Nammuldi-Silvergrass Monitoring and Management Plan

Nammuldi-Silvergrass Expansion

Ministerial Statement 925

October 2024

RTIO-HSE-0185273

Hamersley Iron Pty Limited

152-158 St Georges Terrace, Perth

GPO Box A42, Perth WA 6837

Disclaimer and Limitation

This Environmental Management Plan has been prepared by Hamersley Iron Pty Ltd (the Proponent), specifically for the Nammuldi-Silvergrass Expansion Iron Ore Mine. Neither the document nor its contents may be referred to without the express approval of RTIO, unless the document has been approved for implementation under Ministerial Statement 925.

Document Status					
Rev	Author	Reviewer/s	Date	Approved for Issue	
				To Whom	Date
1	Rio Tinto		April 2016	DWER	
2	Rio Tinto		March 2022	DWER	
3	Rio Tinto		October 2024	DWER	

EXECUTIVE SUMMARY

This Monitoring and Management Plan (MMP) has been prepared by Rio Tinto on behalf of Hamersley Iron Pty Ltd (the Proponent) for the Nammuldi-Silvergrass Iron Ore Project (the Project). The MMP specifically addresses the requirements of Condition 6 and Condition 7 of Ministerial Statement (MS) 925 and includes monitoring and management strategies to prevent long term impacts to environmental values associated with the following key environmental factors:

Flora and Vegetation

- Ground Dependant Vegetation (GDV) Communities of Narraminju Wuntu (Caves Creek)
- GDV Communities of Kartajirri Wuntu (Duck Creek)

Inland Waters

- Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)

The environmental outcomes and management provisions for the key environmental factors to be met through implementation of this MMP are presented in Executive Summary (ES) Table 1.

ES Table 1: Summary of MMP management provisions for the Project.

Proposal title	Nammuldi-Silvergrass Expansion
Proponent name	Hamersley Iron Pty Ltd
Ministerial Statement number	MS 925
Purpose of this MMP	To ensure that there are no unapproved Project-related impacts (direct or indirect) to key environmental factors and associated values, and that the environmental outcomes outlined in MS 925 are met.
EPA Environmental Factor, Value & Objective: Flora and Vegetation - Groundwater Dependent Vegetation Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek). *To protect flora and vegetation so that biological diversity and ecological integrity are maintained.*	
Condition & Environmental Outcome	**Condition 6** - The proponent shall ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks beyond the approved clearing envelope.
Early Response Criteria	1. A ≥15% decrease in *Eucalyptus* tree species mean seasonal foliage cover is evident at a site, compared to baseline and reference data, attributed to the Project. OR 2. A statistically significant change in seasonal canopy condition of overstorey phreatophytes is evident, compared to baseline and reference data, attributed to the Project. OR 3. The monthly groundwater level in an indicator bore exceeds the mean baseline groundwater level as per Footnote Table 1, attributed to the Project.

<table>
<tr><td>Trigger Criteria</td><td>1. A significant change in the seasonal vegetation abundance or foliage cover of three or more individuals of key over-, mid- or understorey species is evident, compared to baseline and reference data, attributed to the Project.
OR
2. A statistically significant negative change in seasonal canopy condition of baseline overstorey phreatophyte extent is evident for two consecutive periods and across one zone, compared to baseline and reference data, attributed to the Project.
OR
3. The monthly groundwater level in an indicator bore exceeds the mean baseline groundwater level as per Footnote Table 1, attributed to the Project.</td></tr>
<tr><td>Threshold Criteria</td><td>1. A significant change in the seasonal vegetation abundance or foliage cover of four or more individuals of key over-, mid- or understorey species is evident for two consecutive monitoring periods, compared to baseline and reference data, attributed to the Project.
OR
2. A statistically significant negative change in seasonal canopy condition of baseline overstorey phreatophyte extent is evident for two or more consecutive periods and across two or more zones, compared to baseline and reference data, attributed to the Project.
OR
3. The monthly groundwater level in an indicator bore exceeds the mean baseline groundwater level as per Footnote Table 1, attributed to the Project.</td></tr>
<tr><td>Irreversible Impact Criteria</td><td>1. Death of 30% of mature trees (where DBH >30 cm) is evident at a site, compared to baseline and reference data, attributed to the Project.
OR
2. A ≥50 % loss of native perennial understorey and ground cover is evident across all sites compared to baseline and reference data, attributed to the Project.
OR
3. A >80% weed cover in the understorey by weed species not previously recorded within the project area and identified as having High Ecological Impact and Low Feasibility of Control under the DPaW (2013) weed prioritisation for the Pilbara Bioregion.</td></tr>
<tr><td colspan="2">EPA Environmental Factor, Indicator & Objective: Inland Waters - Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek).
To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.</td></tr>
<tr><td>Condition & Environmental Outcome</td><td>Condition 7 - The proponent shall ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek.</td></tr>
</table>

Early Response Criteria	1. A statistically significant decrease in macroinvertebrate taxa diversity is evident at a zone, compared to baseline and reference data, attributed to the Project. OR 2. A statistically significant decrease in new recruits and juveniles for Western Rainbowfish or Spangled Perch is evident, based on size class data, at a zone, compared to baseline and reference data, attributed to the Project. OR 3. A statistically significant decrease in fish taxa diversity is evident at a zone, compared to baseline and reference data, attributed to the Project.
Trigger Criteria	1. *Toxicant*: Rolling annual median concentration is statistically higher than the SSTV OR a single value is above the 95%ile of baseline or ANZG (2018) default 90% species protection level; resampling confirms the value still exceeds the SSTV, local baseline and reference sites. *Stressor:* Rolling annual median concentration is statistically higher than the SSTV and resampling confirms the value still exceeds the SSTV, local baseline and reference sites. OR 2. A statistically significant decrease in macroinvertebrate taxa diversity is evident at a zone for two consecutive monitoring events, compared to baseline and reference data, attributed to the Project. OR 3. A statistically significant decrease in new recruits and juveniles for Western Rainbowfish or Spangled Perch is evident, based on size class data, at a zone for two consecutive monitoring events, compared to baseline and reference data, attributed to the Project. OR 4. A statistically significant decrease in fish taxa diversity is evident at a zone for two consecutive monitoring events, compared to baseline and reference data, attributed to the Project.

Threshold Criteria	1. *Toxicant*: The bioavailable concentration also exceeds the SSTV, discharge water is likely to be the cause of the exceedance and expert advice indicates an increased risk to biota. *Stressor:* A significant upward trend is apparent, discharge water is likely to be the cause of the exceedance and expert advice indicates an increased risk to biota. OR 2. A statistically significant decrease in macroinvertebrate taxa diversity is evident at a zone for three or more consecutive monitoring events, compared to baseline reference data, attributed to the Project. OR 3. An absence of new recruits and juveniles of Western Rainbowfish or Spangled Perch is evident, based on size class data, at a zone for two consecutive monitoring events, attributed to the Project. OR 4. A statistically significant decrease in fish taxa diversity is evident at a zone for three or more consecutive monitoring events, compared to baseline and reference data, attributed to the Project.

Corporate endorsement

I hereby certify that to the best of my knowledge, the provisions within this Nammuldi-Silvergrass Monitoring and Management Plan are true and correct.

Name: Josh Bennett

Signed: 

Designation: General Manager,

Date: 10/10/2024

Tables

Figures

Appendices

Abbreviations

Abbreviation	Definition
ACAR	Annual Compliance Assessment Report
ANOVA	One-way Analysis of Variance
ANZG	Australian and New Zealand Guidelines
DCP	Digital Canopy Photography
DGVs	Default Guideline Values
DMSI	Digital Multispectral Imagery
DWER	Department of Water and Environmental Regulation
EPA	Environmental Protection Authority
GDV	Groundwater-dependent Vegetation
LOESS	Locally Weighted Smoothing
MAR	Managed Aquifer Recharge
MMP	Monitoring and Management Plan
MS	Ministerial Statement
RTIO	Rio Tinto Iron Ore
SME	Subject Matter Experts
SPR	Stressor-Pathway-Receptor
SSTVs	Site Specific Trigger Values
WA	Western Australia
WGAC	Wintawarri Guruma Aboriginal Corporation
WV	WorldView

1. CONTEXT

1.1 Scope and Guidance

This Monitoring and Management Plan (MMP) has been prepared by Stantec Australia Pty Ltd on behalf of Hamersley HMS Pty Limited (the Proponent) for the Nammuldi-Silvergrass Iron Ore Project (the Project). This MMP replaces the existing approved Nammuldi-Silvergrass Monitoring and Management Plan from 2016. The revised MMP addresses the requirements of Condition 6 and Condition 7 of Ministerial Statement (MS) 925 and comprises contemporary environmental criteria based on current operational knowledge. The scope of the revised MMP is to manage potential impacts and protect the vegetation and aquatic values of Caves Creek and Duck Creek from dewatering and discharge activities at Nammuldi-Silvergrass.

The revised MMP was developed according to the Conceptual Framework for the Development of Rio Tinto Environmental Management Plans and relevant EPA guidance.

1.2 Project Background

RTIO currently manages and operates the Nammuldi-Silvergrass Iron Ore Project (Nammuldi-Silvergrass), located on the traditional lands of the Muntulgura Guruma People and the Puutu Kunti Kurrama and Pinikura People. Nammuldi-Silvergrass is situated in the western Pilbara region of Western Australia, approximately 65 km northwest of Tom Price and 77 km northeast of Paraburdoo (Figure 1-1). It comprises two separate mines that lie approximately 12 km apart, regarded as one operating unit.

Environmental approval of Nammuldi-Silvergrass was granted in 2000 under MS 558 (EPA 2024b). Mining at Nammuldi-Silvergrass commenced in 2006 and comprises open cut operations above and below the water table across multiple pits (Figure 1-2). An expansion of existing operations at Nammuldi-Silvergrass was approved in 2013 under MS 925 (EPA 2024a) which supersede the conditions of MS 558.

Nammuldi-Silvergrass is located within Mining Lease ML4SA and ore processing and supporting infrastructure are located on a series of General Purpose Leases and Miscellaneous Licences granted under the *Mining Act 1978*. Nammuldi-Silvergrass is owned and operated by RTIO through its wholly owned subsidiary Hamersley Iron Pty Limited and Hamersley Resources Ltd and is operated under the *Iron Ore (Hamersley Range) Agreement Act 1963*.

The two mines are situated within different sub-catchments: Nammuldi is in the Duck Creek (Kartajirri Wuntu) catchment and Silvergrass is in the Caves Creek (Narraminju Wuntu) catchment (Figure 1-3). To access ore below the water table, aquifers are dewatered. This water from both mines is discharged through a single discharge point located in an upstream section of Duck Creek within the Nammuldi-Silvergrass development envelope (Figure 1-2).

1.3 Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)

1.3.1 Hydrology and Hydrogeology

Narraminju Wuntu (Caves Creek) is an ephemeral watercourse with a catchment area of approximately 1,500 km² (Strategen 2012) and is situated within the Narraminju Wuntu (Caves Creek) Valley geological formation. Mallu Mallu (Palm Springs) consists of a series of groundwater fed, permanent pools located on the lower reach of Narraminju Wuntu (Caves Creek) before the confluence with Kartajirri Wuntu (Duck Creek) (Astron 2022b; WRM 2022). The spring is maintained by surface expression of groundwater from a shallow aquifer. There are also several pools located upstream of Mallu Mallu (Plam Springs) that persist in the dry season following substantial wet season rainfall (WSP 2024).

Groundwater in the Narraminju Wuntu (Caves Creek) area comprises shallow and deep aquifers, which are freshwater with similar water quality characteristics, ranging from 300 mg/L to 2,000 mg/L (WSP 2024). Groundwater is shallowest at Mallu Mallu (Plam Springs) where it is expressed at the surface through permanent pools (WSP 2024).

The shallow aquifer at Narraminju Wuntu (Caves Creek) is hosted in a predominantly alluvial geological unit interspersed with calcrete within the detrital sequence. The deep aquifer is hosted in the Wittenoom Formation bedrock foundation, bounded in the north by a steep ridge of the Brockman Iron Formation and in the south by a ridge of the Marra Mamba Formation (WSP 2024). The deep aquifer extends to the confluence with Kartajirri Wuntu (Duck Creek) and then continues further west (Figure 1-3).

The shallow and deep aquifers are largely separated by a low-permeability clay layer that allows a degree of hydraulic separation. There is evidence however, of some connectivity in areas where the confining clay layer at the base of the detrital sequence is absent (WSP 2024).

Kartajirri Wuntu (Duck Creek) has a substantially larger catchment area in comparison to Narraminju Wuntu (Caves Creek), of approximately 6,500 km² (McKenzie *et al.* 2009; Strategen 2012). Kartajirri Wuntu (Duck Creek) drains from east to west, ultimately converging with the Ashburton River (Strategen 2012). The creek comprises semi-permanent to permanent pools, which are evident downstream of the confluence with Narraminju Wuntu (Caves Creek), due to groundwater expression at the surface (WRM 2022) These pools are situated on bedrock structures that impede hydraulic connectivity with the deeper aquifer, or against cliffs where high-flow events have resulted in the creation of pools due to scouring (Pinder *et al.* 2010).

Upstream of the confluence with Narraminju Wuntu (Caves Creek), Kartajirri Wuntu (Duck Creek) is unlikely to contain pools sustained by large-scale aquifers based on physical characteristics. However, localised aquifers where geologies are sufficiently fractured may sustain isolated pools (Biologic 2021a). The geological layers in this area, including the MacLeod Member, Nammuldi Member, and Fortescue Group, are recognised for their lower permeability (Biologic 2021a).

1.3.2 Drawdown

Prior to the commencement of dewatering at Silvergrass, regional groundwater naturally flowed east to west through the Narraminju Wuntu (Caves Creek) Valley geological formation. However, groundwater abstraction from the deep aquifer at Silvergrass East has altered this pattern, causing a reversal in the flow direction from west to east, up to approximately 8 km from Silvergrass (WSP 2024). The shallow and deep aquifers are separated by a low-permeability clay layer that allows a degree of hydraulic separation.

After commencing dewatering at Silvergrass it was realised that some connectivity exists between shallow and deep aquifers in areas where the confining clay layer at the base of the detrital sequence is absent (WSP 2024). The possibility of impact on values potentially dependant on a contribution of flow from the shallow aquifer then resulted in a decision to pause dewatering at Silvergrass. This pause has avoided predicted future impact on Mallu Mallu (Palm Springs) and provided time to test our conceptual understanding of the groundwater system as well as review mitigation strategies.

Further investigation revealed drawdown in the shallow aquifer of approximately 3.5 m (from the baseline average) has been recorded approximately 7 km downstream of Silvergrass (Stantec 2024b). The deep aquifer beneath the Narraminju Wuntu (Caves Creek) Valley merges with Kartajirri Wuntu (Duck Creek) at the confluence and extends westward. Kartajirri Wuntu (Duck Creek) upstream of the confluence is unlikely to comprise large-scale aquifers subject to drawdown based on physical properties as the geological layers in this area have a lower permeability and potentially serve as aquitards (Biologic 2021a).

1.3.3 Discharge

Dewatering of groundwater and consequent discharge commenced at Nammuldi in 2013 and at Silvergrass in April 2016 (Astron 2022b). Excess groundwater from both mines is discharged through a single discharge point in an upstream section of Kartajirri Wuntu (Duck Creek) (Figure 1-2). Discharge currently extends approximately 17.5 km from the discharge point (Astron 2022b).

1.3.4 MAR

A Managed Aquifer Recharge (MAR) scheme is proposed to mitigate potential impacts from continued groundwater drawdown at Silvergrass. The excess water extracted from Silvergrass will be reinjected into the aquifer below Narraminju Wuntu (Caves Creek) to recharge the shallow and deep groundwater reserves (WSP 2024). This recharge will occur at strategic points in a downstream section of Narraminju Wuntu (Caves Creek) to benefit the local GDV communities currently experiencing drawdown (Astron 2022a). Recharged water will be subject to treatment which may include a chlorination system and deoxygenation.

1.3.5 Environmental and Cultural Significance

Permanent and semi-permanent pools and springs along Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) are of local significance, due to their limited occurrence in the region (Strategen 2012). These pools support GDV communities and aquatic ecosystems associated with their unique hydrological and hydrogeological features.

Over 250 native vascular flora taxa have been recorded at Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) (Astron 2022b; Biologic 2021b). The GDV communities of Narraminju Wuntu (Caves Creek) comprise *Eucalyptus camaldulensis*, *Eucalyptus victrix* open woodland over *Acacia citrinoviridis* tall shrubland and mixed open tussock grassland (RTIO 2018b). *Melaleuca argentea* is also present and is most prevalent at Mallu Mallu (Palm Springs). The GDV communities of Kartajirri Wuntu (Duck Creek) are characterised by *Eucalyptus camaldulensis*, *Eucalyptus xerothermica* low woodland over *Acacia citrinoviridis*, *Acacia aneura* tall open shrubland, over *Triodia epactia* very open hummock grassland. *Melaleuca argentea* also occurs along Kartajirri Wuntu (Duck Creek), however at lower densities than Narraminju Wuntu (Caves Creek) (Strategen 2012).

Kartajirri Wuntu (Duck Creek) supports higher densities of *Eucalyptus camaldulensis* than Narraminju Wuntu (Caves Creek), while Narraminju Wuntu (Caves Creek) hosts higher densities of *Eucalyptus victrix* (Strategen 2012). The three dominant riparian tree species are the same in both creeks and include *Eucalyptus camaldulensis*, *Eucalyptus victrix*, and *Melaleuca argentea.* The GDVs in both creeks have been classified according to their dependence on groundwater (and depth to groundwater) and the scale of these communities (Biologic 2021a).

More than 300 macroinvertebrate taxa, 200 microinvertebrate taxa, and 80 hyporheic taxa have been recorded from Kartajirri Wuntu (Duck Creek) and its associated tributaries (WRM 2020a). These include taxa endemic to the Pilbara, such as the Pilbara Pin Damselfly (*Eurysticta coolawanyah*), Pilbara Emerald Dragonfly (*Hemicordulia koomina*) and the calanoid copepod *Eodiaptomus lumholtzi*, which are all listed as Vulnerable on the IUCN Red List (IUCN 2024).

The fish assemblage is also diverse, with eight of the 13 freshwater fish species recorded from the Pilbara occurring in Kartajirri Wuntu (Duck Creek) including the Fortescue Grunter (*Leiopotherapon aheneus* - IUCN Endangered) (IUCN 2024), Spangled Perch (*Leiopotherapon unicolor*), Pilbara tandan (eel-tailed catfish - *Neosilurus* sp., possibly an undescribed species), Western Rainbowfish (*Melanotaenia australis*), Barred Grunter (*Amniataba percoides*), Bony Bream (*Nematalosa erebi*), Flathead Goby (*Glossogobius giurus*), and the Lesser Salmon Catfish (*Neoarius graeffei*). These species comprise both freshwater species and marine migrants (Bray and Thompson 2024).

Both Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) hold cultural significance for the Traditional Owners of the land; the Muntulgura Guruma People and in addition Mallu Mallu holds cultural significance for three Traditional Owner Groups, being Muntulgura Guruma, Puutu Kunti Kurrama and Pinikura People and Robe River Kuruma People. Protecting the environmental and cultural values of the creek systems from potential impacts associated with operations at Nammuldi-Silvergrass is of critical importance to RTIO.

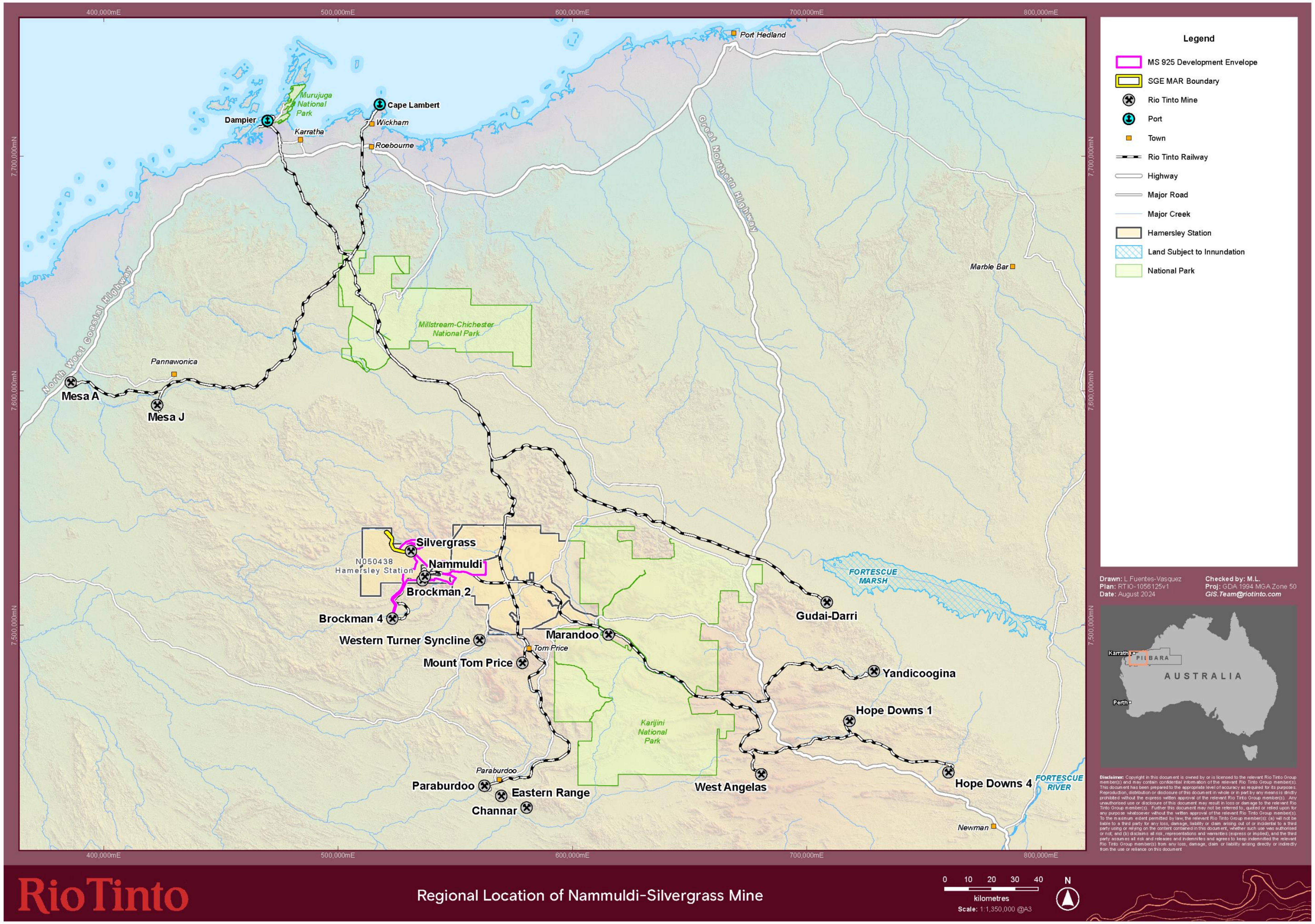


Figure 1-1: **Regional location of the Nammuldi-Silvergrass Project, showing major creeks and rivers.**

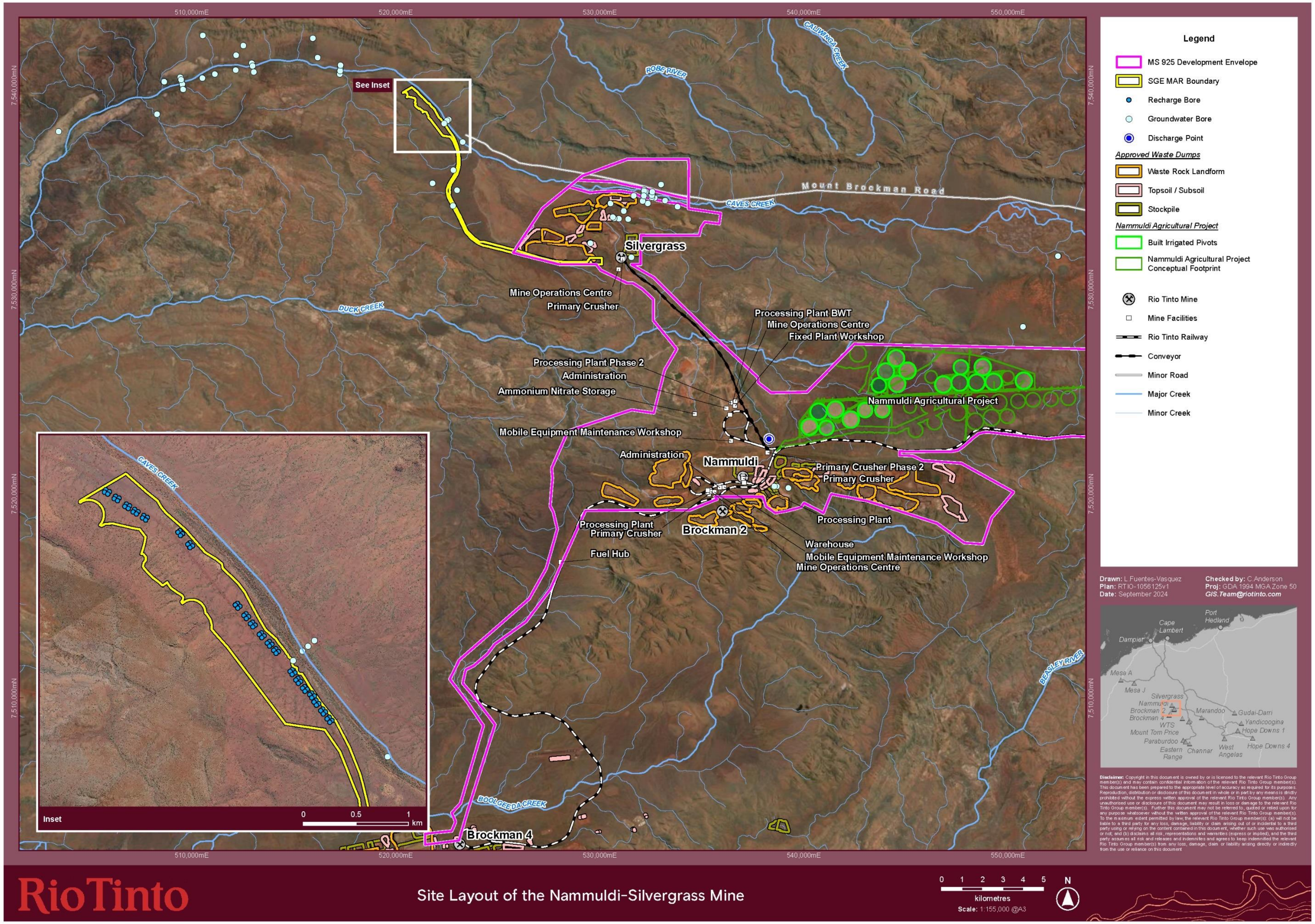


Figure 1-2: **Development envelope and conceptual footprint of the Nammuldi-Silvergrass Project.**

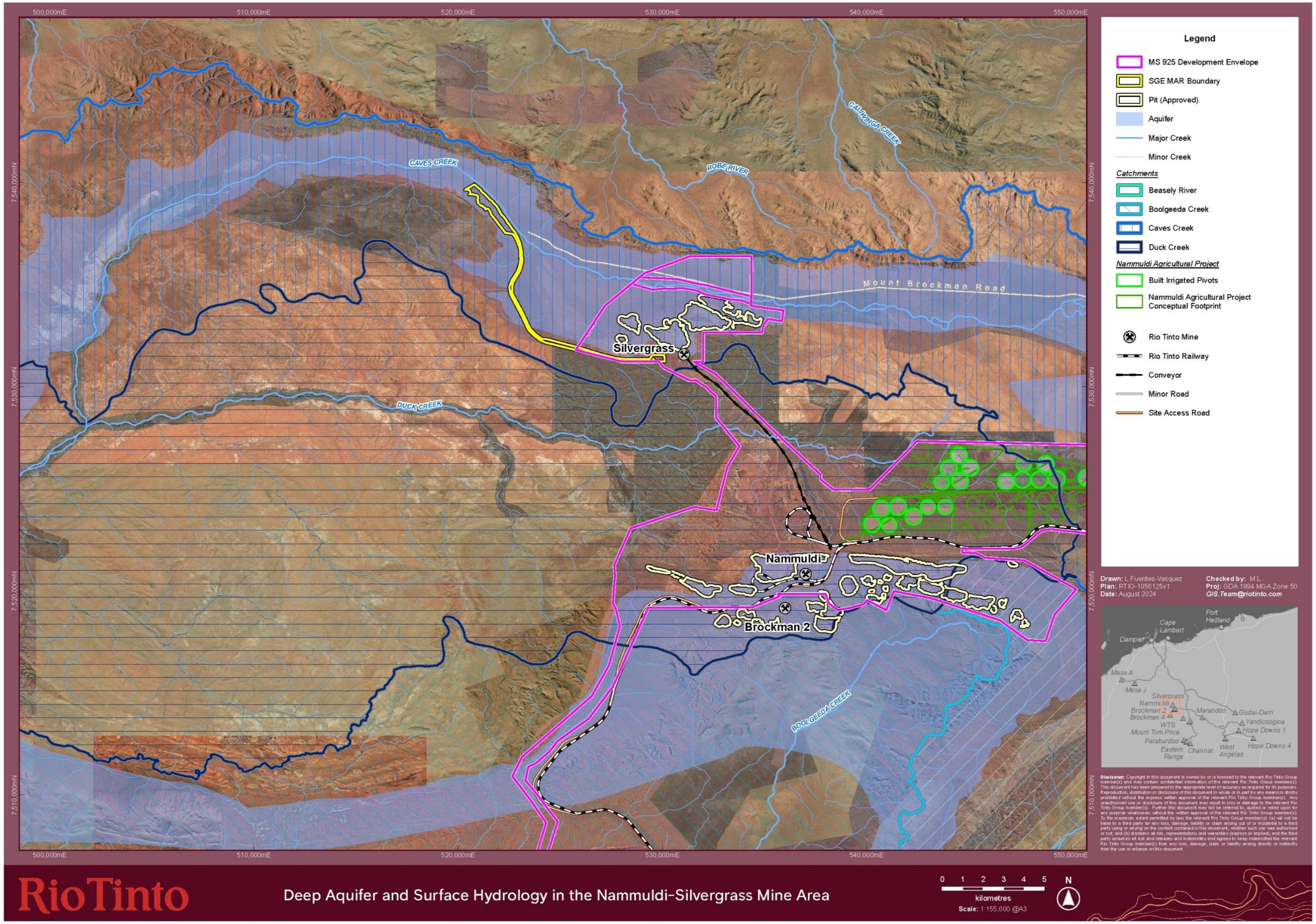


Figure 1-3: Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) surface hydrology and hydrogeology.

1.4 Regulatory Conditions

The regulatory requirements of the Project are outlined in MS 925, with a summary of the conditions relevant to the revised MMP provided in Table 1-1. These comprise Conditions 6 and Condition 7 of MS 925 for the key environmental values of Flora and Vegetation and Inland Waters in Caves Creek and Duck Creek. Condition 6 of the MS 925 is associated with maintaining GDV communities in Caves Creek and Duck Creek, while Condition 7 relates to protecting the aquatic conservation values and water quality of Duck Creek (Table 1-1). The High Level Environmental and Conservation Values Statement for Duck Creek, referred to in Condition 7-2 of MS 925, is also provided in Appendix 1. The compliance monitoring and management actions, including the environmental criteria to address these conditions are outlined in the revised MMP.

1.5 Purpose and Framework

The purpose of this revised MMP is to ensure that there are no unapproved direct or indirect Project-related impacts to the key environmental factors and values of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek), and that the environmental outcomes of Condition 6 and Condition 7 of MS 925 are met.

This MMP was drafted in accordance with the *Conceptual Framework for the Development of Rio Tinto Environmental Management Plans*. This conceptual approach considers the existing knowledge base of environmental values and identified stressors, pathways and receptors as part of the Stressor-Pathway-Receptor Model (SPRM). Management levels (No Management, Low Management, Moderate Management, High Management, or Very High Management) are assigned based on the conservation significance of environmental values and the likelihood of potential impacts from the Project, predicted over spatial and temporal scales.

Appropriate environmental indicators are selected according to the outcome of the SPRM, supported by scientifically robust rationale. The selected indicators have measurable characteristics that reflect the health and condition of the environmental value and are sensitive to detecting potential mine-related impacts from the Nammuldi-Silvergrass operations. Subsequently, environmental criteria are developed assessing available baseline and monitoring data, to ensure that environmental outcomes can be achieved.

For the revised MMP, outcome-based and objective-based management provisions were considered for development. Outcome-based provisions have been applied where sufficient data and information exists for the development of measurable environmental criteria to assess performance against the environmental outcome. Objective-based provisions were not required as part of this MMP. Objective-based provisions identify specific, relevant and auditable management targets, with timelines where appropriate.

Environmental criteria comprise early responses, triggers and thresholds, where possible. Additional irreversible impact criteria are a requirement of Condition 6-2 (7) and (8) of MS 925 and only apply to flora and vegetation values in this revised MMP. Corresponding monitoring has been applied to address environmental values and indicators and to assess the environmental criteria and management targets. The environmental criteria are defined as follows:

Early response criteria	Provide information on changes that are precursors to an environmental impact, used to initiate early response actions before or at the onset of environmental impacts
Trigger criteria	Measures set at a conservative level to forewarn the approach of threshold criteria and ensure trigger level actions are implemented well in advance of the environmental outcome being compromised.

Threshold criteria	Framed to represent the limit of acceptable impact beyond which there is likely to be a significant effect on the environment. This indicates there is risk that the environmental outcome will not be met.
Irreversible impact criteria	*Provides an exceedance limit beyond which flora and vegetation values are not expected to recover. This demonstrates that the environmental outcome will not be met. This criteria category is a requirement of conditions 6-2 (7) and (8) of MS 925 and only applies to flora and vegetation values in this MMP.*

Table 1-1: Relevant regulatory condition requirements of MS 925 relating to this MMP.

MS and Audit Code	Aspect	Regulatory Condition	Associated MMP Section
MS 925 – Condition 6			
Condition 6-1	Vegetation	The proponent shall ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks beyond the approved clearing envelope as shown in Figure 3 and delineated by the coordinates specified in Schedule 2.	MMP
Condition 6-2	Vegetation	To verify that Condition 6-1 is being met, the proponent shall develop a Groundwater Dependent Vegetation Monitoring and Management Plan to the satisfaction of the CEO. The Groundwater Dependent Vegetation Monitoring and Management Plan shall include: 1) identification of potential vegetation impact monitoring and control sites between the discharge points and the confluence of Duck Creek and the Ashburton River; 2) the design of a survey to acquire baseline data, including health and abundance parameters; 3) definition of health and abundance parameters; 4) definition of environmental parameters to be monitored, including groundwater drawdown along Caves Creek; 5) definition of monitoring frequency and timing; 6) identification of criteria to measure decline in health; 7) definition of trigger levels for 'no irreversible impact'; and 8) details of management actions and strategies to be implemented should the 'no irreversible impact' trigger levels be exceeded.	1) Appendix 2 2) Appendix 2 3) Table 1-5 4) Section 1.5.2; Table 1-5; Appendix 2 5) Section 2; Appendix 2 6) Section 2 7) Section 2 8) Section 2
Condition 6-3	Vegetation	The proponent shall implement the Groundwater Dependent Vegetation Monitoring and Management Plan required by Condition 6-2 prior to the start of dewatering until advised otherwise by the CEO.	MMP
Condition 6-4	Vegetation	Prior to the commencement of dewatering, the proponent shall implement the baseline monitoring survey, required by Condition 6-2(2) for all sites identified in Condition 6-2(1) and submit the results to the CEO.	MMP
Condition 6-5	Vegetation	In the event that monitoring required by Condition 6-3 indicates that a trigger level required by Condition 6-2(7) has been exceeded, the proponent shall provide a report to the CEO within 21 days of the exceedance being identified which: 1) describes the decline or change; 2) provides information which allows determination of the likely root cause of the decline or change; and 3) if considered likely to be the result of activities undertaken in implementing the proposal, describe which management actions will be implemented and the associated timelines to remediate the decline or change.	Section 2
Condition 6-6	Vegetation	The proponent shall implement the actions identified in Condition 6-5(3) until the CEO determines that the remedial actions may cease.	MMP
MS 925 – Condition 7			
Condition 7-1	Discharge of Water to Duck Creek	The proponent shall ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek.	MMP
Condition 7-2	Discharge of Water to Duck Creek	To verify that Condition 7-1 is being met, the proponent shall develop a high level environmental and conservation values statement for Duck Creek to the satisfaction of the CEO in consultation with the DEC and the DoW.	Appendix 2
Condition 7-3	Discharge of Water to Duck Creek	The proponent shall ensure that any water discharged to Duck Creek does not exceed whichever is greater of the following: 1) the default trigger for the protection of marine and freshwater ecosystems as per the Australian and New Zealand Environmental and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ (2000)) Australian Water Quality Guidelines for Fresh and Marine Waters and its updates; 2) baseline levels of the receiving environment determined pursuant to Condition 7-4; or 3) other criteria agreed with the DEC and the DoW.	Section 2
Condition 7-4	Discharge of Water to Duck Creek	Prior to discharging water from the Nammuldi or Silvergrass sites, the proponent shall develop a Water Discharge Monitoring and Management Plan in consultation with the DEC and the DoW to the satisfaction of the CEO to ensure that the environmental and conservation values associated with Duck Creek and any downstream ecosystems are maintained. This plan shall: 1) when implemented, identify the water quality baseline levels of the western boundary of the proposal, within Duck Creek and downstream of the water discharge points for the criteria measured under the Australian and New Zealand Environmental and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ (2000)) Australian Water Quality Guidelines for Fresh and Marine Waters and its updates; 2) describe the water discharge program; 3) when implemented, monitor to demonstrate whether Conditions 7-1 and 7-3 are being met; 4) when implemented, manage the implementation of the proposal to meet the requirements of Conditions 7-1 and 7-3; and 5) detail management actions and strategies to be implemented should the monitoring required by Condition 7-4(3) indicate that Condition 7-1 may not be met.	1) Appendix 5 2) Section 1.3.3 3) Section 2; Appendix 2 4) This MMP 5) Section 2
Condition 7-5	Discharge of Water to Duck Creek	The proponent shall implement the Water Discharge Monitoring and Management Plan from the commencement of discharge of excess water from the Nammuldi or Silvergrass sites.	MMP

1.5.1 Key Environmental Factors and Values

This MMP addresses the key environmental factors relevant to the Project approved under MS 925. The environmental factors, values and potential impacts are outlined in Table 1-2.

Table 1-2: Key environmental factors associated environmental values, and potential impacts from the Nammuldi-Silvergrass Project as addressed in this MMP.

Key Environmental Factor and Environmental Value	Potential Impacts	
	Direct Impact	Indirect Impact
Flora and Vegetation		
GDV communities of Narraminju Wuntu (Caves Creek) Potential impacts zones: • Upper Caves; • Homestead; and • Palm Springs	**Groundwater drawdown** • Change in foliage cover of the GDV over-, mid- and understorey communities from reduced soil moisture availability. • Change in tree health of the GDV overstorey community from reduced soil moisture availability. **Managed Aquifer Recharge (water quality)** • Change in foliage cover of the GDV overstorey community from changes in recharge water quality. • Change in tree health of the GDV overstorey community from changes in recharge water quality. **Managed Aquifer Recharge (waterlogging)** • Change in foliage cover of the GDV overstorey community from persistent waterlogging in the unsaturated zone. • Change in tree health of the GDV overstorey community from persistent waterlogging in the unsaturated zone.	**Groundwater drawdown** • Changes to the vegetation abundance of the GDV over- mid- and understorey communities due to altered recruitment or vegetation death from reduced soil moisture availability. **Managed Aquifer Recharge (water quality)** • Changes to the vegetation abundance of the GDV over- mid- and understorey communities due to altered recruitment or vegetation death from changes in recharge water quality. **Managed Aquifer Recharge (waterlogging)** • Changes to the vegetation abundance of the GDV over- mid- and understorey communities due to altered recruitment or vegetation death from increased water availability / persistent waterlogging in the unsaturated zone
GDV communities of Kartajirri Wuntu (Duck Creek) Potential impact zones: • Upper Duck East; • Upper Duck West; and • Downstream Duck.	**Groundwater drawdown** • Change in foliage cover of the GDV over-, mid- and understorey communities from reduced soil moisture availability. • Change in tree health of the GDV overstorey community from reduced soil moisture availability **Discharge (water quality)** • Change in foliage cover of the GDV over-, mid- and understorey communities from changes in discharge water quality. • Change in tree health of the GDV overstorey community from changes in discharge water quality. **Discharge (waterlogging)** • Change in foliage cover of the GDV over-, mid- and understorey communities from persistent waterlogging in the unsaturated zone. • Change in tree health of the GDV overstorey community from persistent waterlogging in the unsaturated zone.	**Groundwater drawdown** • Changes to the vegetation abundance of the GDV over- mid- and understorey communities due to altered recruitment or vegetation death from reduced soil moisture availability. **Discharge (water quality)** • Changes to the vegetation abundance of the GDV over- mid- and understorey communities due to altered recruitment or vegetation death from changes in discharge water quality. **Discharge (waterlogging)** • Changes to the vegetation abundance of the GDV over- mid- and understorey communities due to altered recruitment or vegetation death from increased water availability / persistent waterlogging in the unsaturated zone.
Inland Waters		
Aquatic ecosystems of Kartajirri Wuntu (Duck Creek) Potential impact zones: • Duck Creek Upstream; and • Duck Creek Downstream.	*No direct impacts are predicted to occur.*	**Dewatering discharge** • Changes in aquatic macroinvertebrate abundance and/or taxa diversity (composition) from changes in discharge water quality or habitat characteristics as a result of increased water availability. • Changes in size and age class distribution from changes in discharge water quality or habitat characteristics as a result of increased water availability • Changes in vertebrate fauna (fish) new recruit and juvenile abundances from changes in discharge water quality or habitat characteristics as a result of increased water availability. • Decrease in fish taxa diversity from changes in discharge water quality or habitat characteristics as a result of increased water availability.

1.5.2 Identification of Indicators and Rationale

Based on the outcomes of the data and literature review and the SPRM, nine indicators were identified for the GDV communities of Narraminju Wuntu (Caves Creek), with seven indicators identified for the GDV communities of Kartajirri Wuntu (Duck Creek). For aquatic ecosystems three indicators were identified for Kartajirri Wuntu (Duck Creek).

The earliest flora and vegetation data were collected in 2007, although most monitoring began in 2010, with baseline monitoring conditions considered up to 2015 for Narraminju Wuntu (Caves Creek) and 2012 for Kartajirri Wuntu (Duck Creek), after which monitoring data is operational. Monitoring of aquatic fauna began in 2009, with baseline monitoring conditions considered up to 2013, after which monitoring data is operational. A summary of selected indicators and associated available data are presented in Table 1-3.

The knowledge base, description and rationale for indicators is provided in Table 1-5. As part of the SPRM, management levels for the identified indicators were applied, which for the GDV communities and aquatic ecosystems were ranked as Moderate. The identified indicators comprise sensitive parameters (Table 1-5) that reflect the health of the GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) and the conservation values of Kartajirri Wuntu (Duck Creek). Robust, repeatable monitoring of these indicators against management provisions will enable potential project-related impacts to be detected over time.

Table 1-3: Data availability for environmental values at Nammuldi-Silvergrass.

Environmental Value	Indicator	Data Collection Method	Data Availability	Baseline
GDV Communities of Narraminju Wuntu (Caves Creek)	Vegetation Abundance	On-ground	Astron: 2010 – 2023; annual	2010 – 2015
	Foliage Cover (Transect Monitoring)			
	Foliage Cover (DCP Monitoring)	On-ground	RTIO: 2007 – 2023; biannual	2007 – 2015
	Canopy Condition	Remote sensing	Astron: 1987 – 2023; daily-annually	1987 – 2015
	Groundwater Levels	On-ground	RTIO: 2010 – 2023; daily to monthly	2010 – 2015
	Recharge Water Quality	On-ground	RTIO: 2010 – 2023; daily to monthly	2010 – 2015
	Death of Mature Trees	On-ground	Astron: 2010 – 2023; annual	2010 – 2015
	Native Perennial Understorey Cover			
	Weed Understorey Cover			
GDV Communities of Kartajirri Wuntu (Duck Creek)	Vegetation Abundance	On-ground	Astron: 2010 – 2023; annual	2010 – 2012
	Foliage Cover (Transect Monitoring)			

Environmental Value	Indicator	Data Collection Method	Data Availability	Baseline
	Foliage Cover (DCP Monitoring)	On-ground	RTIO: 2007 – 2023; biannual	2007 – 2012
	Canopy Condition	Remote sensing	Astron: 1987 – 2023; daily-annually	1987 – 2012
	Death of Mature Trees	On-ground	Astron: 2010 – 2023; annual	2010 – 2013
	Native Perennial Understorey Cover			
	Weed Understorey Cover			
Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)	Surface Water Quality	In-situ and gulp samples	WRM/SLR: 2009 – 2023; biannual - annual RTIO: 2009-2023 monthly	2009 – 2013
	Aquatic Fauna (Macroinvertebrate Assemblage)	Kick-sweep; D-frame dip net	WRM/SLR: 2009 – 2023; biannual - annual	2009 – 2013
	Aquatic Fauna (Fish Assemblage)	Seine and gill netting	WRM/SLR: 2009 – 2023; biannual - annual	2009 – 2013

1.5.3 Development of Management Provisions

Management provisions align with Condition 6 and Condition 7 of MS 925 for the revised MMP, with development guided by the outcomes of the SPRM and updates to the knowledge base of environmental values. Development of management provisions and associated environmental criteria required datasets from baseline to present (operational period), allowing for robust statistical analyses and sensitivity testing.

Management provisions and environmental criteria were established for indicators that demonstrated adequate results from the sensitivity testing. Sufficient data and information were available for these indicators to develop outcome-based criteria. Additional irreversible impact provisions are a requirement of conditions 6-2 (7) and (8) of MS 925 for Flora and Vegetation values. A summary of indicators for which outcome-based management provisions were developed is provided in Table 1-4. Indicators with no management provisions were incorporated into response actions to ensure adequate protection of environmental values.

The knowledge base, description and rationale for management provisions is provided in Table 1-5. The management provisions were considered sufficient for the Moderate management level rankings from the SPRM. Environmental criteria are sensitive to detect environmental changes for GDV communities and aquatic ecosystems, applying clearly defined and quantifiable exceedance levels as well as standardised and replicable analysis and testing methods for monitoring data collected over time.

Table 1-4: Management Provisions for environmental values at Nammuldi-Silvergrass.

Environmental Value	Indicator	Management Provisions
GDV Communities of Narraminju Wuntu (Caves Creek)	Vegetation Abundance	**Outcome-based**
	Foliage Cover (Transect Monitoring)	
	Foliage Cover (DCP Monitoring)	**Outcome-based**
	Canopy Condition	**Outcome-based**
	Groundwater Levels	**Outcome-based**
	Death of Mature Trees	**Irreversible Impact**
	Native Perennial Understorey Cover	
	Weed Understorey Cover	
GDV Communities of Kartajirri Wuntu (Duck Creek)	Vegetation Abundance	**Outcome-based**
	Foliage Cover (Transect Monitoring)	
	Foliage Cover (DCP Monitoring)	**Outcome-based**
	Canopy Condition	**Outcome-based**
	Death of Mature Trees	**Irreversible Impact**
	Native Perennial Understorey Cover	
	Weed Understorey Cover	
Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)	Surface Water Quality	**Outcome-based**
	Aquatic Fauna (Macroinvertebrate Assemblage)	**Outcome-based**
	Aquatic Fauna (Fish Assemblage)	**Outcome-based**

Management provisions were not developed for the indicator of recharge water quality. Recharge water quality is not part of this revised MMP, based on the outcome of the data analysis and sensitivity testing. Investigation of recharge water quality data for Narraminju Wuntu (Caves Creek) is instead incorporated into the response actions in the MMP to ensure adequate protection of associated environmental values.

No water quality impacts are expected as the receiving aquifer's water quality is comparable to that of the recharge water (WSP 2024). Managing (via treatment) and monitoring of recharge water will be key to mitigate potential impacts to vegetation which may be sensitive to changes in groundwater quality.

Recharge water quality will be measured at all suitable MAR points and groundwater monitoring bores Rio Tinto will continue to develop an adaptive management approach for the management of recharge water quality as per the EMP conceptual framework.

Table 1-5: Current knowledge and rationale for choice of indicators and environmental criteria for GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)

Current knowledge and description of indicator and management provisions	Key assumptions and uncertainties	Rationale for choice of indicator and management provisions
Environmental Factor: **Flora and Vegetation** **Environmental Value:** **GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)** **Indicator:** **Vegetation Abundance and Foliage Cover (Transect Monitoring)**		
Level of Management[1]: Moderate		
Key surveys and studies: (Astron 2016; 2017a; 2018a; 2019a; 2022b; Biologic 2021b; Biota 2010; 2011; 2012; 2014; 2015)		

Impacts
Temporal trends in vegetation abundance have varied, though generally all zones have had a decreasing trend from 2015 to 2021. Upper Caves recorded an increase in abundance between 2019 and 2021 (Astron 2022b).
From 2015 to 2019, there was a significant decline in the cover of native perennial species. This is likely due to broader environmental conditions. From 2019 to 2021, native species cover increased at all site types except reference sites, where native perennial species cover remained the same (Astron 2022b).
Indicators
Vegetation abundance and foliage cover (transect monitoring) data are collected from Caves Creek and Duck Creek as part of annual riparian vegetation monitoring, conducted by Astron since 2010 (Astron 2022b). Monitoring is undertaken in the main creek channels of both creeks as well as in two un-named tributaries of Duck Creek. A total of 25 sites have been monitored continuously since 2010. A detailed description of monitoring methods for vegetation abundance and foliage cover (transect monitoring) is provided in Appendix 2.
Management Provisions
• Vegetation abundance and foliage cover (transect monitoring) were incorporated in the existing criteria as outcome-based management provisions.
• Vegetation abundance and foliage cover (transect monitoring) criteria have been revised as part of this revised MMP:
  ○ Utilisation of statistically significant differences to determine exceedances of trigger and threshold criteria, to prevent ambiguity and provide quantifiable assessment.
  ○ Development and definition of key indicator species for separate vegetation strata, providing greater sensitivity for detecting impacts.
  ○ A shift to more concise, descriptive criteria, with greater specificity, to improve assessment.
	Indicators
	• Knowledge on the vegetation responses to groundwater changes in the Pilbara region is generally restricted to the key overstorey phreatophytic tree species (Biologic 2021b).
	• Currently, monitoring is described and aggregated according to zones (Astron 2022b). These arbitrary subdivisions may not be well suited to group sites according to floristic compositions of the GDV communities.
	Management Provisions
	• A restricted range of vegetation abundance values may limit data variability, making it difficult to detect significant differences.
	• Foliage cover data with low values were recorded as a default value of '0.1 %', failing to capture natural variability and potentially leading to unreliable test results.
	• Group sizes i.e., number of data points per zone were not always equal which can lead to imbalances and inhomogeneity of variances, affecting the robustness of the Tukey test.
	• Vegetation abundance data may not be normally distributed, limiting the range of values for comparison of means.
		Indicators
		• Vegetation abundance and foliage cover reflect the health of GDV communities, with declines indicating potential impacts from groundwater drawdown, waterlogging, or changes in water quality (Elzinga *et al.* 2001; Froend and Sommer 2010).
		• Accurate and consistent data on vegetation abundance and foliage cover can be collected through repeatable monitoring methods, providing robust datasets for analysing potential mining-related impacts (Barker 2001; EPA 2016).
		• Changes in vegetation abundance and foliage cover can be identified and mitigation measures implemented to prevent prolonged impacts to GDV communities.
		Management Provisions
		• The criteria incorporate clearly defined exceedance levels using statistical significance, ensuring that any deviations beyond these levels are quantifiable.
		• The method used for analysis and testing of monitoring data is standardised and replicable, which ensures that the results can be consistently compared over time. The analysis method is based on well-established methods, providing a strong foundation for the credibility and reliability of the results.
		• The analysis of key indicator species separated by over-, mid- and understorey strata is likely to detect early signs of environmental stress that are not immediately evident when considering the entire community.
		• The results of the exceedance testing demonstrated that the criteria are sensitive enough to detect changes.
		• These exceedance levels are designed to meet or exceed regulatory standards, provide transparency, and ensuring compliance.

[1] Summary of assessment for determination of required management zone provided in Appendix 2,

<table>
<tr><th>Current knowledge and description of indicator and management provisions</th><th>Key assumptions and uncertainties</th><th>Rationale for choice of indicator and management provisions</th></tr>
<tr><td colspan="3">Environmental Factor: Flora and Vegetation
Environmental Value: GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)
Indicator: Foliage Cover (DCP Monitoring)</td></tr>
<tr><td colspan="3">Level of Management: Moderate</td></tr>
<tr><td colspan="3">Key surveys and studies: (RTIO 2018a; 2019; 2020; 2021; 2022)</td></tr>
<tr><td>Impacts
From 2018 to 2022, foliage cover using digital canopy photography (DCP) monitoring has been influenced by both climatic events and project related disturbances. Declines in foliage cover in 2018 and 2019 were observed at zone Upper Caves (sites 9 and 10). A fire in 2019 led to an ongoing decline in foliage cover at a Duck Creek reference zone (site 6) and continues to remain an outlier. Other sites have showed stabilisation or improvement, particularly after high rainfall events in 2020 (RTIO 2018a; 2019; 2020; 2021; 2022).
Indicator
Foliage cover, using DCP monitoring is conducted internally by RTIO staff and has been assessed biannually during the post-wet and post-dry season since 2007. Monitoring is undertaken at Eucalyptus camaldulensis and Eucalyptus victrix trees at 24 sites in the main channels of both creeks as well as in three un-named tributaries of Duck Creek. A detailed description of monitoring methods for foliage cover (DCP monitoring) is provided in Appendix 2.
Management Provisions
• Foliage cover (DCP monitoring) was incorporated in the existing criteria as outcome-based management provisions.
• Foliage cover (DCP monitoring) criteria have been revised as part of this revised MMP:
    ○ Exclusion of trigger and threshold criteria due to the potential for user error, resulting in inconsistent measurements over time. However, the early response criterion is retained as the DCP monitoring can be a valuable early indicator of environmental impacts since data are collected twice a year.
    ○ No change in the exceedance level of the retained early response criterion (≥15%), which was determined to provide sufficient sensitivity to detect potential impacts.
    ○ Separation of data by season into post-wet and post-dry, including revision of the baseline means, providing a more robust analysis.
    ○ A shift to more descriptive criteria, with greater specificity, to improve assessment.</td><td>Indicator
• Knowledge on the vegetation responses to groundwater changes in the Pilbara region is generally restricted to the key overstorey phreatophytic tree species (Biologic 2021b).
Management Provisions
• User errors (i.e., camera angles, lighting, and positioning) may introduce discrepancies and artificial variability, affecting the reliability of the dataset and potentially leading to misleading conclusions.</td><td>Indicator
• Foliage cover is highly sensitive to environmental changes (Elzinga and Salzer 1998; Elzinga et al. 2001), with declines indicating potential impacts from groundwater drawdown, waterlogging, or changes in water quality.
• The monitored Eucalyptus camaldulensis and Eucalyptus victrix trees are key GDV indicator species in both creeks (Biologic 2021a), and reflect groundwater impacts (Doody et al. 2019).
• Changes in foliage cover, related to the dewatering and discharge, can be identified and mitigation measures implemented to prevent prolonged impacts to GDV communities.
Management Provisions
• The criterion incorporates clearly defined exceedance levels using a percentage level, ensuring that any deviations beyond these levels are quantifiable.
• Analysis by season provides a more accurate reflection of the temporal dynamics of GDV communities as it captures the natural variability and cyclical patterns in vegetation abundance.
• The method used for testing of monitoring data is standardised and replicable, which ensures that the results can be consistently compared over time.
• The results of the exceedance testing demonstrate that the criteria are sensitive enough to detect changes in foliage cover (DCP monitoring).
• The exceedance level is designed to meet or exceed regulatory standards, provide transparency and ensuring compliance.</td></tr>
</table>

<table>
<tr><th>Current knowledge and description of indicator and management provisions</th><th>Key assumptions and uncertainties</th><th>Rationale for choice of indicator and management provisions</th></tr>
<tr><td colspan="3">Environmental Factor: Flora and Vegetation
Environmental Value: GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)
Indicator: Canopy Condition</td></tr>
<tr><td colspan="3">Level of Management: Moderate</td></tr>
<tr><td colspan="3">Key surveys and studies: (Astron 2017b; 2018b; 2019b; 2020; 2022a)</td></tr>
<tr><td>Impacts
Canopy condition, i.e., the photosynthetic radiation emitted by plants, is collected for all overstorey phreatophytes, via the remote sensing analysis of multiple multispectral satellite constellations. Satellite imagery availability varies, with WorldView (0.4/1.6m resolution) imagery available from 2017, while Sentinel-2 (10m) and Landsat (30m) imagery available from 2015 and 1987 respectively. Reports and analysis are available from 2017.
At Caves Creek, baseline canopy condition has remained relatively stable, however declines in canopy condition at Upper Caves and Homestead Creek were apparent in all three satellite constellations since 2019. In 2019, a large fire impacted a significant portion of the zones, with canopy condition steadily increasing in all areas impacted. However, in 2021, additional declines were observed in other areas of these zones, unrelated to fire, based on WorldView imagery. Notable canopy condition declines in Upper Caves in the vicinity of Silvergrass. Declines were also seen in the Caves Creek reference zone (Astron 2022a).
Long-term canopy condition at Duck Creek has been relatively neutral for all potential impact and reference zones. An increase in condition, outside of the values of the long-term mean is present at Upper Duck East following commencement of discharge (Astron 2022a). This zone is closest to the discharge point. Following the fire in 2019, canopy condition declined at Upper Duck West however has been recovering since.
Indicator
Canopy condition was selected as an indicator for GDV of Caves Creek and Duck Creek. These data are collected as part of annual post-dry season remote sensing monitoring, conducted by Astron since 2017 (Astron 2022a). Canopy condition monitoring is undertaken in the main creek channels of both creeks as well as in two un-named tributaries of Duck Creek. A detailed description of monitoring methods for canopy condition is provided in Appendix 2.
Management Provisions
• Canopy condition was not incorporated in the existing criteria.
• Canopy condition criteria are added as part of this revised MMP:
  ○ Suitable baseline values were developed where data is available, and data interrogated to ensure a robust analysis.
  ○ Comparative analysis of regional trends through assessment of appropriate reference zones for all criteria.
  ○ Appropriate exceedance levels were developed to test the data against derived baseline or comparative reference zone values. Exceedance levels include significance levels for the trigger and threshold criteria.</td>
<td>Indicator
• For canopy condition using remote sensing monitoring, prior to 2015, only coarse resolution imagery, with a higher temporal range, were available.
• Capture characteristics of high-resolution commercial satellite imagery can vary annually causing slight misalignment in temporal analysis.
Management Provisions
• Estimates of canopy condition for GDV within Caves Creek and Duck Creek relied on medium resolution imagery to establish criteria.
• High-resolution imagery from 2008 to 2015 was available, but data efficacy was questionable due to uncalibrated spectral values between years, leading to inconsistent results.
• Seasonal, long-term trends and comparison to regional reference data was used to justify trigger and threshold criteria. This does not capture changes in phreatophyte extent over time.</td>
<td>Indicator
• Canopy condition leverage non-visible light to quantify the overall health of overstorey phreatophytes (Qi et al. 1994), therefore providing an early indication of potential impacts (Astron 2023).
• Canopy condition is sensitive to changes in water discharge regimes, potential disturbances, or climate-based variables (Astron 2023; Qi et al. 1994).
• Canopy condition data can be collected accurately through repeatable monitoring methods, ensuring consistent results over time (Astron 2023; Stone et al. 2000).
• Changes in canopy condition, related to the dewatering and discharge, can be identified and mitigation measures implemented to prevent prolonged impacts to GDV communities.
• Collection of canopy condition data is not limited by access restrictions (i.e., weather events and pandemics).
• Canopy condition utilises entire phreatophyte canopy extents within riparian zones, increasing sample size of analyses when compared to on-ground methods
Management Provisions
• The criteria incorporate clearly defined exceedance levels using statistical significance, ensuring that any deviations beyond these levels are quantifiable.
• Early response criterion centred around high-temporal satellite sensors facilitating timely responses to operational impacts.
• The method used for analysis is standardised and replicable, which ensures that the results can be consistently compared over time. The testing method is also consistent with regulatory guidelines, providing credibility and reliability to the results.
• Utilising spectral indices as a proxy for canopy condition allows for the quantification of subtle changes in GDV health before any visible alterations in vegetation condition occur.
• The results of the exceedance testing demonstrate that the criteria are sensitive enough to detect changes in canopy condition.
• These exceedance levels are designed to meet or exceed regulatory standards, provide transparency and ensuring compliance.</td></tr>
</table>

<table>
<tr><td>Environmental Factor: Flora and Vegetation
Environmental Value: GDV Communities of Narraminju Wuntu (Caves Creek)
Indicator: Groundwater Levels</td></tr>
</table>

Current knowledge and description of indicator and management provisions	Key assumptions and uncertainties	Rationale for choice of indicator and management provisions
Level of Management: Moderate		
Key surveys and studies: (WSP 2024)		
Impacts Prior to the commencement of dewatering of Nammuldi-Silvergrass, regional groundwater naturally flowed east to west through Caves Creek Valley. However, groundwater extraction at Silvergrass has altered this pattern, causing a reversal in the flow direction from west to east, 8 km from Silvergrass (WSP 2024). Evidence of dewatering is apparent in the groundwater levels at monitoring bore MB11SILV016, situated approximately 7 km downstream of Silvergrass, which shows a drawdown of approximately 3.5 m from the baseline average (Stantec 2024b). **Indicator** Groundwater level monitoring bores are located near Silvergrass and along Caves Creek, with water levels monitored continuously to intermittently since 2010. A total of 22 bores, separated into four clusters, are located within the main channel of Caves Creek. The bores in each cluster have been installed across the creek (perpendicular to the channel) and are located at an increasing distance downstream from the Nammuldi-Silvergrass development envelope. A detailed description of monitoring methods for groundwater level is provided in Appendix 2. **Management Provisions** • Groundwater level was not incorporated in the existing criteria. • Groundwater level is added as part of this revised MMP: ○ One representative groundwater bore was selected from each of the four clusters along Caves Creek, downstream of Silvergrass ○ Suitable baseline values were developed for selected groundwater bores and data interrogated to ensure a robust analysis. ○ Analysis of groundwater level data was conducted on monthly averages to account for natural, short-term groundwater fluctuations. ○ Appropriate exceedance levels were developed to test the data against derived baseline values. Exceedance levels include standard deviations from the mean and 2 m from the mean, depending on the bore.	**Indicator** • Data from all groundwater monitoring bores associated with Caves Creek comprise gaps of varying lengths, ranging from months to years in some cases (WSP 2024), which causes some uncertainty in determining trends in groundwater levels over time. • The design of the MAR is still in progress. There are uncertainties associated with the modelled distance that recharge water will be able to propagate downstream of Caves Creek. **Management Provisions** • Groundwater level criteria have been developed on the assumption that groundwater levels at Caves Creek will revert to baseline following implementation of MAR.	**Indicator** • Groundwater levels sensitive indicator of changes to the groundwater regime such as from drawdown or recharge (e.g., MAR) (Hose *et al.* 2021). • Changes in groundwater levels are an early indicator of potential imminent impacts to GDV due to the lag of plants' biological response (Doody *et al.* 2019; Froend and Sommer 2010). • Groundwater level data can be collected accurately through repeatable monitoring methods ensuring consistent results over time. The use of data loggers facilitates remote monitoring which further supports the early detection of impacts (Doody *et al.* 2019). • Changes in groundwater levels, related to the dewatering, can be identified and mitigation measures implemented to prevent prolonged impacts to GDV communities. **Management Provisions** • The criteria incorporate clearly defined exceedance levels using specific groundwater levels, ensuring that any deviations beyond these levels are quantifiable. • Selecting one groundwater monitoring bore from each of the four clusters along Caves Creek ensures longitudinal monitoring of groundwater levels downstream of Silvergrass, detecting potential drawdown or mounding before it affects sensitive GDV communities. • Analysis of monthly mean groundwater levels reduces the short-term groundwater fluctuations that can occur in response to localised rainfall events. • The method used for testing of monitoring data is standardised and replicable, which ensures that the results can be consistently compared over time. The method used for analysis is based on well-established methods, providing a strong foundation for the credibility and reliability of the results. • The results of the exceedance testing demonstrate that the criteria are sensitive enough to detect changes in groundwater levels. • These exceedance levels are designed to meet or exceed regulatory standards, provide transparency and ensuring compliance.

Environmental Factor:	**Flora and Vegetation**
Environmental Value:	**GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)**
Indicator:	**Death of Mature Trees; Native Perennial Understorey Cover; Weed Understorey Cover**
Level of Management: Moderate	
Key surveys and studies: (Astron 2016; 2017a; 2018a; 2019a; 2022b; Biologic 2021b; Biota 2010; 2011; 2012; 2014; 2015)	

Current knowledge and description of indicator and management provisions	Key assumptions and uncertainties	Rationale for choice of indicator and management provisions
Impacts Declines in GDV saplings and seedlings (DBH <3cm) density i.e., *Eucalyptus victrix, Eucalyptus camaldulensis* and *Melaleuca argentea* have been observed in the Homestead and Plam Springs zone since 2018. However, none of the declines represent deaths in adult trees(Astron 2022b). Significant declines in the cover of native perennial species have been observed from 2015 to 2019, however, this decline is likely due to broader environmental conditions rather than mining impacts. From 2019 to 2021, native species cover increased at all site types except reference sites, where native perennial species cover remained the same (Astron 2022b). Weed cover has generally increased since the baseline period, with higher cover at reference sites in five of the ten monitoring years. Although weed cover has fluctuated over time, it has remained consistently higher at Homestead and Palm Springs zones since 2012, except in 2021 when Upper Caves recorded the highest cover. Between 2019 and 2021, weed cover stayed consistent at Homestead and Plam Springs but increased at other zones (Astron 2022b). **Indicators** Death of mature trees, native perennial understorey cover, and weed understorey cover data are collected from Caves Creek and Duck Creek as part of annual riparian vegetation monitoring, conducted by Astron since 2010 (Astron 2022b). Monitoring is undertaken in the main creek channels of both creeks as well as in two un-named tributaries of Duck Creek. A total of 25 sites have been monitored continuously since 2010 at these locations. A detailed description of monitoring methods for vegetation abundance and foliage cover (transect monitoring) is provided in Appendix 2. **Management Provisions** • Death of mature trees, native perennial understorey cover, and weed understorey cover were incorporated in the existing criteria as irreversible impact management provisions. • Death of mature trees, native perennial understorey cover, and weed understorey cover criteria have been revised. ○ A shift to more concise, descriptive criteria, with greater specificity, to improve assessment.	**Indicators** • Based on a review of literature and the experience of SMEs, the identified indicators are assumed to represent aspects of a GDV community that, if impacted severely, may be irreversibly altered. **Management Provisions** • Irreversible impact management provisions cannot be specified with confidence due to insufficient scientific knowledge.	**Indicators** • Mature trees are critical components of an ecosystem, and their death can indicate severe environmental stress or degradation, often resulting from irreversible impacts like contamination or significant changes in water availability (Souter *et al.* 2009). • Native perennials are adapted to local conditions and play a crucial role in maintaining ecosystem stability and biodiversity. A decline in their cover can signal long-term ecological changes and habitat loss. • An increase in weed cover often indicates ecosystem disturbance and degradation. Weeds can outcompete native species, leading to reduced biodiversity and altered ecosystem functions. • Accurate and consistent data on the death of mature trees, native perennial understorey cover, and weed understorey cover data can be collected through repeatable monitoring methods, providing robust datasets for analysing potential mining-related impacts (Barker 2001; EPA 2016). • Changes in the death of mature trees, native perennial understorey cover, and weed understorey cover can be identified and mitigation measures implemented to prevent prolonged impacts to GDV communities. **Management Provisions** • The criteria incorporate clearly defined exceedance levels, ensuring that any deviations beyond these levels are quantifiable. • The criteria exceedance levels are designed to detect irreversible changes to a vegetation community and represent severe changes from baseline conditions. • The method used for analysis and testing of monitoring data is standardised and replicable. • These exceedance levels are designed to meet or exceed regulatory standards, provide transparency, and ensuring compliance.

Table 1-6: Current Knowledge and rationale for choice of indicators and environmental criteria for aquatic ecosystems of Kartajirri Wuntu (Duck Creek).

Current knowledge and description of indicator and environmental criteria	Key assumptions and uncertainties	Rationale for choice of indicator and management provisions
Environmental Factor: **Inland Waters** **Environmental Value:** **Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)** **Indicator:** **Surface Water Quality**		
Level of Management: Moderate		
Key surveys and studies: (SLR 2024; WRM 2011a; b; 2013; 2014; 2015a; b; 2016; 2017; 2018; 2019a; b; c; 2020a; b; 2021a; 2022; 2023)		
Impacts Nitrogenous compounds and phosphorus in the discharge water to Duck Creek have periodically exceeded trigger levels since 2018 (SLR 2023; WRM 2022; 2023), but concentrations typically return to background levels about 7 km downstream. Other water quality parameters, such as pH, total suspended solids, turbidity, temperature, dissolved oxygen, and various metals, have also exceeded safe levels within downstream pools on multiple occasion, however these were not traced back to the discharge outlet (SLR 2023; WRM 2022; 2023). Elevated nitrogen and phosphorus levels may lead to toxic algal blooms and macrophyte growth, which can deplete oxygen levels and impact other trophic levels (SLR 2023; WRM 2020a; b). Additionally, the discharge is oversaturated with calcium carbonate, which may lead to calcite precipitation that can reduce habitat availability for macroinvertebrates and affect higher trophic groups like fish however this has not been seen in Duck Creek (SLR 2023). High levels of total suspended solids may smother benthic plants and aquatic fauna, reducing light infiltration, and clogging fish gills (SLR 2023; WRM 2020a). **Indicator** Surface water quality is monitored monthly by RTIO at the discharge point (Site 1; DP13NAM001), undertaken since 2013. In addition, as part of the current aquatic fauna monitoring program, undertaken by SLR (previously WRM), water quality is monitored annually or biannually at 19 sites in Duck Creek. A detailed description of monitoring methods for surface water quality is provided in Appendix 2. **Management Provisions** • No change to the existing surface water quality criteria.	**Indicator** • Downstream surface water quality data from Duck Creek has been collected inconsistently since baseline, alternating between annual and biannual monitoring (and wet and dry seasons). The irregularity in sampling may be considered a constraint for interpreting trends over time. **Management Provisions** • Existing surface water quality SSTVs for Duck Creek revised by SLR (2023) have been developed using a combination of baseline and regional reference data, due to a lack of sufficient baseline data, which may not suitably represent pre-mining conditions.	**Indicator** • Changes in surface water quality can result in changes in the composition of aquatic biota, including the dominance of algae, macrophytes, macroinvertebrates, and fish inhabiting the ecosystem (Storey *et al.* 2011). • High-frequency collection of surface water quality data at the discharge point has been undertaken, allowing for the early detection of potential contaminants, which may be harmful to identified aquatic biota (Horwitz *et al.* 1999; Taukulis *et al.* 2014; Taukulis *et al.* 2021; WRM 2020a; b). • Collection of long-term surface water quality data has been undertaken, which improves understanding of the seasonal variations within the creeklines and the capacity of the system to buffer and/or dilute potential contaminants following rainfall (Ruprecht and Ivanescu 2000; Taukulis 2016). • Changes in surface water quality can be identified and mitigation measures implemented to prevent prolonged impacts to aquatic biota. **Management Provisions** • No change to the existing surface water quality criteria.

Current knowledge and description of indicator and environmental criteria	Key assumptions and uncertainties	Rationale for choice of indicator and management provisions
Environmental Factor: **Inland Waters** **Environmental Value:** **Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)** **Indicator:** **Aquatic Fauna – Macroinvertebrate Assemblage**		
Level of Management: Moderate		
Key surveys and studies: (SLR 2024; WRM 2011a; b; 2015a; b; 2016; 2017; 2018; 2019a; b; c; 2020a; b; 2021a; 2022; 2023)		

Impacts
In 2022, the macroinvertebrates taxa richness in Duck Creek zones exposed to dewatering discharge was generally comparable to or greater than baseline conditions. Sites near the discharge outlet showed no adverse impact on macroinvertebrate taxa richness. Increased water availability likely promoted higher dry season taxa richness. Vulnerable species like the Pilbara emerald dragonfly and Pilbara Pin damselfly were recorded, along with the endemic Pilbara tiger dragonfly and fairy shrimp. The fairy shrimp were recorded in the area for the first time since 2009.
Indicator
Macroinvertebrates have been monitored at 19 sites in Duck Creek on an annual or biannual basis as part of the aquatic fauna monitoring program undertaken by SLR (previously WRM). Of these, 11 sites are located upstream of the confluence within Caves Creek, four sites are located downstream of the confluence, and four sites are located within the tributaries of Duck Creek, with a further eight regional reference sites located in nearby waterways. A detailed description of monitoring methods for macroinvertebrates is provided in Appendix 2.
Management Provisions
• Macroinvertebrate assemblage was incorporated in the existing criteria.
• Macroinvertebrate assemblage criteria have been revised.
  ○ Addition of an early response criterion, providing a sensitive measure of change in the macroinvertebrate assemblage of Duck Creek.
  ○ Addition of statistical significance testing, providing rigorous and robust measures to detect changes or trends in macroinvertebrate data over time
  ○ Utilisation of macroinvertebrate taxa diversity, to enable comparison of baseline and early operational macroinvertebrate data that is available at a lower taxonomic resolution.
  ○ A shift to more concise, descriptive criteria, with greater specificity, to improve assessment.
	Indicator
	• Macroinvertebrate data have been collected annually up to 2019 after which, with the exception of 2020, sampling has occurred biannually. The irregularity in sampling may be considered a constraint for interpreting trends over time.
	Management Provisions
	• No estimated abundance data was available for macroinvertebrates.
	• Taxonomic resolution was not standardised across years.
	• Biannual monitoring data was not available for 2014 to 2018 or 2020 for analysis or testing.
	• Small sample size may limit statistical robustness.
	• High variability in sample size due to inconsistencies in sampling across sites.
		Indicator
		• Macroinvertebrates are proven sensitive and reliable indicators of ecosystem health and can respond rapidly to changes in surface water quality, the hydrological regime and habitat availability (Cheal *et al.* 1993; Jähnig *et al.* 2009).
		• Shifts in the macroinvertebrate assemblage can be related to changes in water quality, such as pH, salinity, nutrients or contaminants, which may reflect seasonal variation or the characteristics of the discharge (Cheal *et al.* 1993; Davis *et al.* 2006; Dunlop *et al.* 2008).
		• Changes in the macroinvertebrate assemblage may be considered a surrogate for other trophic levels, indicating impacts to algae, macrophytes and fish (Resh *et al.* 1995; Wallace and Webster 1996).
		• Consistent monitoring of macroinvertebrates in the dry and wet seasons can be used to understand long-term changes to the aquatic ecosystem (WRM 2011b; 2021b).
		• Changes in macroinvertebrate assemblages can be identified and mitigation measures implemented to prevent prolonged impacts to aquatic biota.
		Management Provisions
		• The macroinvertebrate assemblage criteria clearly define exceedance levels of taxa diversity, ensuring that any deviations beyond these levels are quantifiable.
		• The method used for analysis and testing of monitoring data is standardised and replicable, which ensures that the results can be consistently compared over time. The analysis method is based on well-established methods, providing a strong foundation for the credibility and reliability of the results.
		• The results of the sensitivity testing demonstrate that the criteria are sensitive enough to detect changes in macroinvertebrate taxa diversity.
		• The exceedance levels are designed to meet or exceed regulatory standards, provide transparency, and compliance.

Environmental Factor:	**Inland Waters**
Environmental Value:	**Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)**
Indicator:	**Aquatic Fauna – Fish Assemblage**

Current knowledge and description of indicator and environmental criteria	Key assumptions and uncertainties	Rationale for choice of indicator and management provisions
Level of Management: Moderate		
Key surveys and studies: (SLR 2024; WRM 2011a; b; 2015a; b; 2016; 2017; 2018; 2019a; b; c; 2020a; b; 2021a; 2022; 2023)		

Impacts
In 2022, fish fauna assemblages in Nammuldi-Silvergrass reaches exposed to mine-related dewatering or discharge were generally comparable to or more abundant than baseline conditions. Western rainbowfish were well-represented in the Duck Creek Upper and Duck Creek Downstream zones during the 2022 wet season, with new recruits being the largest group. Duck Creek Upper showed breeding in areas with periodic dewatering discharge. Spangled perch recruitment was observed in Duck Creek Upper and Reference Tributaries during the 2022 wet season, and in Duck Creek Downstream and Reference Tributaries during the 2022 dry season. Smaller individuals of Fortescue grunter, Barred grunter, and Flathead Goby, presumed to be new recruits or juveniles, were recorded in Duck Creek in 2022 (WRM 2020b).
Indicator
Fish have been monitored at 19 sites in Duck Creek on an annual or biannual basis as part of the aquatic fauna monitoring program undertaken by SLR (previously WRM). Of these, 11 sites are located upstream of the confluence within Caves Creek, four sites are located downstream of the confluence, and four sites are located within the tributaries of Duck Creek, with a further eight regional reference sites located in nearby waterways. A detailed description of monitoring methods for fish is provided in Appendix 2.
Management Provisions
• Fish assemblage was incorporated in the existing criteria.
• Fish assemblage criteria have been revised.
  ○ Addition of an early response criterion, providing a sensitive measure of change in fish assemblages (size-class abundances and taxa diversity) in Duck Creek.
  ○ Specification of taxa (Western Rainbowfish and Spangled Perch) in relation to fish size-class abundances, where definitions for 'new recruits' and 'juveniles' exist in the literature.
  ○ Inclusion of taxa diversity as a metric for capturing fish assemblage.
  ○ Inclusion of statistically significant testing of data, providing rigorous and robust measures and confidence in observed changes/trends in fish assemblages.
	Indicator
	• Fish data have been collected annually up to 2019 after which, with the exception of 2020, sampling has occurred biannually. The irregularity in sampling may be considered a constraint for interpreting trends over time.
	Management Provisions
	• Literature on fish size-classes and classification of 'new recruit' and 'juvenile' fish only available for Western Rainbowfish and Spangled Perch.
	• Biannual monitoring data was not available for 2014 to 2018 or 2020 for analysis or testing.
	• Small sample size may limit statistical robustness.
	• High variability in sample size due to inconsistencies in sampling across sites.
	• Inconsistent detection of fish taxa across sites and monitoring events due to inherent nature of data collection methods.
		Indicator
		• Fish assemblage provides an indication of ecosystem health, responding to changes in surface water quality, the hydrological regime and habitat availability (Kennard *et al.* 2006).
		• Shifts in fish assemblage may reflect changes in water quality, the hydrological regime or habitat availability as a result of the discharge, reflected by a decrease in these metrics (Bice *et al.* 2014; Waltham and Connolly 2007).
		• The diversity and distribution of native fish species in the creeklines provide an indication of the health of the aquatic ecosystem, with a high species diversity and size class typically reflecting a diverse and resilient community (WRM 2015a; 2010).
		• Consistent monitoring of fish in the dry and wet seasons can be used to understand short-term and long-term changes to the aquatic ecosystem including seasonal variation, climate change or mine-related impacts (Canton *et al.* 2005).
		• Changes in fish assemblages can be identified and mitigation measures implemented to prevent prolonged impacts to aquatic biota, aligning with response actions outlined in the MMP.
		Management Provisions
		• The fish assemblage criteria clearly define exceedance levels of taxa diversity and fish size-class, ensuring that any deviations beyond these levels are quantifiable.
		• The method used for analysis and testing of monitoring data is standardised and replicable, which ensures that the results can be consistently compared over time. The analysis method is based on well-established methods, providing a strong foundation for the credibility and reliability of the results.
		• As timing of wet season surveys after rain events may vary, evidence of recruitment will be demonstrated by presence/absence of new recruits and juveniles, and/or relative abundance of size classes below adult. As presence of multiple class sizes will demonstrate that recruitment has occurred through presence of juveniles/subadults.
		• The results of the sensitivity testing demonstrate that the criteria are sensitive enough to detect changes in fish taxa diversity and new recruit/juvenile abundance.
		• The criteria are designed to detect impacts to aquatic ecosystems by ensuring that fish taxa diversity and recruitment remain within natural ranges.
		• The exceedance levels are designed to meet or exceed regulatory standards, provide transparency, and compliance.

2. MANAGEMENT PROVISIONS

Management provisions will be implemented to ensure that the environmental outcomes outlined in Condition 6 and Condition 7 of MS 925 are met. It is anticipated that the outcome-based (Table 2-1 to Table 2-7) environmental criteria will be reviewed and updated as required, using an adaptive management approach (Section 4).

The revised MMP has considered substantial datasets across all indicators from baseline to 2023, to ensure that environmental criteria are scientifically robust and can be adequately justified. Implementation of monitoring against early response, trigger and threshold criteria aims to prevent impacts from operations on Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek), protecting and maintaining GDV communities and aquatic ecosystems.

2.1 Outcome-Based Provisions

There are seven outcome-based provisions for the key environmental factor of Flora and Vegetation and the environmental value of GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek), comprising vegetation abundance and foliage cover (transect monitoring), foliage cover (DCP monitoring), canopy condition, and groundwater levels (Table 2-1 to Table 2-4).

There are three outcome-based provisions for the key environmental factor of Inland Waters and the environmental value of the aquatic ecosystems of Kartajirri Wuntu (Duck Creek), based on the indicators of surface water quality, aquatic fauna (macroinvertebrate assemblage), and aquatic fauna (fish assemblage) (Table 2-5 to Table 2-7).

Early response criteria, trigger criteria, and threshold criteria along with appropriate response actions to any exceedances, have been developed to ensure management of potential impacts to these environmental values and are presented in Table 2-1 to Table 2-7. An example of the monitoring programs are presented in Appendix 2 and proposed statistical analysis for each of the environmental criteria is provided in Appendix 3. Note, these are subject to change when improved monitoring techniques and analysis are identified without requiring revisions to the MMP.

2.2 Objective-Based Provisions

No objective-based provisions have been developed as part of this MMP.

2.3 Irreversible Impact Provisions

There are three irreversible impact provisions provided for the key environmental factor Flora and Vegetation and for the environmental value of the GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek), based on the indicators of death of mature trees, native perennial understorey cover, and weed understorey cover (Table 2-8). Irreversible impact provisions are a requirement of conditions 6-2 (7) and (8) of MS 925 and only apply to flora and vegetation values in this MMP.

Please note that irreversible impact management provisions cannot be specified with confidence due to insufficient scientific knowledge. Appropriate response actions have been developed to ensure adequate management of potential impacts, with suitable monitoring and reporting outlined to determine if the environmental outcomes outlined in MS 925 have been met.

Table 2-1: Outcome-based provisions for Flora and Vegetation - Vegetation Abundance and Foliage Cover (Transect Monitoring)

EPA Factor and objective: Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained.

Environmental Outcome: MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks.

Key environmental values: GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)

Key impacts and risks: Groundwater drawdown; MAR (waterlogging), dewatering discharge (water quality); dewatering discharge (waterlogging)

Outcome-based Provisions: Vegetation Abundance and Foliage Cover (Transect Monitoring)

Level of Management: Moderate (upper level assigned as conservative approach)

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Trigger Criterion: **1.** A significant change[2] in the seasonal[3] vegetation abundance or foliage cover of three or more individuals of key over-, mid- or understorey species[4] is evident, compared to baseline and reference data, attributed to the Project.	**Trigger Criterion Actions** **Investigate potential cause of exceedance which may include but is not limited to:** • Conduct on-ground visual inspections of affected areas. • Review groundwater level data, in comparison to baseline and reference data, including groundwater abstraction, recharge and/or discharge volumes. • Review conceptual groundwater model. • Review groundwater/recharge/discharge water quality data. • Review weed monitoring data and efficacy of current weed treatment program (e.g. timing and herbicide selection). • Compare on-ground monitoring data to canopy condition and extent for each monitoring zone and/or DCP monitoring data to validate areas of exceedance. • Review phreatophyte species distribution and adaptability to localised impacts. • Assess seasonal, long-term and regional trends using external data (i.e., fire, rainfall, evapotranspiration) to validate lack of any seasonal recovery. • Review groundwater recharge rate, in relation to the extent of the cone of depression and the footprint of drawdown. • Inspect water infrastructure maintenance & calibration and verify compliance and operational effectiveness. **If investigations indicate that trigger exceedance is due to the Proposal, implement trigger criterion actions, where appropriate. This may include but is not limited to:** • Review current monitoring programs to ensure fit for purpose. • Investigate remediation options (e.g., MAR) and implement preferred options. • Revise groundwater/surface water quality SSTVs. • Undertake an additional on-ground monitoring survey (riparian vegetation monitoring) within the impacted area(s) or alternative monitoring method/increased monitoring frequency to validate results. • Modify volumes and/or location, of groundwater recharge/discharge. • Review and recalibrate groundwater/recharge/discharge model if required. • Complete risk assessment of likelihood of continued impact. • Change or implement feral animal or weed management program.	• On-ground riparian vegetation survey. • Monitoring sites and zones are presented in Figure 2-1 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-dry)	• RTIO	• The environmental outcome will be reported against the trigger criterion for each calendar year in the ACAR. • If the trigger criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.
Threshold Criterion: **1.** A significant change[2] in the seasonal vegetation abundance or foliage cover of four or more individuals of key over-, mid- or understorey species[4] is evident for two consecutive monitoring periods[5], compared to baseline and reference data, attributed to the Project.	**Threshold Criterion Actions:** **Implement threshold contingency actions (in addition to trigger criteria actions), where appropriate**: **This may include but is not limited to:** • Review effectiveness and modify effectiveness of trigger criteria actions. • Analyse high-resolution remote sensing and on-ground monitoring data for correlation between Project activities and measured impact. • Revise abstraction/recharge/discharge strategy, including reducing, expanding or redistributing abstraction/recharge/discharge. • Review and implement changes to mine plans. • Investigate alternative remediation options and implement preferred options. **Monitor to validate success of threshold contingency actions.**	• On-ground riparian vegetation survey. • Monitoring sites and zones are presented in Figure 2-1 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-dry)	• RTIO	• In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven days of the exceedance being identified • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. • If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

[2] A statistically significant change is based on a significance level (denoted as "p") of $p = 0.05$.

[3] 'Seasonal' is defined as monitoring events undertaken during the post-wet and/or post-dry season. Note that for analyses, only like seasons should be compared (i.e. compare post-dry with post-dry and post-wet with post-wet).

[4] Key indicator species for over-, mid- or understorey strata are defined in Appendix 4.

[5] When testing for exceedances of criteria, consecutive seasonal monitoring events are considered together to identify broader trends and impacts (e.g. two consecutive monitoring events can be post-wet and post-dry).

Table 2-2: Outcome-based provisions for Flora and Vegetation – Foliage Cover (DCP Monitoring)

EPA factor and objective: Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained. **Environmental outcome**: MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks. **Key environmental values:** GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) **Key impacts and risks:** Groundwater drawdown; MAR (waterlogging), dewatering discharge (water quality); dewatering discharge (waterlogging)					
Outcome-based Provisions: Foliage Cover (DCP Monitoring)					
Level of Management: Moderate (upper level assigned as conservative approach)					
Environmental Criteria	**Response Actions**	**Monitoring**	**Timing/Frequency of Assessment**	**Monitoring Responsibility**	**Reporting**
Early Response Criterion: **1.** A ≥15% decrease in *Eucalyptus* tree species[6] mean seasonal[3] foliage cover is evident at a site, compared to baseline and reference data, attributed to the Project.	**Early Response Criterion Actions:** **Investigate potential cause of exceedance which may include but is not limited to:** • Conduct on-ground visual inspections of affected areas. • Review other environmental factors such as climate, fire, grazing intensity, insect activity. • Review transect monitoring and/or remote sensing monitoring data, in comparison to baseline and reference to provide a more comprehensive understanding of system. • Review groundwater level data, in comparison to baseline and reference data, including groundwater abstraction, recharge and/or discharge volumes. • Review groundwater/recharge/discharge water quality data. • Inspect water infrastructure maintenance & calibration and verify compliance and operational effectiveness. **If investigations indicate the early response exceedance is attributed to the Project, implement early response actions, where appropriate. This may include but is not limited to:** • Review current monitoring programs to ensure fit for purpose. • Undertake an additional on-ground monitoring survey (riparian vegetation monitoring) within the impacted area(s) or alternative monitoring method/increased monitoring frequency to validate results. • Complete risk assessment of likelihood of continued impact.	• On-ground DCP monitoring survey. • Monitoring sites are presented in Figure 2-2 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-dry)	• RTIO	

[6] *Eucalyptus victrix* and *Eucalyptus camaldulensis* subsp. *refulgens*.

Table 2-3: Outcome-based provisions for Flora and Vegetation – Canopy Condition

EPA Factor and objective: Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained.					
Environmental Outcome: MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks.					
Key environmental values: GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)					
Key impacts and risks: Groundwater drawdown; MAR (waterlogging), dewatering discharge (water quality); dewatering discharge (waterlogging)					
Outcome-based Provisions: Canopy Condition					
Level of Management: Moderate (upper level assigned as conservative approach)					
Environmental Criteria	**Response Actions**	**Monitoring**	**Timing/Frequency of Assessment**	**Monitoring Responsibility**	**Reporting**
Early Response Criterion: **1.** A statistically significant change[2] in seasonal[3] canopy condition[7] of overstorey phreatophytes is evident, compared to baseline and reference data, attributed to the Project.	**Early Response Actions:** **Investigate potential cause of exceedance which may include but is not limited to:** • Conduct on-ground visual inspections of affected areas. • Review other environmental factors such as climate, fire, grazing intensity, insect activity. • Review transect monitoring and/or DCP monitoring data, to provide a more comprehensive understanding of system. • Review other high resolution data sources (i.e., LiDAR or UAV). • Review groundwater level data, in comparison to baseline and reference data, including groundwater abstraction, recharge and/or discharge volumes. • Review groundwater/recharge/discharge water quality data. • Inspect water infrastructure maintenance & calibration and verify compliance and operational effectiveness. **If investigations indicate the early response exceedance is attributed to the Project, implement early response actions, where appropriate. This may include but is not limited to:** • Review current monitoring programs to ensure fit for purpose. • Undertake an additional on-ground monitoring survey within the impacted area(s) or alternative monitoring method/increased monitoring frequency to validate results. • Complete risk assessment of likelihood of continued impact.	• Remote sensing vegetation survey. • Monitoring zones are presented in Figure 2-3 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-dry)	• RTIO	
Trigger Criterion: **1.** A statistically significant negative change[2] in seasonal[3] canopy condition[7] of baseline overstorey phreatophyte extent[8] is evident for two consecutive periods[5] and across one zone, compared to baseline and reference data, attributed to the Project.	**Trigger Criteria Actions:** **Investigate potential cause of exceedance (in addition to early response actions) which may include but is not limited to:** • Compare canopy condition data to on-ground transect monitoring, canopy extent and/or DCP monitoring data to validate areas of exceedance. If areas of change are outside current on-ground monitoring programs, conduct an additional survey and/or inspection to validate results. • Review phreatophyte species distribution and adaptability to localised impacts. • Assess seasonal, long-term and regional trends using external data (i.e., fire, rainfall, evapotranspiration) to validate lack of any seasonal recovery. • Review groundwater recharge rate, in relation to the extent of the cone of depression and the footprint of drawdown. • Review conceptual groundwater model. **If investigations indicate the trigger exceedance is attributed to the Project, implement trigger level actions (in addition to early response actions), where appropriate. This may include but is not limited to:** • Investigate remediation options (e.g., MAR) and implement preferred options. • Revise groundwater/surface water quality SSTVs. • Implement monthly remote sensing monitoring. • Modify volumes and/or location, of groundwater recharge/discharge. • Review and recalibrate groundwater/recharge/discharge model if required.	• Remote sensing vegetation survey. • Monitoring zones are presented in Figure 2-3 and Appendix 2. • Indicative methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-dry)	• RTIO	• The environmental outcome will be reported against the trigger criterion for each calendar year in the ACAR. • If the trigger criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

[7] Canopy condition is a vegetation index (e.g., Modified Soil-adjusted Vegetation Index - MSAVI) that quantifies vegetation health and is suitable for arid/semi-arid environments.

[8] For trigger and threshold criteria, canopy condition assessments are anchored within baseline canopy extents.

EPA Factor and objective:	Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained.
Environmental Outcome:	MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks.
Key environmental values:	GDV Communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)
Key impacts and risks:	Groundwater drawdown; MAR (waterlogging), dewatering discharge (water quality); dewatering discharge (waterlogging)

Outcome-based Provisions: Canopy Condition

Level of Management: Moderate (upper level assigned as conservative approach)

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Threshold Criterion: **1.** A statistically significant negative change[2] in seasonal[3] canopy condition[7] of baseline overstorey phreatophyte extent[8] is evident for two or more consecutive periods[5] and across two or more zones, compared to baseline and reference data, attributed to the Project.	**Threshold Criteria Actions:** **Implement threshold contingency actions (in addition to early response and trigger criteria actions), where appropriate. This may include but is not limited to:** • Review effectiveness and modify early response and trigger criteria actions. • Revise abstraction/recharge/discharge strategy, including reducing, expanding or redistributing abstraction/recharge/discharge. • Review and implement changes to mine plans. • Investigate alternative remediation options and implement preferred options. **Monitor to validate success of threshold contingency actions.**	• Remote sensing vegetation survey. • Monitoring zones are presented in Figure 2-3 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-dry)	• RTIO	• In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven days of the exceedance being identified • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. • If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

Table 2-4: Outcome-based provisions for Flora and Vegetation – Groundwater Level

EPA Factor and objective: Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained.

Environmental Outcome: MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks.

Key environmental values: GDV communities of Narraminju Wuntu (Caves Creek)

Key impacts and risks: Groundwater drawdown; MAR (waterlogging)

Outcome-based Provisions: Groundwater Level

Level of Management: Moderate (upper level assigned as conservative approach)

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Early Response Criterion[9]: **1.** The monthly groundwater level in an indicator bore[10] exceeds the mean baseline groundwater level as per Footnote Table 1[11], attributed to the Project.	**Early Response Criterion Actions:** **Investigate potential cause of which may include but is not limited to:** • Review groundwater abstraction and rejection volumes. • Review climatic and weather trends and compare to groundwater level data. • Inspect water infrastructure maintenance and calibration and verify compliance and effectiveness. **If investigations indicate the early response exceedance is attributed to the Project, implement early response actions, where appropriate. This may include but is not limited to:** • Review current monitoring programs to ensure fit for purpose. • Undertake an additional on-ground monitoring survey or alternative monitoring method/increased monitoring frequency to validate results. • Complete risk assessment of likelihood of continued impact.	• Groundwater monitoring bores. • Monitoring bores are presented in Figure 2-4 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Monthly	• RTIO	
Trigger Criterion[9]: **1.** The monthly groundwater level in an indicator bore[10] exceeds the mean baseline groundwater level as per Footnote Table 1[11], attributed to the Project.	**Trigger Criterion Actions:** **Investigate potential cause of exceedance (in addition to early response actions) which may include but is not limited to:** • Assess seasonal, long-term and regional trends using external data (i.e., fire, rainfall, evapotranspiration) to validate results. • Review groundwater recharge rate, in relation to the extent of the cone of depression and the footprint of drawdown. • Review conceptual groundwater model. **If investigations indicate the trigger exceedance is attributed to the Project, implement trigger level actions (in addition to early response actions), where appropriate. This may include but is not limited to:** • Modify volumes and/or location, of groundwater recharge. • Review and recalibrate groundwater/recharge model if required.	• Groundwater monitoring bores. • Monitoring bores are presented in Figure 2-4 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Monthly	• RTIO	• The environmental outcome will be reported against the trigger criterion for each calendar year in the ACAR. • If the trigger criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

[9] Reporting against criterion will only commence once implementation of MAR has returned groundwater levels to baseline levels.

[10] Key indicator bores are MB11SILV023, MB11SILV019, MB11SILV013, and MB11SILV005.

[11] Footnote Table 1: Groundwater level management provision levels for key indicator bores.

Criteria Category	MB11SILV023	MB11SILV019	MB11SILV013	MB11SILV005
Baseline Mean	*5.547 mbgl*	*2.809 mbgl*	*2.288 mbgl*	*1.628 mbgl*
Early Response Criterion	5.350 and 5.744 mbgl	3.452 mbgl	2.779 mbgl	2.044 mbgl
Trigger Criterion	5.153 and 5.941 mbgl	4.095 mbgl	3.269 mbgl	2.460 mbgl
Threshold Criterion	3.547 and 7.547 mbgl	4.738 mbgl	3.759 mbgl	2.877 mbgl

EPA Factor and objective: Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained.

Environmental Outcome: MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks.

Key environmental values: GDV communities of Narraminju Wuntu (Caves Creek)

Key impacts and risks: Groundwater drawdown; MAR (waterlogging)

Outcome-based Provisions: Groundwater Level

Level of Management: Moderate (upper level assigned as conservative approach)

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Threshold Criterion[9]: **1.** The monthly groundwater level in an indicator bore[10] exceeds the mean baseline groundwater level as per Footnote Table 1[11], attributed to the Project.	**Threshold Criterion Actions:** **Implement threshold contingency actions (in addition to early response and trigger criteria actions), where appropriate. This may include but is not limited to:** • Review effectiveness and modify early response and trigger criteria actions. • Revise abstraction and/or recharge strategy, including reducing, expanding or redistributing abstraction/recharge. • Review and implement changes to mine plans. • Investigate alternative remediation options and implement preferred options. **Monitor to validate success of threshold contingency actions.**	• Groundwater monitoring bores. • Monitoring bores are presented in Figure 2-4 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Monthly	• RTIO	• In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven days of the exceedance being identified • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. • If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

Table 2-5: Outcome-based provisions for Inland Waters – Surface Water Quality

EPA Factor and objective: Inland Waters – to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected. **Environmental Outcome**: MS 925 Condition 7 – ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek. **Key environmental values:** Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek) **Key impacts and risks:** Dewatering discharge					
Outcome-based Provisions: Surface Water Quality					
Level of Management: Moderate					
Environmental Criteria	**Response Actions**	**Monitoring**	**Timing/Frequency of Assessment**	**Monitoring Responsibility**	**Reporting**
Trigger Criterion: **1.** *Toxicant:* Rolling annual median concentration is statistically higher than the SSTV[12] OR a single value is above the 95%ile of baseline or ANZG (2018) default 90% species protection level; resampling confirms the value still exceeds the SSTV, local baseline and reference sites. *Stressor:* Rolling annual median concentration is statistically higher than the SSTV and resampling confirms the value still exceeds the SSTV, local baseline and reference sites.	**Trigger Criterion Actions** **Investigate potential cause and impacts of exceedance which may include but is not limited to:** • Conduct on-ground visual inspections of affected areas. • Review surface water quality data for potential sampling or analytical errors and resample as required. • Review local and regional data and climatic information to determine trends. • Review in-pit groundwater quality, and pit management for potential causes (such as bore iron bacteria/biofouling, contamination, spills, or nitrate infiltration etc). • Review potential natural causes such as rainfall events, eutrophication, invasive species, or climate change etc.). • Review water flow paths for potential causes (such as landform erosion, sedimentation, or change in flow, cattle impacts, etc.). • Increase monitoring of other indicators and/or commence additional studies. • Review surface water quality SSTVs and if exceedance is not due to the Proposal, revise SSTVs. • Seek expert advice on potential risk to the environment and assess bioavailability of toxicants if warranted. **If investigations and indicate that trigger exceedance is due to the Proposal, implement trigger criterion actions, where appropriate. This may include but is not limited to:** • If other sources identified as a result of operations, then remove / eliminate source from the most likely pathway. • Implement changes to mine operations, planning and/or mine water management activities. • Adjust abstraction, or discharge volumes and/or strategy. • Revise surface water SSTVs for Duck Creek.	• Water quality monitoring program. • Monitoring sites are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3. • Exceedance workflow is presented in Appendix 6.	• Monthly	• RTIO	• The environmental outcome will be reported against the trigger criterion for each calendar year in the ACAR. • If the trigger criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.
Threshold Criterion: **1.** *Toxicant:* The bioavailable concentration also exceeds the SSTV[12], discharge water is likely to be the cause of the exceedance and expert advice indicates an increased risk to biota. *Stressor:* A significant upward trend is apparent, discharge water is likely to be the cause of the exceedance and expert advice indicates an increased risk to biota.	**Threshold Criterion Actions:** **Implement threshold contingency actions (in addition to trigger criteria actions), where appropriate. This may include but is not limited to**: • Review effectiveness and modify trigger criterion actions. • If impacts on fauna indicate it is necessary, undertake remedial actions as required and permitted on advice from relevant stakeholders. • Change of surplus water discharge regime (timing, duration and/or location). • Implement changes to mine operations, planning and/or mine water management activities. • Investigate and implement water treatment methodology. • Investigate and implement water storage and reuse opportunities. **Monitor to validate success of threshold contingency actions.**	• Water quality monitoring program. • Monitoring sites are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3. • Exceedance workflow is presented in Appendix 6.	• Monthly	• RTIO	• In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven days of the exceedance being identified • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. • If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

[12] Surface water SSTVs for Duck Creek are presented in Appendix 5.

Table 2-6: Outcome-based provisions for Inland Waters – Aquatic Fauna (Macroinvertebrate Monitoring)

EPA Factor and objective: Inland Waters – to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.					
Environmental Outcome: MS 925 Condition 7 – ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek.					
Key environmental values: Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)					
Key impacts and risks: Dewatering discharge					
Outcome-based Provisions: Aquatic Fauna (Macroinvertebrate Monitoring)					
Level of Management: Moderate					
Environmental Criteria	**Response Actions**	**Monitoring**	**Timing/Frequency of Assessment**	**Monitoring Responsibility**	**Reporting**
Early Response Criterion: **1.** A statistically significant decrease[2] in macroinvertebrate taxa diversity is evident at a zone, compared to baseline and reference data, attributed to the Project.	**Early Response Actions:** **Investigate potential cause of exceedance which may include but is not limited to:** • Conduct on-ground visual inspections of affected areas. • Review aquatic invertebrate data for potential sampling and analytical errors. • Review surface water quality data for any exceedances and correlation to aquatic invertebrates. • Review abstraction and discharge volumes for any changes and correlation to aquatic invertebrates. • Review potential natural causes such as rainfall events, eutrophication, invasive species, or climate change etc.). • Review local and regional data and climatic information to assess trends. • Review discharge water quality for potential causes (such as velocity, substrate armouring, surface water quality changes or interactions etc). **If investigations indicate the early response exceedance is attributed to the Project, implement early response actions, where appropriate. This may include but is not limited to:** • Adjust abstraction, or discharge volumes and/or strategy. • Increase monitoring of other indicators and/or commence additional studies to understand potential impacts.	• Aquatic fauna monitoring program. • Monitoring sites and zones are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post wet season where pools occur)	• RTIO	
Trigger Criterion: **1.** A statistically significant decrease[2] in macroinvertebrate taxa diversity is evident at a zone for two consecutive monitoring events[5], compared to baseline and reference data, attributed to the Project.	**Trigger Criteria Actions:** **Investigate potential cause of exceedance which may include but is not limited to:** • Review in-pit groundwater quality and pit management for potential causes (such as bore iron bacteria/biofouling, contamination, spills, nitrate infiltration etc). • Review water flow paths for potential causes (such as landform erosion, sedimentation, or change in flow etc). • Seek expert advice on probably causes and environmental risk of changes observed. • Identify probable causes and risk to the environment in consultation with external experts. **If investigations indicate the trigger exceedance is attributed to the Project, implement trigger level actions (in addition to early response actions), where appropriate. This may include but is not limited to:** • Undertake an options assessment study to identify management actions that may be implemented. • Implement changes to mine operations, planning and/or mine water management activities. • Adjust abstraction, or discharge volumes and/or strategy.	• Aquatic fauna monitoring program. • Monitoring sites and zones are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-wet season where pools occur)	• RTIO	• The environmental outcome will be reported against the trigger criterion for each calendar year in the ACAR. • If the trigger criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

EPA Factor and objective: Inland Waters – to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.

Environmental Outcome: MS 925 Condition 7 – ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek.

Key environmental values: Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)

Key impacts and risks: Dewatering discharge

Threshold Criterion: **1.** A statistically significant decrease[2] in macroinvertebrate taxa diversity is evident at a zone for three or more consecutive monitoring events[5], compared to baseline reference data, attributed to the Project.	**Threshold Criteria Actions:** **Implement threshold contingency actions, in addition to early response and trigger criteria actions, where appropriate. This may include but is not limited to:** • Review effectiveness and modify early response and trigger criteria actions. • Improve and implement management and mitigation identified from the options assessment study. • Conduct risk assessment to assess potential impacts on the receiving environment and implement appropriate remediation actions, undertaking additional studies, where required. • If impacts on fauna indicate it is necessary, undertake remedial actions as required and permitted on advice from relevant stakeholders. • Change of surplus water discharge regime (timing, duration and/or location). • Implement changes to mine operations, planning and/or mine water. management activities. • Investigate and implement water treatment methodology. • Investigate and implement water storage and reuse opportunities. **Monitor to validate success of threshold contingency actions.**	• Aquatic fauna monitoring program. • Monitoring sites and zones are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-wet season where pols occur)	• RTIO	• In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven days of the exceedance being identified • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. • If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

Table 2-7: Outcome-based provisions for Inland Waters – Aquatic Fauna (Fish Monitoring)

EPA Factor and objective:	Inland Waters – to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Environmental Outcome:	MS 925 Condition 7 – ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek.
Key environmental values:	Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)
Key impacts and risks:	Dewatering discharge

Outcome-based Provisions: Aquatic Fauna (Fish Monitoring)

Level of Management: Moderate

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Early Response Criterion: **1.** A statistically significant decrease[2] in new recruits and juveniles for Western Rainbowfish or Spangled Perch is evident, based on size class data[13], at a zone, compared to baseline and reference data, attributed to the Project. OR **2.** A statistically significant decrease[2] in fish taxa diversity is evident at a zone, compared to baseline and reference data, attributed to the Project.	**Early Response Actions:** **Investigate potential cause and impacts of exceedance which may include but is not limited to:** • On-ground visual observation of potentially affected creek sections. • Review fish data for potential sampling and analytical errors. • Review surface water quality data for any exceedances and correlation to fish. • Review abstraction and discharge volumes for any changes and correlation to fish. • Review potential natural causes such as rainfall events, eutrophication, invasive species, or climate change etc.). • Review local and regional data and climatic information to assess trends. • Review discharge water quality for potential causes (such as velocity, substrate armouring, surface water quality changes or interactions etc). • Increase monitoring of other indicators and/or commence additional studies to understand potential impacts. **If investigations indicate the early response exceedance is attributed to the Project, implement early response actions, where appropriate This may include but is not limited to:** • Adjust abstraction, or discharge volumes and/or strategy. • Increase monitoring of other indicators and/or commence additional studies to understand potential impacts.	• Aquatic fauna monitoring program. • Monitoring sites and zones are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-wet season where pools occur)	• RTIO	
Trigger Criterion: **1.** A statistically significant decrease[2] in new recruits and juveniles for Western Rainbowfish or Spangled Perch is evident, based on size class data[13], at a zone for two consecutive monitoring events[5], compared to baseline and reference data, attributed to the Project. OR **2.** A statistically significant decrease[2] in fish taxa diversity is evident at a zone for two consecutive monitoring events[5], compared to baseline and reference data, attributed to the Project.	**Trigger Criteria Actions:** **Investigate potential cause of exceedance which may include but is not limited to:** • Review in-pit groundwater quality and pit management for potential causes (such as bore iron bacteria/biofouling, contamination, spills, nitrate infiltration etc). • Review water flow paths for potential causes (such as landform erosion, sedimentation, or change in flow etc). • Seek expert advice on probably causes and environmental risk of changes observed. • Identify probable causes and risk to the environment in consultation with external experts. **If investigations indicate the trigger exceedance is attributed to the Project, implement trigger level actions (in addition to early response actions), where appropriate This may include but is not limited to:** • Undertake an options assessment study to identify management actions that may be implemented in the short or long-term. • Implement changes to mine operations, planning and/or mine water management activities. • Adjust abstraction, or discharge volumes and/or strategy.	• Aquatic fauna monitoring program. • Monitoring sites and zones are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-wet season where pools occur)	• RTIO	• The environmental outcome will be reported against the trigger criterion for each calendar year in the ACAR. • If the trigger criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

[13] As timing of wet season surveys after rain events may vary, evidence of recruitment will be based on presence/absence of new recruits and juveniles, as well as relative abundance of juvenile and subadult size classes.

EPA Factor and objective:	Inland Waters – to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Environmental Outcome:	MS 925 Condition 7 – ensure that the discharge of surplus water from the Nammuldi or Silvergrass sites as a result of mining does not cause long term impacts on the environmental and conservation values of Duck Creek.
Key environmental values:	Aquatic Ecosystems of Kartajirri Wuntu (Duck Creek)
Key impacts and risks:	Dewatering discharge

Outcome-based Provisions: Aquatic Fauna (Fish Monitoring)

Level of Management: Moderate

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Threshold Criterion: **1.** An absence of new recruits and juveniles of Western Rainbowfish or Spangled Perch is evident, based on size class data[13], at a zone for two consecutive monitoring events[5], attributed to the Project. OR **2.** A statistically significant decrease[2] in fish taxa diversity is evident at a zone for three or more consecutive monitoring events[5], compared to baseline and reference data, attributed to the Project.	**Threshold Criteria Actions:** **Implement threshold contingency actions, in addition to early response and trigger criteria actions, where appropriate. This may include but is not limited to:** • Review effectiveness of early response and trigger criteria actions. • Improve and implement management and mitigation identified from the options assessment study. • Conduct risk assessment to assess potential impacts on the receiving. environment and implement appropriate remediation actions, undertaking additional studies, where required. • Change of surplus water discharge regime (timing, duration and/or location). • Implement changes to mine operations, planning and/or mine water management activities. • Investigate and implement water treatment methodology. • Investigate and implement water storage and reuse opportunities. **Monitor to validate success of threshold contingency actions.**	• Aquatic fauna monitoring program. • Monitoring sites and zones are presented in Figure 2-5 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2. • Indicative analysis methods are presented in Appendix 3.	• Annual (post-wet season where pools occur)	• RTIO	• In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven days of the exceedance being identified • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. • If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the outcomes of the investigation and the action/s that have been implemented to manage the potential impact.

Table 2-8: Irreversible Impact Provisions for Flora and Vegetation – Death of Mature Trees; Native Perennial Understorey Cover; Weed Understorey Cover

EPA factor and objective:	Flora and Vegetation – to protect flora and vegetation so that biological diversity and ecological integrity are maintained.
Environmental outcome:	MS 925 Condition 6 – ensure that dewatering and discharge do not cause long term impacts on the health and abundance of groundwater-dependent vegetation communities in Duck and Caves creeks.
Key environmental values:	GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)
Key impacts and risks:	Groundwater drawdown; MAR (waterlogging), dewatering discharge (water quality); dewatering discharge (waterlogging)

Outcome-based Provisions: Death of Mature Trees; Native Perennial Understorey Cover; Weed Understorey Cover

Level of Management: Moderate (upper level assigned as conservative approach)

Environmental Criteria	Response Actions	Monitoring	Timing/Frequency of Assessment	Monitoring Responsibility	Reporting
Irreversible Impact Criteria: **1.** Death of 30% of mature trees (where DBH >30 cm)[14] is evident at a site, compared to baseline and reference data, attributed to the Project. OR **2.** A ≥50 % loss of native perennial understorey and ground cover is evident across all sites compared to baseline and reference data, attributed to the Project. OR **3.** A >80% weed cover in the understorey by weed species not previously recorded within the project area and identified as having High Ecological Impact and Low Feasibility of Control under the DPaW (2013) weed prioritisation for the Pilbara Bioregion.	**Irreversible Impact Criteria Actions:** **Investigate potential cause of exceedance which may include but is not limited to:** • Conduct on-ground visual inspections of affected areas. • Review groundwater level data, in comparison to baseline and reference data, including groundwater abstraction, recharge and/or discharge volumes. • Review conceptual groundwater model. • Review groundwater/recharge/discharge water quality data. • Review groundwater abstraction rate and recharge volume, in relation to the extent of the cone of depression and the footprint of drawdown. • Review weed monitoring data and efficacy of current weed treatment program (e.g. timing and herbicide selection). • Compare on-ground monitoring data to annual canopy extent and canopy condition for each monitoring zone and/or DCP monitoring data to validate areas of exceedance. • Review phreatophyte species distribution and adaptability to localised impacts. • Assess seasonal, long-term and regional trends using external data (i.e., fire, rainfall, evapotranspiration) to validate lack of any seasonal recovery. • Review groundwater recharge rate, in relation to the extent of the cone of depression and the footprint of drawdown. • Inspect water infrastructure maintenance & calibration and verify compliance and operational effectiveness. **If investigations indicate the irreversible impact exceedance is attributed to the Project, implement irreversible impact actions, where appropriate. This may include but is not limited to:** • Review current monitoring programs to ensure fit for purpose. • Review and implement changes to mine plans. • Investigate alternative remediation options and implement preferred options. • Revise weed and feral animal management plan as appropriate. • Revise abstraction/recharge/discharge strategy, including reducing, or redistributing abstraction/recharge/discharge as appropriate. • Develop and implement a rehabilitation and/or restoration program. • Monitor to validate success of irreversible impact contingency actions. **Monitor to validate success of irreversible impact contingency actions.**	• On-ground transect monitoring survey. • Monitoring sites are presented in Figure 2-1 and Appendix 2. • Indicative monitoring methods are presented in Appendix 2.	• Annual (post-dry)	• RTIO	• In the event that monitoring indicates that an irreversible impact level required by Condition 6-2(7) has been exceeded, the proponent shall provide a report to the CEO within 21 days of the exceedance being identified which: (1) describes the decline or change; (2) provides information which allows determination of the likely root cause of the decline or change; and (3) if considered likely to be the result of activities undertaken in implementing the proposal, describe which management actions will be implemented and the associated timelines to remediate the decline or change.

[14] The mean DBH of *Eucalyptus victrix* and *Eucalyptus camldulensis* recorded across Caves Creeks and Duck Creek in baseline monitoring years was >30 cm (Biota 2012a).

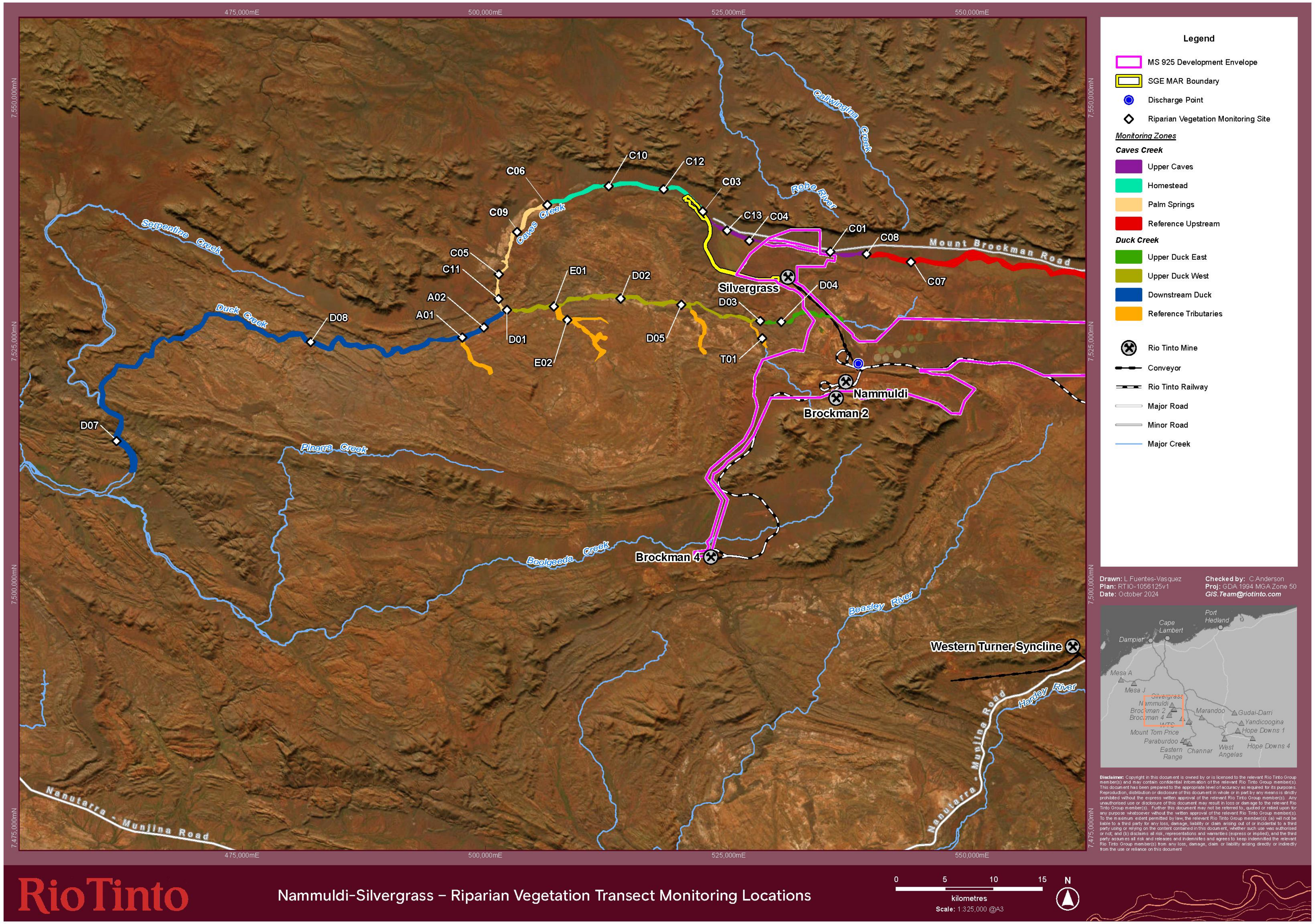


Figure 2-1: On-ground transect monitoring (vegetation abundance and foliage cover) locations

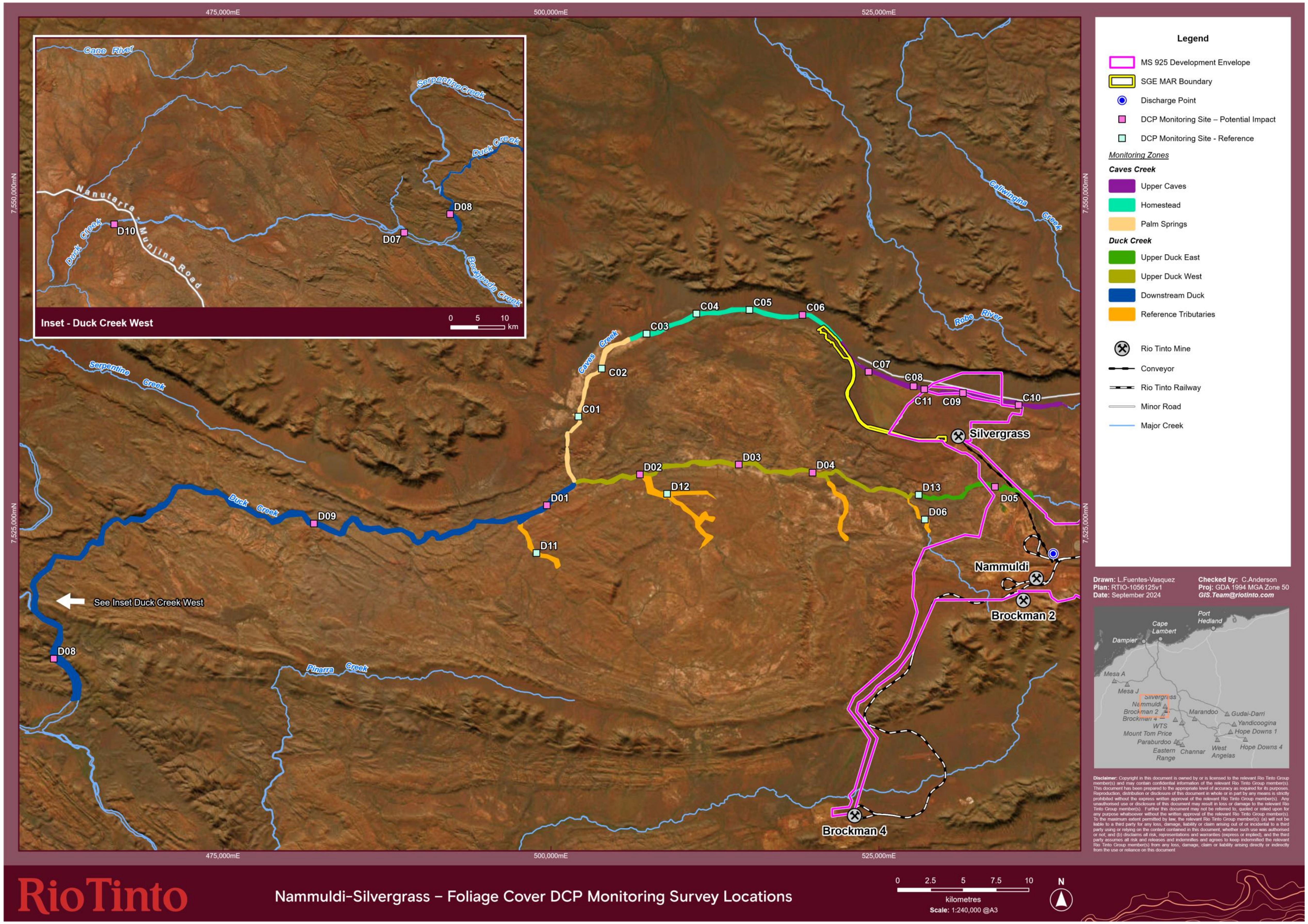


Figure 2-2: On-ground DCP monitoring (foliage cover) locations.

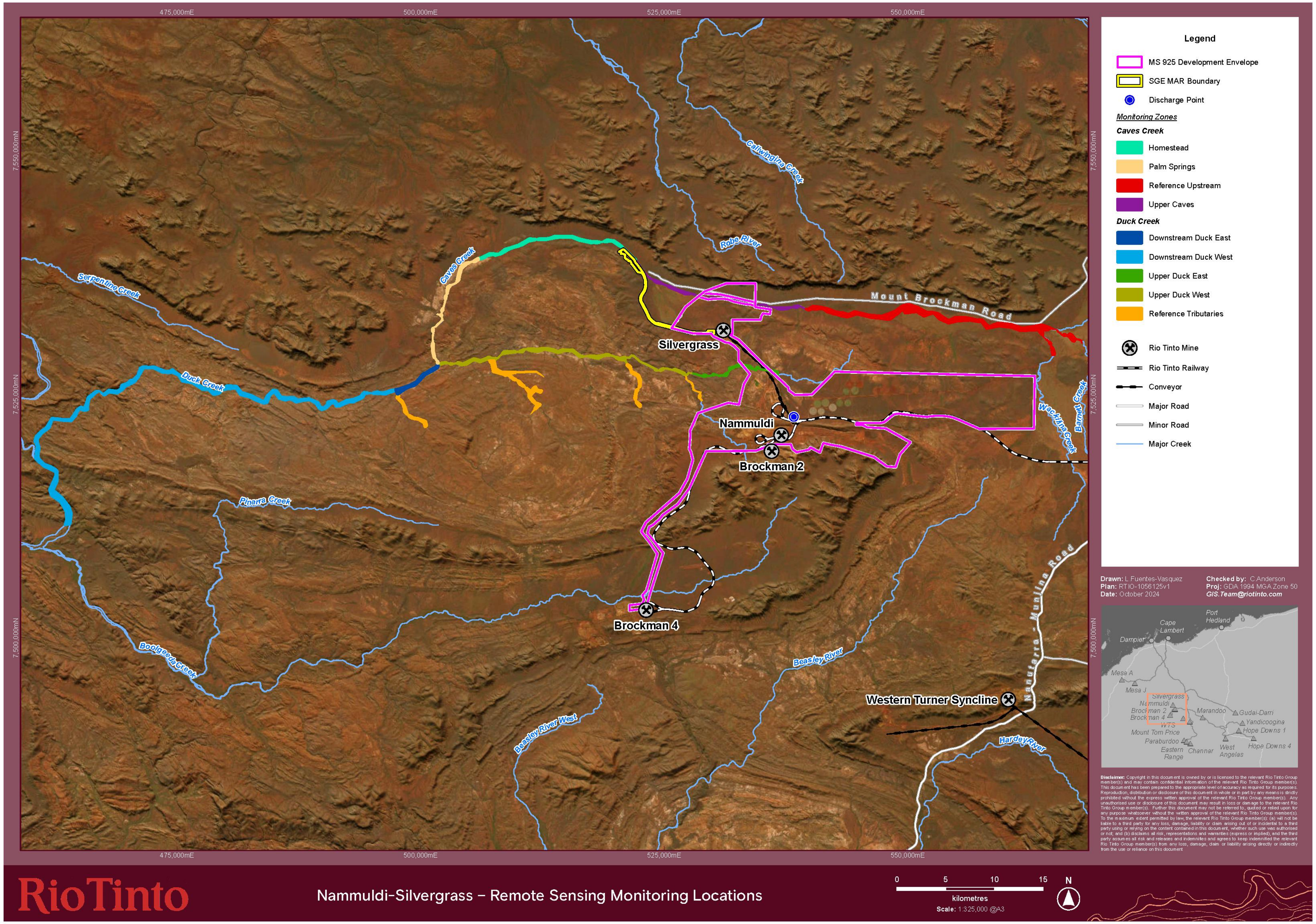


Figure 2-3: Remote sensing monitoring (canopy condition) locations.

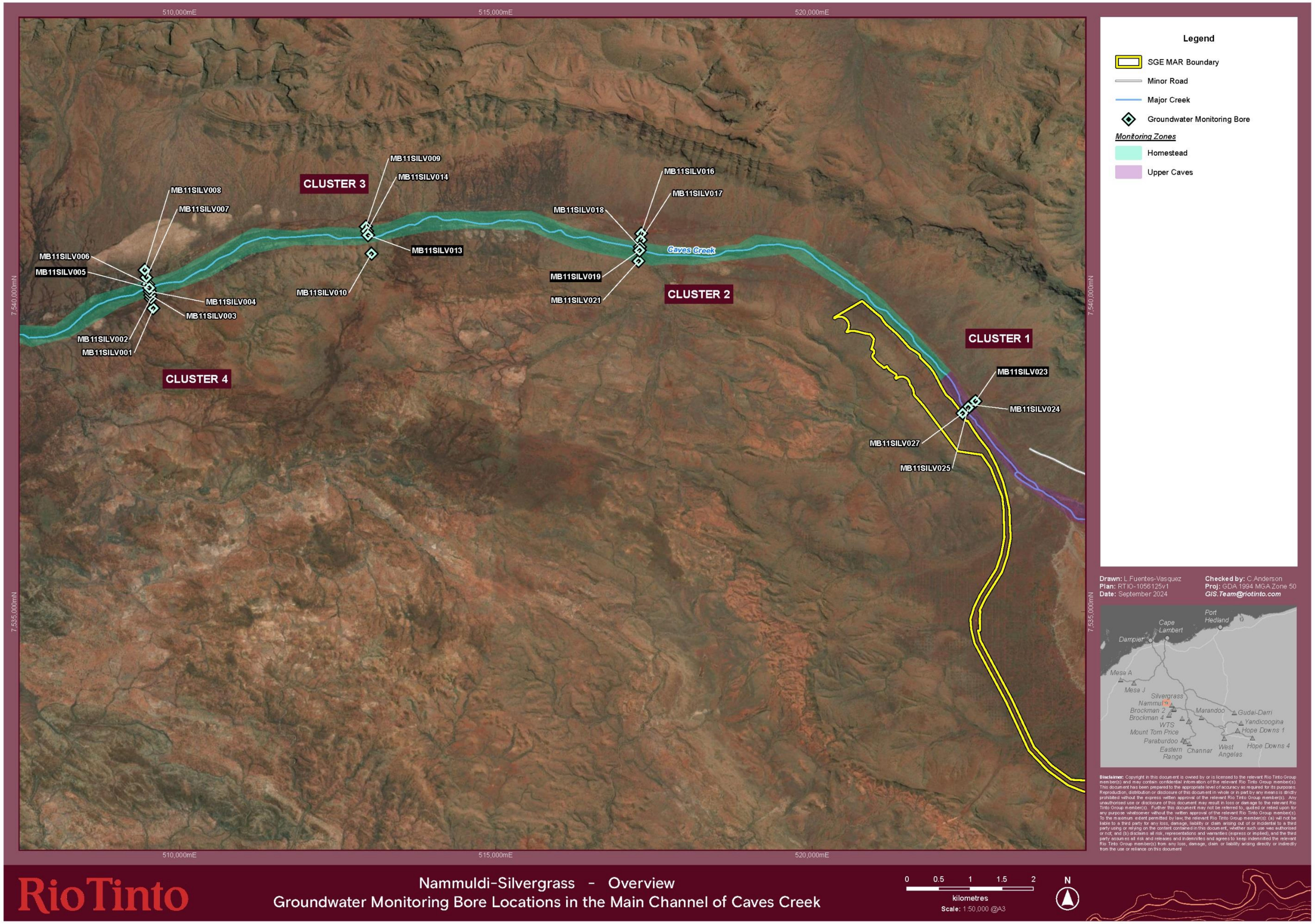


Figure 2-4: Groundwater level monitoring bore locations.

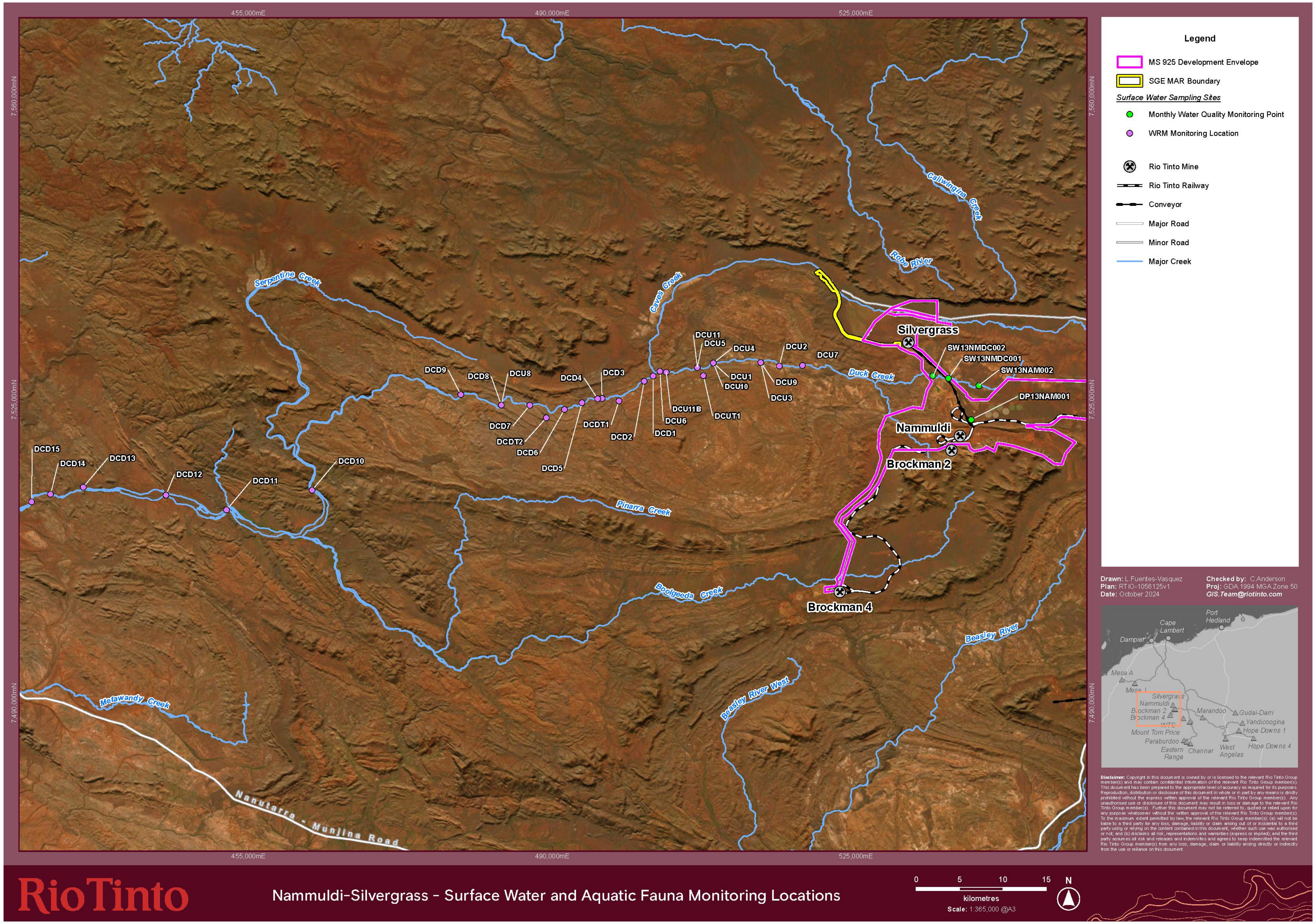


Figure 2-5: Duck Creek Surface water quality and aquatic fauna monitoring locations.

3. MONITORING AND REPORTING

3.1 Monitoring

The purpose of monitoring programs is to ensure that the:

- environmental outcomes of MS 925 are achieved;
- exceedances of the early response, trigger, threshold and/or irreversible impact criteria can be detected; and
- where exceedances are detected, contingency management and response actions are implemented where appropriate.

A description of the indicative monitoring programs for each indicator is summarised in Appendix 2. Monitoring sites associated with these programs are presented in Figure 2-1 to Figure 2-5. An example of the indicative statistical data analyses for each indicator and the associated environmental criteria are provided in Appendix 3. Note, these are subject to change when improved monitoring techniques and analysis are identified without requiring revisions to the MMP.

3.2 Reporting

Reporting will be undertaken in line with Condition 4 and Condition 6-5 of MS925. For each reporting period, the environmental outcomes will be reported against their associated environmental criteria in the Annual Compliance Assessment Report (ACAR) (Table 3-1 to Table 3-2).

In the event that trigger and threshold criteria are exceeded or management targets are not met during the reporting period, the ACAR will include a description of the effectiveness of any management contingency actions that have been implemented to manage the impact.

In the event that investigations indicate exceedance of threshold criteria, the exceedance will be reported in writing to the CEO within seven (7) days.

In the event that monitoring indicates that an irreversible impact level required by Condition 6-2(7) has been exceeded, the proponent shall provide a report to the CEO within 21 days of the exceedance being identified which: (1) describes the decline or change; (2) provides information which allows determination of the likely root cause of the decline or change; and (3) if considered likely to be the result of activities undertaken in implementing the proposal, describe which management actions will be implemented and the associated timelines to remediate the decline or change.

Table 3-1: Nammuldi-Silvergrass MMP outcome-based provisions reporting table for GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)

Key environmental factors: Flora and Vegetation – GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)		
Indicator	**Environmental Criteria**	**Reporting periods 1 January-31 December**
Trigger Criteria:		**Status report:** Trigger criteria not exceeded Trigger criteria exceeded
Vegetation Abundance and Foliage Cover (Transect Monitoring)	1. A significant change in the seasonal vegetation abundance or foliage cover of three or more individuals of key over-, mid- or understorey species is evident, compared to baseline and reference data, attributed to the Project.	
Canopy Condition	2. A statistically significant negative change in seasonal canopy condition of baseline overstorey phreatophyte extent is evident for two consecutive periods and across one zone, compared to baseline and reference data, attributed to the Project.	
Groundwater Levels[9]	3. The monthly groundwater level in an indicator bore exceeds the mean baseline groundwater level as per Footnote Table 1, attributed to the Project.	
Threshold criteria:		**Status report:** Threshold criteria not exceeded Threshold criteria exceeded
Vegetation Abundance and Foliage Cover (Transect Monitoring)	1. A significant change in the seasonal vegetation abundance or foliage cover of four or more individuals of key over-, mid- or understorey species is evident for two consecutive monitoring periods, compared to baseline and reference data, attributed to the Project.	
Canopy Condition	2. A statistically significant negative change in seasonal canopy condition of baseline overstorey phreatophyte extent is evident for two or more consecutive periods and across two or more zones, compared to baseline and reference data, attributed to the Project.	
Groundwater Levels[9]	3. The monthly groundwater level in an indicator bore exceeds the mean baseline groundwater level as per Footnote Table 1, attributed to the Project.	

Table 3-2: Nammuldi-Silvergrass MMP outcome-based provisions reporting table for aquatic ecosystems of Kartajirri Wuntu (Duck Creek)

<table>
<tr><th colspan="3">Key environmental factors: Inland Waters – Aquatic ecosystems of Kartajirri Wuntu (Duck Creek)</th></tr>
<tr><td>Indicator</td><td>Environmental Criteria</td><td>Reporting periods 1 January-31 December</td></tr>
<tr><td colspan="2"><u>Trigger Criteria:</u></td><td>Status report:
Trigger criteria not exceeded
Trigger criteria exceeded</td></tr>
<tr><td>Surface Water Quality</td><td>1. Toxicant:
Rolling annual median concentration is statistically higher than the SSTV OR a single value is above the 95%ile of baseline or ANZG (2018) default 90% species protection level; resampling confirms the value still exceeds the SSTV, local baseline and reference sites.
Stressor:
Rolling annual median concentration is statistically higher than the SSTV and resampling confirms the value still exceeds the SSTV, local baseline and reference sites.</td><td></td></tr>
<tr><td>Aquatic Fauna (Macroinvertebrate Assemblage)</td><td>2. A statistically significant decrease in macroinvertebrate taxa diversity is evident at a zone for two consecutive monitoring events, compared to baseline and reference data, attributed to the Project.</td><td></td></tr>
<tr><td>Aquatic Fauna (Fish Assemblage)</td><td>3. A statistically significant decrease in new recruits and juveniles for Western Rainbowfish or Spangled Perch is evident, based on size class data, at a zone for two consecutive monitoring events, compared to baseline and reference data, attributed to the Project.
OR
4. A statistically significant decrease in fish taxa diversity is evident at a zone for two consecutive monitoring events, compared to baseline and reference data, attributed to the Project.</td><td></td></tr>
<tr><td colspan="2"><u>Threshold criteria:</u></td><td>Status report:
Threshold criteria not exceeded
Threshold criteria exceeded</td></tr>
</table>

Key environmental factors: Inland Waters – Aquatic ecosystems of Kartajirri Wuntu (Duck Creek)		
Surface Water Quality	1. *Toxicant*: The bioavailable concentration also exceeds the SSTV, discharge water is likely to be the cause of the exceedance and expert advice indicates an increased risk to biota. *Stressor:* A significant upward trend is apparent, discharge water is likely to be the cause of the exceedance and expert advice indicates an increased risk to biota.	
Aquatic Fauna (Macroinvertebrate Assemblage)	2. A statistically significant decrease in macroinvertebrate taxa diversity is evident at a zone for three or more consecutive monitoring events, compared to baseline reference data, attributed to the Project.	
Aquatic Fauna (Fish Assemblage)	3. An absence of new recruits and juveniles of Western Rainbowfish or Spangled Perch is evident, based on size class data, at a zone for two consecutive monitoring events, attributed to the Project. OR 4. A statistically significant decrease in fish taxa diversity is evident at a zone for three or more consecutive monitoring events, compared to baseline and reference data, attributed to the Project.	

Table 3-3: Nammuldi-Silvergrass MMP irreversible impact provisions reporting table for GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)

Key environmental factors: Flora and Vegetation – GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)			
Indicator	**Environmental Criteria**		**Reporting periods 1 January-31 December**
Irreversible Impact Criteria:			**Status report:** **Irreversible impact criteria not exceeded** **Irreversible impact criteria exceeded**
Death of Mature Trees	1.	Death of 30% of mature trees (where DBH >30 cm)[14] is evident at a site, compared to baseline and reference data, attributed to the Project.	
Native Perennial Understorey Cover	2.	A ≥50 % loss of native perennial understorey and ground cover is evident across all sites compared to baseline and reference data, attributed to the Project.	
Weed Understorey Cover	3.	A >80% weed cover in the understorey by weed species not previously recorded within the project area and identified as having High Ecological Impact and Low Feasibility of Control under the DPaW (2013) weed prioritisation for the Pilbara Bioregion.	

4. ADAPTIVE MANAGEMENT AND REVIEW

The *Conceptual Framework for the Development of Rio Tinto Environmental Management Plans* provides details of the review and adaptive management process. This approach, will include (although is not limited to) evaluation of the following:

- monitoring data and comparison to baseline and reference site data on a regular basis to verify responses to potential impacts;
- the effectiveness and relevance of trigger and threshold criteria against environmental outcomes, on an annual basis, to determine if any changes to the criteria or monitoring is required; and
- The effectiveness and relevance of management actions and targets against environmental objectives, on an annual basis, to determine if any changes to actions, targets or monitoring are required.

Based on the results, RTIO will update and adjust environmental criteria, management measures and strategies, monitoring programs or response actions in consultation and following approval from the DWER.

5. STAKEHOLDER CONSULTATION

The Proponent has a long-term commitment to working with Pilbara communities and recognises that local communities have a direct interest in their activities. Substantial community consultation and public review of existing and proposed future operations at the Mt Brockman, Nammuldi and Silvergrass Iron Ore Mines has occurred as part of environmental approval processes. Community consultation will continue to be undertaken to keep relevant communities up-to-date.

During the compilation of the Public Environmental Review for the Nammuldi Below Water Table Project (NBWT) (MS 925), consultation was undertaken with the following stakeholders:

- Office of the Environmental Protection Authority (EPA)
- Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA):
- Department of Water and Environment Regulation (DWER) - Pilbara regional office (Karratha) and Perth
- Department of Minerals and Petroleum (now DEMIRS)
- Department of Indigenous Affairs (DIA)
- Department of Water (DoW) – Pilbara regional office (Karratha) and Perth office (now DWER)
- Shire of Ashburton
- Conservation Council of Western Australia
- Eastern Guruma People (now Muntulgura Guruma People)

5.1 Regulatory Consultation

Consultation with regulators relevant to this MMP are presented in Table 5-1.

Table 5-1: EPA / DWER Engagement relevant to this MMP.

Date	Engagement Details
April 2021	Rio Tinto briefing to EPA Services of Rio Tinto's intention to implement SGE MAR, including intention to update the MS 925 Monitoring and Management Plan (MMP) and seek the necessary secondary approvals to support MAR implementation. No opposition to Rio Tinto's approach raised by EPA Services.
May 2021	Rio Tinto briefing to DWER Compliance Branch of Rio Tinto's intention to implement SGE MAR, including intention to update the MS 925 MMP and seek the necessary secondary approvals to support MAR implementation. No opposition to Rio Tinto's approach raised by DWER Compliance Branch.
March 2022	Rio Tinto submitted the updated MS 925 MMP to DWER.
August 2023	Rio Tinto received DWER comments on the updated MS 925 MMP.
Throughout 2023	Ongoing discussions between Rio Tinto and EPA Services regarding Rio Tinto's intention to implement SGE MAR and intended approval pathway (as presented to EPA Services and DWER in April/May 2021 briefing sessions).
November 2023	Meeting with EPA Chair and Executive Director to advise of Rio Tinto's intention to implement SGE MAR, and to seek alignment on Rio Tinto's intended approval pathway and agree timeframes for progressing. EPA Chair did not oppose Rio Tinto's intended approval pathway (as originally presented to EPA Services and DWER in 2021) and suggested timely progress should be achievable.
Q1 2024	Ongoing discussions between Rio Tinto and EPA Services regarding progress of Rio Tinto's intended approval pathway as topic was a standing item on monthly meeting agenda.
April 2024	Email confirmation from EPA Services that they had advised DMA's that they are not constrained by s.41(3) of the EP Act from progressing secondary approval applications required to support implementation of SGE MAR.

5.2 Aboriginal Heritage Consultation

The Project Area is located within the traditional lands of the Muntulgura Guruma people. The identification and management of cultural heritage within the traditional lands of the Muntulgura Guruma people is in accordance with the principles and practices outlined within Rio Tinto's Communities and Social Performance Guidelines, the Rio Tinto Cultural Heritage Group Procedure, and the heritage protocols within the Participation Agreement and Indigenous Land Use Agreement.

RTIO regularly consults with Traditional Owners on the protection and management of cultural heritage sites within their country. Matters relevant to the Muntulgura Guruma People are discussed at monthly board meetings and ad hoc engagements as required (Table 5-2).

Table 5-2: Muntulgura Guruma people engagement relevant to this MMP.

Date	Engagement Details with WGAC
25/02/2021	Introduced SGE MAR to the Board.
07/04/2021	Further discussions about SGE MAR with the Board
24/05/2021	RTIO letter to WGAC in response to Brockman Syncline Proposal Social Surroundings Report including queries relating to SGE MAR.
24/11/2022	Discussed SGE MAR with the Board including Section 18 Heritage approvals, proposed design, trial and pipeline options.
11/07/2023	Shared Silvergrass East Operational Water Update with WGAC that outlined the groundwater operating strategy addendum relating to the SGE dewatering pause.
20/09/2023	Shared SGE MAR project update and next steps with WGAC Board including progress, design, Heritage, water quality and timelines.
12/01/2024	Discussed heritage survey component of the SGE MAR with WGAC staff. Including a commitment to share the H3 risk assessment (WSP 2024) for review.
06/02/2024	Updated WGAC Board that the dewatering of SGE BWT pits had been paused. Discussed that for below water table mining to re-commence there would need to be a level of comfort from the SGE MAR to be implemented.
15/02/2024	Shared draft H3 risk assessment for SGE MAR with WGAC for review.
26/02/2024	Discussed SGE MAR H3 risk assessment with WGAC environmental staff.
10/05/2024	Completed Ethnographic Heritage survey of the SGE MAR project area with Muntulgura Guruma. This included infield discussions with RTIO hydrogeological SME.
22/05/2024	Presented at the WGAC Board meeting on the SGE MAR approval process and discussed queries relating to water quality as well as pipeline alignment.
31/05/2024	Received support from WGAC Board to proceed with the SGE MAR scheme as presented on the 31/05/2024 (email).
23/07/2024	Shared email update to WGAC on SGE MAR design and planning process including planned drilling locations and clearing estimates.
Future Engagement	
October 2024	Share draft Nammuldi-Silvergrass Expansion MMP with WGAC
October 2024	Present Nammuldi-Silvergrass Expansion MMP to WGAC Representatives
November 2024	WGAC board meeting

6. PUBLIC AVAILABILITY OF DATA

Rio Tinto will ensure the public availability of data in line with Condition 5 of MS925 and the OEPA Post Assessment Guideline 4 “Making Information Publicly Available”. All information and/or documentation required to be made publicly available, where no exemption is in place, will be made available to stakeholders, including members of the public, upon request and within 7 days of the proponent receiving the request.

7. CHANGES TO THE MMP

Updates to the MMP will be undertaken in line with Section 4.

Table 7-1: Changes to the Nammuldi-Silvergrass MMP

Complexity of Changes	**Minor Revisions** ☐		**Moderate Revisions** ☐	**Major Revisions** ☐
Number of Key Environmental Factors	**One** ☐		**Two – Three** ☐	**> Three** ☐
Date Revision submitted to EPA: DD/MM/YYYY				
Proponent's Operational Requirement Timeframe for approval of revision **Reason for Timeframe:**	**< One Month** ☐	**< Six Months** ☐	**> Six Months** ☐	**None** ☐
Item No.	**MMP Section No.**	**MMP Page No.**	**Summary of Change**	**Reason for Change**

8. REFERENCES

ANZG. (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia.

Astron. (2016). Nammuldi Creeks Riparian Vegetation Monitoring. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2017a). Nammuldi Creeks Riparian Vegetation Monitoring. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2017b). Remote Sensing of Riparian Vegetation Background and Methods. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2018a). Nammuldi Creeks Riparian Vegetation Monitoring Program. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2018b). Remote Sensing of Riparian Vegetation – Nammuldi, November 2018. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2019a). Cave and Duck Creeks Discharge Vegetation Monitoring Program. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2019b). Remote Sensing of Riparian Vegetation – Nammuldi, May 2019. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2020). Remote Sensing of Riparian Vegetation – Nammuldi, March 2020. Unpublished report prepared for RTIO, Perth, Western Australia.

Astron. (2021). Rhodes Ridge Targeted Northern Quoll Fauna Assessment. Unpublished report prepared for Rio Tinto Iron Ore.

Astron. (2022a). Remote Sensing of Riparian Vegetation Nammuldi November 2022. Unpublished report prepared for Rio Tinto, Perth, Western Australia.

Astron. (2022b). West Pilbara Discharge Riparian Vegetation Monitoring Duck and Caves Creeks May-June 2021. Unpublished report prepared for Rio Tinto, Perth, Western Australia.

Astron. (2023). Remote Sensing of Riparian Vegetation Background and Methods. Unpublished report prepared for RTIO, Perth, Western Australia.

Barker, P. (2001). A technical manual for vegetation monitoring. Citeseer,

Bice, C. M., Gehrig, S. L., Zampatti, B. P., Nicol, J. M., Wilson, P., Leigh, S. L. and Marsland, K. (2014). Flow-induced alterations to fish assemblages, habitat and fish–habitat associations in a regulated lowland river. *Hydrobiologia* 722(1): 205-222.

Biologic. (2021a). Brockman Syncline Proposal - Baseline Groundwater Dependent Ecosystem Exposure Assessment for the Greater Brockman Operations. Unpublished report prepared for RTIO, Perth, Western Australia.

Biologic. (2021b). Brockman Syncline Riparian Vegetation Survey Duck Creek. Unpublished Report Prepared for Rio Tinto, Perth, Western Australia.

Biota. (2010). Greater Nammuldi Creeks Monitoring Report on Riparian Vegetation. Unpublished report prepared for RTIO, Perth, Western Australia.

Biota. (2011). Greater Nammuldi Creeks Monitoring Report on Riparian Vegetation. Unpublished report prepared for RTIO, Perth, Western Australia.

Biota. (2012). Greater Nammuldi Creeks Monitoring: Report on Riparian Vegetation. Unpublished report prepared for Rio Tinto.

Biota. (2014). Nammuldi Creeks Riparian Vegetation Monitoring: Phase 4. Unpublished report prepared for RTIO, Perth, Western Australia.

Biota. (2015). Nammuldi Creeks Riparian Vegetation Monitoring: Phase 5. Unpublished report prepared for RTIO, Perth, Western Australia.

Bray, D. J. and Thompson, V. J. (2024). Fishes of Australia. Museums Victoria and OzFishNet. Available online at http://fishesofaustralia.net.au/. Accessed on 27 June.

Canton, S. P., Bergstedt, L. C., Chadwick, J. W. and Conklin. (2005). The importance of identifying natural variation in aquatic communities: the Thompson Creek Molybdenum Mine example.

Cheal, F., Davis, D. A. and Growns, J. E. (1993). Relationships between macroinvertebrates and environmental variables. In: J. A. Davis, R. S. Rosich, J. S. Bradley, J. E. Growns, L. G. Schmidt and F. Cheal (eds) Wetland classification on the basis of water quality and invertebrate community data, vol Wetlands of the Swan Coastal Plain Volume 6. Water Authority of Western Australia, pp 171-190

Davis, J., Horwitz, P., Norris, R., Chessman, B., McGuire, M. and Sommer, B. (2006). Are river bioassessment methods using macroinvertebrates applicable to wetlands? *Hydrobiologia* 572: 115-128.

Doody, T., Hancock, P. and Pritchard, J. (2019). Information Guidelines Explanatory Note: Assessing groundwater-dependent ecosystems. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2019.

DPaW, Department of Parks and Wildlife. (2013). Weed Prioritisation Process for DPaW (formerly DEC) – "An integrated approach to Weed Management on DPaW-managed lands in WA".

Dunlop, J. E., Horrigan, N., McGregor, G., Kefford, B. J., Choy, S. and Prasad, R. (2008). Effect of spatial variation on salinity tolerance of macroinvertebrates in Eastern Australia and implications for ecosystem protection trigger values. *Environmental Pollution* 151(3): 621-630.

Elzinga, C. L. and Salzer, D. W. (1998). Measuring & monitoring plant populations. US Department of the Interior, Bureau of Land Management,

Elzinga, C. L., Salzer, D. W., Willoughby, J. W. and Gibbs, J. P. (2001). Monitoring plant and animal populations: a handbook for field biologists. John Wiley & Sons,

EPA, Environmental Protection Authority. (2016). Technical Guidance: Flora and Vegetation Surveys for Environmental Impact Assessment. Government of Western Australia, Perth, Western Australia.

EPA, Environmental Protection Authority. (2024a). Nammuldi-Silvergrass Expansion Project. Available online at https://www.epa.wa.gov.au/proposals/nammuldi-silvergrass-expansion-project. Accessed on.

EPA, Environmental Protection Authority. (2024b). Nammuldi—Silvergrass Iron Ore Project, 55 km north-west of Tom Price. Available online at https://www.epa.wa.gov.au/proposals/nammuldi%E2%80%94silvergrass-iron-ore-project-55-km-north-west-tom-price. Accessed on.

Froend, R. and Sommer, B. (2010). Phreatophytic vegetation response to climatic and abstraction-induced groundwater drawdown: Examples of long-term spatial and temporal variability in community response. *Ecological Engineering* 36(9): 1191-1200.

Horwitz, P., van Etten, E., Sommer, B., Loomes, R. and Clark, V. (1999). Survey of receiving wetlands, and impacts of dewatering discharge for the Cuddingwarra prospect. A report prepared for Wirralie Gold Mines Pty Ltd. Centre for Ecosystem Management, Edith Cowan University, Perth, Western Australia.

Hose, G. C., Dabovic, J., Nelson, T., Pollitt, L. and Korbel, K. L. (2021). Groundwater Dependent Aquatic and Terrestrial Ecosystems*. In: Reference Module in Earth Systems and Environmental Sciences. Elsevier

IUCN. (2024). *The IUCN Red List of Threatened Species.* Version 2024-1.

Jähnig, S. C., Lorenz, A. W. and Hering, D. (2009). Restoration effort, habitat mosaics, and macroinvertebrates—does channel form determine community composition? *Aquatic Conservation: Marine and Freshwater Ecosystems* 19(2): 157-169.

Jakeman, A. J., Barreteau, O., Hunt, R. J., Rinaudo, J.-D. and Ross, A. (2016). Integrated Groundwater Management: Concepts, Approaches and Challenges. *Springer Open*: E1-E1.

Kennard, M. J., Pusey, P. D., Arthington, A. H., Harch, B. D. and MacKay, H. (2006). Development and application of a predictive model of freshwater fish assemblage composition to evaluate river health in eastern Australia. *Hydrobiologia* 572: 33-57.

McKenzie, N. L., van Leeuwen, S. and Pinder, A. M. (2009). Introduction to the Pilbara Biodiversity Survey, 2002-2007. *Records of the Western Australian Museum Supplement* 78: 3-89.

Pinder, A. M., Halse, S. A., Shiel, R. J. and McRae, J. M. (2010). An arid zone awash with diversity: patterns in the distribution of aquatic invertebrates in the Pilbara region of Western Australia. *Records of the Western Australian Museum* Supplement 78: 205-246.

Qi, J., Chehbouni, A., Huete, A. R., Kerr, Y. H. and Sorooshian, S. (1994). A modified soil adjusted vegetation index. *Remote Sensing of Environment* 48: 119-126.

Resh, V. H., Norris, R. H. and Barbour, M. T. (1995). Design and implementation of rapid assessment approaches for water resource monitoring using benthic macroinvertebrates. *Australian Journal of Ecology* 20: 108-121.

RTIO, Rio Tinto Iron Ore. (2017). Brockman 2 and Nammuldi Mine Closure Plan. Perth, Western Australia.

RTIO, Rio Tinto Iron Ore. (2018a). Environmental Protection Act 1986 (WA) Part IV Ministerial Statement - Annual Compliance Assessment Report.

RTIO, Rio Tinto Iron Ore. (2018b). Silvergrass East Closure Plan. Perth, Western Australia.

RTIO, Rio Tinto Iron Ore. (2019). Environmental Protection Act 1986 (WA) Part IV Ministerial Statement - Annual Compliance Assessment Report.

RTIO, Rio Tinto Iron Ore. (2020). Environmental Protection Act 1986 (WA) Part IV Ministerial Statement - Annual Compliance Assessment Report.

RTIO, Rio Tinto Iron Ore. (2021). Environmental Protection Act 1986 (WA) Part IV Ministerial Statement - Annual Compliance Assessment Report.

RTIO, Rio Tinto Iron Ore. (2022). Environmental Protection Act 1986 (WA) Part IV Ministerial Statement - Annual Compliance Assessment Report.

Ruprecht, J. and Ivanescu, S. (2000). Surface hydrology of the Pilbara region: summary report. In: Surface Water Hydrology Report Series. Report SWH 32. Water and Rivers Commission. Perth, WA.

Ryan, B. and Joiner, B. L. (2001). Minitab Handbook. Duxbury Press, Pacific Grove, California.

SLR. (2023). Greater Brockman Operations - Rio Tinto (WA) Environment Operations Site Specific Water Quality Guidelines Review. Unpublished report prepared for RTIO, Perth, Western Australia.

SLR. (2024). DRAFT Nammuldi - Silvergrass Project Aquatic Fauna Monitoring – Wet & Dry Season 2023. Unpublished report prepared for RTIO, Perth, Western Australia.

Souter, N. J., Watts, R. A., White, M. G., George, A. K. and McNicol, K. J. (2009). Method manual for the visual assessment of Lower River Murray floodplain trees. River Red Gum (*Eucalyptus camaldulensis*). DWLBC Report 2009/025, DWLBC Report 2009/025, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Stantec. (2024a). DRAFT Nammuldi Silvergrass Iron Ore Project - Monitoring and Management Plan: Indicator Memorandum. Unpublished report prepared for RTIO, Perth, Western Australia.

Stantec. (2024b). DRAFT Nammuldi Silvergrass Iron Ore Project - Monitoring and Management Plan: Rationale Memorandum. Unpublished report prepared for RTIO, Perth, Western Australia.

Stone, C., Coops, N. and Culvenor, D. (2000). Conceptual Development of a Eucalypt Canopy Condition Index Using High Resolution Spatial and Spectral Remote Sensing Imagery. *Journal of Sustainable Forestry* 11(4): 23-45.

Storey, A. W., Halse, S. A., Shiel, R. J. and Creagh, S. (2011). Aquatic fauna and water chemistry of the mound springs and wetlands of Mandora Marsh, north-western Australia. *Journal of the Royal Society of Western Australia* 94: 419-437.

Strategen. (2012). Nammuldi-Silvergrass Expansion Project - Public Environmental Review. Perth, Western Australia.

Taukulis, F. E. (2016). Dewatering discharge in the Goldfields: ecology, monitoring, management and mitigation. Goldfields Environmental Management Group, Kalgoorlie.

Taukulis, F. E., Hay, B. L. and Puglisi, J. M. (2014). A 10 year overview of the ecological effects associated with dewatering discharge to Lake Carey. Goldfields Environmental Management Group, Kalgoorlie.

Taukulis, F. E., Thomas, E., Puglisi, J., de Silva, T. and Krassoi, R. (2021). Assessing Metal Toxicity from Dewatering Discharge to Receiving Environments. In Goldfields Environmental Management Group Conference. Kalgoorlie, WA. City

Wallace, J. B. and Webster, J. R. (1996). The Role of Macroinvertebrates in Stream Ecosystem Function. *Annual Review of Entomology* 41: 115-139.

Waltham, N. J. and Connolly, R. M. (2007). Artificial waterway design affects fish assemblages in urban estuaries. *Journal of Fish Biology* 71(6): 1613-1629.

Water Quality Australia. (2018). Australian & New Zealand Guidelines for Fresh & Marine Water Quality.

WRM. (2011a). Nammuldi-Silvergrass Project: Baseline Assessment of Aquatic Fauna & Water Quality. Dry 2010 / Wet 2011 Survey. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2011b). Nammuldi-Silvergrass Project: Baseline Assessment of Aquatic Fauna & Water Quality. November 2009 / April 2010 Survey. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2013). Nammuldi-Silvergrass Projects - Interim Water Quality Guidelines for Dewatering Discharge. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2014). Nammuldi-Silvergrass Expansion Projects - Interim Water Quality Guidelines for Dewatering Discharge: Revision 2014. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2015a). Nammuldi-Silvergrass Expansion Project - Aquatic Fauna & Water Quality Baseline Condition Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2015b). Nammuldi Expansion Project - Aquatic Fauna & Water Quality Monitoring Duck Creek March 2014 Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2016). Nammuldi-Silvergrass Project - Aquatic Fauna & Water Quality Post-discharge Impact Assessment Duck Creek April 2015 Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2017). Nammuldi-Silvergrass Project - Aquatic Fauna & Water Quality Post-discharge Impact Assessment Duck Creek April 2016 Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2018). Nammuldi-Silvergrass Project - Aquatic Fauna & Water Quality Post-discharge Impact Assessment Duck Creek April 2017 Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2019a). Memo - Addendum to Nammuldi-Silvergrass: Post-discharge Monitoring Wet 2019 Report. Perth, Western Australia.

WRM. (2019b). Nammuldi-Silvergrass Project - Aquatic Fauna & Water Quality Post-discharge Impact Assessment Duck Creek April 2018 Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2019c). Nammuldi-Silvergrass Project - Aquatic Fauna & Water Quality Post-discharge Impact Assessment Duck Creek April 2019 Final Report. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2020a). Brockman Syncline EIA Studies - Hazard Analysis and Risk Assessment for Dewatering Discharge to Boolgeeda Creek and Duck Creek. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2020b). Brockman Syncline Expansion - Baseline Aquatic Fauna and Water Quality Survey of Caves, Duck and Boolgeeda Creeks Dry Season 2019. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2021a). Nammuldi-Silvergrass Project - Aquatic Fauna & Water Quality Post-discharge Monitoring Duck Creek & Caves Creek Dry Season 2020. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2022). Nammuldi-Silvergrass Project - Aquatic Fauna Monitoring Kartajirri “Duck Creek” & Narraminju “Caves Creek” Wet & Dry Season 2021. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM. (2023). Nammuldi-Silvergrass Project - Aquatic Fauna Monitoring Wet & Dry Season 2022. Unpublished report prepared for RTIO, Perth, Western Australia.

WRM, Wetland Research and Management. (2010). Developing trigger values as indicators of aquatic ecosystem health at Weeli Wolli Creek. Unpublished report by Wetland Research & Management to Rio Tinto Hamersley Hope Management Services.

WRM, Wetland Research and Management. (2021b). Weeli Wolli Creek - Current Ecological Condition and Future Trends. Rio Tinto,.

WSP. (2024). Caves Creek Managed Aquifer Recharge Project - H3 Hydrogeological and Risk Assessment. Unpublished report prepared for RTIO, Perth, Western Australia.

9. APPENDICES

Appendix 1: High Level Environmental and Conservation Values Statement for Kartajirri Wuntu (Duck Creek)

Table A 1: High level environmental and conservation values statement for Kartajirri Wuntu (Duck Creek).

High-Level Values	Kartajirri Wuntu (Duck Creek)
Hydrology / hydrogeology	Kartajirri Wuntu (Duck Creek) has a catchment area of approximately 6,500 km² (McKenzie *et al.* 2009; Strategen 2012), the upper reaches of which lie adjacent to Nammuldi. Kartajirri Wuntu (Duck Creek) is a largely ephemeral watercourse that supports semi-permanent to permanent pools downstream of the confluence with Narraminju Wuntu (Caves Creek), due to a combination of groundwater expression at the surface and surface water flow (WRM 2022). The creek typically has a well-defined and relatively stable drainage channel that meanders within an active floodplain and drains from east to west, ultimately converging with the Ashburton River (Strategen 2012), The major tributaries of Kartajirri Wuntu (Duck Creek) are Narraminju Wuntu (Caves Creek) and Boolgeeda Creek. The pools in Kartajirri Wuntu (Duck Creek) are situated on bedrock structures that impede hydraulic connectivity with the deep aquifer, or against cliffs where high-flow events have resulted in the creation of deeper pools due to scouring (Pinder *et al.* 2010). Upstream of the confluence with Narraminju Wuntu (Caves Creek), Kartajirri Wuntu (Duck Creek) is unlikely to contain pools sustained by large-scale aquifers based on physical characteristics but rather localised aquifers where geologies are sufficiently fractured M(Biologic 2021a). The geological layers in this area, including the MacLeod Member, Nammuldi Member, and Fortescue Group, are recognised for their lower permeability (Biologic 2021a). At Nammuldi, the pre-mining groundwater level was approximately 40 mbgl and groundwater was typically fresh (RTIO 2017; Strategen 2012).
Flora and Vegetation	The GDV communities of Kartajirri Wuntu (Duck Creek) are characterised by *Eucalyptus camaldulensis*, *Eucalyptus xerothermica* low woodland over *Acacia citrinoviridis*, *Acacia aneura* tall open shrubland, over *Triodia epactia* very open hummock grassland. *Melaleuca argentea* also occurs along Kartajirri Wuntu (Duck Creek) but at lower densities than Narraminju Wuntu (Caves Creek) (Strategen 2012). However, Kartajirri Wuntu (Duck Creek) exhibits higher densities of *Eucalyptus camaldulensis* than Narraminju Wuntu (Caves Creek). Groundwater dependence of vegetation in Kartajirri Wuntu (Duck Creek) has been classified using a tiered structure (Biologic 2021a). High density obligate GDV communities, generally coinciding with shallow groundwater of 0-4 m below ground level (mbgl) are classified as tier 1, small to large scale GDV communities with groundwater occurring ≤ 5 m from the surface are classified as tier 2 while smaller, facultative GDV communities where groundwater typically occurs between 5-10 mbgl are classified as tier 3. The majority of upper Kartajirri Wuntu (Duck Creek) host tier 3 GDVs but shifts into tier 2 GDV communities approximately 9 km from the confluence with Narraminju Wuntu (Caves Creek) (Biologic 2021a). The three dominant riparian tree species of *Eucalyptus camaldulensis*, *Eucalyptus victrix*, and *Melaleuca argentea* have varying dependence on groundwater. *Melaleuca argentea* is classified as an obligate phreatophyte and almost exclusively reliant on groundwater. The species is therefore regarded as the best indicator of shallow groundwater levels. *Eucalyptus camaldulensis* and *Eucalyptus victrix*, classified as facultative phreatophytes, can utilise water from a range of different sources including rainfall, floodwater, or stored soil water and are therefore only partially reliant on groundwater (Biologic 2021a). In addition to these phreatophytic tree species, other mesophytic mid- and understorey species indicative of surface or sub-surface water have also been recorded from the creek. These include *Sesbania formosa, Livistona alfredii* (P4) and *Samolus* sp. Millstream (M.I.H. Brooker 2076)*, Acacia ampliceps, Cullen leucanthum, Gymnanthera cunninghamii* and *Melaleuca bracteate* (Biologic 2021b). It is important to note that understorey and midstorey vegetation may be subject to short-term climatic changes rather than groundwater changes, largely due to their smaller root systems that may not reach the groundwater aquifer. However, vegetation groups present in a riparian system can be a longer-term indicator of groundwater proximity and surface water permanence (Biologic 2021b). Three vegetation units are considered to have higher local significance due to the presence of permanent water, *Livistona alfredii* (P4) and the obligate GDV species *Melaleuca argentea.* 1. Eucalyptus victrix and *Eucalyptus camaldulensis* subsp. *refulgens* woodland to open forest over *Acacia coriacea* subsp. *pendent*, *Acacia citrinoviridis* and *Melaleuca glomerate* tall open shrubland to tall shrubland over a very open mixed tussock grassland. This vegetation unit predominately occurs in the upper reaches of Kartajirri Wuntu (Duck Creek). Semi-permanent and permanent pools occur in association with this vegetation. 2. *Eucalyptus camaldulensis* subsp. *refulgens* woodland to open forest over *Acacia coriaces* subsp. *pendens*, *Acacia citrinoviridis* and *Melaleuca glomerate* tall open shrubland to tall shrubland over *Cyperus vaginatus* open sedgeland. This vegetation occurs downstream of the confluence of Duck and Narraminju Wuntu (Caves Creek). Scattered juvenile *Livistona alfredii* palms occur within this vegetation unit. 3. Eucalyptus victrix and *Eucalyptus camaldulensis* subsp. *refulgens* woodland to open woodland over *Melaleuca argentea*, *Acacia citrinoviridis* low open woodland to scattered low trees over *Melaleuca linophylla* with scattered *Cenchrus* spp. Over 250 native vascular flora taxa have been recorded at Kartajirri Wuntu (Duck Creek) and its tributaries (Biologic 2021b). Ten priority species have been previously recorded at the creek, including *Aristida lazaridis* (P2), *Ipomoea racemigera* (P2*), Gymnanthera cunninghamii* (P3), *Indigofera* sp. Bungaroo Creek (S. van Leeuwen 4301) (P3), *Livistona alfredii* (P4), *Rhynchosia bungarensis* (P4), *Eragrostis surreyana* (P3), *Glycine falcata* (P3), *Oxalis* sp. *Pilbara* (M.E. Trudgen 12725) (P2) and *Sida* sp. Hamersley Range (K. Newbey 10692) (P3) (Astron 2022b; Biologic 2021b).
Fauna	The riparian woodland and ephemeral nature of Kartajirri Wuntu (Duck Creek) provides habitat for a range of fauna, including terrestrial, avian, aquatic and subterranean. Assemblages include aquatic fauna (micro and macro invertebrates and fish) and animals of the hyporheic zone. The creek contains semi-permanent and permanent pools that act as refugia for aquatic fauna. Three IUCN-listed species (Near Threatened) occur at Kartajirri Wuntu (Duck Creek): • Fortescue grunter *Leiopotheran aheneus*; • Pilbara emerald dragonfly *Hemicordulia koomina*; and • Pilbara pin damselfly *Eurysticta coolawanya*. Species considered restricted to the hyporeos include the stygobitic amphipods *Melitidae* sp., and *Paramelitidae* sp., and the candonid ostracods *Areacandona* sp. Each of these species also occurs in adjoining Narraminju Wuntu (Caves Creek) and/or the nearby Beasley River. In general, the aquatic faunal communities of seasonal waterbodies along Kartajirri Wuntu (Duck Creek) downstream of the discharge point are well represented by communities upstream and in nearby Narraminju Wuntu (Caves Creek), Boolgeeda Creek and the Beasley River. Aquatic faunal communities of downstream permanent and semi-permanent water bodies are well represented by communities at Mallu Mallu (Palm Springs) and in the lower reaches of Narraminju Wuntu (Caves Creek) and at other permanent regional reference sites within the Pilbara.

Appendix 2: Description of Indicative Monitoring Programs

Management Zones

For environmental management purposes, Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) have been divided into several zones (Table A 2). These zones differ for the key environmental factors of Flora and Vegetation and Inland Waters and applicable monitoring.

Table A 2: Environmental management zones of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) for key environmental factors.

Creek	Flora and Vegetation Zones		Inland Waters Zones
	On-ground Monitoring	Remote Sensing	
Narraminju Wuntu (Caves Creek)	Upper Caves		N/A
	Homestead		N/A
	Palm Springs		N/A
	Reference		N/A
Kartajirri Wuntu (Duck Creek)	Upper Duck East		Duck Creek Upstream
	Upper Duck West		
	Downstream Duck	Downstream Duck East[15]	Duck Creek Downstream
		Downstream Duck West[16]	
	Reference Tributaries		Reference Tributaries

Flora and Vegetation

Vegetation Abundance, Foliage Cover, Death of Mature Trees, Native Perennial Understorey Cover and Weed Understorey Cover (Transect Monitoring)

Vegetation abundance (number of individuals of each taxa) and foliage cover (percentage cover), death of mature trees (percentage of mature trees where DBH >30 cm), native perennial understorey cover (percentage cover) and weed understorey cover (percentage cover) data is collected through transect monitoring from Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) as part of annual riparian vegetation monitoring, conducted by Astron since 2010 (Astron 2022b). Species that cannot be identified are collected for later identification in an herbarium. Data is recorded by experienced botanists in the field, ensuring repeatability of monitoring results.

Monitoring is undertaken in the main creek channels of both creeks as well as in two un-named tributaries of Kartajirri Wuntu (Duck Creek). A total of 25 sites have been monitored continuously since 2010 at these locations (Figure 2-1). At each monitoring site, transects have been established perpendicular to the creek channel, and consist of a series of 10 m by 10 m quadrats. The transects capture the full cross-sectional profile of the creeks and vary in length from 30 m to 260 m, depending on the width of the channel (Table A 3). Abundance is recorded for all perennial tree and shrub species that would usually grow larger than 1 m in height and for all introduced flora species present (Astron 2022b). Foliage cover is recorded on-ground as percentage cover for all vascular plant species present in a quadrat.

Sites at both creeks are grouped into four zones each, including a reference zone, that divide the creeks into subsections. For vegetation abundance and foliage cover, Kartajirri Wuntu (Duck Creek) sites D07

[15] Previously Downstream Duck DD.

[16] Previously Downstream Duck East.

and D08, classified as downstream reference sites by Astron (2022b), were grouped together with sites A01 and A02 into the Downstream Duck Zone. This regrouping was done as surface water flows, although potentially a combination of discharge and rainfall derived flows, were noted as far as ~100 km from the discharge point, indicating that these sites may share the same potential impact type (Astron 2022b). Merging of the sites also ensured a large enough dataset was available for the later data analysis as part of the criteria development (Stantec 2024b). Review of the floristic composition of D07 and D08 was undertaken to confirm that these sites were comparable to A01 and A02 in the Downstream Duck Zone.

.

Table A 3: Survey design of the annual Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) riparian vegetation monitoring survey (Astron 2021).

Location	Site	Zone	Current Site Type	Transect Length	No. of Quadrats
Narraminju Wuntu (Caves Creek)	C01	Upper Caves	Drawdown	50	5
	C03	Upper Caves	Drawdown	50	5
	C04	Upper Caves	Drawdown	30	3
	C05	Palm Springs	Drawdown	80	8
	C06	Homestead	Drawdown	100	10
	C07	Reference	Reference	50	5
	C08	Reference	Reference	50	5
	C09	Palm Springs	Drawdown	110	11
	C10	Homestead	Drawdown	50	5
	C11	Palm Springs	Drawdown	150	15
	C12	Homestead	Drawdown	30	3
	C13	Upper Caves	Drawdown	40	4
Kartajirri Wuntu (Duck Creek)	D01	Upper Duck West	Discharge	80	8
	D02	Upper Duck West	Discharge	40	4
	D03	Upper Duck East	Discharge	50	5
	D04	Upper Duck East	Discharge	60	6
	D05	Upper Duck West	Discharge	50	5
	DC01	Upper Duck East	Discharge	30	3
	D07	Downstream Duck	Potential Discharge	260	26
	D08	Downstream Duck	Potential Discharge	140	14
	A01	Downstream Duck	Potential Discharge	90	9
	A02	Downstream Duck	Potential Discharge	120	12
	E01	Reference	Reference	50	5
	E02	Reference	Reference	50	5
	T01	Reference	Reference	50	5

Foliage Cover (DCP Monitoring)

Digital Cover Photography (DCP) is a ground-based method, where vertically oriented digital photographic images are captured of the crown of targeted tree species; *Eucalyptus camaldulensis* and *Eucalyptus victrix* to record foliage and crown cover over time (Pekin and Macfarlane 2009). Mature facultative phreatophytes such as *Eucalyptus camaldulensis* and *Eucalyptus victrix* are dependent on access to groundwater or water from the capillary fringe when soil water originating from surface recharge (rainfall) becomes limited. In stressed trees, defoliation will occur and reduce both crown extent and density.

DCP monitoring has been conducted by RTIO on a biannual basis (post-wet and post-dry season) since 2007. A total of 24 sites are monitored in the main channels of both creeks as well as in three un-named tributaries of Kartajirri Wuntu (Duck Creek) (Table A 4; Figure 2-2). At each site, a total of 10 to 15 trees are monitored. Two digital photos taken at two different positions in canopy of each sample tree.

A third-party consultant analyses all captured photographs and determines the foliage cover values. Percentage change in mean foliage cover of indicator tree species across a site is assessed over time.

Table A 4: Survey design of the biannual Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) foliage cover DCP monitoring survey.

Location	Site	Zone	Current Site Type	No. of Trees
Narraminju Wuntu (Caves Creek)	1	Palm Springs	Reference	10
	2	Palm Springs	Reference	10
	3	Homestead	Reference	10
	4	Homestead	Reference	10
	5	Homestead	Reference	10
	6	Homestead	Drawdown	10
	7	Upper Caves	Drawdown	10
	8	Upper Caves	Drawdown	10
	9	Upper Caves	Drawdown	10
	10	Upper Caves	Drawdown	10
	11	Upper Caves	Drawdown	10
Kartajirri Wuntu (Duck Creek)	1	Downstream Duck	Potential Discharge	10
	2	Upper Duck West	Discharge	10
	3	Upper Duck West	Discharge	10
	4	Upper Duck West	Discharge	10
	5	Upper Duck East	Discharge	10
	6	Tributary	Reference	10
	7	Downstream Duck	Potential Discharge	15
	8	Downstream Duck	Potential Discharge	15
	9	Downstream Duck	Potential Discharge	15
	10	Downstream Duck	Potential Discharge	15
	11	Tributary	Reference	10

Location	Site	Zone	Current Site Type	No. of Trees
	12	Tributary	Reference	10
	13	Upper Duck East	Discharge	10

Canopy Extent and Canopy Condition (Remote Sensing Monitoring)

Remote sensing of riparian vegetation canopy extent and canopy condition has been conducted annually since 2017 (Astron 2022a) across Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek). Canopy extent monitoring is undertaken in the main creek channels of both creeks as well as in two un-named tributaries of Kartajirri Wuntu (Duck Creek). Remote sensing monitoring utilises a combination of high- (WorldVIew-2 (WV-2), WorldView-3 (WV-3)), medium- (Sentinel-2) and coarse (Landsat) resolution satellite imagery. Each of these data sources have ranging capture periods, with Landsat and Sentinel-2 having freely accessible data from 1986 or 2015 to current respectively, and WV-2 and WV-3 from 2017. The image resolution of each satellite varies, with resolution ranging from 30m (Landsat), 10m (Sentinel-2) and 40cm/1.6m (WV-2 and WV-3). In addition to the satellite imagery, Digital Multispectral Imagery (DMSI) is available from 2008 to 2015 for most monitoring zones. Though captured at a high resolution (1-2m), no spectral calibration was completed during the imagery pre-processing, hence no spectral indices can be applied to the imagery to extract baseline photosynthetic condition and compare overtime. The imagery is only used to extract a likelihood layer of overstorey phreatophyte canopy extent (i.e., *Eucalyptus camaldulensis*, *Eucalyptus victrix* and *Melaleuca argentea*).

To extract phreatophyte canopy extent across all monitoring zones, a machine learning algorithm, using high resolution multi-spectral imagery, is applied. The algorithm utilises vegetation indexes, threshold to likely overstorey phreatophytes and other input layers to train the classification. An accuracy assessment is completed, and classification further refined as required (Astron 2022a). The classification is applied to each year, resulting in an annual overstorey phreatophyte canopy extent for each monitoring zone which is used to extract trends in photosynthetic condition for each monitoring zone.

Canopy condition i.e., the photosynthetic radiation emitted by plants, is collected for all overstorey phreatophytes identified within the canopy extent. Long-term canopy condition data are extracted from high resolution satellite images (WorldView-3) between 2017 to 2023 and from multi-temporal sensors (Landsat & Sentinel) between 1987 to 2017. The Modified Soil Vegetation Index (MSAVI) is used to quantify canopy condition and data were subsequently aggregated and reported on nine survey zones throughout Narraminju Wuntu (Caves Creek), Kartajirri Wuntu (Duck Creek), and the identified tributaries (Table A 5; Figure 2-3). Other environmental factors, such as fire extent and rainfall distribution are assessed as part of the annual monitoring.

Table A 5: Survey zones of the annual Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) remote sensing monitoring.

Location	Zone	Reach	Current Site Type
Narraminju Wuntu (Caves Creek)	Upper Caves	Upper Caves	Potential Impact
	Reference	Upper Caves	Reference
	Homestead	Lower Caves	Potential Impact
	Palm Springs	Lower Caves	Potential Impact
Kartajirri Wuntu (Duck Creek)	Upper Duck East	Upper Duck	Potential Impact
	Upper Duck West	Upper Duck	Potential Impact
	Downstream Duck East[17]	Lower Duck	Potential Impact
	Downstream Duck West[18]	Lower Duck	Potential Impact
	Reference Tributaries	Tributary	Reference

[17] Previously Downstream Duck DD.

[18] Previously Downstream Duck East.

Groundwater Level

Groundwater monitoring bores are located near Silvergrass and along Narraminju Wuntu (Caves Creek), with water levels monitored continuously to intermittently since 2010. A total of 22 bores, separated into four clusters, are located within the main channel of Narraminju Wuntu (Caves Creek) (Table A 6). The bores in each cluster have been installed across the creek (perpendicular to the channel) and are located at an increasing distance downstream from the Nammuldi-Silvergrass development envelope (Figure 2-4).

Cluster 1 is located closest to the Nammuldi-Silvergrass development envelope approximately 7 km downstream, cluster 2 ~14 km, cluster 3 ~18 km, and cluster 4 ~22 km. The proposed recharge location for the MAR scheme is near the first cluster, approximately 7 km downstream from Silvergrass (Figure 2-4). Groundwater level monitoring comprises continuous data collection via loggers installed at each groundwater bore, with data downloaded regularly or transferred via telemetry and the results presented as part of the ACAR.

Table A 6: Groundwater monitoring bores within the main channel of Narraminju Wuntu (Caves Creek).

Cluster 1	Cluster 2	Cluster 3	Cluster 4
MB11SILV023	MB11SILV016	MB11SILV009	MB11SILV001
MB11SILV024	MB11SILV017	MB11SILV010	MB11SILV002
MB11SILV025	MB11SILV018	MB11SILV013	MB11SILV003
MB11SILV027	MB11SILV019	MB11SILV014	MB11SILV004
MB11SILV028	MB11SILV021		MB11SILV005
			MB11SILV006
			MB11SILV007
			MB11SILV008

Inland Waters

Surface Water Quality

Surface water quality is monitored monthly by RTIO at the discharge point (Site 1; DP13NAM001) (Figure 2-5), undertaken since 2013. In addition, as part of the current aquatic fauna monitoring program, undertaken by SLR (previously WRM), water quality is monitored annually or biannually at 19 sites in Kartajirri Wuntu (Duck Creek) (Table A 7). Of these, 11 sites are located upstream of the confluence with Narraminju Wuntu (Caves Creek), four sites are located downstream of the confluence, and four sites are located within the tributaries of Kartajirri Wuntu (Duck Creek), with a further eight regional reference sites located in nearby creeklines (Table A 7, Figure 2-5). The frequency of surface water quality monitoring comprises biannual from 2010 to 2012, annual data from 2009 to 2013.

Surface water quality monitoring was undertaken using standardised methods including *in situ* measurements of general parameters such as dissolved oxygen (% and mg/L), temperature and pH, and gulp water samples for analysis of major ions, conductivity, dissolved metals and nutrients. Metals and nutrient samples are field filtered (using 0.45 µm Millipore nitrocellulose filters) prior to analysis, and all samples analysed by a NATA-accredited laboratory.

The SSTVs for surface water quality were developed for Kartajirri Wuntu (Duck Creek) in 2014, using baseline and regional reference data (WRM 2013; 2014), and were subsequently revised in 2023 (SLR 2023). Surface water quality data have routinely been compared to the SSTVs and the Water Quality Australia (2018) default guideline values (DGVs), where applicable, with the results presented as part of the ACAR. The revised SSTVs developed by SLR (2023) are presented in Appendix 5.

Table A 7: Kartajirri Wuntu (Duck Creek) aquatic monitoring program survey design.

Location	Site	Reach	Current Site Type	Frequency
Kartajirri Wuntu (Duck Creek)	DP13NAM001	Duck Creek Discharge Point	Discharge	Monthly
	DCU1	Duck Creek Upstream	Discharge	2009 – 2013: Annual 2010 – 2012: Biannual 2014 – 2018: Annual 2019: Biannual 2021: Biannual 2020: Annual 2022 – 2023: Annual
	DCU2	Duck Creek Upstream	Discharge	
	DCU3	Duck Creek Upstream	Discharge	
	DCU4	Duck Creek Upstream	Discharge	
	DCU5	Duck Creek Upstream	Discharge	
	DCU6	Duck Creek Upstream	Discharge	
	DCU7	Duck Creek Upstream	Discharge	
	DCU10	Duck Creek Upstream	Discharge	
	DCU11	Duck Creek Upstream	Discharge	
	DCU11B	Duck Creek Upstream	Discharge	
	DCU12	Duck Creek Upstream	Discharge	
	DCD1	Duck Creek Downstream	Discharge	
	DCD2	Duck Creek Downstream	Discharge	
	DCD3	Duck Creek Downstream	Discharge	
	DCD7	Duck Creek Downstream	Discharge	
	DCUT1	Duck Creek Tributaries	Reference	

Location	Site	Reach	Current Site Type	Frequency
	DCDT1	Duck Creek Tributaries	Reference	
	DCDT1B	Duck Creek Tributaries	Reference	
	DCDT2	Duck Creek Tributaries	Reference	

Aquatic Fauna (Macroinvertebrate Monitoring)

Macroinvertebrates have been monitored at 19 sites in Kartajirri Wuntu (Duck Creek) on an annual or biannual basis as part of the aquatic fauna monitoring program undertaken by SLR (previously WRM). Of these, 11 sites are located upstream of the confluence with Narraminju Wuntu (Caves Creek), four sites are located downstream of the confluence, and four sites are located within the tributaries of Kartajirri Wuntu (Duck Creek), with a further eight regional reference sites located in nearby waterways (Table A 7, Figure 2-5). The frequency of macroinvertebrate monitoring comprises biannual from 2010 to 2012, annual data from 2009 to 2013.

Macroinvertebrate monitoring currently comprises of kick/sweep sampling over a standardised (10 m) distance, using a 250 µm Freshwater Biological Association (FBA) 'D' frame style dip net, covering all habitats at each site. Each sample is washed through a 250 µm sieve, transferred to a 1L polypropylene container and preserved in 70% ethanol for laboratory enumeration and identification. Samples are sorted under a low-power dissecting microscope, collected specimens identified to lowest level of taxonomic resolution, where possible, and enumerated to log10 scale abundance classes.

Aquatic Fauna (Fish Monitoring)

The fish assemblage has been monitored from 19 sites in Kartajirri Wuntu (Duck Creek) on an annual or biannual basis as part of the aquatic fauna monitoring program undertaken by SLR (previously WRM). Of these, 11 sites are located upstream of the confluence with Narraminju Wuntu (Caves Creek), four sites are located downstream of the confluence, and four sites are located within the tributaries of Kartajirri Wuntu (Duck Creek), with a further eight regional reference sites located in nearby creeklines (Table A 7, Figure 2-5). The frequency of fish monitoring comprises biannual from 2010 to 2012, annual data from 2009 to 2013.

Fish monitoring currently comprises of two standard fishing methods: seine and gill netting. Gill nets consist of light-weight fine mesh gill nets with 10 m net length, 2 m drop and four mesh sizes (10 mm, 13 mm, 19 mm, and 25 mm). These are set in deeper water for a set duration at each site, checked and cleared every 15-20 minutes, or as frequently as required. A beach seine is used to target smaller species and juveniles, consisting of a 12 m net length, 2 m drop and 6 mm mesh size. The net is deployed twice at each site, by walking out from the bank and dragging the seine for a 10 m distance through shallow areas. All captured fish are identified, measured (standard length) and released in the field.

Appendix 3: Descriptions of Indicative Statistical Analyses for Management Provisions

Flora and Vegetation

Vegetation Abundance and Foliage Cover (Transect Monitoring)

Key Indicator Species Selection

Vegetation abundance and foliage cover (transect monitoring) criteria are based on key indicator species for each stratum (overstorey, midstorey and understorey). Classifications of overstorey, midstorey and understorey species is based to available literature. The selection of key indicator species for each stratum was based on the following:

- Inclusion of only native perennial flora species.
- Species with high total abundance as well as high total and average foliar cover relative to other species, which reflected dominance in vegetation abundance.
- Species with sufficient data recorded over multiple years including baseline and operational phases (2010 to 2023) to ensure a robust dataset for statistical and sensitivity analysis.
- Key riparian species identified as indicative of groundwater or perennial soil moisture availability (Biologic (2021b).

A total of 13 key indicators species are identified for the over- mid- and understorey strata of the GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek) (Appendix 4). The indicator species of the understorey stratum varied between Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek), based on the outcome of the selection criteria outlined above. Macrophytes were not selected as key indicator species as there was no robust dataset available.

Statistical Analysis

Statistical analysis of the vegetation abundance and foliage cover (transect monitoring) criteria is undertaken for the key indicator species. Quadrat data for abundance and foliage cover from 2010 to 2023 (Stantec 2024a), grouped by zones (Table A 3), are utilised for the statistical analysis. Abundance and foliage cover values are not standardised as quadrat size (10 m x 10 m) is consistent across sites and years. Any missing abundance values that have an associated foliage cover value are converted to zero as it is assumed that these records represent a plant with the stem located outside of the quadrat. The following statistical analysis are applied:

- One-way Analysis of Variance (ANOVA) testing is used to identify significant differences in the mean abundance and foliage cover of each key indicator species assessed for a monitoring year against the baseline and reference zone conditions.
- The results are interrogated and a confidence level of 95% (p value of <0.05) is considered statistically significant.
- The dataset is subjected to normality testing and where required data is transformed to reduce skewness (or testing is performed on untransformed data).
- Post-hoc testing is applied to significant results using Tukey's pairwise comparison to identify significantly differences in the abundance or foliage cover of a key indicator species in a zone from the baseline and the reference zone.
- These results are then compared to the number of significant differences identified within the vegetative stratum, to determine exceedances of the trigger or threshold criteria.

It should be noted that ANOVA testing is dependent on the data provided satisfying several assumptions including normal distribution, equality of variance, and independence and randomness. However, transect-based monitoring is rarely random or independent and the use of quadrats leads to pseudo-replication. In addition, vegetation data is also often not normally distributed, with datasets typically displaying a relatively restricted range of values for comparison of means. Regardless, ANOVA is considered a relatively robust statistical test and fulfilling normality is not necessarily important if group sizes are approximately equal (Ryan and Joiner 2001).

Foliage Cover (DCP Monitoring)

Foliage cover environmental criteria for DCP monitoring compare data from monitoring years to baseline and reference site means. Baseline means have been revised to account for seasonal variation. The baseline site means have been developed for the post-wet (March to May) and post-dry (August to November) seasons. For each site (Table A 4), a seasonal baseline mean has been calculated from 2007 to 2015 data for Narraminju Wuntu (Caves Creek) and from 2007 to 2012 for Kartajirri Wuntu (Duck Creek). No baseline data were available for Kartajirri Wuntu (Duck Creek) sites 11, 12, and 13. A seasonal mean based on all other sites was used as the baseline value for these sites. The revised baseline site means are provided in Table A-9.

Table A 8:Foliage cover using DPC monitoring revised seasonal baseline means.

Location	Site Number	Post-wet Baseline Mean	Post-dry Baseline Mean
Narraminju Wuntu (Caves Creek)	1	0.46	0.43
	2	0.46	0.45
	3	0.46	0.44
	4	0.44	0.42
	5	0.41	0.39
	6	0.50	0.50
	7	0.57	0.56
	8	0.58	0.57
	9	0.52	0.50
	10	0.47	0.45
	11	0.65	0.62
Kartajirri Wuntu (Duck Creek)	1	0.55	0.47
	2	0.50	0.47
	3	0.49	0.43
	4	0.47	0.43
	5	0.52	0.50
	6	0.49	0.41
	7	0.52	0.48
	8	0.56	0.51
	9	0.58	0.49
	10	0.60	0.55
	11	0.53	0.47

Location	Site Number	Post-wet Baseline Mean	Post-dry Baseline Mean
	12	0.53	0.47
	13	0.53	0.47

Canopy Condition (Remote Sensing)

Baseline Data Revision

Early response, trigger and threshold criteria were developed utilising the available imagery data for each of the monitoring zones. Zones are defined in Appendix 2.

For early response criteria, baseline values were developed for the post-wet (March to May) and post-dry (August to November) seasons for each monitoring zone and year using the Landsat dataset (1986 to current). A Locally Weighted Smoothing (LOESS) regression is then used to reduce seasonal effects, noise, and outliers in baseline data and establish a trend of canopy conditions across time. LOESS uses a weighted average approach to create a continuous curve, i.e., regression line, that adapts to the input data's unique structure, minimising the impact of outliers and incomplete data points. This analysis was chosen due its non-parametric nature, which allows for complex, non-linear relationships to be extracted without assuming a specific functional form. Based on the LOESS output, the median value across the trend line within baseline years was extracted and used for early response criteria testing.

Trigger and threshold criteria were developed using Sentinel-2 medium resolution imagery. As there is no high-resolution spectral information available for the monitoring zones at baseline, baseline photosynthetic condition of overstorey GDVs cannot be analysed. Though the WV datasets provide annual high-resolution dry season photosynthetic condition, there is insufficient data to extract long-term trends outside of operational years and compare to baseline. Sentinel-2 data is available from 2015 and though it does not cover the baseline years for either creek, it captures imagery every five days, allowing for local and regional seasonal trends to be determined[19]. To retain a connection to baseline conditions and ensure reliability of medium-resolution reference data, an average baseline GDV likelihood canopy extent layer (herein referred to as the baseline canopy extent layer) was developed from the available DMSI data (2008 to 2012). Machine learning methods, utilising both textural and spectral indices and appropriate training data were applied to each image to extract the canopy of likely GDV (Astron 2023). An area filter was applied to the layer to remove polygons smaller than $10m^2$ to reduce noise in the dataset. Baseline canopy extent layer was generated for all potential impact and reference zones, excluding Reference Tributaries which canopy extents were extracted from the WV dataset (Astron 2022a). These final baseline canopy extents were then used to extract canopy condition for each season, and zone. Conditions in reference zones were extracted within baseline canopy extents between 2015-2019; the median value across this time for each zone was then used as a basis for criteria testing.

Statistical Analysis

Statistical analysis of the canopy condition (MSAVI) data is undertaken to test the early response, trigger, and threshold criteria. This is conducted by using the extracted 5^{th} percentile MSAVI data within the baseline canopy extents. Sentinel 2A & 2B 5^{th} percentile MSAVI data within reference tributaries are used to test the statistical significance for trigger and threshold criteria, with MSAVI data collected from 2015 to 2022. Landsat 8 & 9 MSAVI data for baseline years are used to test the statistical significance for early response criteria. The following statistical analysis are applied:

[19] As remote sensing analysis and technology advances, new high resolution and temporal data may be more suitable for the analysis and methods revised. Rio Tinto will continue to adapt to these emerging technologies and assess the efficacy.

- ANOVA testing are used to identify significant differences in the 5th percentile MSAVI values for each season and was assessed across each zones baseline or reference value.
- The results are interrogated and a confidence level of 95% (p value of <0.05) was considered statistically significant.
- The dataset is subjected to normality testing and where required data is transformed to reduce skewness (or testing is performed on untransformed data).
- Post-hoc testing is applied to significant results using Tukey's pairwise comparison to identify in which year there is a significant difference from baseline/reference values.

It should be noted that ANOVA testing is dependent on the data provided satisfying several assumptions including normal distribution, equality of variance, and independence and randomness. Although MSAVI data was extracted out across Caves and Kartajirri Wuntu (Duck Creek) through repeated observations, the vegetation index data are inherently truncated and often deviate from a normal distribution. Therefore, the results should be interpreted considering the inherent truncation and distributional properties of the MSAVI data.

Groundwater Level

Key Indicator Bore Selection

Groundwater level criteria are based on the selection of appropriate monitoring bores in Narraminju Wuntu (Caves Creek). Of the available monitoring bores, data from those located within the main creek channel, above the aquifer that is subject to dewatering and in the vicinity of the proposed MAR location were reviewed. These bores are clustered in four groups (clusters 1 to 4) and comprised four to eight bores perpendicular to the creek. The bores also occurred at regular intervals at increasing distance from Silvergrass, providing a longitudinal assessment of groundwater levels associated with the creek. Cluster 1 is located closest to the mine, approximately 7 km downstream while clusters 2 to 4 are located approximately 14 km, 18 km and 22 km downstream of Silvergrass, respectively (Table A 6).

From each cluster, one bore has been selected as a representative bore for groundwater levels. Bore selection was based on the location of the bores within the same geological formation, the availability of a robust and continuous dataset during both the baseline and the operational periods, a dataset that demonstrated seasonal variation without major outliers or erroneous groundwater levels, and the location of the bores along the creek cross section and depth of bores.

1) Selection by geological layers

Geological layers have been mapped over the bore locations in clusters 1 to 4, confirming they occurred in the same geological formation. The aquifer accessed by these bores is predominantly linked to the Wittenoom Formation beneath Narraminju Wuntu (Caves Creek). However, two bores (MB11SILV010 and MB11SILV021), are situated in the Marra Mamba Iron Formation, and were considered unsuitable and were subsequently omitted as representative groundwater bores.

2) Selection by continuous datasets

Data from the remaining bores in clusters 1 to 4 were interrogated and examined for continuity during baseline and operational periods. Several bores from cluster 1 (MB11SILV024 – 27), cluster 2 MB11SILV016 to 18 and MB11SILV021), cluster 3 (MB11SILV010 and MB11SILV013) and cluster 4 (MB11SILV004, MB11SILV006 and MB11SILV007) have been excluded due to insufficient data availability.

3) Selection by non-outlier heavy datasets

Data from the remaining bores in clusters 1 to 4, with continuous datasets, have been examined for anomalies and significant outliers. Bores MB11SILV027 and MB11SILV009 have been excluded due to the occurrence of significant outliers (50 mbgl and 10 mbgl respectively).

4) Selection by positioning and depth

The location of all remaining bores has been verified and bores were selected that had similar positions along the cross section of the creek, predominantly within or close to the creek bed (including bores MB11SILV005 from cluster 4 and MB11SILV013 from cluster 3 and MB11SILV019 from cluster 2). Although not situated within the centre of the creek bed, bore MB11SILV023 from cluster 1 was selected as it had the most robust and continuous dataset. Bore depth has also been considered, with all selected bores approximately 10m deep. However, MB11SILV023 is 35 m deep and was included to accurately reflect increased drawdown near Silvergrass. The final selection of representative bores is presented in Table A 9 and shown in Figure 2-4.

Table A 9: Final selection of representative groundwater bores for the revised Nammuldi-Silvergrass MMP.

Cluster 1	Cluster 2	Cluster 3	Cluster 4
MB11SILV023	MB11SILV019	MB11SILV013	MB11SILV005

Statistical Analysis

Statistical analysis of groundwater level criteria is undertaken for selected representative bores. Groundwater level measurements comprise metres below ground level (mbgl), relative to surface for each bore. Lower limits apply for each bore; however an upper limit only applies for bore MB11SILV023. To account for rainfall-related variation and outliers, monthly means are calculated for the groundwater levels. One, two and three standard deviations below the baseline mean were used to determine the early response, trigger and threshold criteria levels respectively. Bore MB11SILV023 is an exception, where a 2 m deviation from the baseline mean was used as the threshold criterion, due to proximity to the Nammuldi-Silvergrass mine and more pronounced drawdown. Exceedance levels only apply to a decrease in groundwater levels, with the exception of MB11SILV023 where an increase in groundwater level was included in the criteria due to the bore's vicinity to the proposed MAR location. Calculated exceedance levels for each bore are presented in Table A 10.

Table A 10: Groundwater level management provision levels for key indicator bores.

Criteria Category	MB11SILV023	MB11SILV019	MB11SILV013	MB11SILV005
Baseline Mean	5.547 mbgl	2.809 mbgl	2.288 mbgl	1.628 mbgl
Early Response Criterion	5.350 and 5.744 mbgl	3.452 mbgl	2.779 mbgl	2.044 mbgl
Trigger Criterion	5.153 and 5.941 mbgl	4.095 mbgl	3.269 mbgl	2.460 mbgl
Threshold Criterion	3.547 and 7.547 mbgl	4.738 mbgl	3.759 mbgl	2.877 mbgl

Inland Waters

9.1.1.1 Surface Water Quality

Analysis of surface water quality trigger criterion is conducted by statistically testing the rolling annual median concentration of surface water quality parameters against the revised surface water SSTVs for Kartajirri Wuntu (Duck Creek) (Appendix 5) and the 95%ile of baseline or ANZG (2018) default 90% species protection level. Analysis of the threshold criterion is conducted by testing the bioavailable concentration of surface water quality parameters against the revised surface water SSTVs for Kartajirri Wuntu (Duck Creek) (Appendix 5) and determining if a significant upward trend is apparent.

9.1.1.2 Aquatic Fauna (Macroinvertebrate Assemblage)

Statistical analysis of the macroinvertebrate assemblage criteria is undertaken using seasonal (wet and dry season) diversity data from sites grouped by zone (Table A 7). Taxa diversity data are not standardised. However, data results comprise standard enumeration techniques. The following statistical analysis and sensitivity testing is applied:

- One-way Analysis of Variance (ANOVA) testing is used to identify significant differences in the macroinvertebrate taxa diversity of each zone assessed for each monitoring event against the baseline, separated for the wet and dry season.
- The results are interrogated and a confidence level of 95% (p value of <0.05) is considered statistically significant.
- The dataset is subjected to normality testing and where required data is transformed to reduce skewness (or testing was performed on untransformed data).
- Post-hoc testing is applied to significant results using Tukey's pairwise comparison to identify significant differences in the taxa diversity in a zone from the baseline and reference zone.
- These results are then compared to the number of significant differences identified within the zones, to determine exceedances in early response, trigger or threshold criteria.

It should be noted that ANOVA testing is dependent on the data provided satisfying several assumptions including; normal distribution, equality of variance, and independence and randomness. Regardless, ANOVA is considered a relatively robust statistical test and fulfilling normality is not necessarily important if group sizes are approximately equal (Ryan and Joiner 2001). It was also assumed that sites where no data was available for a given monitoring event, these were not sampled, and the data were excluded from analysis.

9.1.1.3 Aquatic Fauna (Fish Assemblage)

Statistical analysis of the fish assemblage (taxa diversity and new recruit/juvenile abundance) is undertaken using total fish taxa diversity (up to eight taxa) and new recruit/juvenile abundance of a monitoring event, from individual sites from Kartajirri Wuntu (Duck Creek) grouped by zone. Taxa diversity data were standardised across sites and monitoring events. The following statistical analysis and sensitivity testing was applied:

- One-way Analysis of Variance (ANOVA) testing is used to identify significant differences in the fish taxa diversity and new recruit/juvenile abundance of each zone assessed for a given monitoring event against the baseline, separated for wet and dry season.
- The results are interrogated and a confidence level of 95% (p value of <0.05) is considered statistically significant.
- The dataset is subjected to normality testing and where required data is transformed to reduce skewness (or testing was performed on untransformed data).

- Post-hoc testing is applied to significant results using Tukey's pairwise comparison to identify significant differences in the taxa diversity during a monitoring event in a zone from the baseline.
- These results are then compared to the number of significant differences identified within the zones, to determine exceedances in early response, trigger or threshold criteria.

It should be noted that ANOVA testing is dependent on the data provided satisfying several assumptions including normal distribution, equality of variance, and independence and randomness. Regardless, ANOVA is considered a relatively robust statistical test and fulfilling normality is not necessarily important if group sizes are approximately equal (Ryan and Joiner 2001). It was also assumed that sites where no data was available for a given monitoring event, these were not sampled, and the data were excluded from analysis. For fish new recruits/juvenile abundance data, it was confirmed that the site was not sampled, prior to excluding data from analysis.

Appendix 4: Key GDV Indicator Species

Table A 11: Key Indicator Species for GDV communities of Narraminju Wuntu (Caves Creek) and Kartajirri Wuntu (Duck Creek)

Vegetation Strata	Narraminju Wuntu (Caves Creek)		Kartajirri Wuntu (Duck Creek)	
	Key Indicator Species	Lifeform	Key Indicator Species	Lifeform
Overstorey	*Eucalyptus camaldulensis* subsp. *refulgens*	Tree - Phreatophyte	*Eucalyptus camaldulensis* subsp. *refulgens*	Tree - Phreatophyte
	Eucalyptus victrix	Tree - Phreatophyte	*Eucalyptus victrix*	Tree - Phreatophyte
	Melaleuca argentea	Tree - Phreatophyte	*Melaleuca argentea*	Tree - Phreatophyte
Midstorey	*Acacia citrinoviridis*	Tree - Mesophyte	*Acacia citrinoviridis*	Tree - Mesophyte
	Acacia coriacea subsp. *pendens*	Tree - Mesophyte	*Acacia coriacea* subsp. *pendens*	Tree - Mesophyte
	Melaleuca glomerata	Shrub - Mesophyte	*Melaleuca glomerata*	Shrub - Mesophyte
	Acacia ampliceps	Shrub - Mesophyte	*Acacia ampliceps*	Shrub - Mesophyte
Understorey	*Gossypium robinsonii*	Shrub - Mesophyte	*Gossypium robinsonii*	Shrub - Mesophyte
	Gossypium sturtianum var. *sturtianum*	Shrub - Mesophyte	*Gossypium sturtianum* var. *sturtianum*	Shrub - Mesophyte
	Tephrosia rosea var. Fortescue creeks (M.I.H. Brooker 2186)	Shrub - Mesophyte	*Indigofera rivularis*	Shrub - Mesophyte
	Corchorus crozophorifolius	Shrub - Mesophyte	*Androcalva luteiflora*	Shrub - Mesophyte

Appendix 5: Revised Kartajirri Wuntu (Duck Creek) and Boolgeeda Creek SSTVs

Table A 12: Revised Kartajirri Wuntu (Duck Creek) and Boolgeeda Creek site specific trigger values (SSTVs) for Nammuldi-Silvergrass water quality monitoring parameters by SLR (2023).

Surface Water Parameter	Footnote	ANZG 2018 DGV 95%	80%ile Baseline + Reference Data (to 2022)	Revised SSTVs
Aluminium (Al)	T	0.055	0.011	-
Alkalinity (as $CaCO_3$)		np	341	-
Ammonia - total ($N\text{-}NH_3$)	T, P	0.9	0.01	0.18
Ammonium ($N\text{-}NH_4^+$) - eutrophication		0.01	nr	0.01
Arsenic (As) total	T, A	0.013^{A}	<0.001	0.013
Barium (Ba)	T	np	0.09	Duck Cr.= 0.09 Boolgeeda Cr.= 0.1
Boron (B)	T	0.94	0.4	0.94
Bicarbonate (HCO_3)		np	395	-
Cadmium (Cd)	T	0.0002	<0.0001	0.0002
Calcium (Ca)		np	65	-
Chloride (Cl)		np	296	-
Chromium (Cr-total)	T, C	0.001	<0.0005	0.001
Cobalt (Co)	T	np	0.0004	0.001
Copper (Cu)	T, D	0.00047	0.0014	0.00047
Dissolved Oxygen (%)		85 - 120%	1.06	64 - 120%
Electrical Conductivity (µS/cm EC)	E	20 - 900	1682	1682
Hardness		np	510	-
Iron (Fe)	T, F	0.3	0.09	0.3
Lead (Pb)	T, H	0.0034	<0.0001	0.0034
Magnesium (Mg)		np	88	-
Manganese (Mn)	T	1.9	0.04	1.9
Mercury-inorganic (Hg)	T, B	0.00006	--	0.0001
Molybdenum (Mo)	T	np	0.001	0.001
Nickel (Ni)	T	0.011	<0.001	0.011
Nitrate nitrogen ($N\text{-}NO_3$)	T, N	2.1	0.09	15
Nitrate-nitrite nitrogen (N-NOx) - eutrophication		0.03	0.25	0.04
Nitrogen-total (N-total) - eutrophication		0.3	0.7	0.7
pH		6.0 - 8.0	7.5 - 8.5	7.5 - 8.5

Surface Water Parameter	Footnote	ANZG 2018 DGV 95%	80%ile Baseline + Reference Data (to 2022)	Revised SSTVs
Phosphorus-total (P-total) - eutrophication		0.01	0.02	0.02
Potassium (K)		np	12.4	-
Selenium-total (Se)	T	0.005	<0.001	0.005
Silica (SiO_2)		np	--	-
Sodium (Na)		np	167	-
Sulphate sulphur (S-SO_4)		np	131	-
Temperature (°C)		np	29.4	29.2
Total Dissolved Solids (TDS)		np	1000	1100
Total Suspended Solids (TSS)		np	9	9
Turbidity (field, NTU)		np	--	-
Uranium (U)	T	np	0.0014	0.002
Vanadium (V)	T	np	0.003	0.004
Zinc (Zn)	T, H	0.008	0.014	0.014

Footnotes:

A. *SSTV for As-total is equivalent to 95% species protection level DGV for As (V). For monitoring, if As-total concentration is >0.013 mg/L, then re-sample and analyse for metal species (i.e. As V and As III) concentrations and compare against default ANZG GVs.*

B. *DGV for 99% species protection recommended due to the ability of these metals to bioaccumulate. However, laboratory analysis of mercury for routine screening is only achievable to 0.0001 mg/L Hg-inorganic or 0.00005 mg/L Hg-total; the latter by persulfate digestion on low salinity samples.*

C. *SSTV for Cr-total equivalent to 95% species protection level DGV for Cr (VI). For monitoring, if Cr-total concentration is >0.001, then re-sample and analyse for metal species (i.e. Cr VI and Cr III) concentrations and compare against default DGVs.*

D. *SSTV for Cu should be modified for dissolved organic carbon at the time of sampling using the default algorithms provided by ANZG (2023b).*

E. *Conductivity (EC) and associated ions (e.g. Ca, Mg, S-SO_4) will vary depending on flow; values higher than the SSTV may occur naturally during the dry season if water levels are reduced due to evapo-concentration.*

F. *DGV for Fe is low reliability value.*

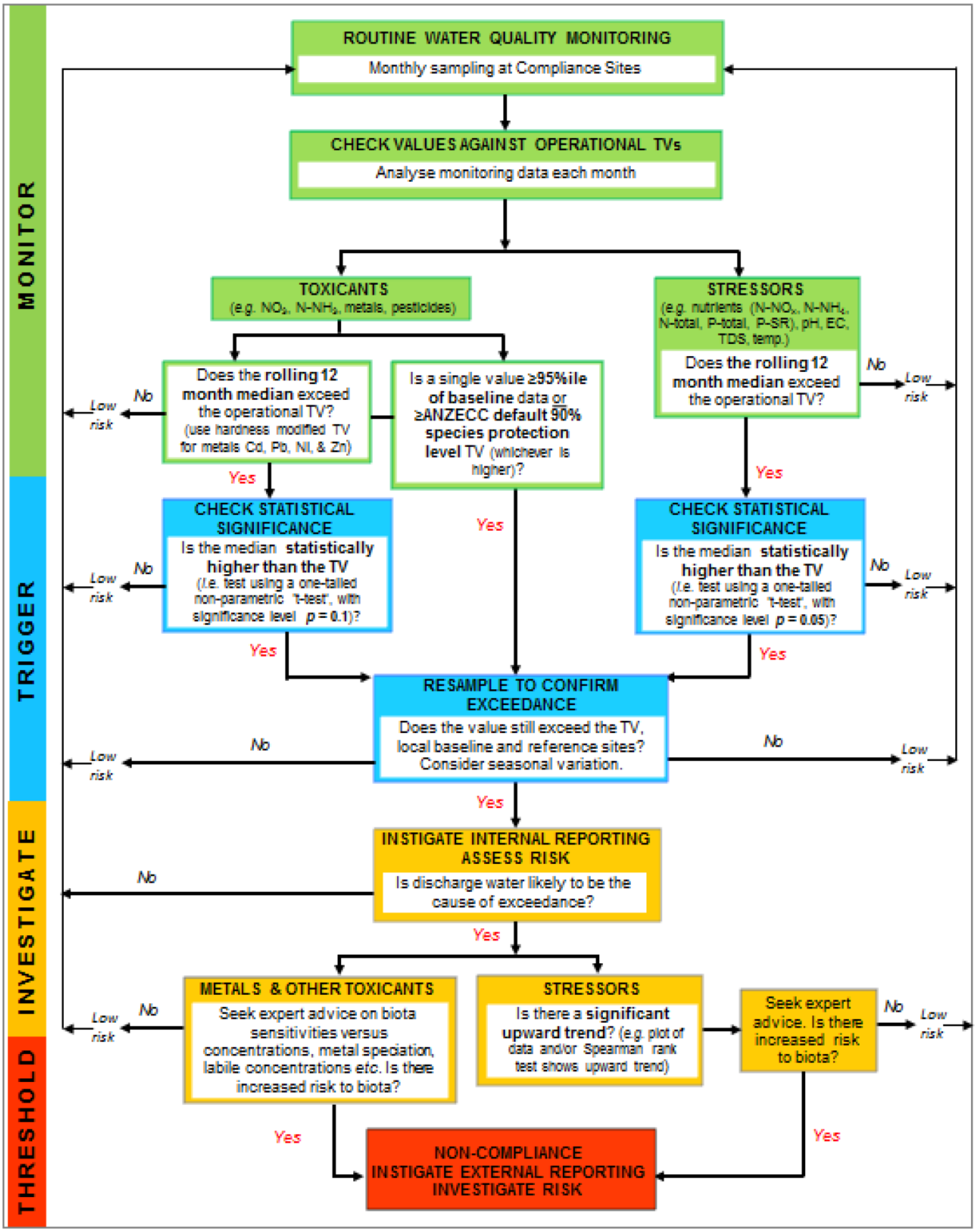
H. *SSTV for Zn should be modified for water hardness at the time of sampling using the default algorithms provided by ANZG (2018).*

N. *SSGV for N-NO_3 is based on the van Dam et. al (2022) study "Derivation of site-specific guideline values for nitrate toxicity in Pilbara receiving waters with high hardness". DGV value shown for nitrate is for N-NO_3; to convert to NO_3, multiply the concentration by 4.43.*

P. *This proposed SSTV assumes pH = 8.1 and temperature = 26ºC (median values from the baseline + reference dataset). However, toxicity thresholds should be reviewed on a case-by-case basis, if pH deviates by more than ± 0.1 or temperature ± 1.0 ºC then trigger value should be revised (see ANZG 2023a). For example, using the 80th %ile baseline + reference values (pH = 8.5, temperature = 29.4ºC) the 95% DGV total ammonia-N = 0.074 mg/L.*

T. *Toxicant*

Appendix 6: Surface Water Quality Exceedance Workflow Diagram



Appendix 7: Baseline Flora and Vegetation Surveys

Baseline Flora and Vegetation Surveys

The following baseline monitoring reports are submitted in conjunction with this revised Nammuldi-Silvergrass MMP:

- Biota. (2010). Greater Nammuldi Creeks Monitoring Report on Riparian Vegetation. Unpublished report prepared for RTIO, Perth, Western Australia.
- Biota. (2011). Greater Nammuldi Creeks Monitoring Report on Riparian Vegetation. Unpublished report prepared for RTIO, Perth, Western Australia.
- Biota. (2012). Greater Nammuldi Creeks Monitoring: Report on Riparian Vegetation. Unpublished report prepared for Rio Tinto.
- Biota. (2014). Nammuldi Creeks Riparian Vegetation Monitoring: Phase 4. Unpublished report prepared for RTIO, Perth, Western Australia.
- Biota. (2015). Nammuldi Creeks Riparian Vegetation Monitoring: Phase 5. Unpublished report prepared for RTIO, Perth, Western Australia.

Background

Baseline Phase 1-3

A riparian vegetation monitoring programme at Caves Creek and Duck Creek was designed and implemented by Biota Environmental Sciences. Baseline phases 1-3 of the program occurred between 2010 and 2012 (Biota 2010, 2012a, 2012b). Prior to 2012, several options for the discharge location were under consideration by Rio Tinto, and there were limited data on anticipated surplus water discharge volumes and the impact footprint. Consequently, monitoring sites were not classified as impact or control/reference. Instead, sites were grouped into reaches (see Biota 2012b), which were defined by their spatial location in each creek and from a preliminary assessment of site characteristics (morphology, soil and vegetation type).

At the end of the phase 1-3 of baseline monitoring and with confirmation of the discharge location, it was identified that a) the preliminary groupings of sites into reaches needed revision and, if retained, justification (for example, by using floristic analyses); b) there are no adequate locations to establish true Control sites on Duck Creek; and c) in light of this, Caves Creek and/or the tributaries of Duck Creek should be investigated as potential analogue control sites.

Baseline Phase 4-5

Phase 4 and 5 of the program consisted of the first and second year after the commencement of surplus water discharge into Duck Creek. The phase 4 and 5 report summarises the findings from these phases and comparing data to the baseline phases as appropriate. Sites have not been grouped into reaches, as in the baseline phases; rather they have been evaluated by treatment (Impact, Non-Impact and Reference), discharge extent along Duck Creek and/or individually.

Objectives

The overall objective of the monitoring programme is to detect change in the riparian vegetation in Duck and Caves Creek. As far as possible, the sampling has been designed and implemented in accordance with the following:

- Environmental Protection Authority (EPA) Position Statement No. 3 “Terrestrial Biological Surveys as an Element of Biodiversity Protection” (EPA 2002);

- EPA Guidance Statement No. 51 “Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia” (EPA 2004); and
- Rio Tinto Scope of Work; and • Nammuldi-Silvergrass Monitoring and Management Plan (Rio Tinto 2013).

Appendix 8: Hydrogeological Study and Risk Assessment

Hydrogeological Study and Risk Assessment
The following hydrogeological study is submitted in conjunction with this revised Nammuldi-Silvergrass MMP:

- Caves Creek Managed Aquifer Recharge Project H3 Hydrogeologic and Risk Assessment

Background
Rio Tinto Iron seek regulatory approval and licensing to undertake managed aquifer recharge (MAR) activities to support mining at their Silvergrass East (SGE) deposit, located in Caves Creek Catchment. Groundwater dewatering is required to facilitate mining at SGE and RTIO propose implementation of a MAR scheme via 'recharge without recovery', to mitigate groundwater drawdowns that are observed during dewatering operations. The MAR scheme aims to maintain environmental and heritage values of groundwater dependent ecosystems (GDEs) that have been identified at Caves Creek.

The H3 hydrogeological assessment has been undertaken for the project by RTIO and comprises MAR related assessments over the preceding three years and more recently conducted during 2022. These assessments are detailed in this report with supporting documentation attached in the appendices. A groundwater impact assessment including effects to groundwater quality and hydrogeological, and risk assessment are presented in this report. It is noted that the risk assessment is a living document and risks have been informed based on the available studies. Therefore, as further data is collected and knowledge gained then the risk assessment and controls will be revised, where required.

Objectives
Identify and quantitatively assess hazards and risks to groundwater and groundwater receptors due to the proposed MAR scheme, in accordance with the criteria specified in Part V of the EP Act 1986, the MAR Policy 2021 and the Western Australian Water in Mining guideline (DWER, 2013).

Further assess MAR related risks in relation to the Department of Environmental Regulation (DWER) 2021a guideline (Water and environmental considerations for MAR operations in WA) and processes outlined in the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) and Managed Aquifer Recharge (Phase 2) (NRMMC, EPHC, AHMC, 2006 & 2009).