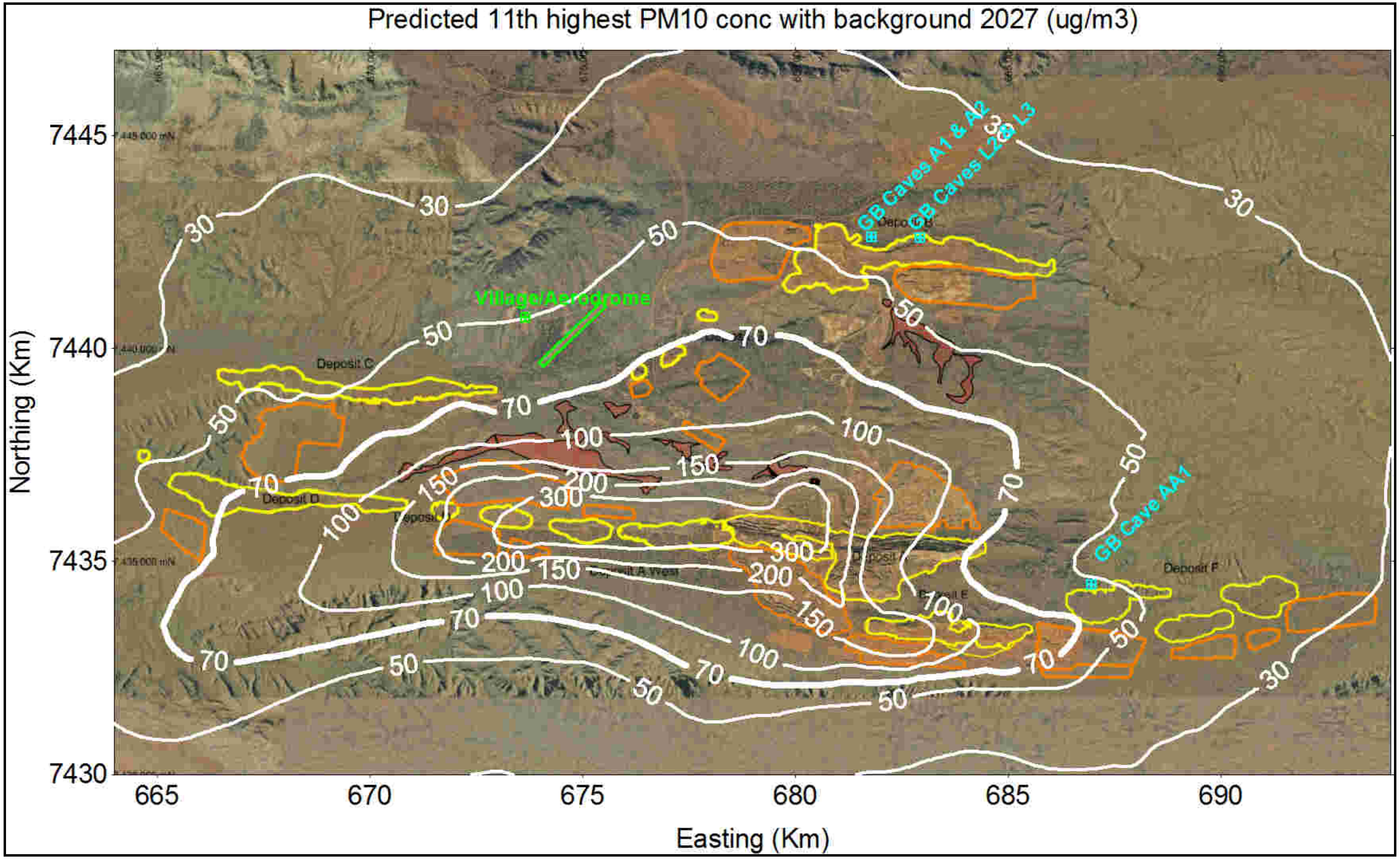

Figure 15 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2027

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

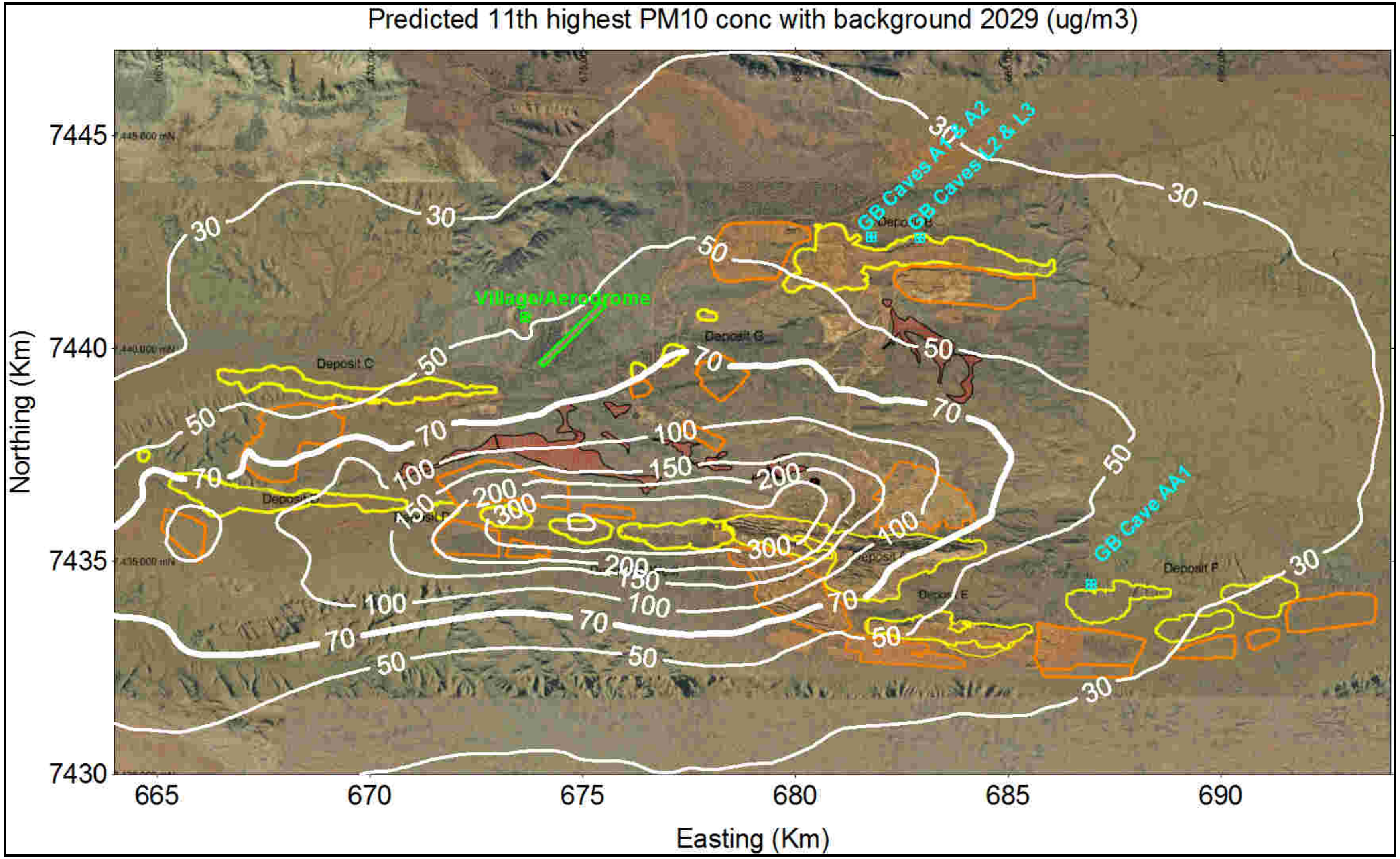

Figure 16 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2029

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

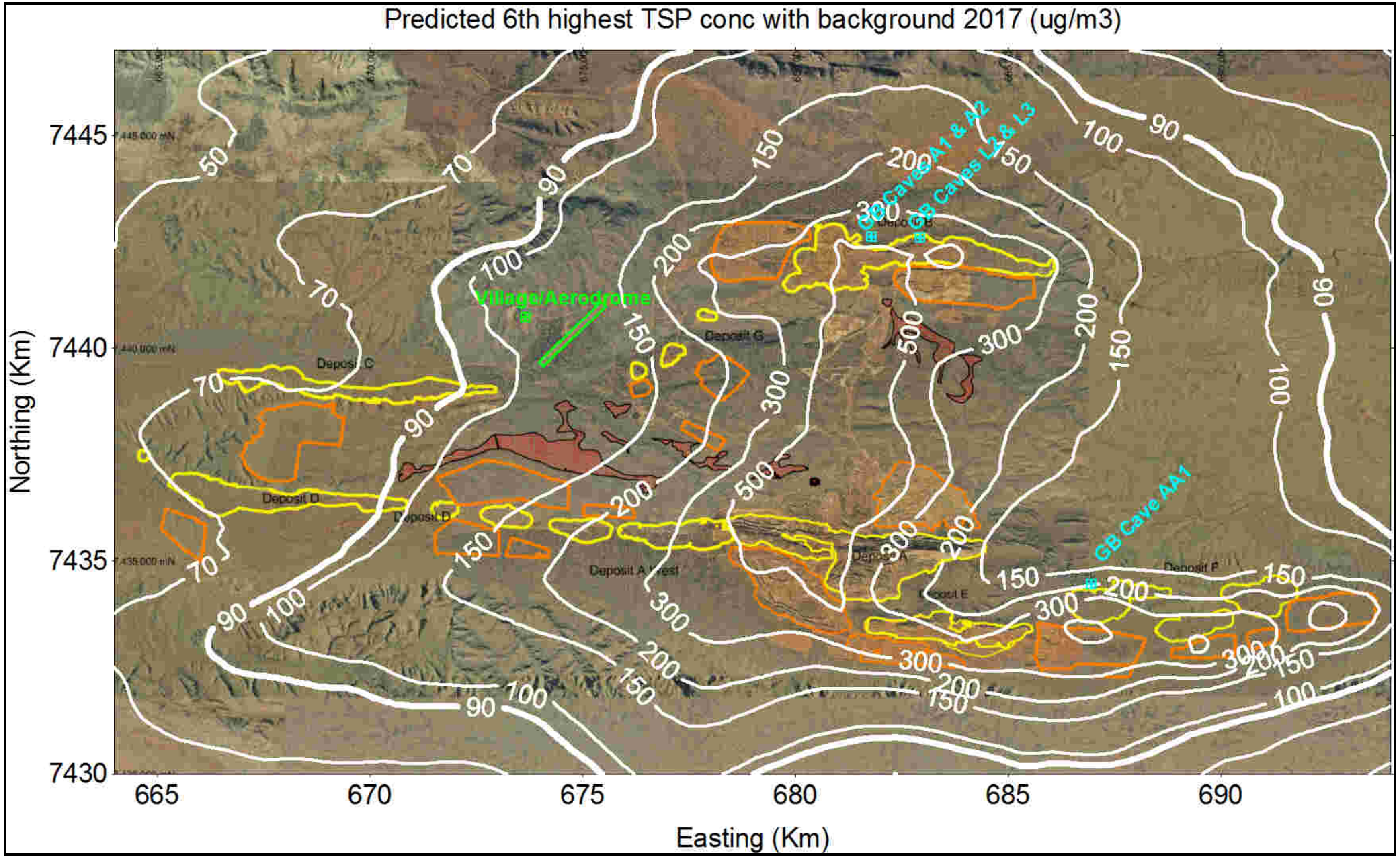

Figure 17 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2017

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

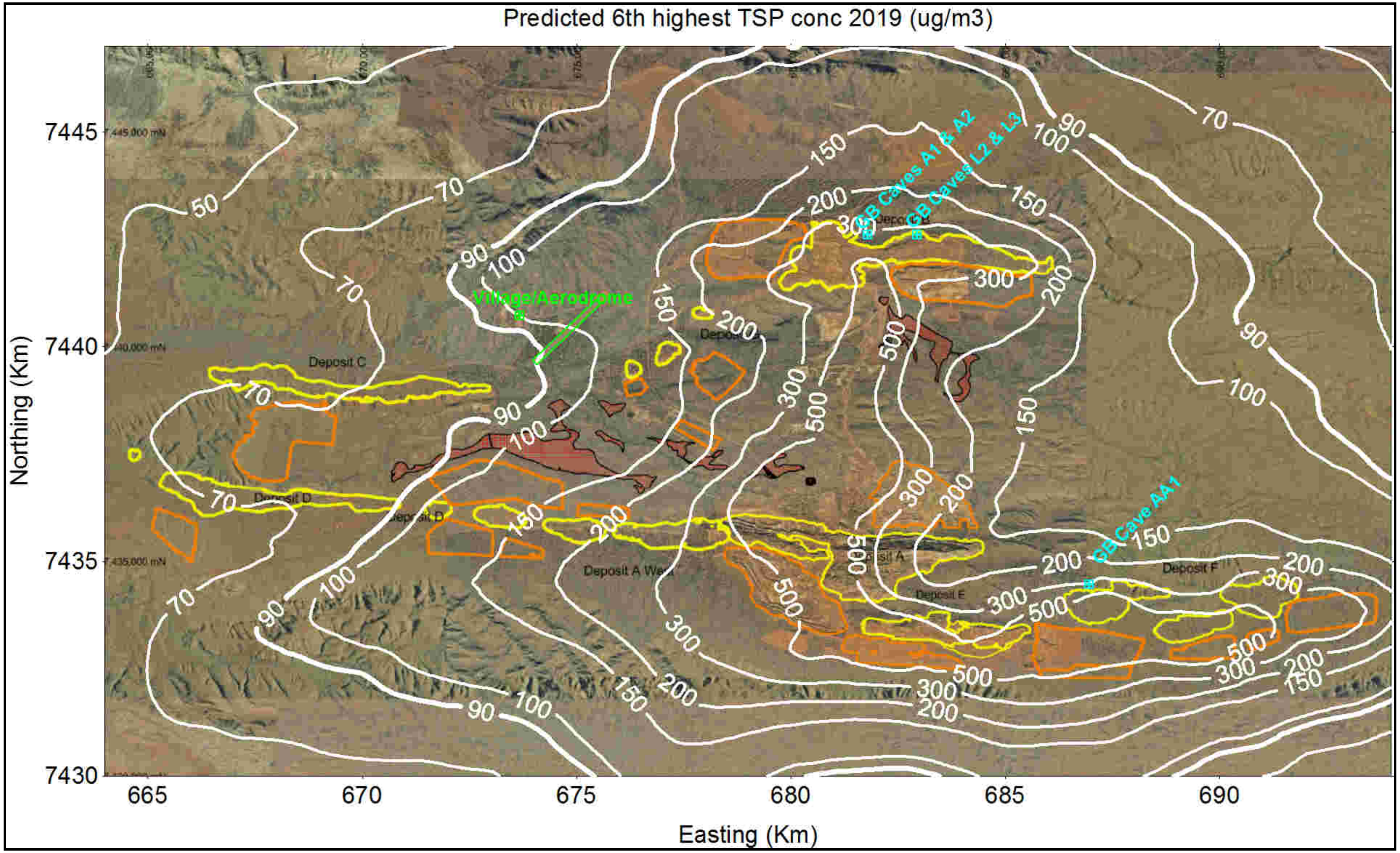

Figure 18 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2019

Notes: 1) Criterion is 90 µg/m³. An allowance of 33 µg/m³ has been added to the model predictions to account for background.

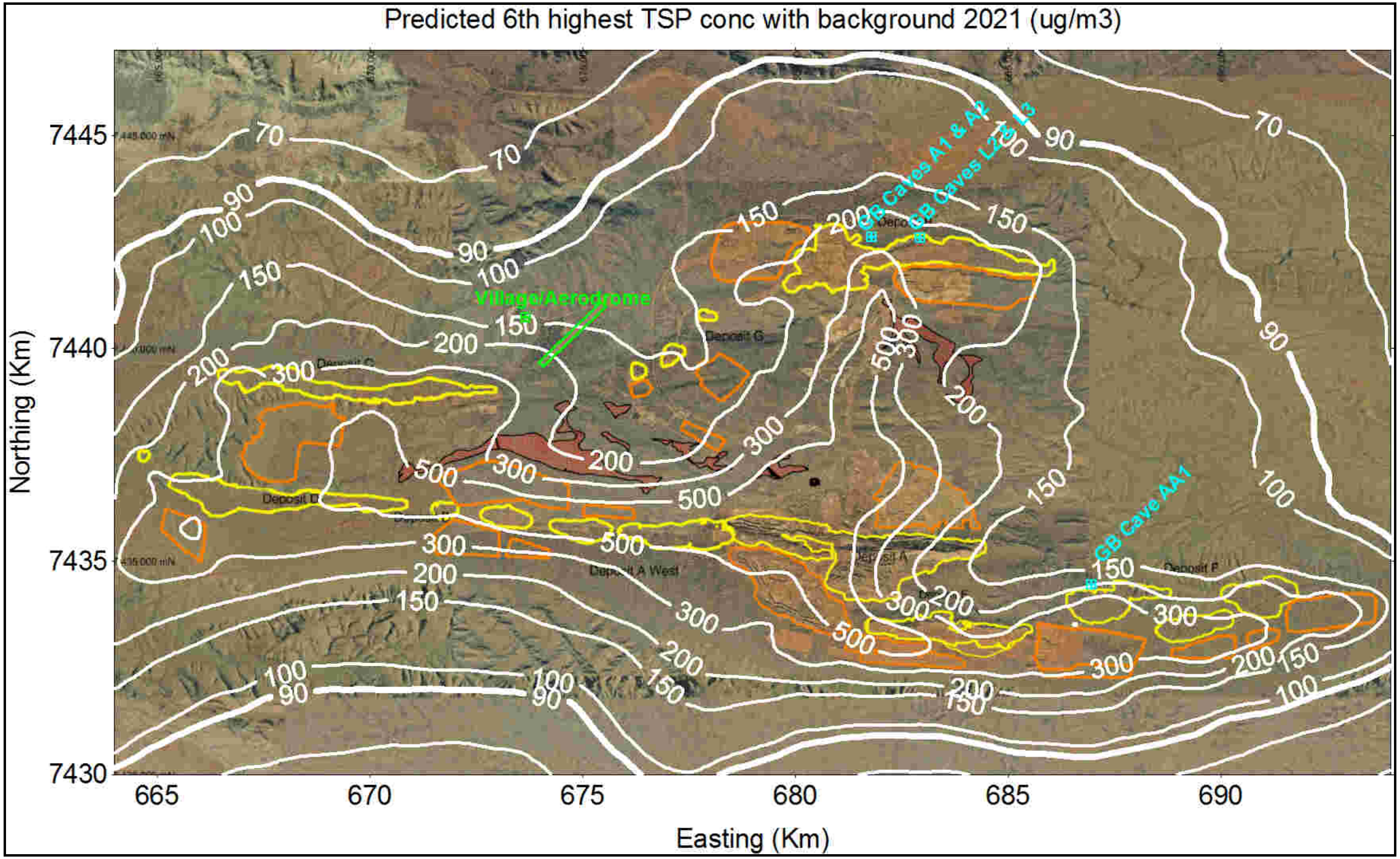

Figure 19 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2021

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

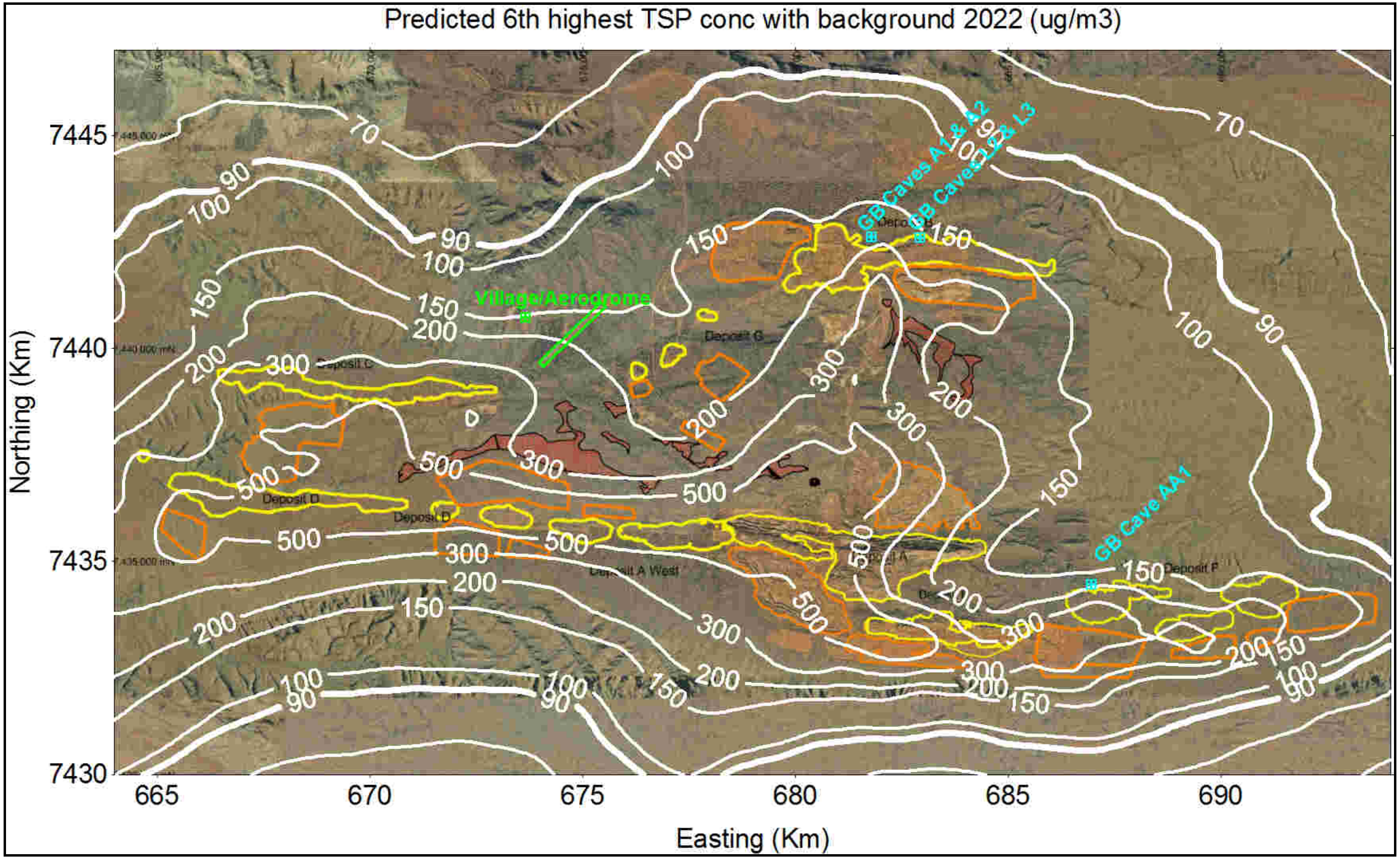

Figure 20 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2022

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

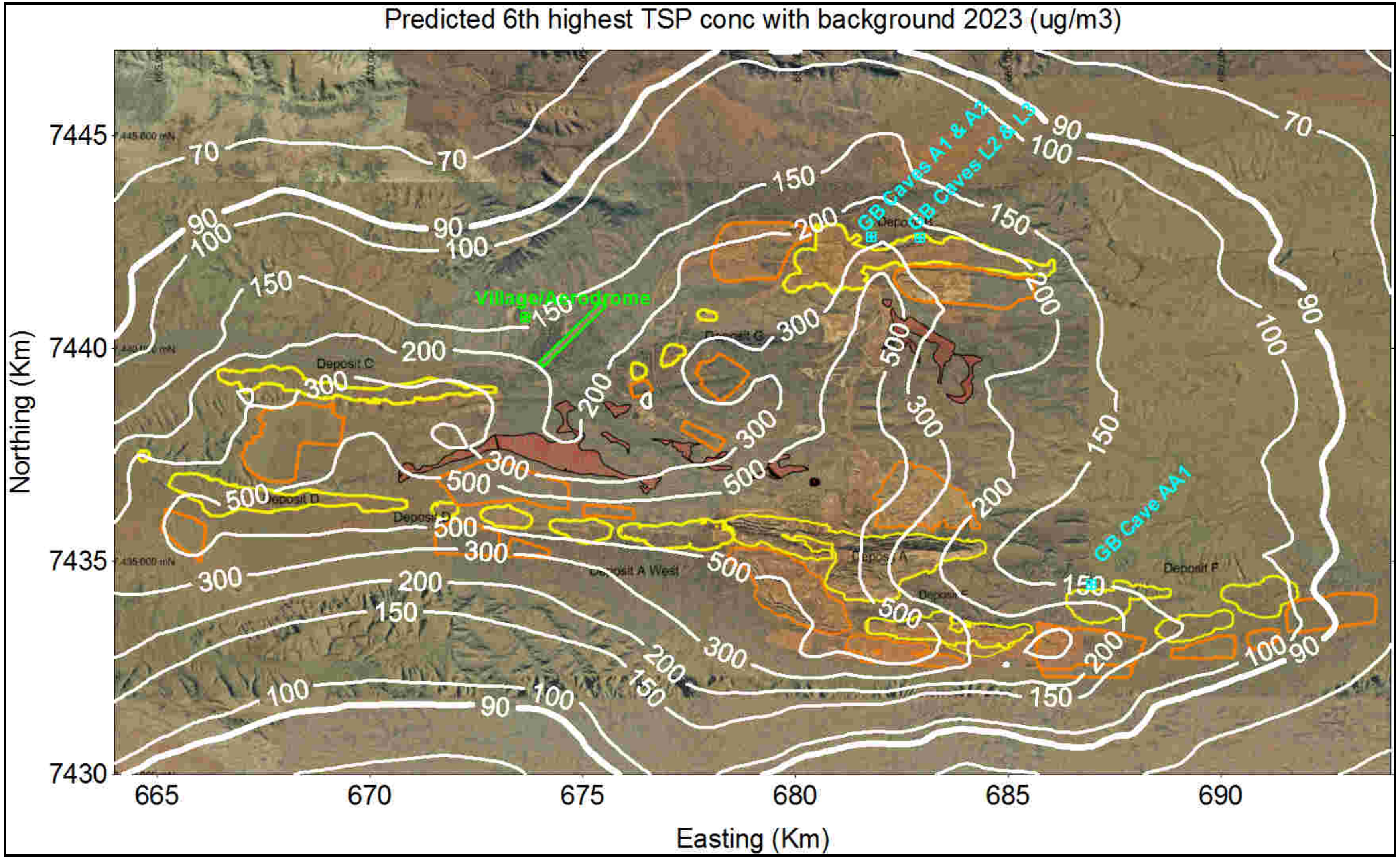

Figure 21 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2023

Notes: 1) Criterion is 90 µg/m³. An allowance of 33 µg/m³ has been added to the model predictions to account for background.

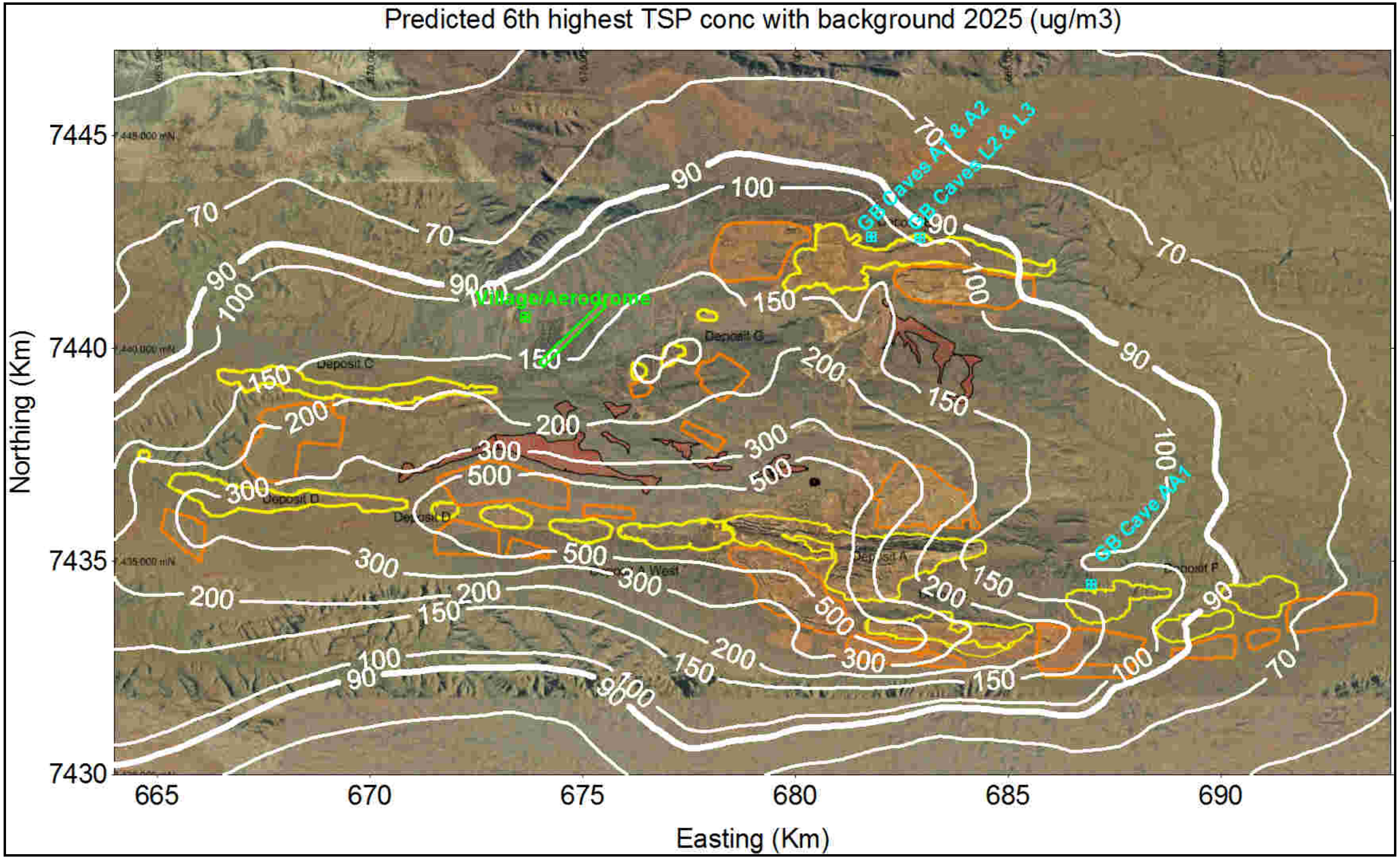

Figure 22 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2025

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

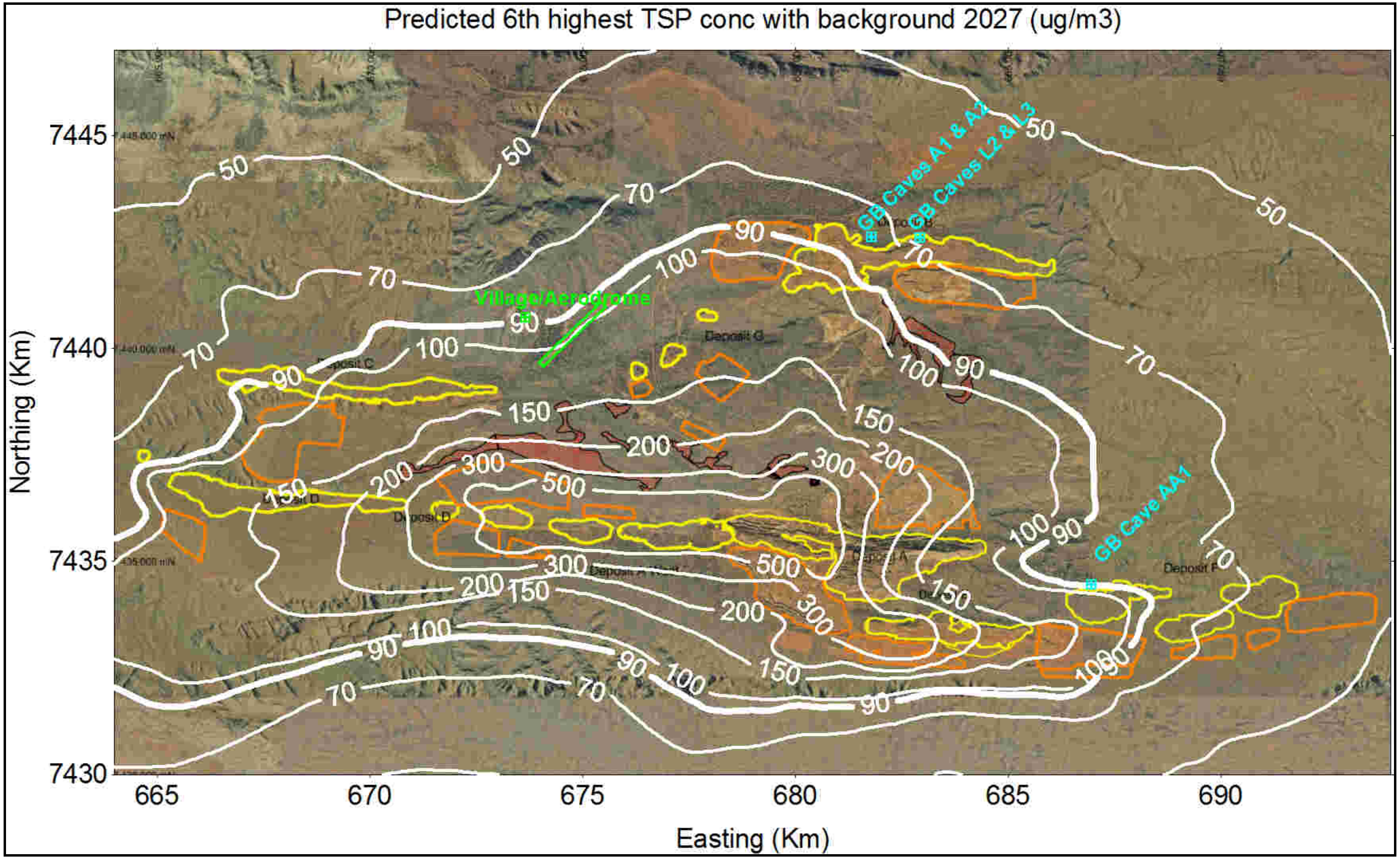

Figure 23 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2027

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

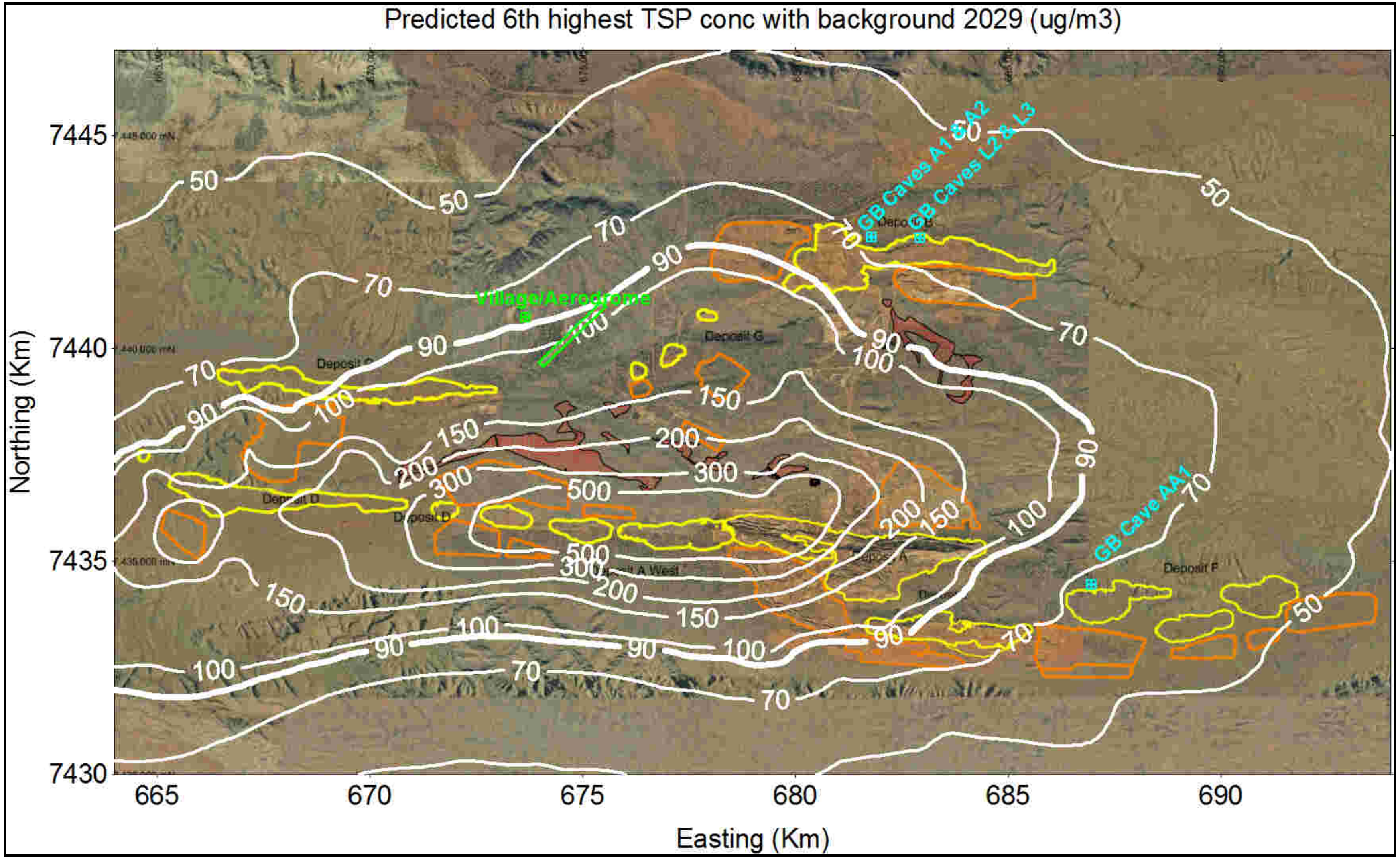

Figure 24 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2029

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

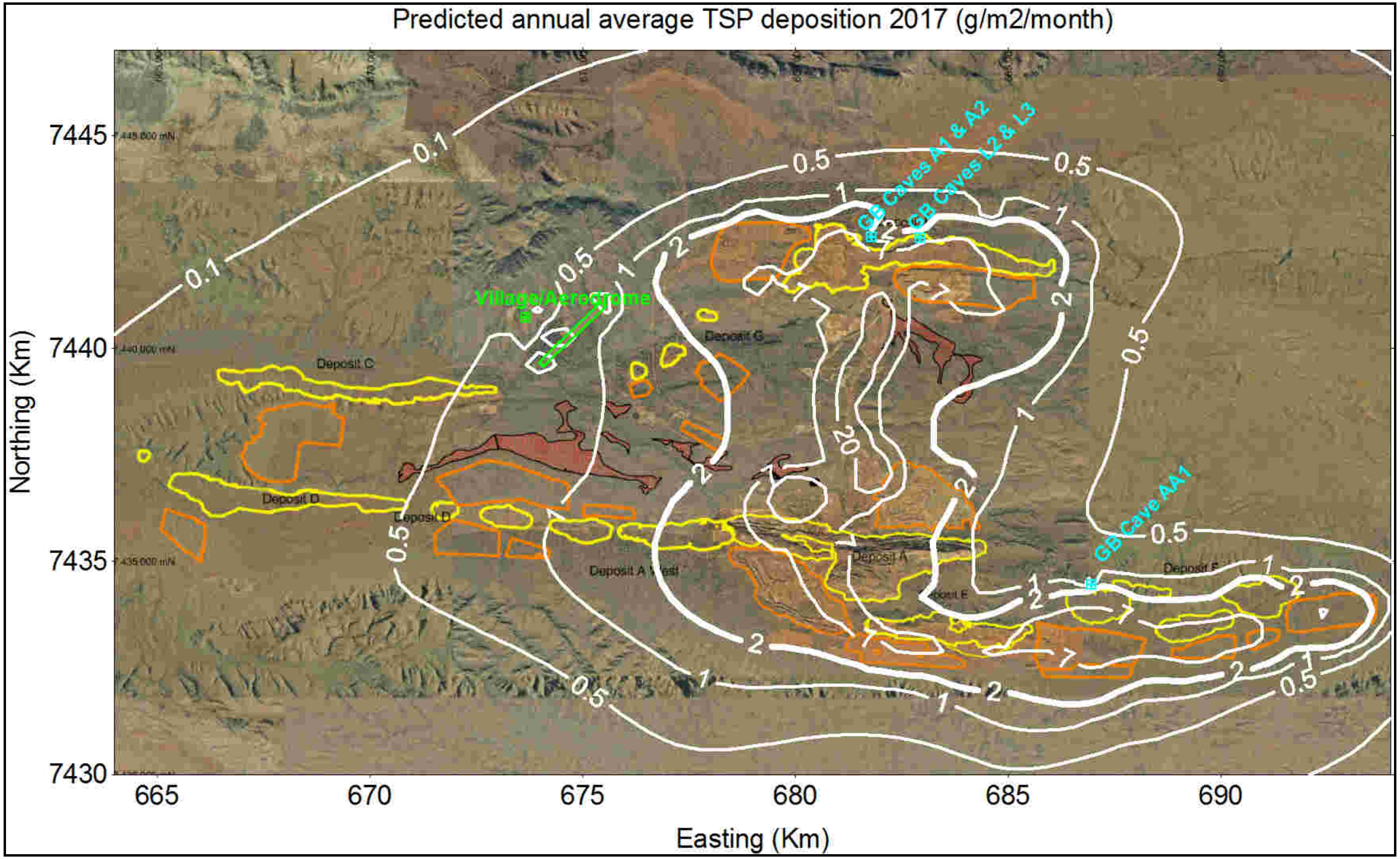

Figure 25 Predicted annual average dust deposition from West Angelas operations at 2017

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

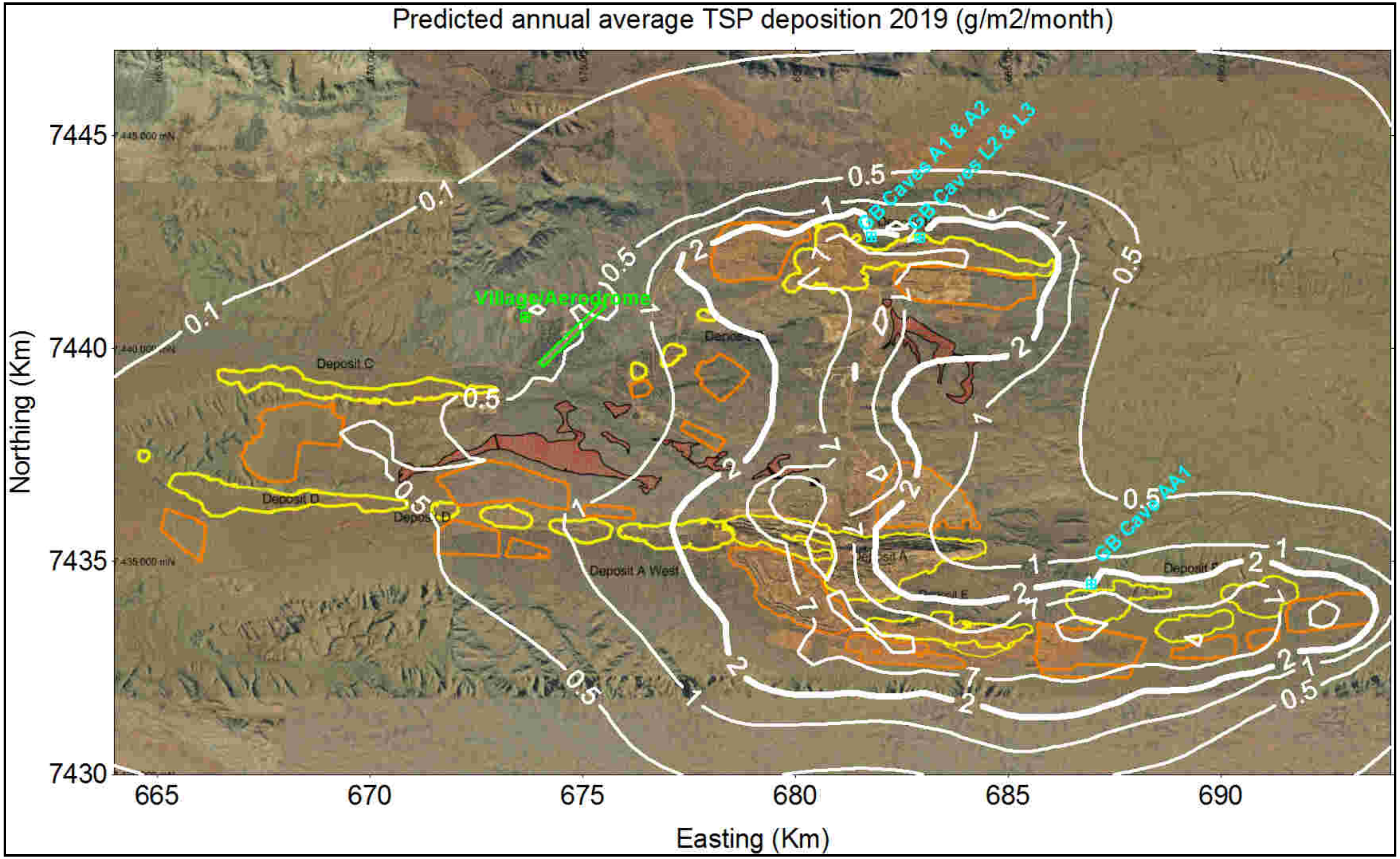

Figure 26 Predicted annual average dust deposition from West Angelas operations at 2019

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

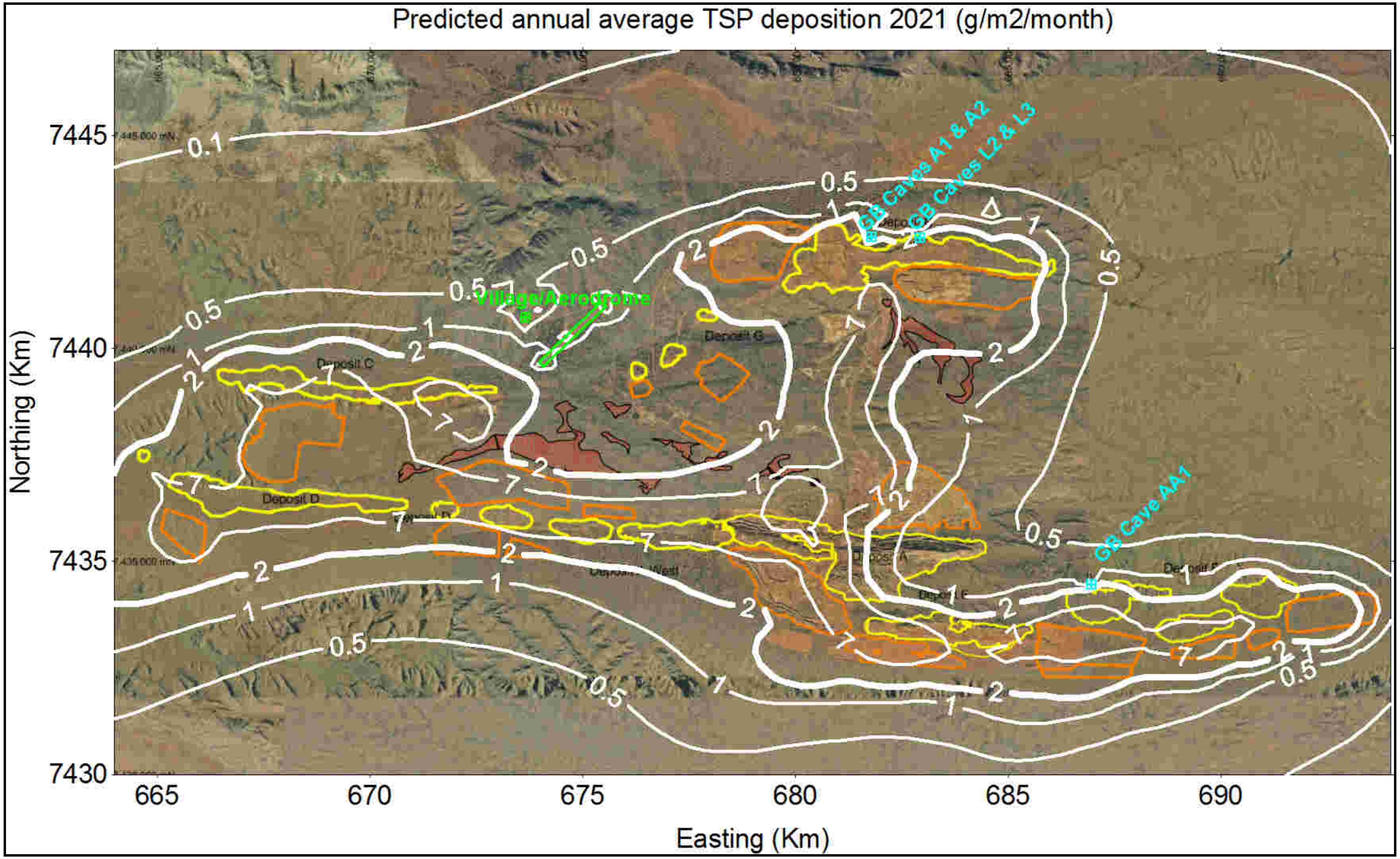

Figure 27 Predicted annual average dust deposition from West Angelas operations at 2021

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

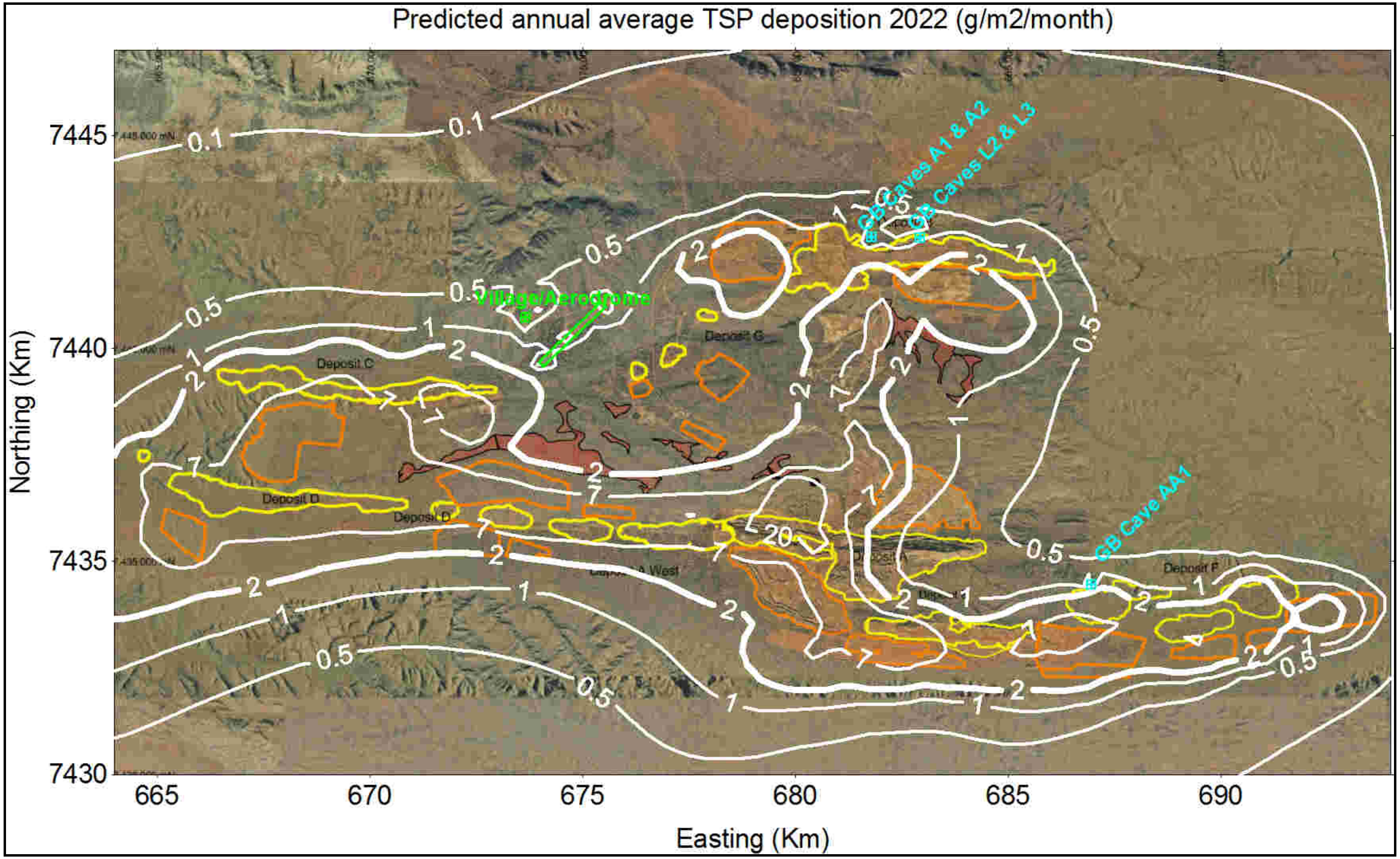

Figure 28 Predicted annual average dust deposition from West Angelas operations at 2022

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

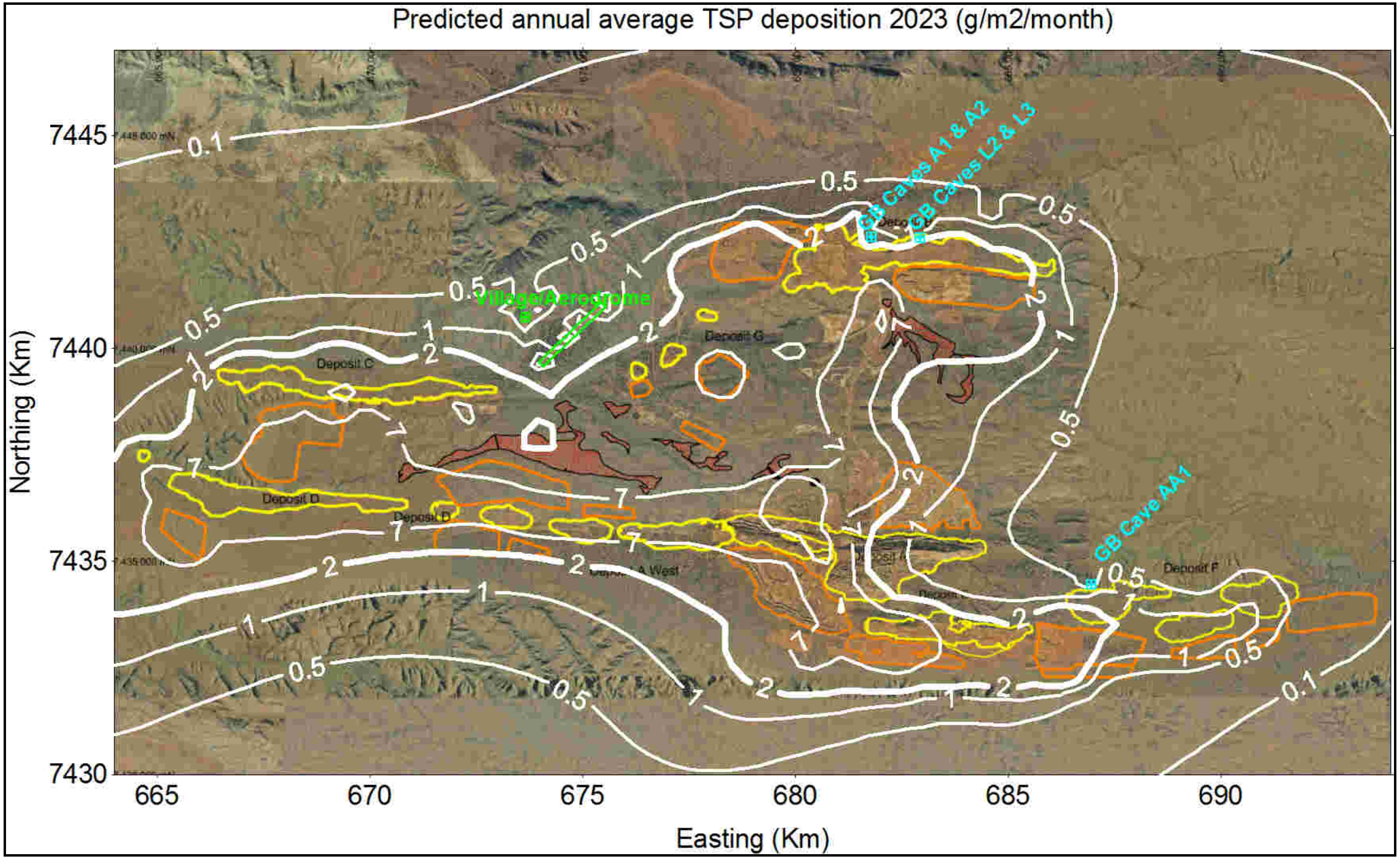

Figure 29 Predicted annual average dust deposition from West Angelas operations at 2023

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

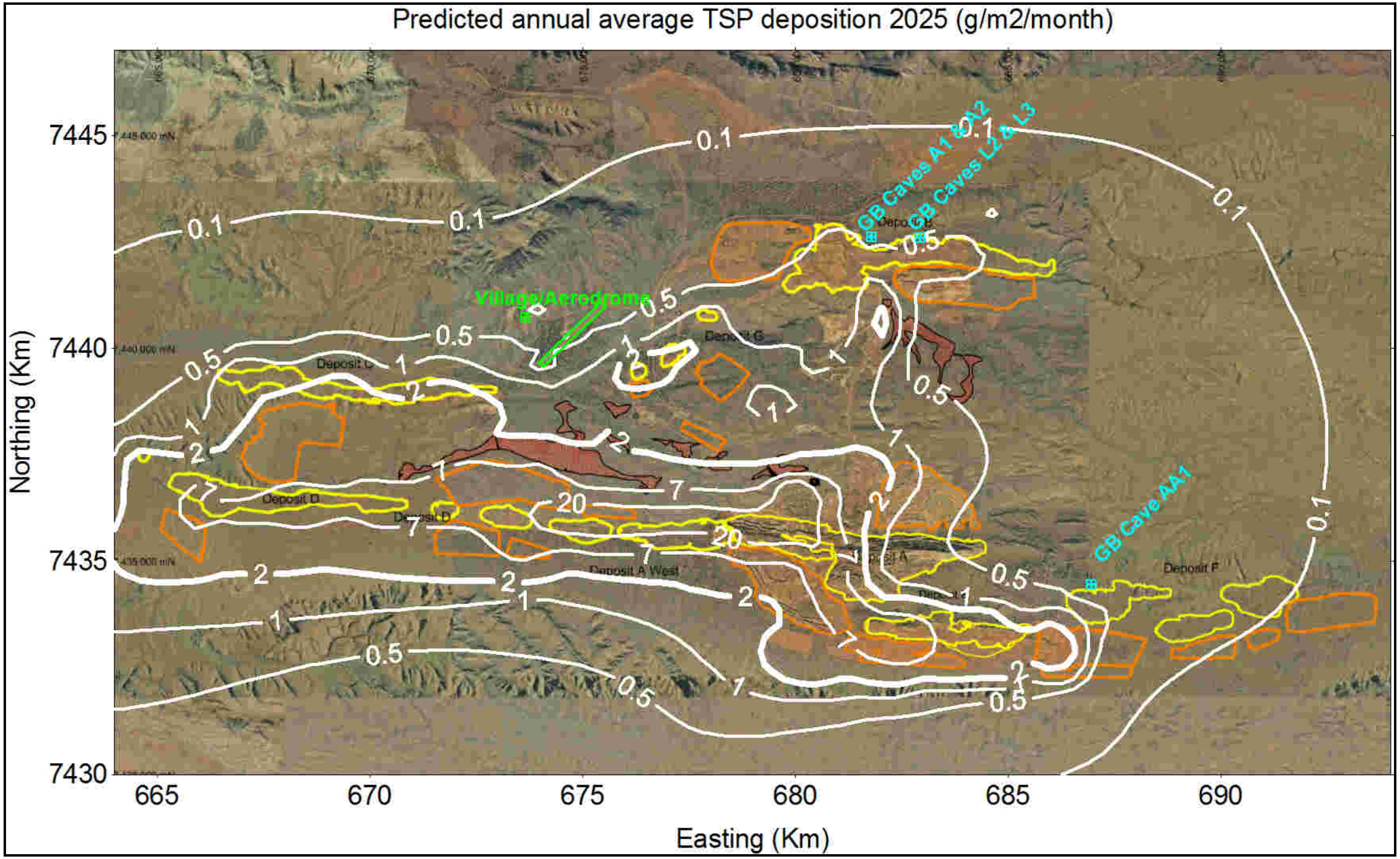

Figure 30 Predicted annual average dust deposition from West Angelas operations at 2025

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

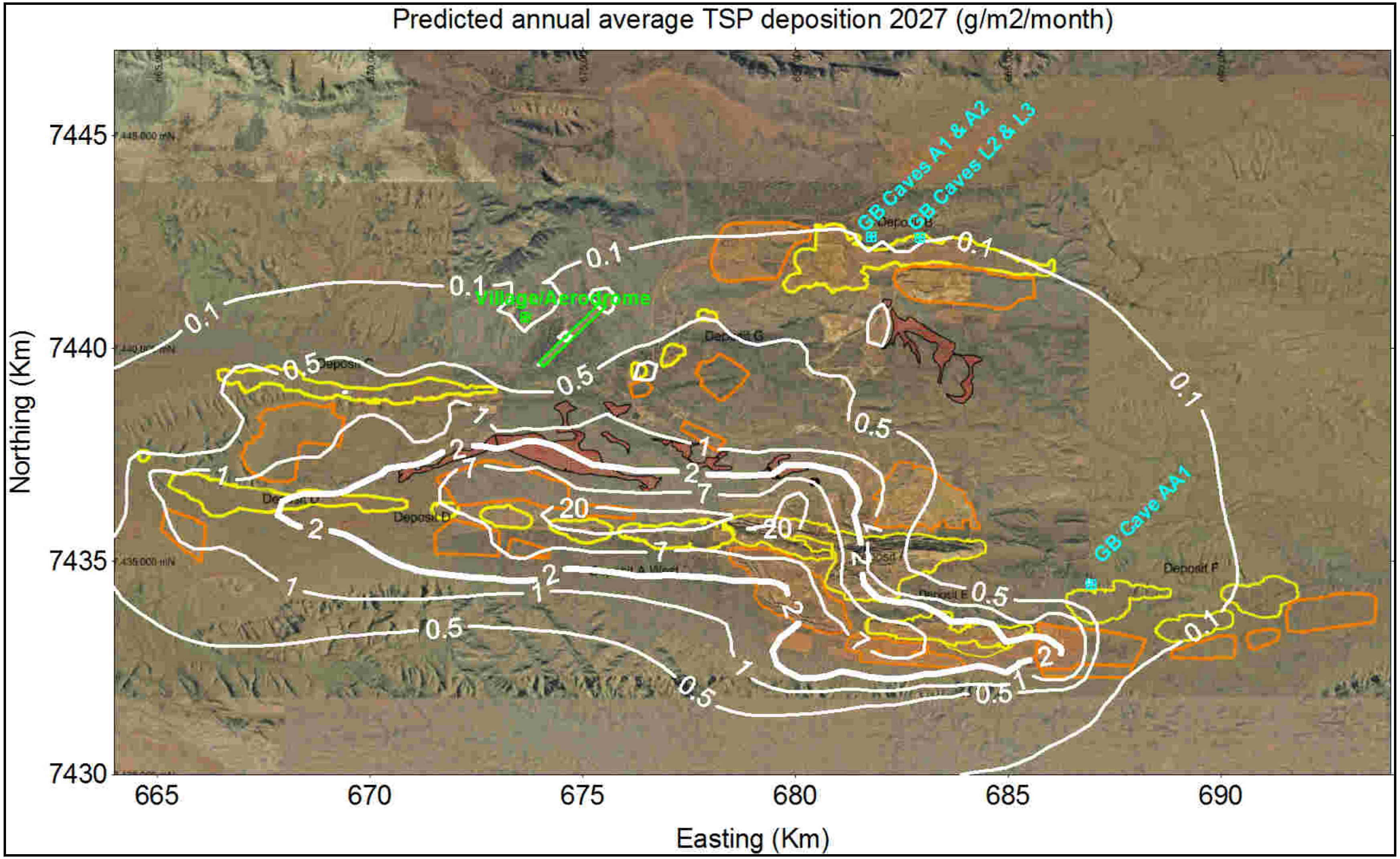

Figure 31 Predicted annual average dust deposition from West Angelas operations at 2027

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

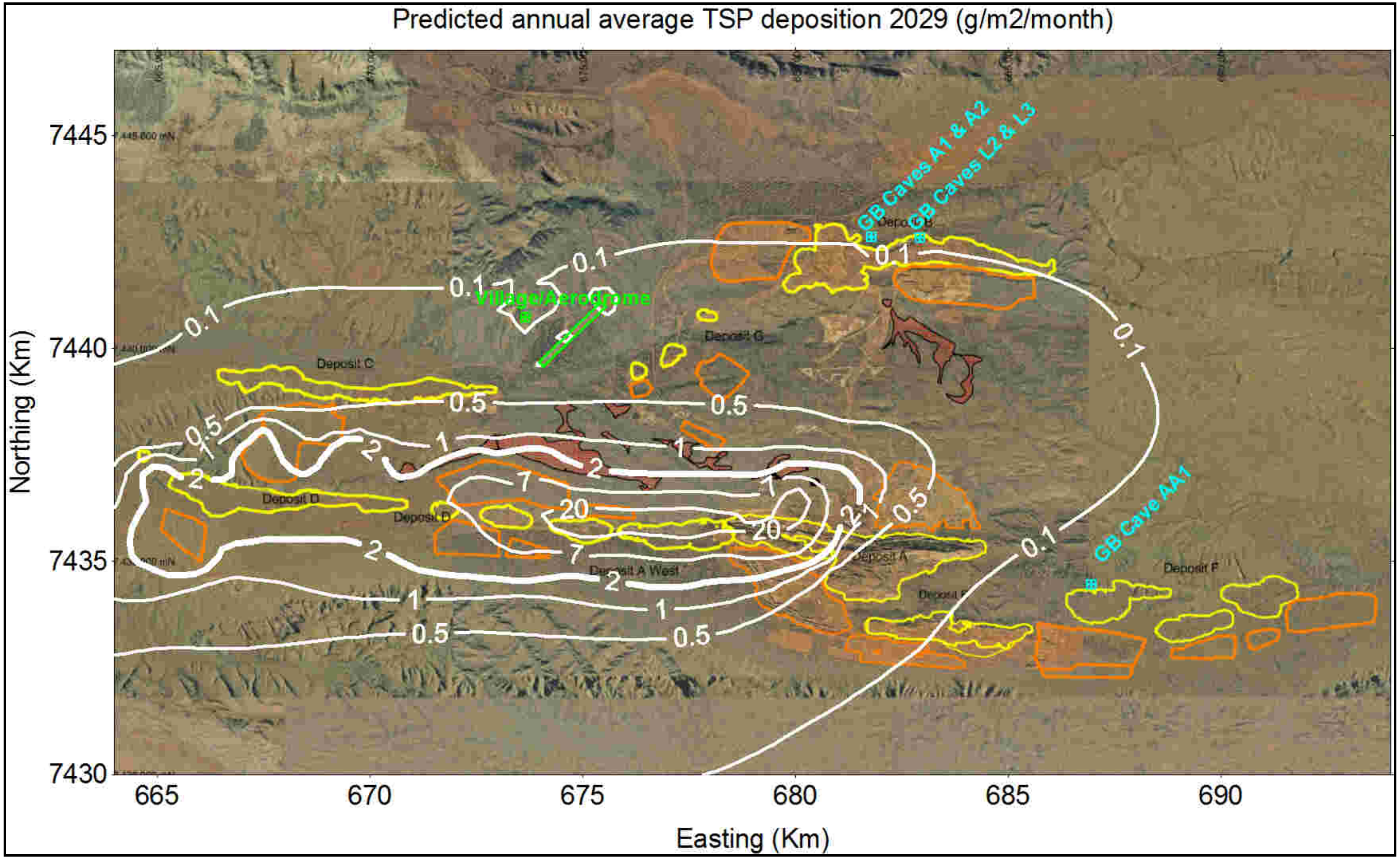

Figure 32 Predicted annual average dust deposition from West Angelas operations at 2029

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

9. SUMMARY AND RECOMMENDATIONS

This report describes a dust dispersion modelling study of predicted dust impacts arising from the West Angelas Deposits A, B, E, F, Awest, C, D and G from 2017 to 2031. The assessment has been based on the early designs of the mine, therefore the results and recommendations should be interpreted in the context that design, layout and management strategies will be subject to change and refinement.

The nearest populated area in the region is the existing West Angelas village, which is approximately 1.4 kms from Deposit C and 2.4 kms from Deposit G. Another dust-sensitive facility is the aerodrome, which is approximately 1.3 kms from Deposit G.

The US EPA's CALPUFF Version 6 dispersion model was used to predict ambient concentrations around the operation arising from dust emissions. Aspects included in the modelling included terrain effects on dispersion and deposition of dust particles. Meteorological data for the modelling was derived primarily from on-site measurements.

Dust emissions estimates were based on those reported through the NPI. These estimates carry uncertainties, with dust emissions from haul roads being particularly uncertain, as these depend on the level of control applied in practice.

Based on the above approach:

- the maximum predicted dust levels for all parameters at the Village are at 2022; and
- the maximum predicted dust levels at the most impacted area of the aerodrome are also at 2022.

The reasons the highest dust levels occur at the Village and aerodrome during 2022 are:

- over the year 2022, the TMM, and therefore dust emissions, peak for Deposit C;
- the peak annual TMM from Deposit C is reasonably high (approximately 57 Mtpa);
- Deposit C is relatively close to the Village and aerodrome (approximately 1 -2 kms to the west-south-west);
- winds from the west-south-west, are reasonably frequent at approximately 7 – 8% of the time. Furthermore, winds from the due west, which would also cause dust from the western end of Deposit C to impact the Village and aerodrome, are even more frequent at approximately 11% of the time; and
- the dimensions of Deposit C are largest along the east-west axis, which means that dust emissions result in a narrow, more concentrated plume for winds near westerly.

It is therefore recommended that a dust monitor be installed between the Village and south-west end of the aerodrome during, or prior to, 2019. The installation of a monitor would invoke the application of the on-site IEMS Procedure – "Methodology and Instructions for Estimating Site Contributions to E-Sampler Dust Levels" for purposes of managing potential impacts at the Village. This Procedure describes the methodology used on-site to estimate individual site percentage contributions to 24-hour PM10 levels, as measured from dust monitoring units (E-Samplers) located at, or near, sensitive receptors nearest to a mining operation. An investigation is undertaken into the causes of any exceedence of the internal 24 hour PM10 criteria of 70 µg/m^3. This then provides a platform for continuously identifying and rectifying the causes of circumstances that lead to excessive dust levels so that the criterion concentration of 70 µg/m^3 can be limited to less than 11 times per year, as stipulated by the RTIO Cleaner Air Management Plan. The modelling has included conservative estimates for dust control from hauls roads, hence it is anticipated that improving dust control from the Deposit C hauls roads will be the most effective measure to reduce dust levels at the Village and aerodrome if required. Aerodrome Management Services (AMS) is assisting RTIO in aerodrome operations in relation to potential dust impacts.

In relation to the ghost bat caves:

- the maximum predicted dust levels at the ghost bat caves A1 and A2 are at 2017 after which they decrease;
- the maximum predicted dust levels at the ghost bat caves L2 and L3 are at 2017 after which they decrease; and
- the maximum predicted dust levels at the ghost bat caves AA1 are at 2019 after which they decrease.

The dust impacts at the ghost bat caves are simply coincidental to the year that the highest TMM occurs from the adjacent deposit.

The West Angelas Operational Environmental Management Plan (Ministerial Statement 970) specifies the requirement to protect Ghost Bat habitat in close proximity to deposits. For this reason, RTIO have Blast Management Plans in place for Deposits E and B, and further plans will be developed specific to each deposit (i.e. Deposit F) as required. The Management Plans cover aspects such as monitoring, blast prediction and utilisation of sonic fencing for protection against noise and dust from blasting. As Deposit B and Deposit E fauna and heritage sites are currently being adequately managed under existing regulatory requirements, it is anticipated that Deposit F fauna habitat will follow the same management principles.

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United States Environmental Protection Agency (US EPA), 2006, “Compilation of Air Pollutant Emissions Factors (AP-42)”, Chapter 13.2.5 Industrial Wind Erosion, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, November 2006.

Victoria Government Gazette, 2001, “State Environment Protection Policy (Air Quality Management)”, No. S 240 Friday 21 December 2001.

11. GLOSSARY

Abbreviation	Definition
$\mu g/m^3$	micrograms per cubic metre of air.
µm	microns or micrometers.
BoM	Bureau of Meteorology.
CALPUFF	CALifornian PUFF model
DEC	Department of Environment and Conservation
g/m^2/month	grams per square metre per month.
g/s	grams per second.
hr	hour.
Kg	kilograms.
Km	kilometres.
m	metres.
m/s	metres per second.
m^3/s	cubic metres per second.
Mtpa	Mega tonnes per annum.
NEPM	National Environment Protection Measure for Ambient Air Quality dated 26 June 1998.
NPI	National Pollutant Inventory.
percentile	The division of a distribution into 100 groups having equal frequencies.
PM10	Airborne particles with an equivalent aerodynamic diameter of less than 10 µm.
PM2.5	Airborne particles with an equivalent aerodynamic diameter of less than 2.5 µm.
TAPM	The Air Pollution Model
TMM	Total Materials Moved.
TSP	Total Suspended Particulates.

Appendix 1 Brief description of TAPM model

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research. Briefly, TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components, eliminating the need to have site-specific meteorological observations. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM incorporates the following databases for input to its computations:

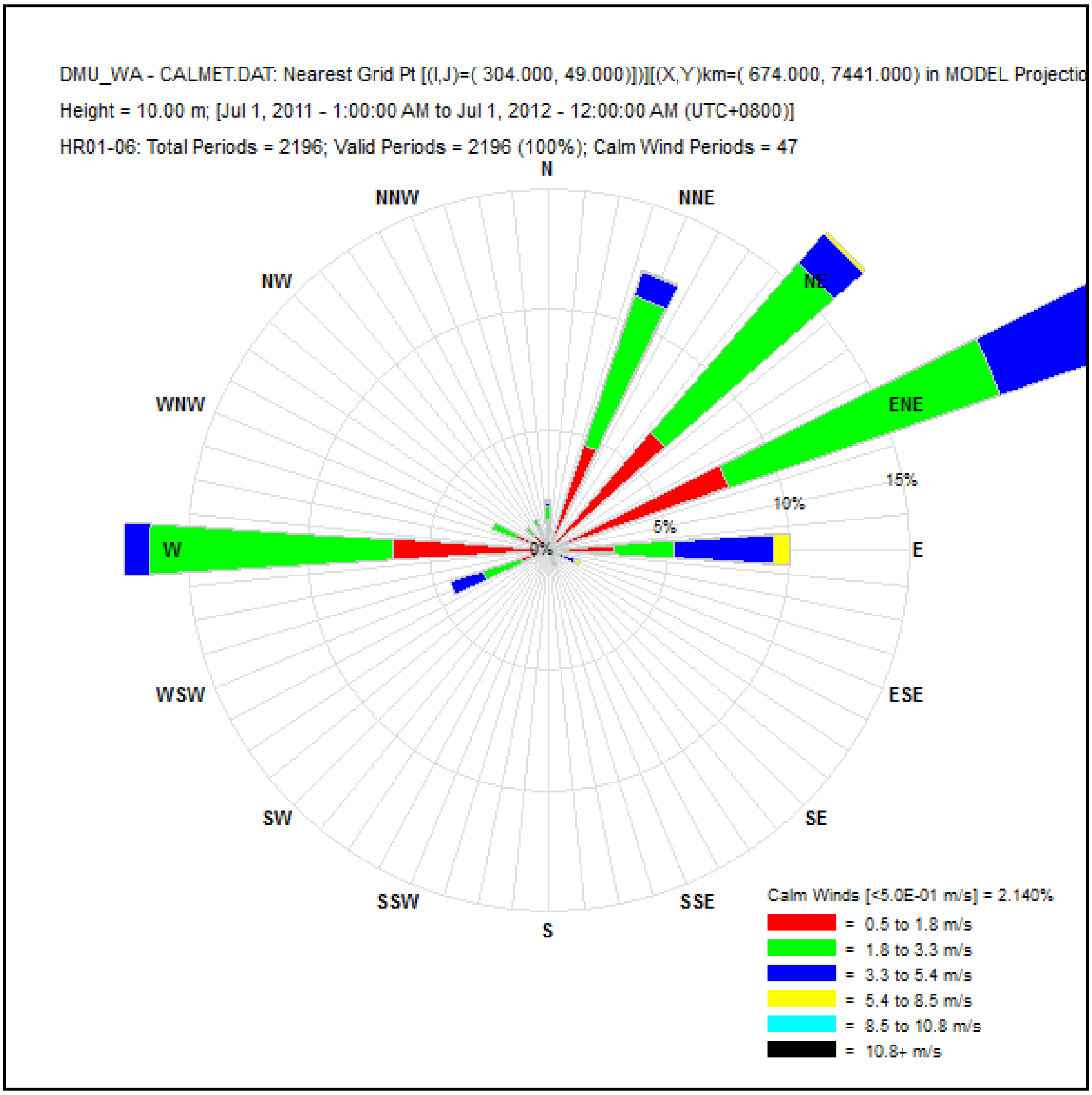
- Gridded database of terrain heights on a longitude/latitude grid of 30 second grid spacing, (approximately 1 km). This default dataset was supplemented by finer resolution data at 90m spacing for this study.
- Australian vegetation and soil type data at 3 minute grid spacing, (approximately 5 km).
- Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at 1 degree grid spacing, (approximately 100 km).
- Six-hourly synoptic scale analyses on a longitude/latitude grid at 0.75-degree grid spacing, (approximately 75 km), derived from the LAPS analysis data from the Bureau of Meteorology.
- Prognostically derived surface and upper air meteorological data (from TAPM) are increasingly being used in dispersion modelling where no observational meteorological data exists or where the network is sparse. This method of coupling derived meteorological with observational data has been used in modelling the dispersion of pollutants for this study.

The TAPM setups for this study were:

- grid domain of 130 x 76 cells nested at 30 km, 10 km and 3 km;
- initial soil moistures were set at 0.05 kg/kg for all months except for January-February (highest rainfall months) where 0.10 kg/kg was used – these choices were based on dispersion modelling in the Pilbara coast (Physick and Blockley 2001) where 0.05 kg/kg was used for all months.

All other settings were defaults including no incorporation of any surface wind observations.

Appendix 2 Wind roses – diurnal and seasonal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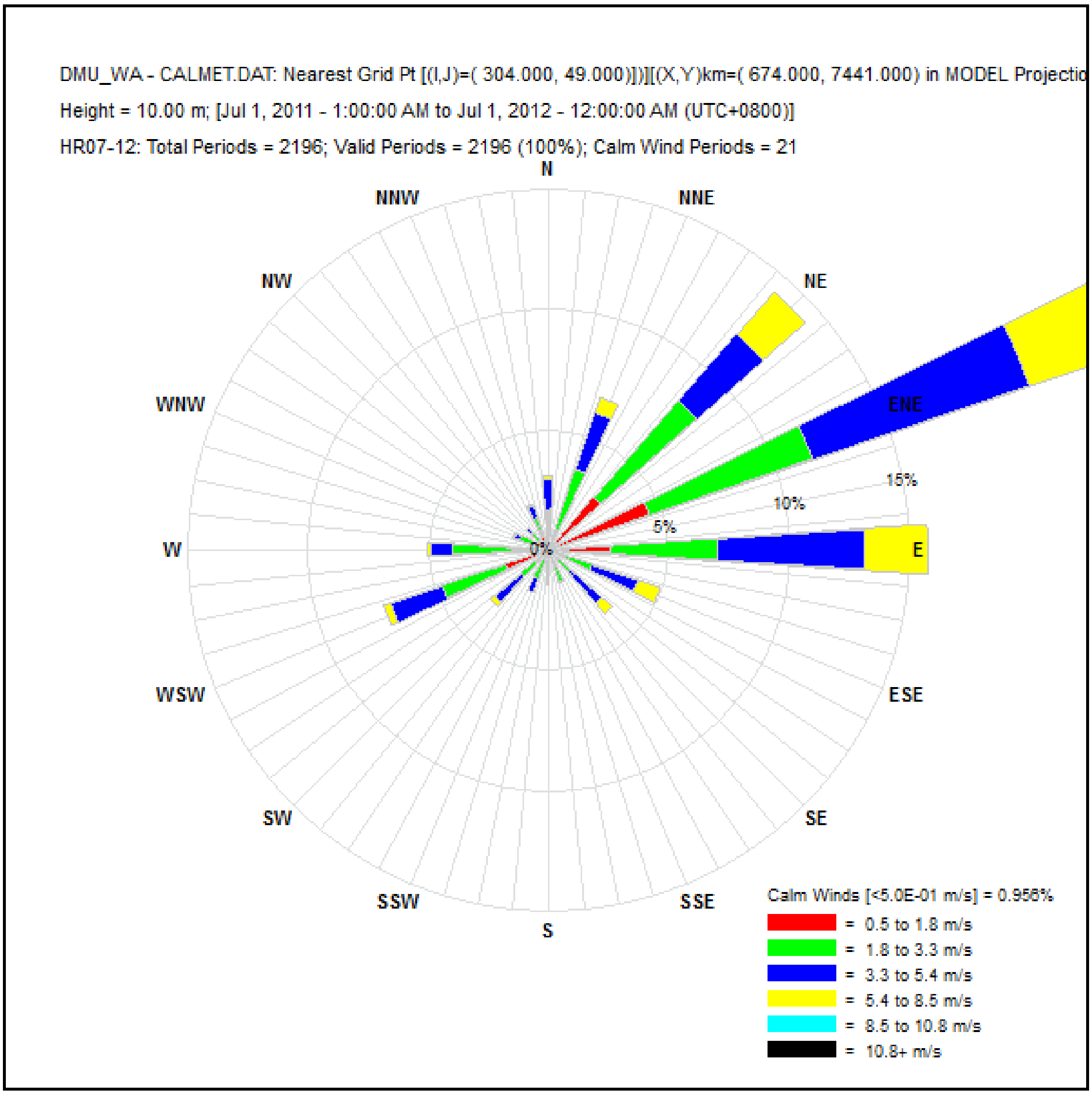
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.140%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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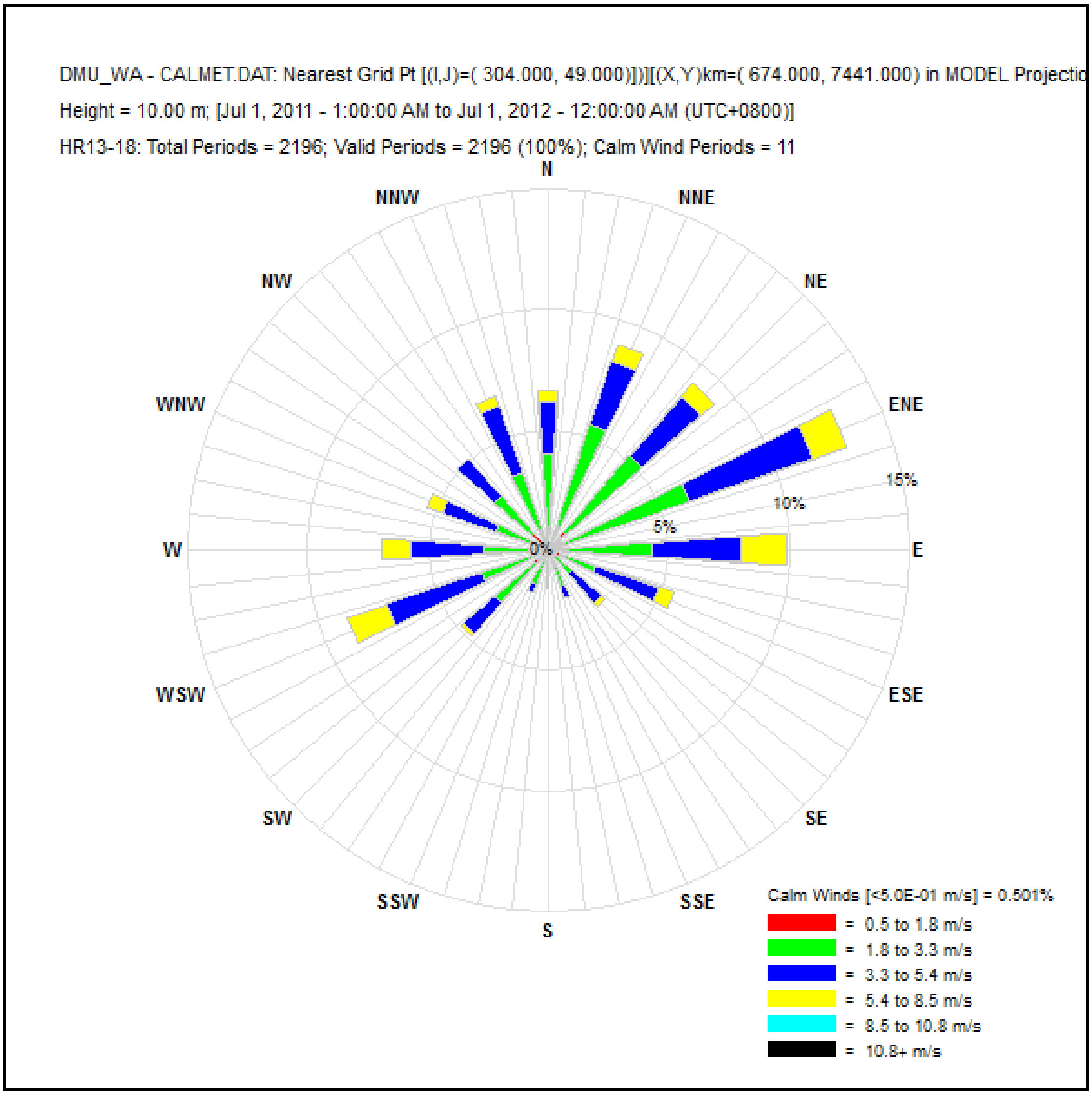
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 0.956%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s


DMU_WA - CALMET.DAT: Nearest Grid Pt [(I,J)=(304.000, 49.000)])][(X,Y)km=(674.000, 7441.000) in MODEL Projectio
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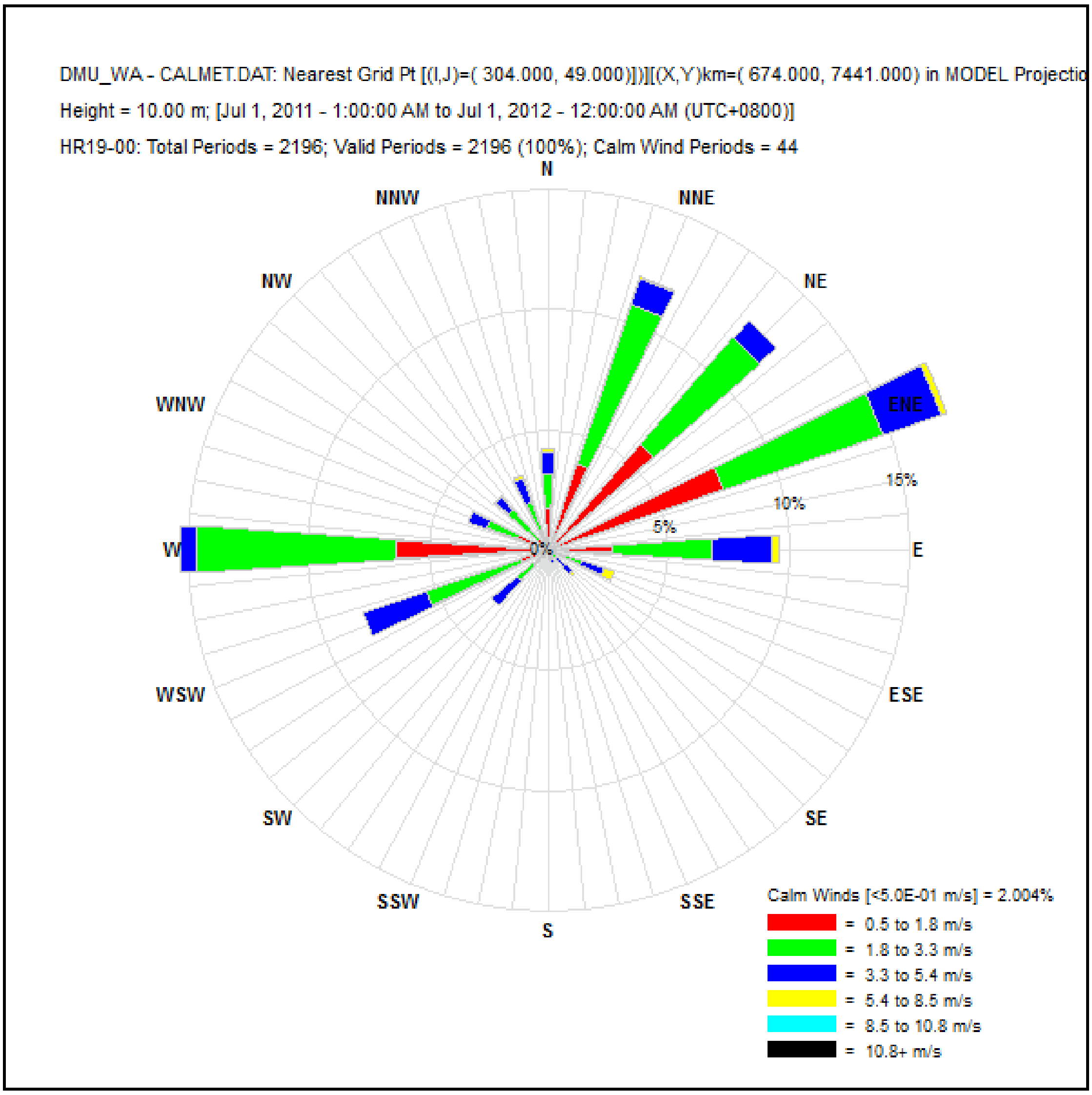
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 0.501%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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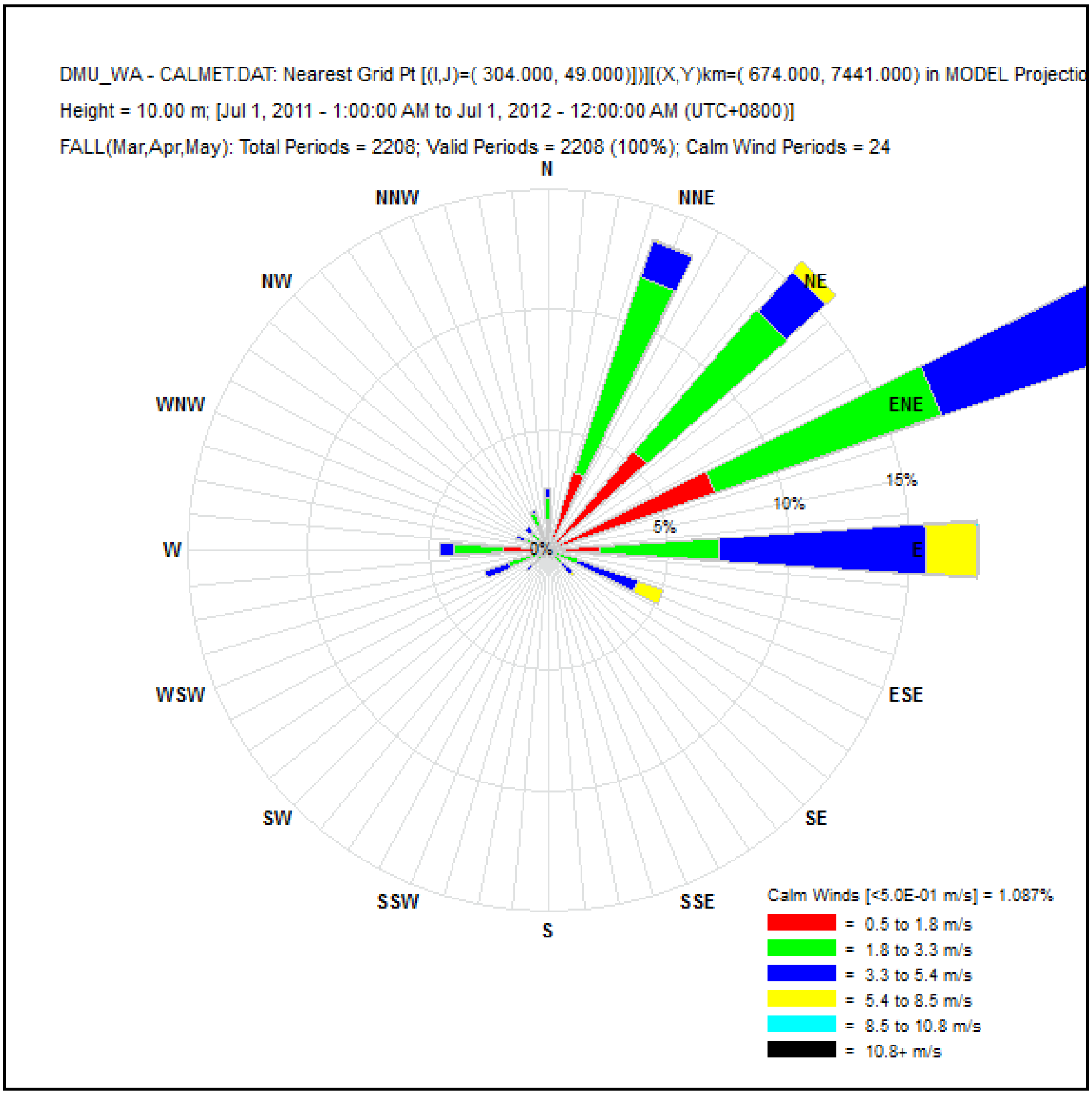
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.004%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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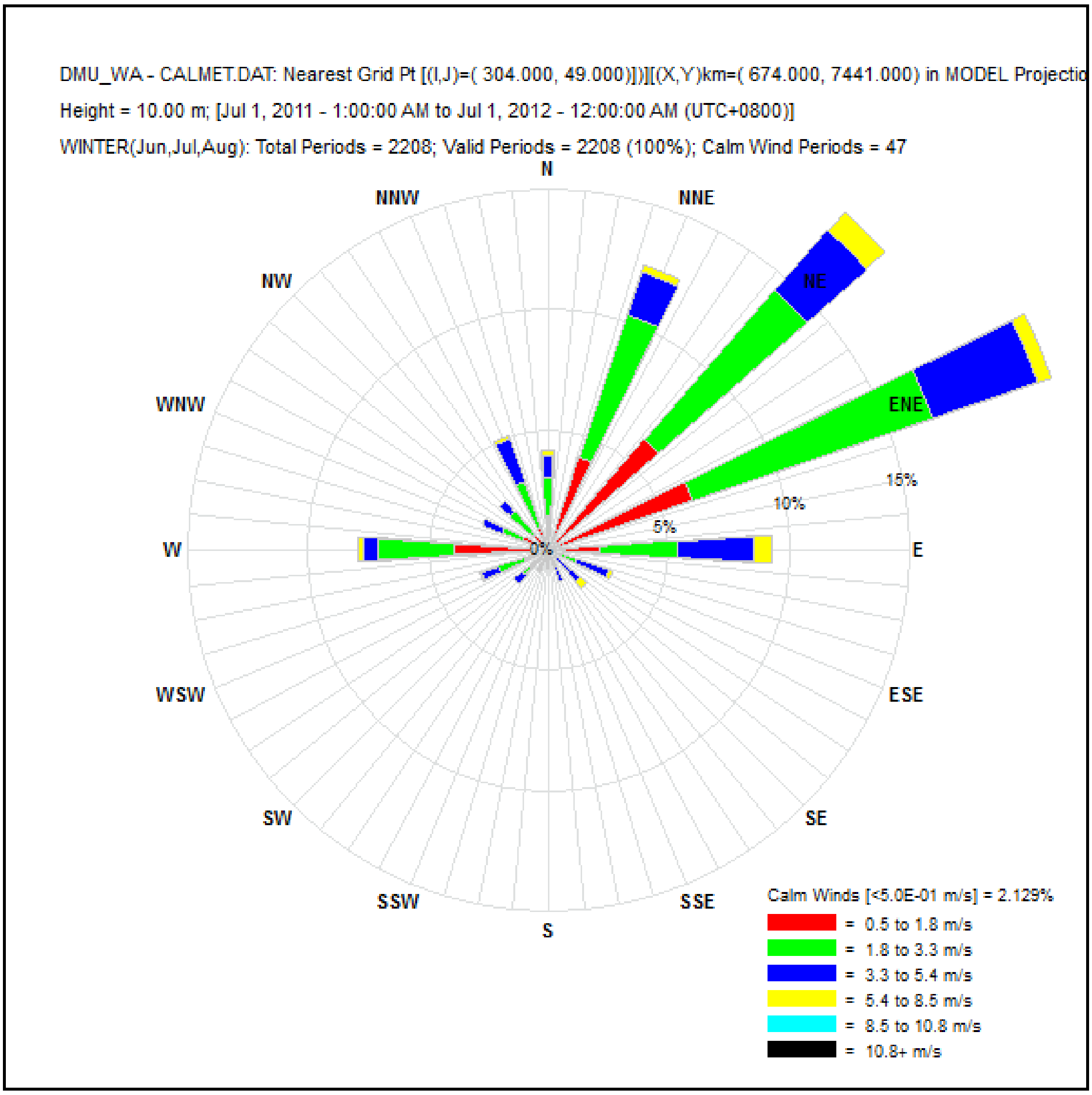
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 1.087%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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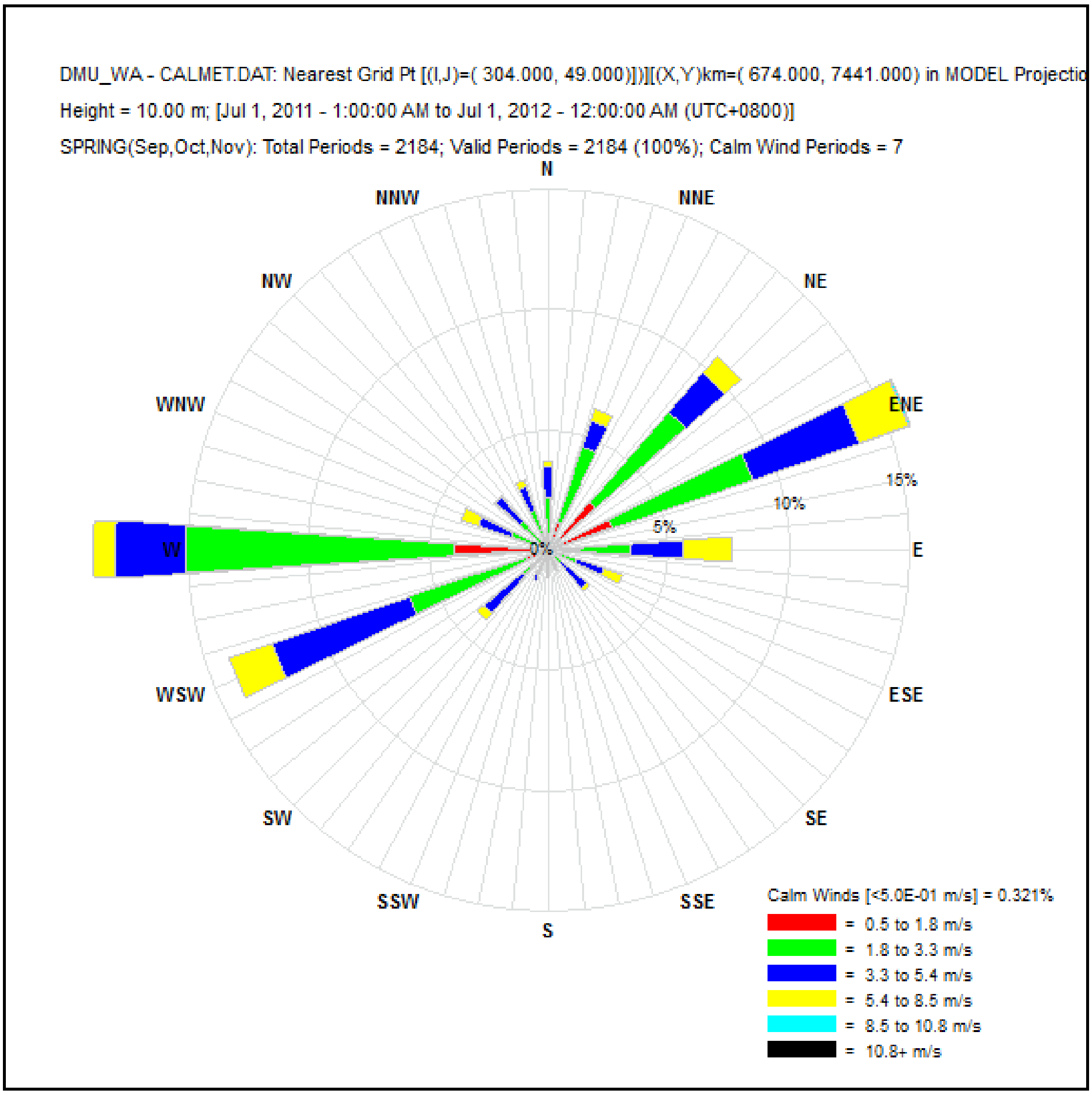
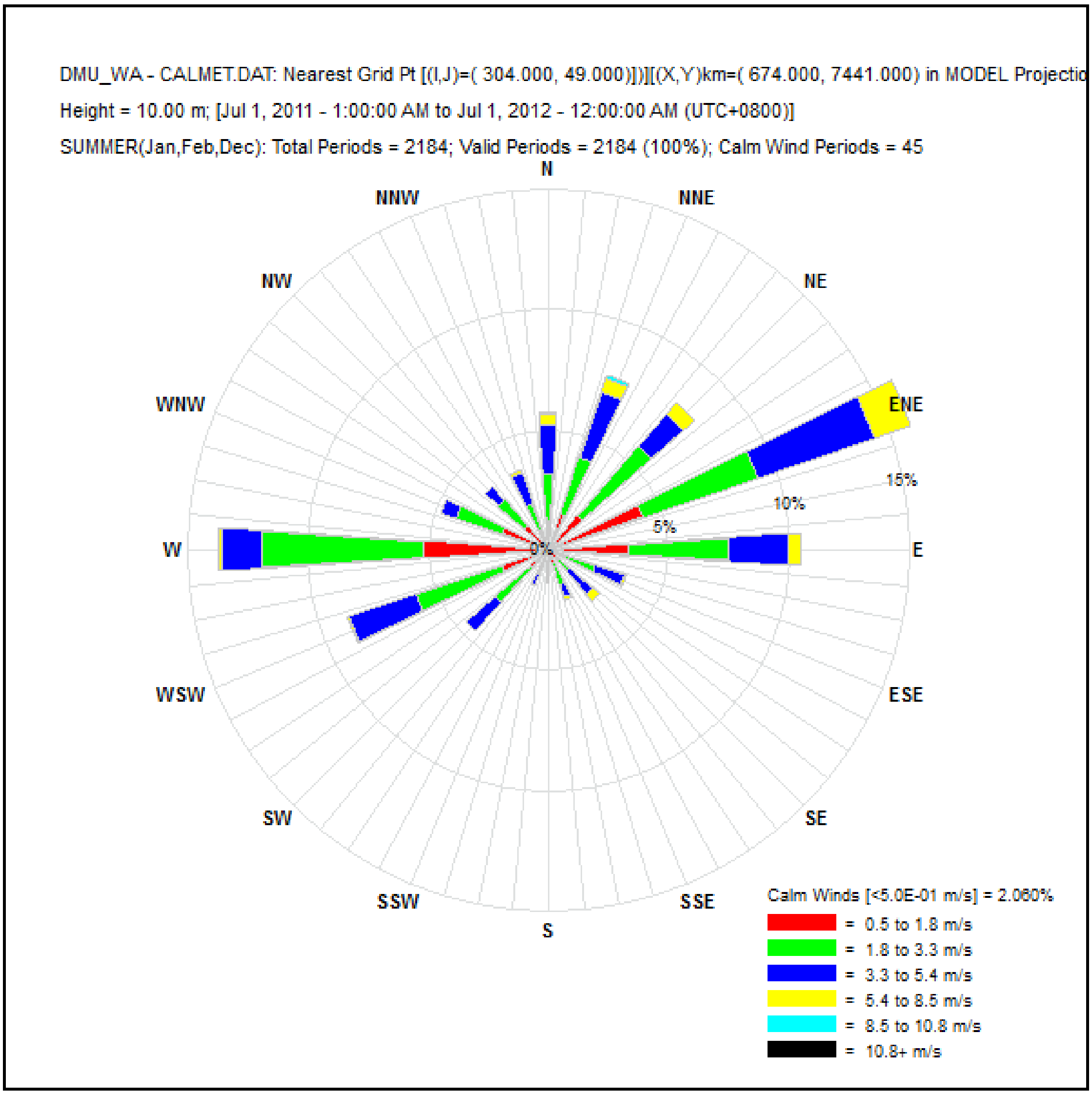
Height = 10.00 m; [Jul 1, 2011 - 1:00:00 AM to Jul 1, 2012 - 12:00:00 AM (UTC+0800)]
WINTER(Jun,Jul,Aug): Total Periods = 2208; Valid Periods = 2208 (100%); Calm Wind Periods = 47
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.129%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s


DMU_WA - CALMET.DAT: Nearest Grid Pt [(I,J)=(304.000, 49.000)])][(X,Y)km=(674.000, 7441.000) in MODEL Projectio
Height = 10.00 m; [Jul 1, 2011 - 1:00:00 AM to Jul 1, 2012 - 12:00:00 AM (UTC+0800)]
SPRING(Sep,Oct,Nov): Total Periods = 2184; Valid Periods = 2184 (100%); Calm Wind Periods = 7
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 0.321%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s


DMU_WA - CALMET.DAT: Nearest Grid Pt [(I,J)=(304.000, 49.000)])][(X,Y)km=(674.000, 7441.000) in MODEL Projectio
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SUMMER(Jan,Feb,Dec): Total Periods = 2184; Valid Periods = 2184 (100%); Calm Wind Periods = 45
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.060%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s

Appendix 3 Dust emissions from haul roads

A major uncertainty in the dust modelling results in this study is the dust emissions from the haul roads outside the pits, as reasonable variations in the assumptions used can lead to very high (order of magnitude) changes in the calculated emissions. The issues are discussed below.

NPI Mining Handbook

The NPI Mining Handbook (2012) uses the AP-42 Chapter 13.2.2 (Nov 2006) equation for wheel generated dust as below:

$$EF_{(kg/VKT)} = \frac{0.4536}{1.6093} \times k \times \left(\frac{s_{(\%)}}{12}\right)^a \times \left(\frac{W_{(t)}}{3}\right)^b$$

Where:

k_{TSP}	= 4.9 for total suspended particles
$k_{PM_{10}}$	= 1.5 for PM_{10}
$s_{(\%)}$	= silt content of material (%)
$W_{(t)}$	= vehicle mass (t)
a_{TSP}	= 0.7 (empirical constant)
$a_{PM_{10}}$	= 0.9 (empirical constant)
b	= 0.45 (empirical constant)

The NPI Handbook then gives a default uncontrolled emissions factor EF PM10 of 1.25 (kg/VKT) based on W(t) = 48 tonnes; s(%) = 10 . This is often used as the basis for estimating dust emissions from haul trucks modelling despite the underlying parameterisations being inconsistent – most obviously, vehicle mass. In the version before this (up to 2011), a different equation was used which resulted in the default emission rate of 0.96 kg/VKT.

It is noteworthy that the above equation:

- does not include a vehicle speed parameter – which is well known to be proportional to dust emissions; and
- does not take into account rainfall periods, which would obviously reduce dust emissions to negligible during rainfall and substantially after rainfall up to the time the road surface has dried out.

Reduction in emissions from controls

For control, the NPI provides three levels of control of:

- 50% for level 1 watering (up to 2 litres/m2/hr);
- 75% for level 2 watering (> 2 litres/m2/hr); and

- 100% for sealed or salt-encrusted roads[9].

The two levels of watering controls were based on calculations undertaken for typical Hunter Valley haul road usage in the 1990s and evaporation using the equation of Cowherd et al (1988) where:

$$C = 100 - (0.8\ P\ d\ t)/\ I$$

Where

- C = average control efficiency percent (%);
- P = potential average daytime evaporation rate mm/hr based on a maximum extreme hourly evaporation rate of 2 mm/hr for a hot windy day;
- d = average hourly traffic rate of 30 truck passes per hour;
- I = application intensity of 1 and 2 L/m2/hr; and
- t = time between applications of 1 hour.

Therefore, the default recommended values are just two discrete points on a continuum. With higher water application rates, higher controls could occur.

Since this earlier work, the USEPA have revised their formulation based the control on the ratio of the controlled moisture content to the uncontrolled moisture content (see Figure 33).

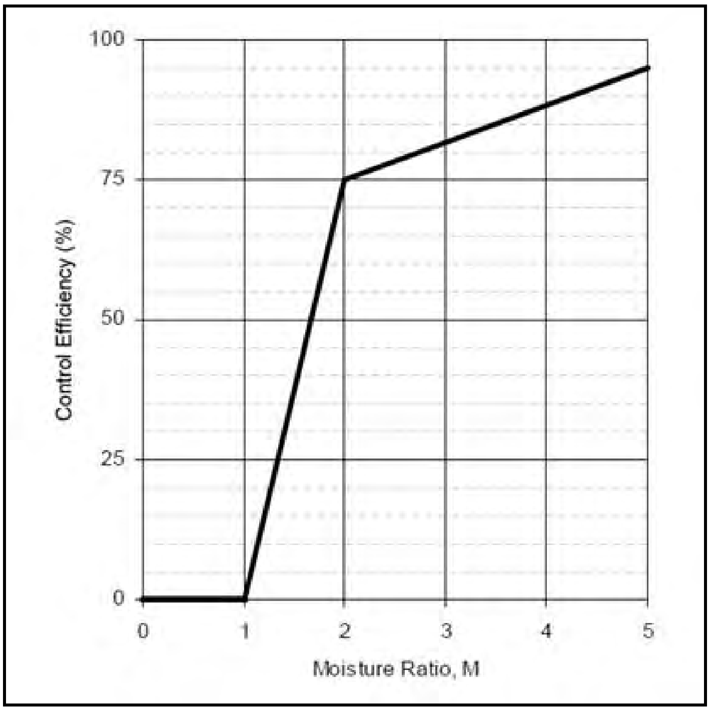

Figure 33 Watering control effectiveness for unpaved travel services from AP42 13.2.2

[9] The control sealed or salt-encrusted road of 100% is considered incorrect (added only to this 2012 version by the editors) as paved roads do emit airborne particulate as illustrated by the USEPA providing a paved road emissions factor.

By increasing the surface moisture content of the road by two, a 75% control is achieved. After this the increase in control decreases with a 95% control achieved by increasing the moisture 5 times. The uncontrolled moisture content depends on the surface and may vary from typically 0.5 to 3%.

Note the WRAPAIR emission factor handbook recommends the following applicable factors (Countess, 2006);

- limiting maximum speed on unpaved roads to 25 miles per hour achieved 44% reduction;
- implementing watering twice a day for industrial unpaved road achieved 55% reduction; and
- paving unpaved roads and unpaved parking areas achieved 99% reduction.

Monitoring of haul truck dust at Dampier port operations (2004)

This control efficiency agrees with monitoring results by Environmental Alliances (2007). The PM10 emissions from haul trucks during bulking at Dampier port used for dust modelling are shown in Table 15.

Table 15 Haul truck emissions factors

Surface condition	Control (%)	PM10 emissions factors for 125 t haul truck (kg/VKT)
very wet	90	0.15 [(a)]
wet	75	0.40
medium	50	0.80
very dry	0	3.5

[(a)] Wind speed during monitoring 4.8 m/s at 10m; Haul truck speed 25 km/hr. The actual measured emission factor was 0.085 kg/VKT on a road surface wet enough immediately after watering to cause the haul truck to slide around corners and being frequently watered. This was assumed to represent 95% control. Note that the measurements also include dust emissions from the vehicle itself, which is correlated with vehicle speed.

Reference:

Environmental Alliances, 2007, “Dust Dispersion Modelling for Pilbara Iron Dampier Port Expansion to 145 Mtpa (Phase B) – Development of Dust Emissions Estimates”, Version 7b (J5104), Prepared for Sinclair Knight Merz, May 2007. Source data in Environmental Alliances, 2004, “Hamersley Iron – Dampier Port Operations – Compliance with Dust Management Conditions in Ministerial Statement of Approval for 95 Mtpa Expansion”, (J4048), August 2004.

These emissions factors were developed from a combination of direct monitoring for the “very wet conditions” plus the monitoring of other vehicles of varying masses and road wetness conditions, then using the AP-42 equations of the time to adjust for mass, speed and road wetness in an effort to produce a consistent dust emissions factors for such parameterisations. The emissions factors ultimately used were considered reasonable of the basis of good results from modelling verification studies using ambient PM10 monitoring.

Emissions factor used for this study

For this study, the following assumptions were used:

- average haul truck mass: 355 t;
- default NPI silt (10%) and moisture (2%) values;

- dust control from road watering: 75% (from road watering of 2 $l/m^2/hr$);
- average speed outside pit areas: 50 km/hr;
- activity ratio (i.e. fraction of total operating time travelling at above speed): 0.2.

The resulting PM10 emissions factor is 0.76 kg/VKT.

Appendix 4 Previous modelling validation studies

A summary of the modelling validation performance (using Calpuff) for the Yandi, Hope Downs, Brockman 2/Nammuldi and Mesa A operations undertaken previously by ENVALL is shown in Figure 34. Emissions for these operations were derived from NPI reports. This shows the modelling predictive PM10 accuracy at E-Sampler monitors (i.e. where y=1 is perfect correspondence between predicted and measured concentrations), against an index defined as the ratio of the annual NPI PM10 emission to annual TMM. This form of this index is based on the expectation that emissions from the same general type of operation – iron ore mines, should be reasonably correlated with the volume of materials handling (i.e. ore plus waste volumes). This is because most of the dust impacts from mining operations arise from activity sources and assumes that exposed areas subject to wind erosion are progressively stabilised and hence not vastly dissimilar in proportion to production between operations.

Figure 34 shows that a PM10:TMM index of about 0.032 – 0.035 kg PM10 emitted/tonne TMM has been associated with good modelling validation results.

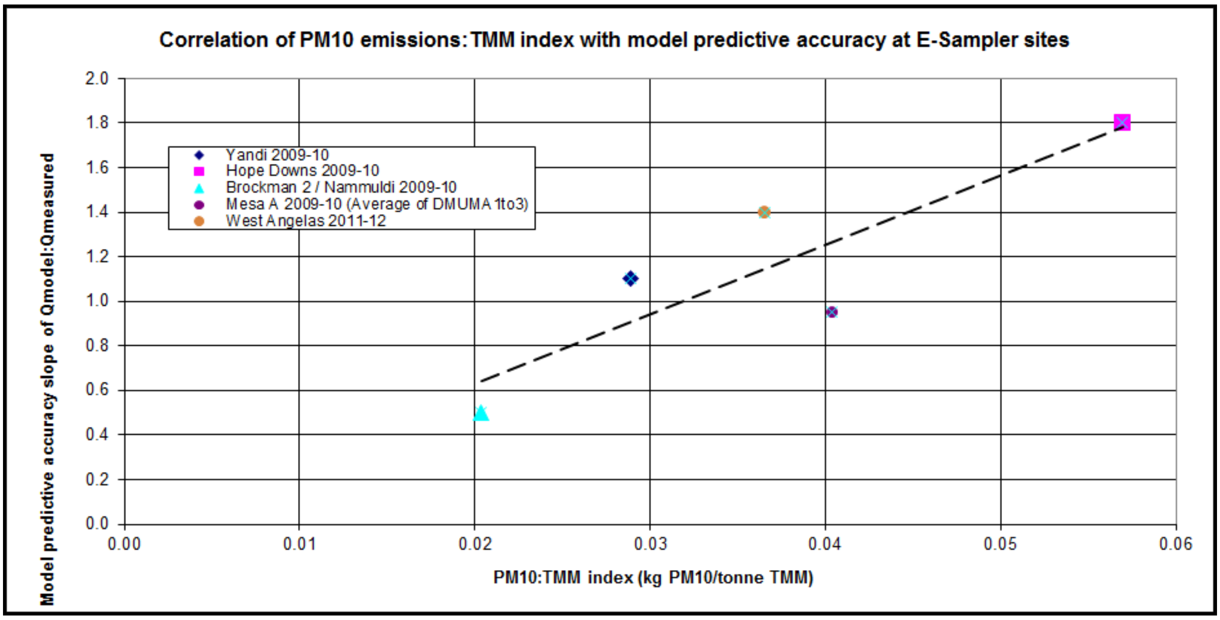

Figure 34 Relationship between emissions and modelling predictive accuracy for previous RTIO minesite validation studies

The PM10:TMM index for the West Angelas 2013-14 operation was 0.028 kg/tonne. It is therefore considered that there is a risk of under-predicting dust levels. Hence the NPI-calculated emissions were increased by 1.25 (i.e. 0.035/0.028).

Appendix 5 Wind-generated dust

The NPI dust estimates are annual aggregates. It would be unrealistic to model wind generated dust as constant dust emission rate, therefore time-varying emissions were estimated based on prevailing meteorology.

Dust lift-off from open areas is wind-speed and rainfall dependent.

Dust emissions as a function of wind speed were estimated as follows:

$$Q_{PM10,a} = K_{s,a} U_{10}^{3} \left(1 - \frac{U_t^{2}}{U_{10}^{2}}\right) \quad (U_{10} > U_t) \qquad \textbf{Equation 1}$$

$$Q_{PM10} = Q_{PM10,a} x A \qquad \textbf{Equation 2}$$

where-

$Q_{PM10,a}$ = PM10 unit area emission rate (g/s/m^2).

$K_{s,a}$ = Site specific empirical constant (g.s^2/m^5).

U_{10} = Local wind speed measured at 10 m (m/s).

U_t = Wind speed threshold for lift off of the material expressed in terms of wind speed measured at 10 m (m/s), assumed to be 5.4 m/s.

Q_{PM10} = PM10 emission rate (g/s).

A = Source surface area (m^2).

The onset of sufficient rainfall dampens surface materials and prevents dust emissions.

The NPI emission equation for wind generated dust from uses a daily total rainfall of 0.25 mm to reflect loss of dust potential from rainfall. This is a very coarse approximation of the effect of rainfall in reducing dust potential. For example, a 1-hour rainfall event of exactly 0.25 mm has the same dust mitigating effect as a much larger 1-hourly rainfall, which is clearly unrealistic.

For the modelling performed in this report, a scheme that approximates that used in RWEQ (Fryrear et al, 1998) was used that defines a soil wetness (SW) factor. The hourly soil wetness was defined by:

For R > 0

$$SW_{1\text{-}hour} = SW_{1\text{-}hour,previous} + R - (1.5 \times Evap) \quad \text{for } R > 1.5Evap \qquad \textbf{Equation 3}$$

$$SW_{1\text{-}hour} = SW_{1\text{-}hour,previous} + Evap + (R - Evap)/1.5 \quad \text{for } Evap < R \leq 1.5Evap \qquad \textbf{Equation 4}$$

$$SW_{1\text{-}hour} = SW_{1\text{-}hour,previous} + R - Evap \quad \text{for } R \leq Evap \qquad \textbf{Equation 5}$$

For R = 0

$SW_{1\text{-hour}} = SW_{1\text{-hour,previous}} - Evap$ **Equation 6**

Where-

$SW_{1\text{-hour}}$ = the soil wetness for a given hour.

$SW_{1\text{-hour,previous}}$ = the soil wetness for the preceding hour.

R = the rainfall for that hour.

Evap = the evaporation rate for that hour - determined from the monthly daily average evaporation rate divided by 24.

The use of the factor of 1.5 times the evaporation allows for infiltration and runoff once the hourly rainfall has exceeded the evaporation rate.

Where SW1-hour exceeded 0.25 mm, no dust emission was assumed for that hour.

The net effect of this scheme was a more realistic time-varying profile of dust emission potential around periods of rainfall, while retaining consistency with the NPI approach.

It is noted that the NPI method is still an approximation, since actual dust emission potential depends largely on the complex process underlying whether crusts are formed. If a crust is formed (which depends on the soil properties and the amount of rain), the surface will remain non-erodable until it is disturbed. Therefore, the actual erosion potential is dependent on quite a few parameters such as the rainfall, crusting ability of the material and disturbance frequency of the area.

It should also be noted that the NPI methodology does not take into account the effect of rainfall in reducing emissions from activity-based sources (eg dust from vehicles wheels). This is unrealistic but this study has maintained consistency with the NPI approach in the calculation of 1-hourly dust emissions from activity sources by simply assuming there is no rainfall effect.

Appendix 6 CALPUFF model set-up parameters

Note: File is for source ID: M:\L5103\Cal\Tilt2017\Puf\AREPM75.INP (PM7.5 fraction for 2017 model run).

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CALPUFF.INP     2.0             File version record
L5103 West Angelas - 1 Km Grid
File is: AREPM75.INP  Source is M:\...\PM75\AREWA000.SRC

---------------- Run title (3 lines) ------------------------------------------

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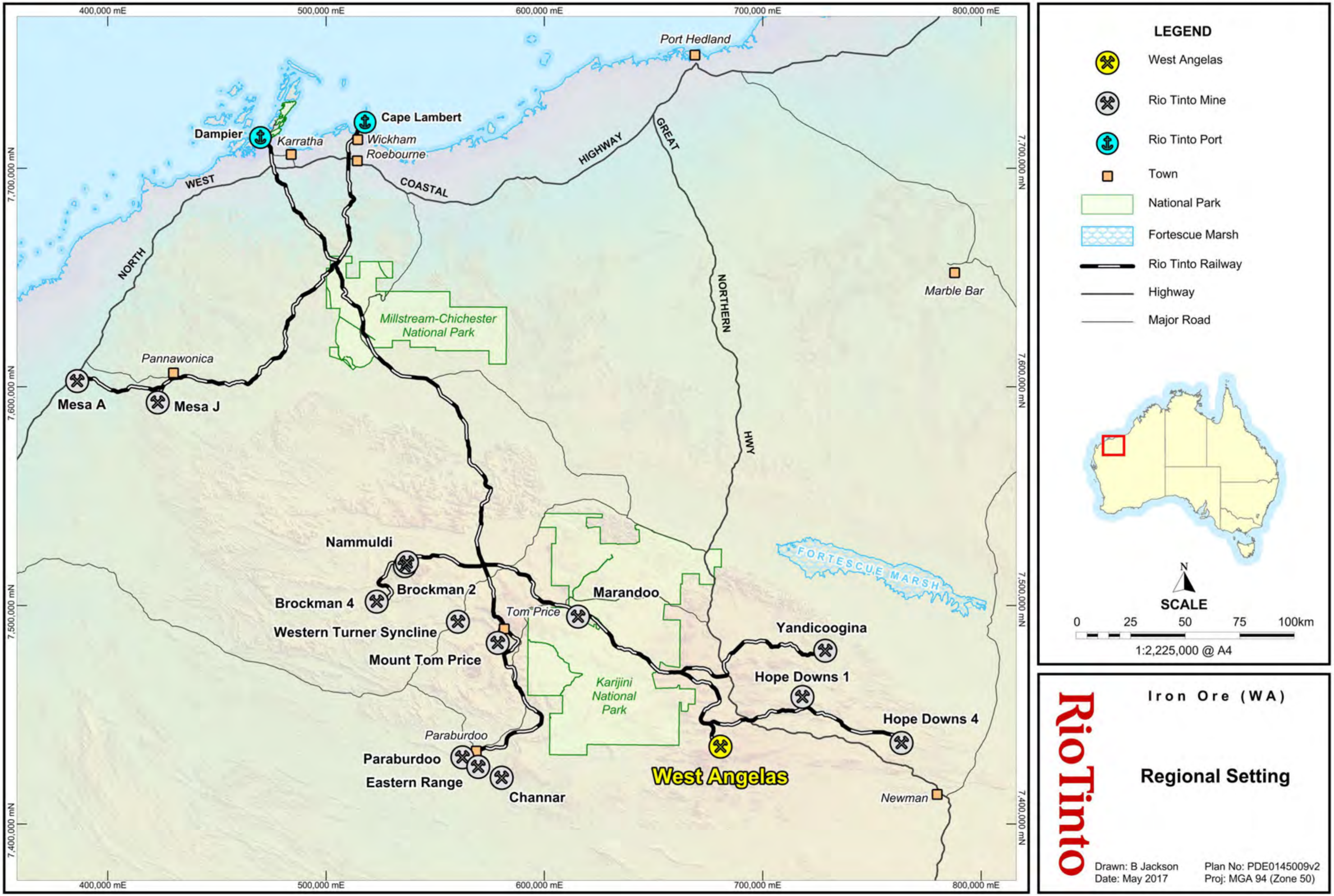
! CONDAT =M:\L5103\CAL\TILT2017\PUF\AREPM75.CON     !
! DFDAT  =M:\L5103\CAL\TILT2017\PUF\AREPM75.DRY     !
! ARDAT  =M:\L5103\CAL\TILT2017\EMIS\PM75\AREWA000.SRC  !
! AUXEXT =AUX     !
! LCFILES = F !
! NMETDOM =   1   !
! NMETDAT =   6   !
! NPTDAT =   0   !
! NARDAT =   0   !
! NVOLDAT =   0   !
!END!
! METDAT1 = M:\L5103\CAL\MET\PILB1107.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1109.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1111.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1201.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1203.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1205.MET     !
! METRUN =   0  !
! IBYR  =  2011  !
! IBMO  =  7  !
! IBDY  =  1  !
! IBHR  =  0  !
! IBMIN =  0  !
! IBSEC =  0  !
! IEYR  =  2012  !
! IEMO  =  6  !
! IEDY  =  30  !
! IEHR  =  0  !
! IEMIN =  0  !
! IESEC =  0  !
! ABTZ= UTC+0800 !
! NSECDT =  3600  !
! NSPEC =  1   !
! NSE =  0   !
! ITEST =  2   !
! MRESTART =  0   !
! NRESPD =  0   !
! METFM =  1   !
! MPRFFM =  1   !
! AVET = 60. !
! PGTIME = 10. !
! IOUTU =  1   !
! IOVERS =  2   !
!END!
! MGAUSS =  1   !
! MCTADJ =  3   !
! MCTSG =  0   !
! MSLUG =  0   !
! MTRANS =  1   !
! MTIP =  1  !
! MRISE =  1  !
! MBDW =   1  !
! MSHEAR =  1  !
! MSPLIT =  0  !
! MCHEM =  0   !
! MAQCHEM =  0   !
! MLWC =  1   !
! MWET =  1   !
! MDRY =  1   !
! MTILT =  1   !
! MDISP =  2   !
```

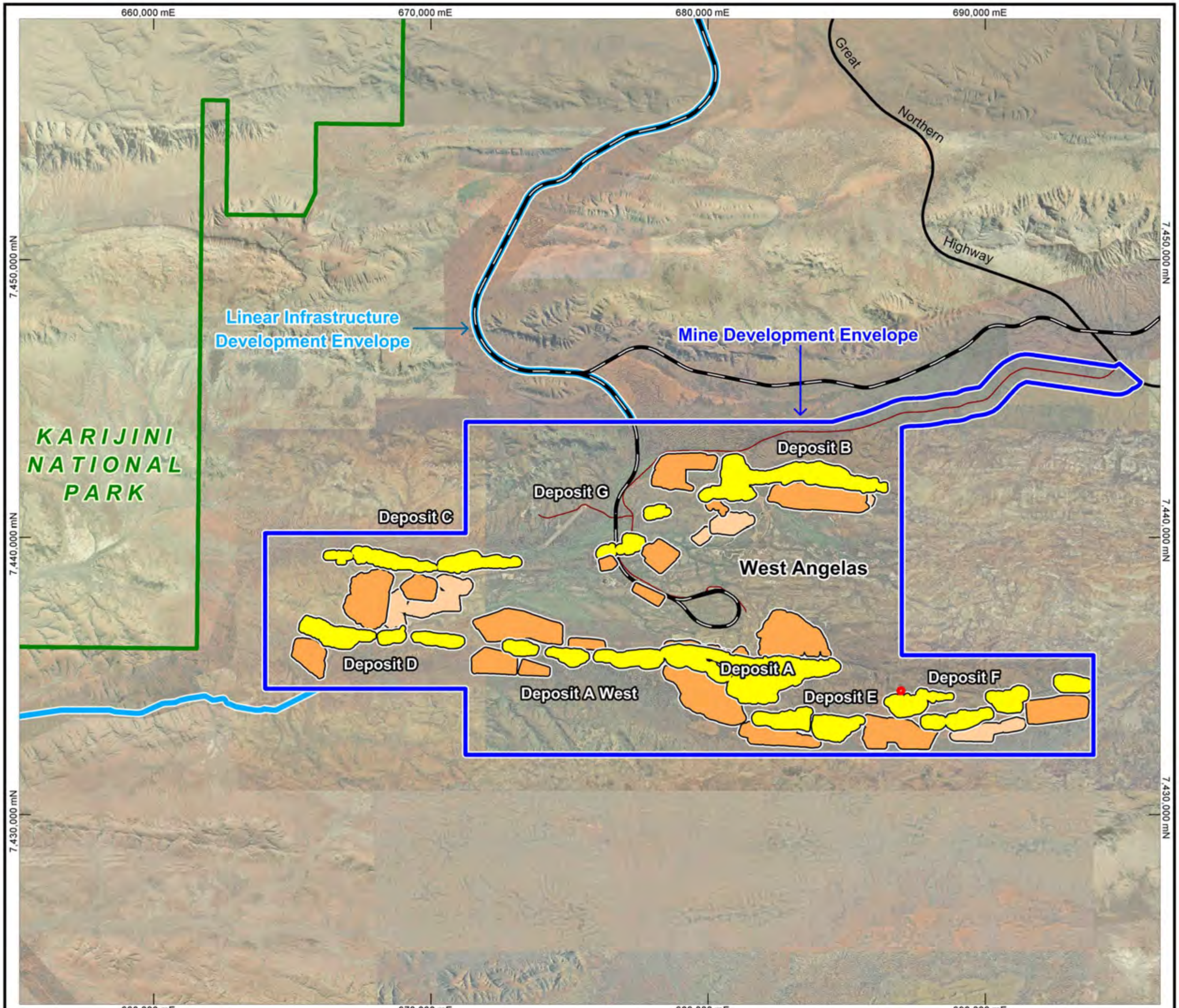
```
! MTURBVW =  3  !
! MDISP2 =  3  !
! MTAULY =  0  !
! MTAUADV =  0  !
! MCTURB =  1  !
! MROUGH =  0  !
! MPARTL =  1  !
! MPARTLBA =  0  !
! MTINV =  0  !
! MPDF =  0  !
! MSGTIBL = 0  !
! MBCON = 0  !
! MSOURCE = 0  !
! MFOG =  0   !
! MREG =  0   !
!END!
! CSPEC =       PM75_2 !
!       PM75_2  =         1,                0,            2,                  0   !
!END!
! PMAP = UTM  !
! FEAST  = 0.000  !
! FNORTH = 0.000  !
! IUTMZN =  50   !
! UTMHEM = S  !
! RLAT0 = -20.6N  !
! RLON0 = -116.67W  !
! XLAT1 = -30N  !
! XLAT2 = -60N  !
! DATUM = WGS-84  !
! NX =  389   !
! NY =  227   !
! NZ =  6   !
! DGRIDKM = 1.0 !
! ZFACE = .0, 20.0, 80.0, 200.0, 380.0, 680.0, 1200.0 !
! XORIGKM = 370.5 !
! YORIGKM = 7392.5 !
! IBCOMP =  292   !
! JBCOMP =  38   !
! IECOMP =  324   !
! JECOMP =  55   !
! LSAMP = T !
! IBSAMP =  292   !
! JBSAMP =  38   !
! IESAMP =  324   !
! JESAMP =  55   !
! MESHDN =  2  !
!END!
!  ICON =  1   !
!  IDRY =  1   !
!  IWET =  0   !
!  IT2D =  0   !
!  IRHO =  0   !
!  IVIS =  0   !
! LCOMPRS = T !
!  IQAPLOT =  1   !
! IMFLX =  0  !
! IMBAL =  0  !
! INRISE =  0  !
! ICPRT =  1   !
! IDPRT =  1   !
! IWPRT =  0   !
! ICFRQ =  12   !
! IDFRQ =  12   !
! IWFRQ =  1   !
! IPRTU =  3   !
! IMESG =  2   !
!       PM75_2 =     1,           1,           1,           1,           0,           0,
0   !
! LDEBUG = F !
! IPFDEB =  1  !
! NPFDEB =  1  !
! NN1 =  1   !
! NN2 =  10  !
!END!
! NHILL =  0   !
! NCTREC =  0   !
```

```
! MHILL =  2   !
! XHILL2M = 1.0 !
! ZHILL2M = 1.0 !
! XCTDMKM = 0 !
! YCTDMKM = 0 !
! END !
!END!
!       PM75_2 =           7.5,                      .0   !
!END!
!  RCUTR = 30.0 !
!    RGR = 10.0 !
! REACTR = 8.0 !
!   NINT =  9  !
!   IVEG =  1   !
!END!
!       PM75_2 =         1.0E-04,             3.0E-05 !
!END!
! MOZ =  0   !
!  BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
!
! MNH3 =  0   !
! MAVGNH3 =  1   !
!  BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
!
! RNITE1 = .2 !
! RNITE2 = 2.0 !
! RNITE3 = 2.0 !
! MH2O2 =  1   !
!  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
!  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
!  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
!  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
!
! NDECAY =  0   !
!END!
! SYTDEP = 5.5E02 !
! MHFTSZ =  0   !
! JSUP =  5   !
! CONK1 = .01 !
! CONK2 = .1 !
! TBD = .5 !
! IURB1 =  10  !
! IURB2 =  19  !
! ILANDUIN =  70  !
! Z0IN = .05 !
! XLAIIN = .05 !
! ELEVIN = .0 !
! XLATIN = -20.67 !
! XLONIN = -116.72 !
! ANEMHT = 10.0 !
! ISIGMAV =  1  !
! IMIXCTDM =  0  !
! XMXLEN = 1.0 !
! XSAMLEN = 1.0 !
! MXNEW =  99   !
! MXSAM =  99   !
! NCOUNT =  2   !
! SYMIN = 1.0  !
! SZMIN = 1.0  !
! SZCAP_M = 5.0E06 !
! SVMIN = 0.400, 0.400, 0.400, 0.400, 0.400, 0.400, 0.370, 0.370, 0.370, 0.370, 0.370, 0.370!
! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!
! CDIV = .0, .0 !
! NLUTIBL =  4  !
! WSCALM = .5 !
! XMAXZI = 3000.0 !
! XMINZI = 50.0 !
! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !
! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !
! PTG0 = 0.020,   0.035 !
!  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !
! SL2PF = 10.0 !
! NSPLIT =  3  !
!  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !
! ZISPLIT = 100.0 !
! ROLDMAX = 0.25 !
```

```
! NSPLITH =  5  !
! SYSPLITH = 1.0 !
! SHSPLITH = 2.0 !
! CNSPLITH = 1.0E-07 !
! EPSSLUG = 1.0E-04 !
! EPSAREA = 1.0E-06 !
! DSRISE = 1.0 !
! HTMINBC = 500.0 !
! RSAMPBC = 10.0 !
! MDEPBC =  1  !
!END!
!  NPT1 =  0  !
!  IPTU =   1  !
!  NSPT1 =  0  !
!  NPT2 =  0  !
!END!
!  NAR1 =  0   !
!  IARU =   1  !
!  NSAR1 =  0  !
!  NAR2 =  69   !
!END!
!  NLN2 =  0   !
! NLINES =  0  !
!  ILNU =   1  !
!  NSLN1 =  0  !
! MXNSEG =  7  !
! NLRISE =  6  !
! XL = .0 !
! HBL = .0 !
! WBL = .0 !
! WML = .0 !
! DXL = .0 !
! FPRIMEL = .0 !
!END!
!  NVL1 =  0   !
!  IVLU =   1  !
!  NSVL1 =  0  !
!  NVL2 =   0   !
!END!
!  NREC =  25   !
!END!
! X =   674.31604, 7441.08447,     725.000,       2.000!
! X =  673.660034, 7440.73047,     728.000,       2.000!
! X =     681.792,   7442.618,     740.000,       2.000!
! X =      681.78,    7442.62,     740.000,       2.000!
! X =     681.784,   7442.669,     740.000,       2.000!
! X =     681.792,   7442.618,     740.000,       2.000!
! X =      681.78,    7442.62,     740.000,       2.000!
! X =     682.876,   7442.598,     743.000,       2.000!
! X =     682.928,   7442.614,     743.000,       2.000!
! X =      681.78,    7442.62,     740.000,       2.000!
! X =     682.876,   7442.598,     743.000,       2.000!
! X =     684.534,   7443.153,     779.000,       2.000!
! X =     682.379,   7442.595,     743.000,       2.000!
! X =     682.899,   7442.582,     743.000,       2.000!
! X =     686.953,   7434.461,     810.000,       2.000!
! X =    675.4408,   7441.096,     715.000,       2.000!
! X =    675.5523,   7440.985,     715.000,       2.000!
! X =    674.0715,   7439.585,     701.000,       2.000!
! X =    673.9687,   7439.686,     700.000,       2.000!
! X =    674.5593,   7440.248,     701.000,       2.000!
! X =    674.5002,   7440.311,     701.000,       2.000!
! X =    673.6537,   7441.381,     728.000,       2.000!
! X =    673.9534,   7440.913,     728.000,       2.000!
! X =    673.6843,   7440.418,     700.000,       2.000!
! X =    673.1397,   7440.795,     728.000,       2.000!
```



LEGEND
West Angelas
Rio Tinto Mine
Rio Tinto Port
Town
National Park
Fortescue Marsh
Rio Tinto Railway
Highway
Major Road
SCALE
0 25 50 75 100km
1:2,225,000 @ A4
N
400,000 mE
500,000 mE
600,000 mE
700,000 mE
800,000 mE
7,700,000 mN
7,600,000 mN
7,500,000 mN
7,400,000 mN
Port Hedland
Cape Lambert
Dampier
Karratha
Wickham
Roebourne
NORTH
WEST
COASTAL
HIGHWAY
GREAT
NORTHERN
HWY
Marble Bar
Millstream-Chichester National Park
Pannawonica
Mesa A
Mesa J
Nammuldi
Brockman 2
Brockman 4
Western Turner Syncline
Tom Price
Marandoo
Mount Tom Price
FORTESCUE MARSH
Yandicoogina
Hope Downs 1
Hope Downs 4
Karijini National Park
Paraburdoo
Eastern Range
Channar
West Angelas
Newman
Rio Tinto
Iron Ore (WA)
Regional Setting
Drawn: B Jackson
Date: May 2017
Plan No: PDE0145009v2
Proj: MGA 94 (Zone 50)



LEGEND

- Mine Development Envelope
- Linear Infrastructure Development Envelope
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Ghost Bat Cave AA1 Exclusion Zone
- Railway
- Highway
- Site Access Road

N

SCALE

0 2 4 6 8 10km

1:200 000 @ A4

Disclaimer

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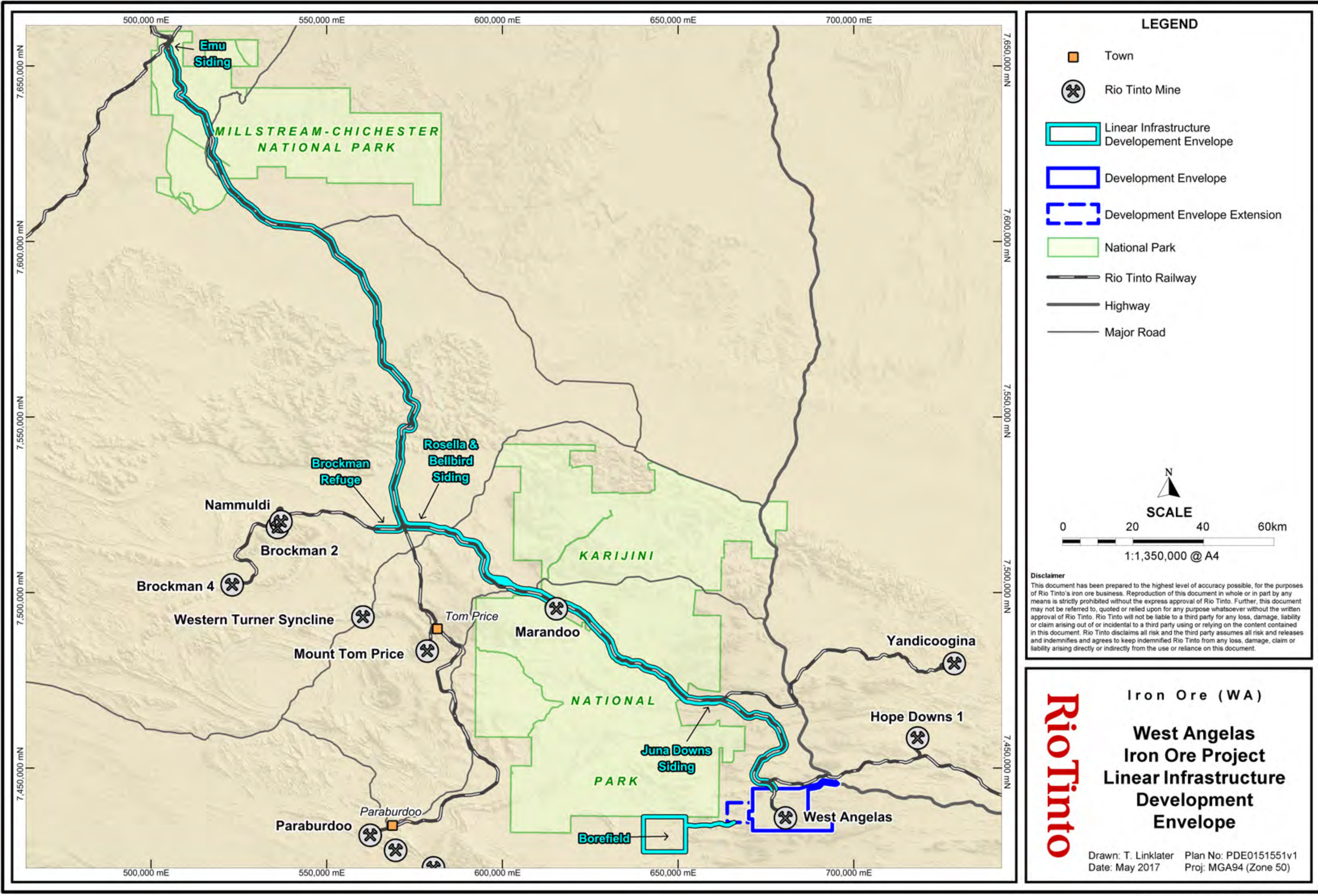
RioTinto

Iron Ore (WA)

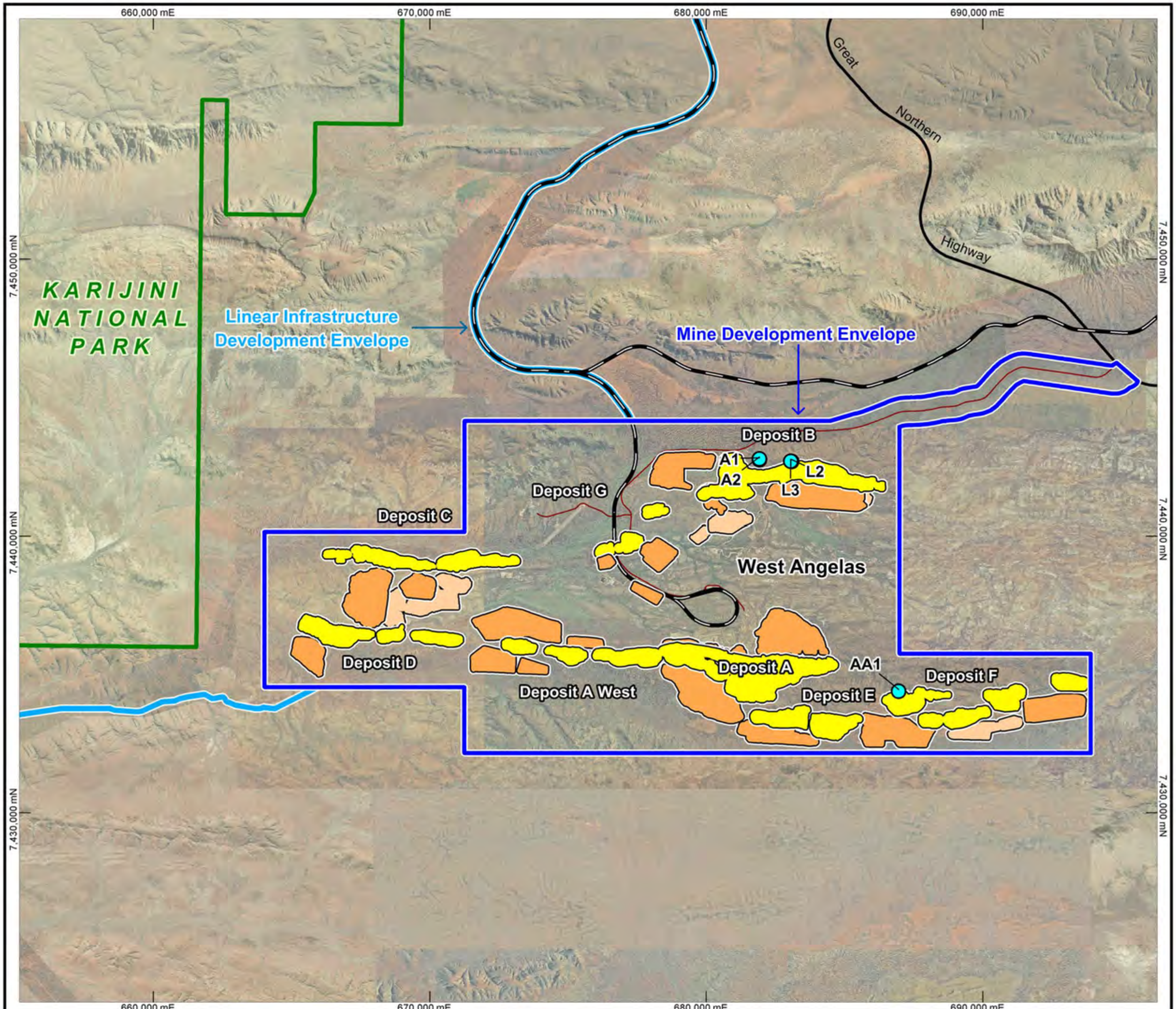
West Angelas Iron Ore Project Mine Development Envelope and conceptual layout

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151559v1
Proj: MGA94 (Zone 50)



Geospatial Information and Mapping



LEGEND

- Mine Development Envelope
- Linear Infrastructure Development Envelope
- Ghost Bat cave
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Railway
- Highway
- Site Access Road

N

SCALE

0 2 4 6 8 10km

1:200 000 @ A4

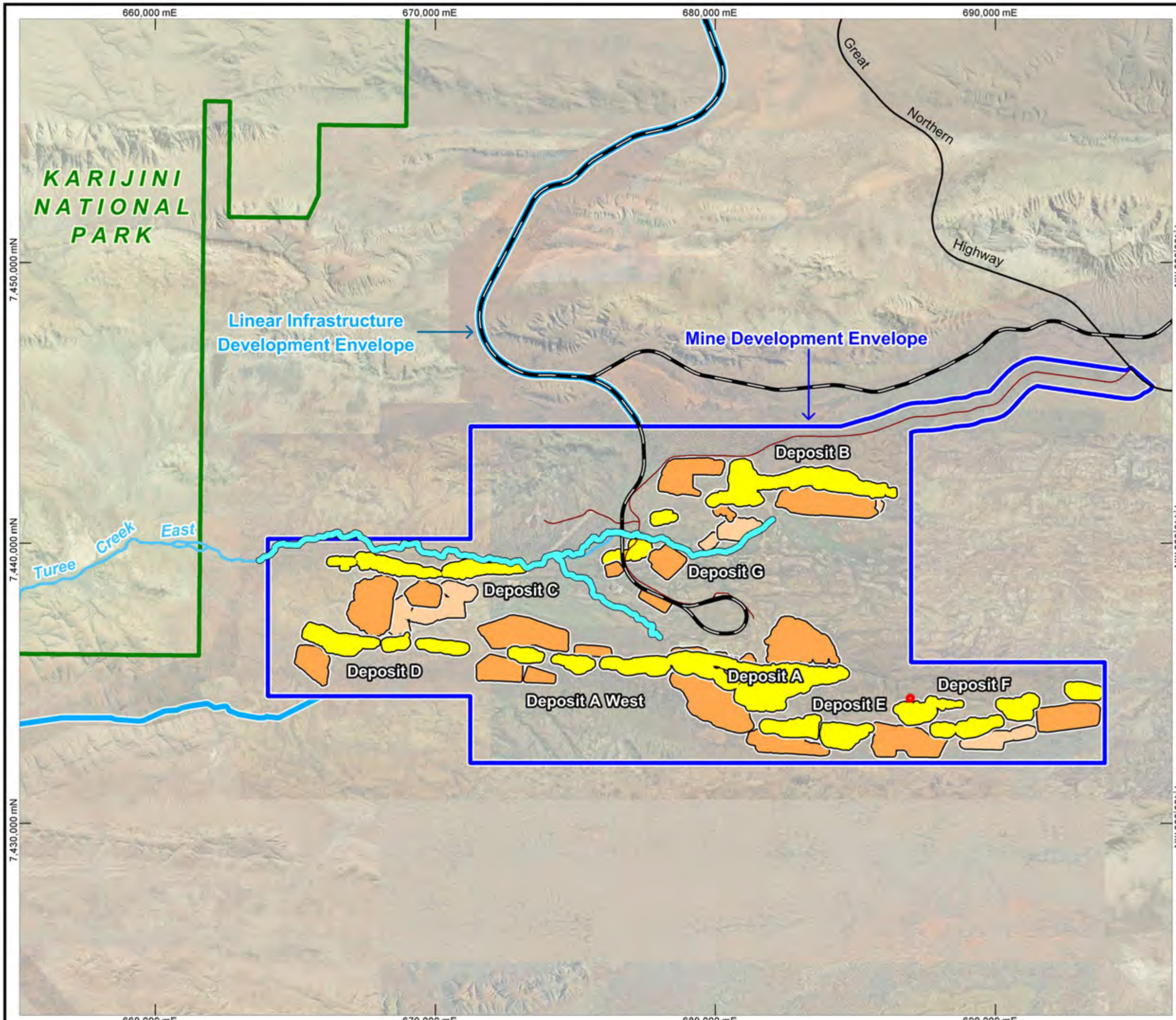
RioTinto

Iron Ore (WA)

Ghost bat (Macroderma gigas) roosts

Drawn: B Jackson
Date: June 2017

Plan No: PDE0152062v1
Proj: MGA94 (Zone 50)



LEGEND

- Mine Development Envelope
- Linear Infrastructure Development Envelope
- Surplus Water Discharge Extent
- Major Creek
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Ghost Bat Cave AA1 Exclusion Zone
- Railway
- Highway
- Site Access Road

N

SCALE

0 2 4 6 8 10km

1:200 000 @ A4

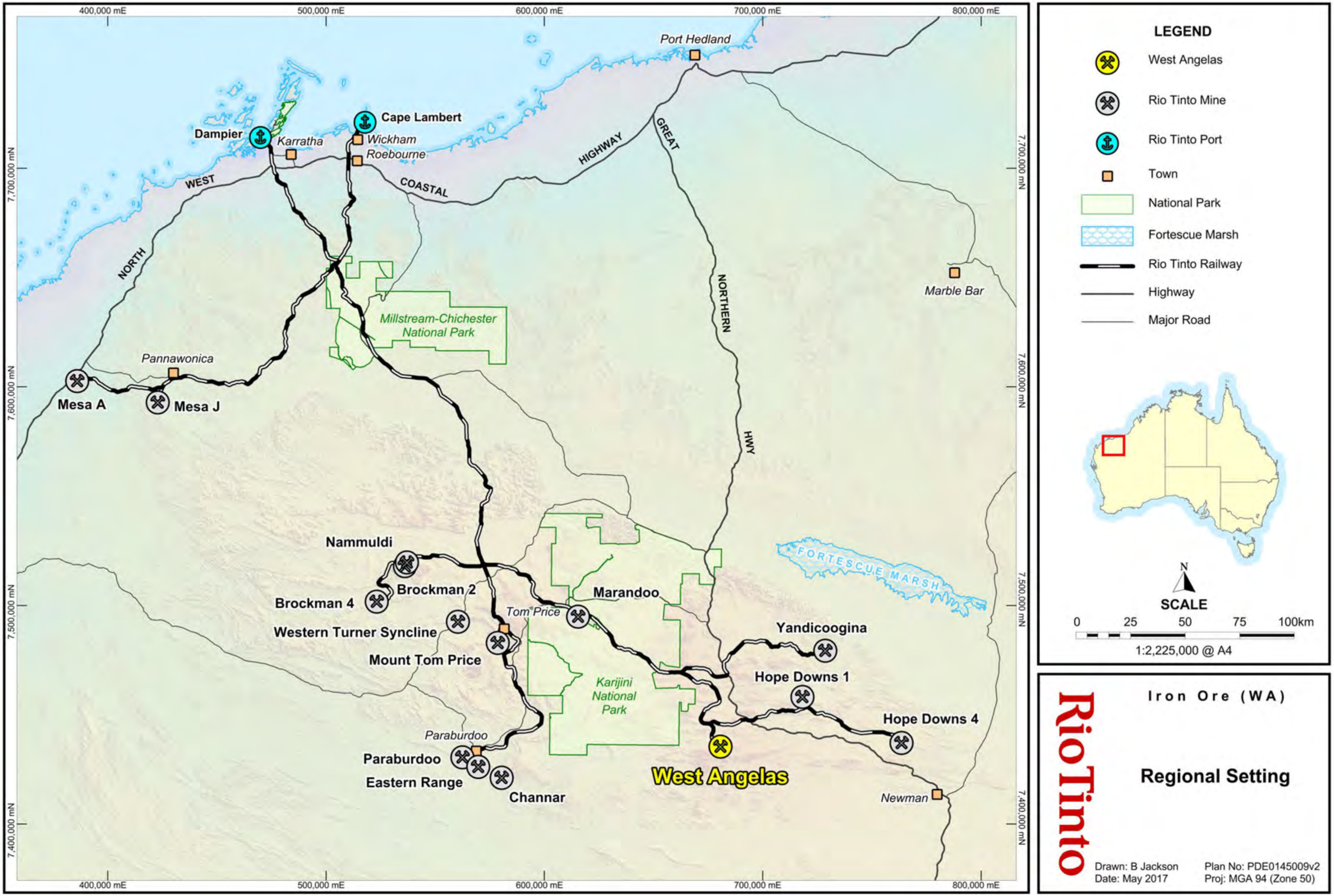
Disclaimer

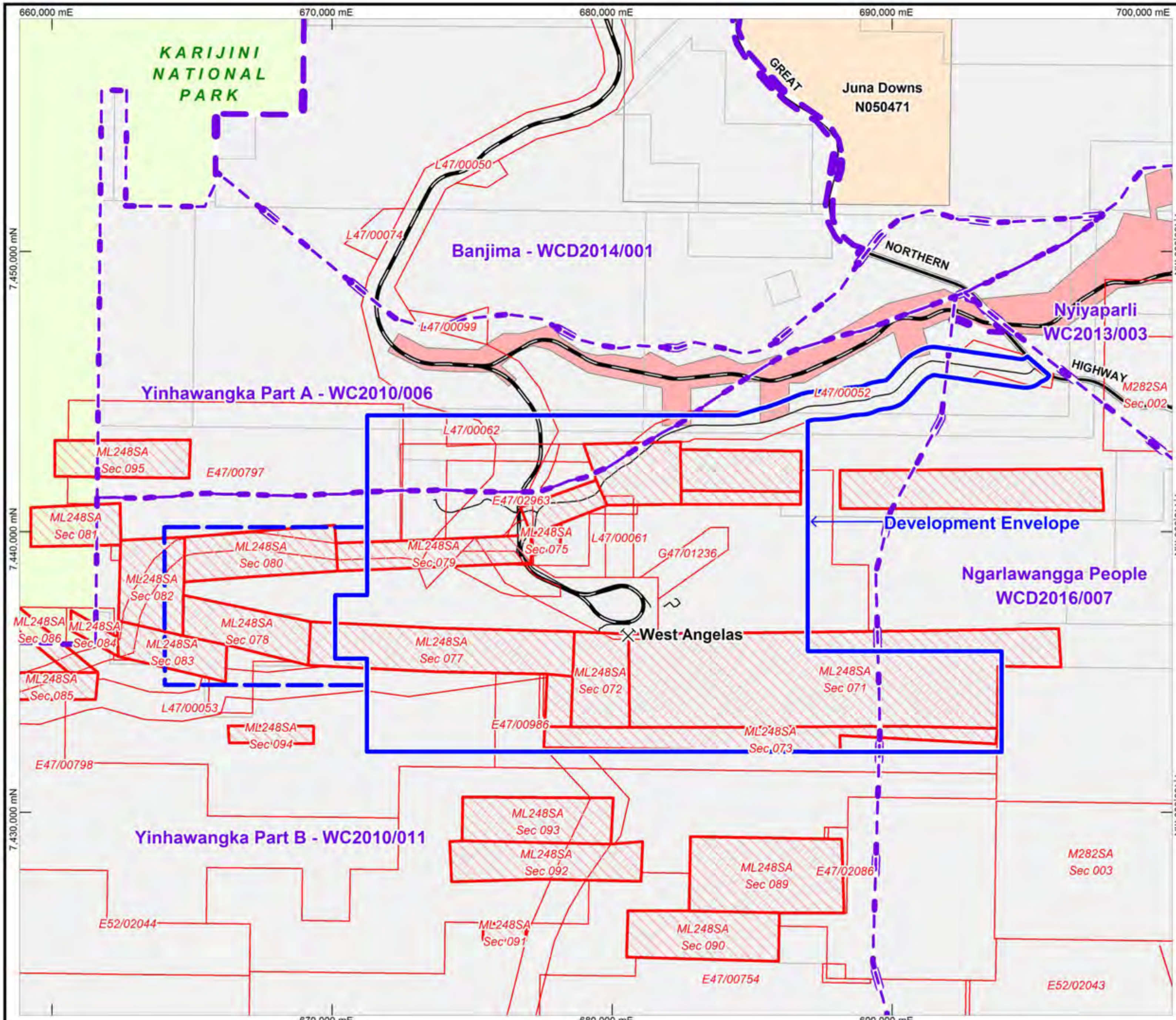
RioTinto

Iron Ore (WA)

Surplus dewatering water surface discharge extent

Drawn: B Jackson
Date: May 2017
Plan No: PDE0151562v1
Proj: MGA94 (Zone 50)


LEGEND
West Angelas
Rio Tinto Mine
Rio Tinto Port
Town
National Park
Fortescue Marsh
Rio Tinto Railway
Highway
Major Road
SCALE
0 25 50 75 100km
1:2,225,000 @ A4
RioTinto
Iron Ore (WA)
Regional Setting
Drawn: B Jackson
Date: May 2017
Plan No: PDE0145009v2
Proj: MGA 94 (Zone 50)
400,000 mE
500,000 mE
600,000 mE
700,000 mE
800,000 mE
7,700,000 mN
7,600,000 mN
7,500,000 mN
7,400,000 mN
Port Hedland
Cape Lambert
Dampier
Karratha
Wickham
Roebourne
NORTH WEST COASTAL HIGHWAY
GREAT NORTHERN HWY
Marble Bar
Millstream-Chichester National Park
Pannawonica
Mesa A
Mesa J
Nammuldi
Brockman 2
Brockman 4
Western Turner Syncline
Tom Price
Mount Tom Price
Marandoo
Karijini National Park
FORTESCUE MARSH
Yandicoogina
Hope Downs 1
Hope Downs 4
Paraburdoo
Eastern Range
Channar
West Angelas
Newman



LEGEND

- Development Envelope
- Proposal Area
- M248SA
- RTIO Live Mining Act Tenure
- Other Live Mining Act Tenure
- RTIO General Lease
- Unallocated Crown Land
- Juna Downs Pastoral Station
- Native Title Claim/Determination
- Existing Mine
- Railway
- Highway
- Site Access Road

N

SCALE

0 2 4 6 8 10km

1:200 000@ A4

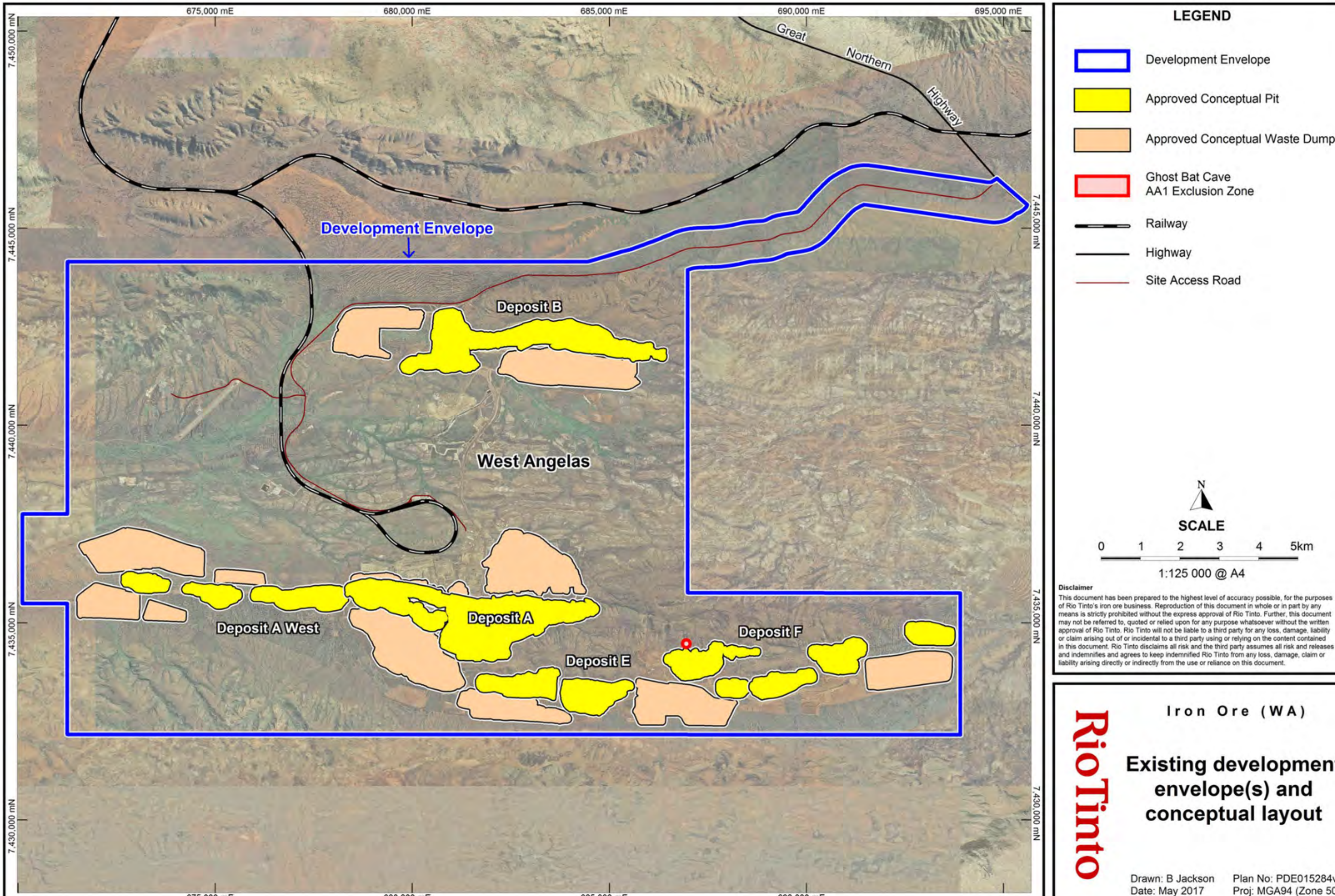
RioTinto

Iron Ore (WA)

Tenure and Native Title Claim boundaries

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151287v1
Proj: MGA94 Zone50



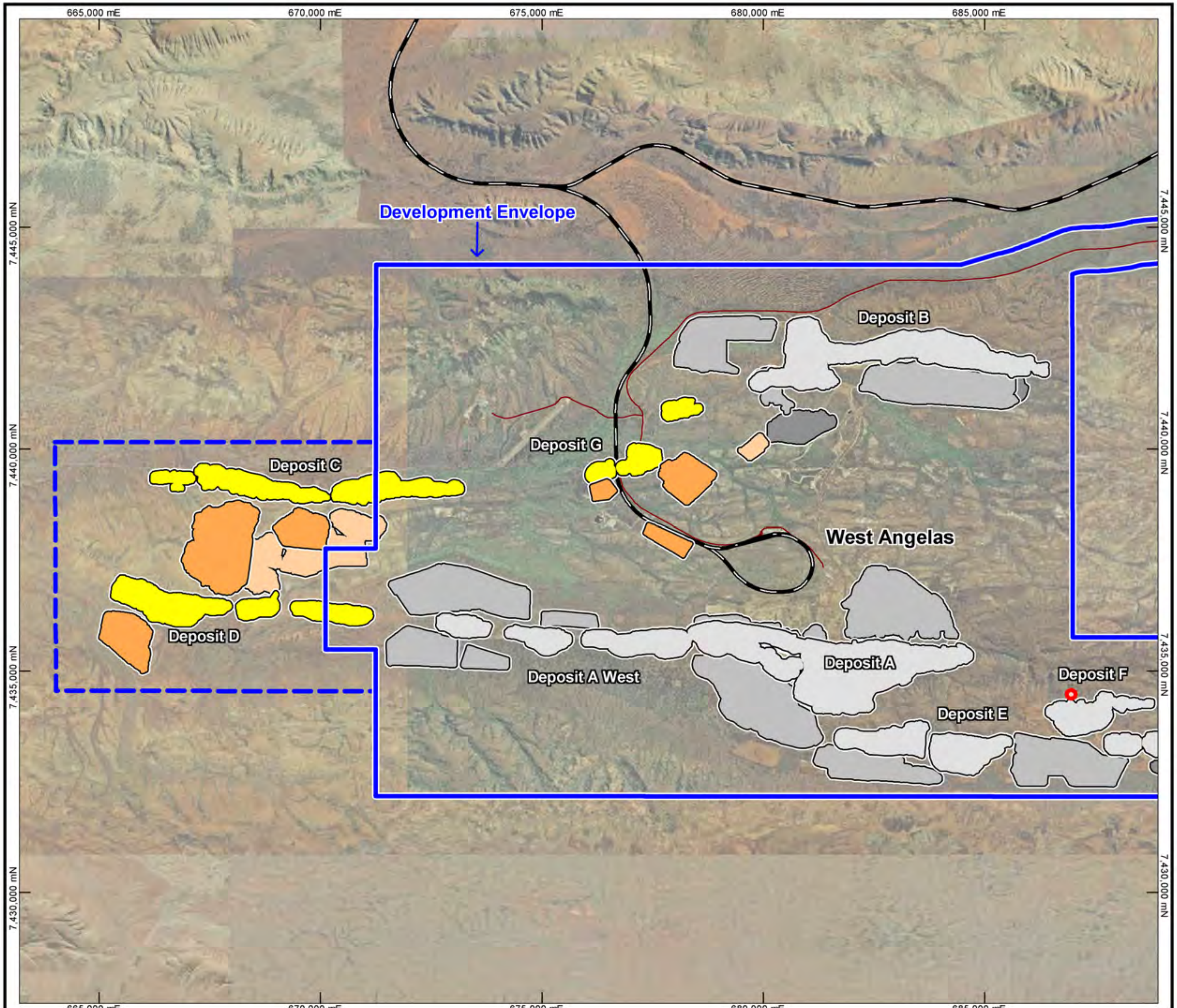
RioTinto

Iron Ore (WA)

Existing development envelope(s) and conceptual layout

Drawn: B Jackson
Date: May 2017

Plan No: PDE015284v1
Proj: MGA94 (Zone 50)



LEGEND

- Development Envelope
- Development Envelope Extension
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Approved Conceptual Pit
- Approved Conceptual Waste Dump
- Approved Conceptual Stockpile
- Ghost Bat Cave AA1 Exclusion Zone
- Railway
- Site Access Road

N

SCALE

0 1 2 3 4 5km

1:125 000 @ A4

RioTinto

Iron Ore (WA)

Revised Mine Development Envelope(s) and conceptual layout

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151363v1
Proj: MGA94 (Zone 50)

Vegetation Mapping Legend

RioTinto

AaAc - Acacia aptaneura and A. pruinocarpa open woodland over Aristida contorta sparse tussock grassland over Pterocaulon sphacelatum and Ptilotus nobilis subsp. nobilis isolated forbs.

AaEcTp - Acacia aptaneura and A. pruinocarpa open woodland over Eremophila caespitosa and Tribulus suberosus isolated shrubs over Triodia pungens open hummock grassland.

AaEffTp - Acacia aptaneura and A. pruinocarpa open woodland over sparse Eremophila fraseri subsp. fraseri and Acacia marramamba sparse shrubland over Triodia pungens sparse hummock grassland.

AanAxTe - Acacia aneura, A. xiphophylla tall o pen scrub over mixed open shrubland over Triodia epactia open hummock grassland.

AaPoTp - Acacia aptaneura open woodland over Ptilotus obovatus isolated shrubs over Themeda triandra and Eriachne mucronata open tussock grassland.

AaPoTt - Acacia aptaneura open woodland over Ptilotus obovatus sparse shrubland over Themeda triandra open tussock grassland.

AaSaoTp - Acacia aptaneura open woodland over Senna artemisioides subsp. oligophylla sparse shrubland over Triodia pungens open hummock grassland

AaTb - Acacia aptaneura and A. pruinocarpa open woodland over A. bivenosa isolated shrubs Triodia basedowii and T. pungens open hummock grassland.

AaTp - Acacia pruinocarpa, A. aptaneura and A. ayersiana woodland over Triodia pungens open hummock grassland.

AaTssp - Acacia aptaneura and A. pruinocarpa open woodland over A. tetragonophylla, Senna glutinosa subsp. glutinosa and S. artemisioides subsp. oligophylla isolated shrubs over Triodia wiseana and T. pungens open hummock grassland.

AaTt - Acacia aptaneura and Eucalyptus xerothermica woodland over Ptilotus obovatus isolated shrubs over Themeda triandra open tussock grassland

AlAp - Aristida latifolia, Astrebla pectinata and Brachyachne convergens tussock grassland with isolated Salsola australis, Boerhavia paludosa and Ptilotus nobilis subsp. nobilis forbs.

AmTw - Eucalyptus leucophloia subsp. leucophloia isolated trees over Acacia maitlandii sparse shrubland over Triodia wiseana and T. longiceps hummock grassland.

ApTssp - AcAcacia pruinocarpa and Eucalyptus leucophloia subsp. leucophloia open woodland over Senna glutinosa subsp. glutinosa and A. maitlandii isolated shrubs over Triodia basedowii or T. pungens or T. wiseana open hummock grassland.

EgSggTb - Eucalyptus gamophylla and Corymbia deserticola subsp. deserticola open woodland over Senna artemisioides subsp. oligophylla and Indigofera monophylla sparse shrubland over Triodia basedowii and T. pungens open hummock grassland.

EllAmTssp - Eucalyptus leucophloia subsp. leucophloia and E. gamophylla open woodland over Acacia maitlandii, A. hamersleyensis, Keraudrenia velutina and Senna glutinosa subsp. glutinosa open shrubland over Triodia wiseana and/or T. pungens and/or T. basedowii o

EllSggTp - Eucalyptus leucophloia subsp. leucophloia and Acacia marramambra open woodland over Senna glutinosa subsp. glutinosa open shrubland over Triodia pungens open hummock grassland.

EllSggTw - Eucalyptus leucophloia subsp. leucophloia and Acacia aptaneura open woodland over Senna glutinosa subsp. glutinosa and S. artemisioides subsp. oligophylla open shrubland over Triodia wiseana or T. pungens open hummock grassland.

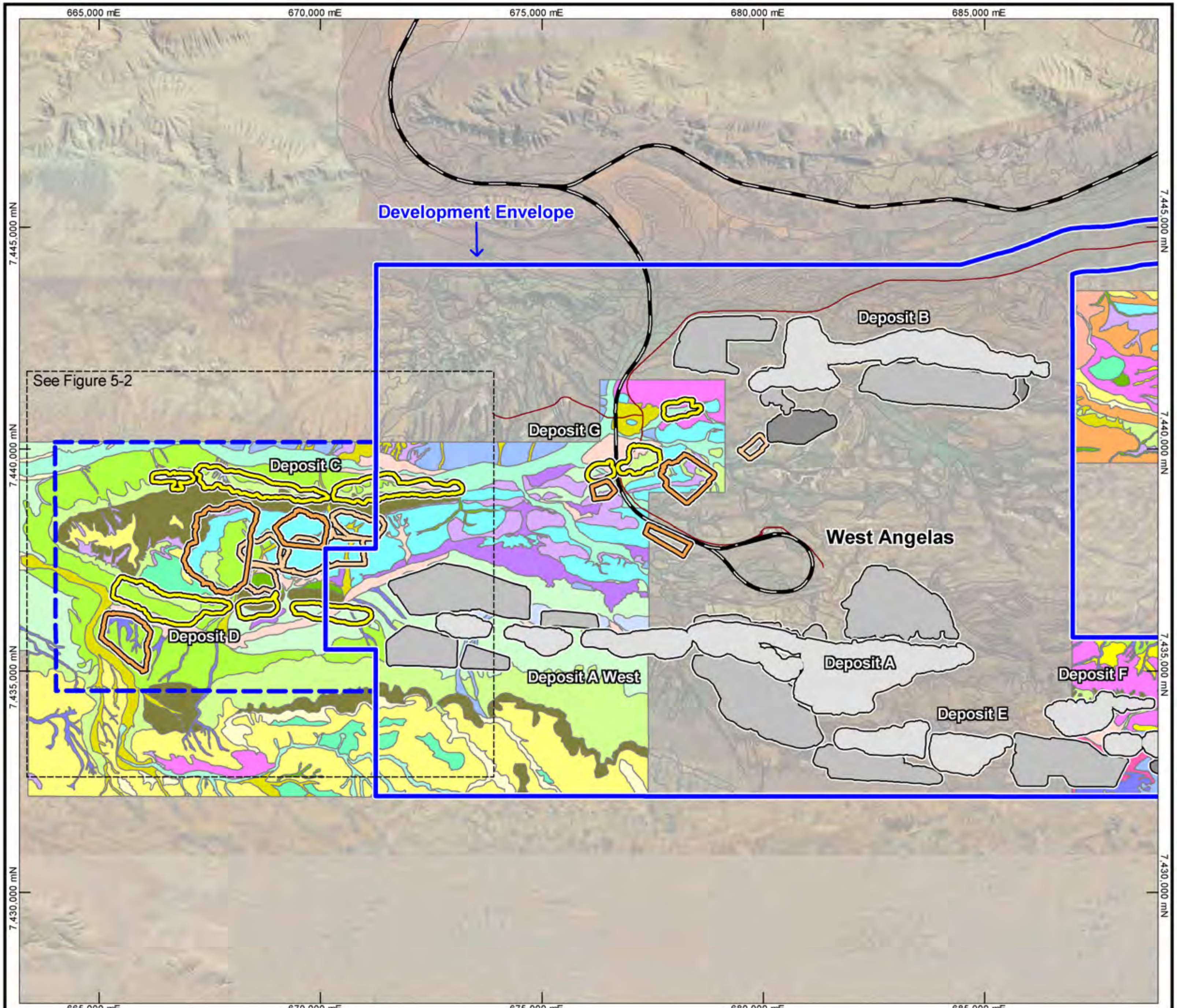
PsTp - Acacia aptaneura or A. ayersiana open woodland over Pterocaulon sphacelatum and Dysphania kalparri sparse forbland with Triodia pungens open hummock grassland.

SggAbTp - Acacia pruinocarpa and Eucalyptus leucophloia subsp. leucophloia or Corymbia hamersleyana isolated trees over Senna glutinosa subsp. glutinosa, Acacia bivenosaand Gossypium robinsonii open shrubland over Triodia pungens hummock grassland

SggIrTw - Acacia inaequilatera isolated trees over Senna glutinosa subsp glutinosa and Indigofera rugosa open shrubland over Triodia wiseana hummock grassland.

SggTp - Eucalyptus leucophloia subsp. leucophloia and Corymbia hamersleyana isolated trees over Senna glutinosa subsp. glutinosa and Acacia maitlandii sparse shrubland over Triodia pungens open hummock grassland.

Tp -Eucalyptus leucophloia subsp. leucophloia and Acacia pruinocarpa isolated trees over Senna glutinosa subsp. glutinosa, A. bivenosa and Ptilotus rotundifolius isolated shrubs over Triodia pungens or T. basedowii or T. sp. Mt Ella hummock grassland.



LEGEND

- Development Envelope
- Development Envelope Extension
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Approved Conceptual Pit
- Approved Conceptual Waste Dump
- Approved Conceptual Stockpile
- Trudgen Vegetation Mapping 1998
- Railway
- Site Access Road

N

SCALE

0 1 2 3 4 5km

1:125 000 @ A4

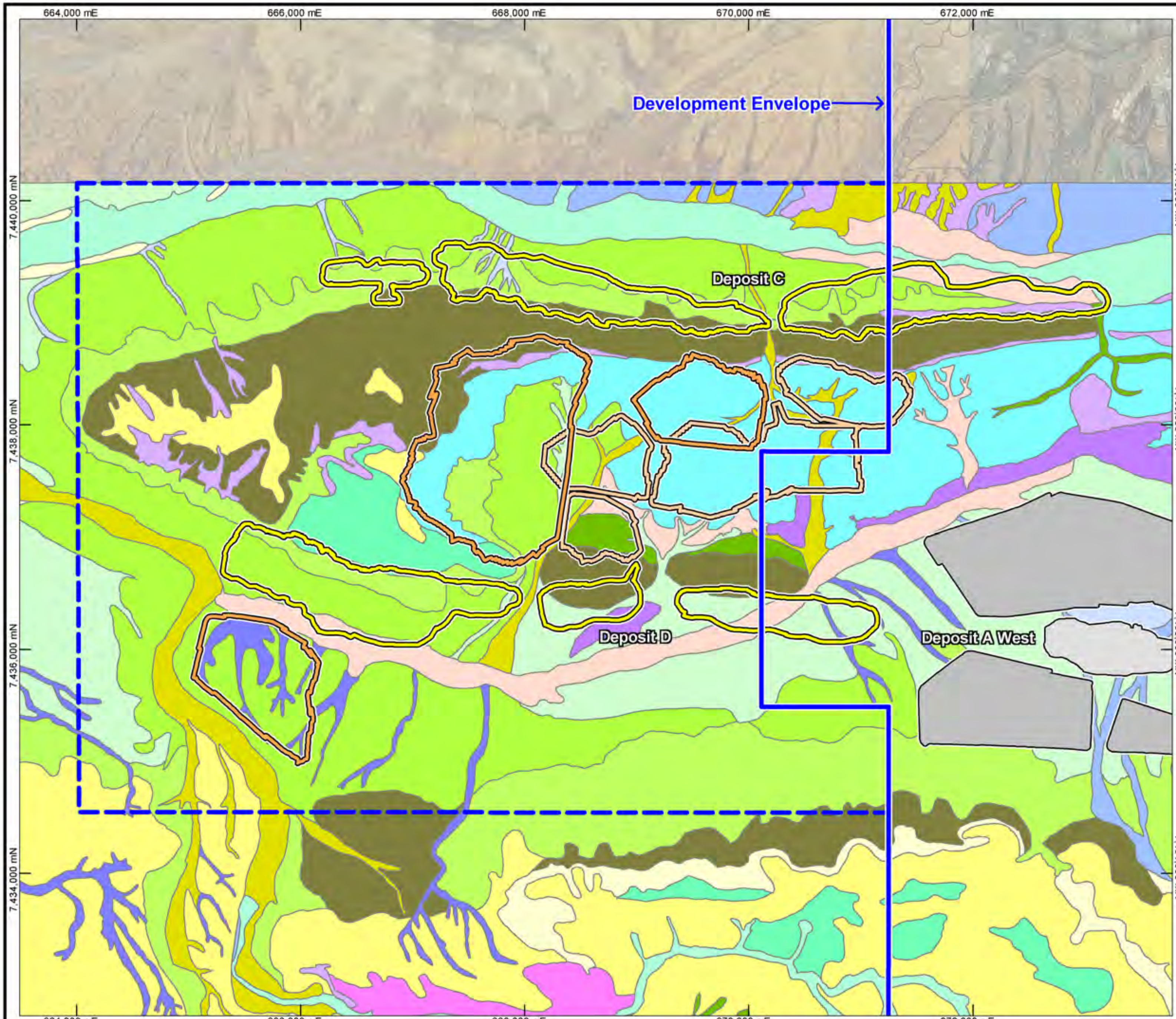
RioTinto

Iron Ore (WA)

Vegetation Mapping

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151366v2
Proj: MGA94 (Zone 50)



LEGEND

- Development Envelope
- Development Envelope Extension
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Approved Conceptual Pit
- Approved Conceptual Waste Dump
- Approved Conceptual Stockpile
- Trudgen Vegetation Mapping 1998

N

SCALE

0 0.5 1 1.5 2 2.5km

1:50 000 @ A4

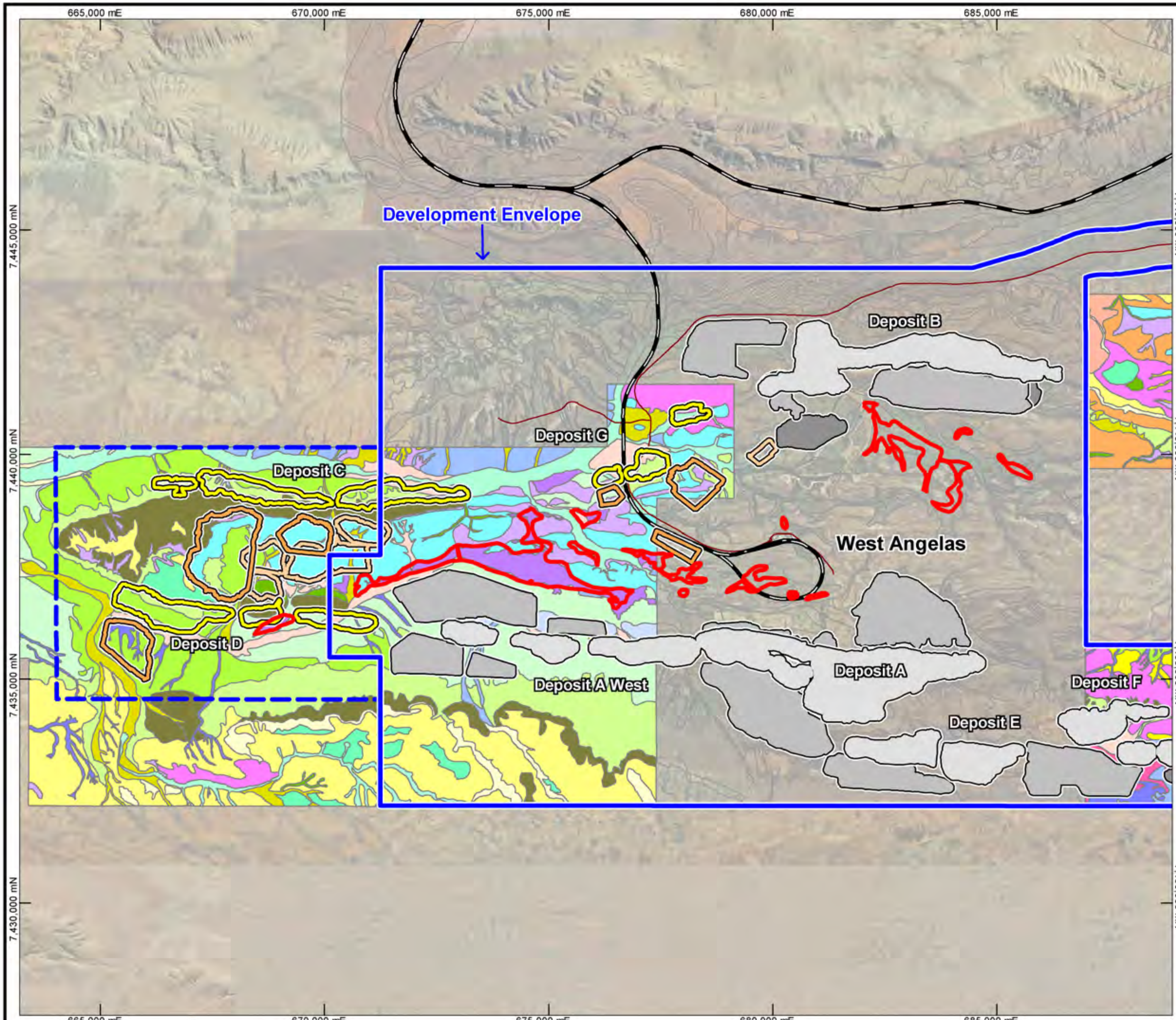
RioTinto

Iron Ore (WA)

Vegetation Mapping (Map 2)

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151367v2
Proj: MGA94 (Zone 50)



LEGEND

- Development Envelope
- Development Envelope Extension
- PEC - Cracking Clay
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Approved Conceptual Pit
- Approved Conceptual Waste Dump
- Approved Conceptual Stockpile
- Trudgen Vegetation Mapping 1998
- Railway
- Site Access Road

N

SCALE

0 1 2 3 4 5km

1:125 000 @ A4

RioTinto

Iron Ore (WA)

West Angelas Cracking Clay Priority Ecological Community Mapping

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151482v1
Proj: MGA94 (Zone 50)