6 Other Environmental Factors or Matters

6.1 Other Environmental Factors

Environmental Factors that are not expected to be impacted by any aspect of this Proposal are summarised in Table 6-1.

Table 6-1: Other Environmental Factors

Theme	Factor	EPA Objective	Relevance to Revised Proposal
Sea	Benthic Communities and Habitat	To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.	The Mine DE is located over 18 km from the nearest marine environment. The activities associated with the Proposal will not impact the marine environment and therefore marine related environmental factors are not relevant.
	Coastal processes	To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected.	
	Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected.	
	Marine Fauna	To protect marine fauna so that biological diversity and ecological integrity are maintained.	
Land	Landforms	To maintain the variety and integrity of distinctive physical landforms so that environmental values are protected.	The proposed activities in the Mine DE are not expected to significantly impact the existing landforms and are not considered to be environmentally significant. The environmental values supported by landforms that will be impacted by the proposed works are addressed in the Flora and Vegetation, Terrestrial Fauna, Terrestrial Environmental Quality, and Social Surroundings sections (Sections 5.2, 5.3, 5.4, and 5.7).
	Subterranean fauna	To protect subterranean fauna so that biological diversity and ecological integrity are maintained.	It is considered unlikely that the proposed activities will have a significant effect on subterranean fauna. Subterranean fauna is unlikely to be present in the Northern Jarrah Forest. The area is characterized by lateritic duricrust and kaolinitic clay zones, with only minor local aquifers present, making it a low prospect for subterranean fauna (Phoenix Environmental, 2019). Furthermore, neighbouring projects in the Jarrah Forest Bioregion undergoing EIA have not been asked to consider

Theme	Factor	EPA Objective	Relevance to Revised Proposal
			subterranean fauna by the EPA, who did not consider subterranean fauna to be a significant environmental factor in this region (Phoenix Environmental, 2019; EPA, 2018c; Strategen, 2013).
Air	Air quality	To maintain air quality and minimise emissions so that environmental values are protected.	An Air Quality Impact Assessment was conducted across the Mine DE where potential emissions of particulate matter and combustions pollutants that could arise from construction and mining operations within the 5 year mine plans were investigated. The impacts of dust are effectively managed under the procedures detailed in the dust management plan. The studies concluded that all gaseous emissions associated with both construction and mining activities are considered manageable and relatively minor. Consequently, no air quality impacts from gaseous emissions are anticipated. Further details on the air quality assessments are detailed in Section 5.7 – Social Surroundings.
People	Human health	To protect human health from significant harm	The Mine DE is located 13 km from the nearest town. The activities and emissions associated with the proposal are not expected to have a direct impact on human health. There is a low risk of indirect impacts to human health that have been deemed unlikely due to mitigation measures. The proposed activities have the potential to contaminate the Public Drinking Water Catchments, which could have indirect impacts on human health. The level of risk is currently unknown, ongoing investigations being conducted to quantify this.

6.2 Rehabilitation Program

Alcoa has implemented a comprehensive progressive rehabilitation program for disturbed areas by mining and associated activities, dating back to 1966. As of June 2023, 16,981 ha had been rehabilitated at the Huntly and Willowdale mines. Alcoa had rehabilitated 22,490 ha (79.8%) of areas cleared for all mining operations across ML1SA (28,175 ha), including the Jarrahdale mine which was closed in 1999. In this case, rehabilitated means the area has been contoured to blend with the surrounding unmined forest; has received topsoil and seed; and where revegetation is at various ages of regrowth.

Alcoa includes rehabilitation activities within each annual iteration of the MMP, as per MMP Approval Condition 15a which states that Alcoa must consecutively increase rehabilitated and stabilised areas yearly. The Proposal commits to a rehabilitation goal of at least 3,159 ha from 2024 to 2027. The Exemption Order clause 5 requires defined mining areas to be stabilised (to prevent erosion, promote infiltration, and manage water runoff) within 12 months of completion and rehabilitated as soon as practicable afterwards completion.

Alcoa's current rehabilitation objective, as per the 2016 onwards Completion Criteria endorsed by MMPLG is to '*Establish, and return to the State, a self-sustaining Jarrah Forest ecosystem, planned to enhance or maintain water, timber, recreation, conservation and other nominated forest values. Rehabilitated areas must become amenable to similar management practices employed in the surrounding Jarrah Forest*' (Alcoa, 2023c). The rehabilitation completion criteria are reviewed and updated approximately every five years.

Table 6-2: Rehabilitation Principles to align with Completion Criteria

Principle	Intent
Water	To ensure that mined areas do not impact water quality and quantity
Timber*	Establish a forest that has the potential for sawlog production
Recreation	To maintain existing recreational values where possible and to provide increased opportunities for forest based recreational activities in accordance with DBCA district and regional recreation plans.
Land Management	To conserve the residual soil, to control *Phytophthora* dieback spread and to ensure the rehabilitation areas are resilient to fire hazards.
Landscape	To create a rehabilitated landscape visually compatible with the adjoining indigenous forest.
Conservation	To encourage the development of flora and fauna assemblages similar to those within the unmined Jarrah Forest
Long-term Resilience	Management: to establish and ecosystem that is self-sustaining without ongoing applications of management resources greater than those needed within the unmined forest.

* *consistent with the 2014-2023 Forest Management Plan (FMP) and will be reviewed as part of the updated completion criteria for alignment with the 2024-2033 FMP.*

Alcoa's rehabilitation completion criteria are currently under review to align with the 2024-2033 FMP and key stakeholder expectations.

Ministerial condition 23 of the 2023–2027 MMP requires Alcoa to reach agreement with the DBCA in drafting a revised set of rehabilitation completion criteria. To date, six collaborative workshops have been held with representatives from DBCA, along with initial engagement with Gnaala Karla Booja Aboriginal Corporation (GKB AC). The agreed draft rehabilitation

completion criteria will be submitted to the State Development Minister by 31 December 2024.

In consideration of Ministerial Statement 728 and the *Pinjarra Alumina Refinery (Pinjarra) Agreement Act (1969)*, the agreed rehabilitation completion criteria will then be further reviewed in consultation with the BSEC before the public consultation period.

Alcoa's rehabilitation performance is measured against Completion Criteria that indicate the success of rehabilitation towards a goal of relinquishment of land back to the State and cessation of a proponent's liability and management requirements.

Alcoa's current rehabilitation monitoring framework assesses rehabilitation performance against Completion Criteria throughout the various stages of mine site rehabilitation – from planning, rehabilitation execution and then passing through different levels of ecosystem development. Through ongoing monitoring and research, Alcoa aims to continuously improve rehabilitation standards and performance. Alcoa will continue to implement the rehabilitation program throughout the Proposal.

6.2.1 The Mine Rehabilitation Process

Alcoa's rehabilitation standards and techniques have evolved, being informed by interactions in research and practice (Grant & Koch, 2007). Alcoa has undertaken extensive research and development in rehabilitation for over 50 years, with the publication of findings in peer reviewed journals.

The temporary nature of Alcoa's bauxite mining operations requires the integration of land rehabilitation activities during the mine operations, mine closure, and the post-closure phases. This integrated approach will result in mining areas being progressively rehabilitated.

The process is detailed in Alcoa's Current Approach to Rehabilitation, Monitoring and Area Certification provided within the Rehabilitation Management Plan and Schedule (Appendix 8).

Alcoa's rehabilitation strategies include:

- Rehabilitation prescriptions for each mined area;
- Research programmes to improve rehabilitation procedures;
- Rehabilitation monitoring to determine capacity to meet objectives; and
- Remedial treatments where monitoring indicates that rehabilitation objectives were not achieved.

Rehabilitation planning occurs over a three-year time scale as a part of mine planning to:

- schedule mining to maximise direct soil return;
- plan soil stockpiles;
- minimise non-ore clearing;
- undertake efficient seed collection;
- allow for nursery plant production; and
- plan *Phytophthora* dieback hygiene.

Detailed rehabilitation planning occurs on a pit-by-pit basis, to schedule rehabilitation for the optimum time of the year, plan soil movements, access and *Phytophthora* dieback hygiene.

Alcoa's rehabilitation method has been documented in published journals and is set out in DBCA Working Arrangements and the Rehabilitation Design Manual (under development). A summary of current rehabilitation activities is provided in Table 6-3, which is subject to ongoing development and refinement and may be subject to change during the Proposal.

Alcoa has integrated adaptive management practices within its rehabilitation monitoring program to ensure that the rehabilitation quality is on an appropriate trajectory towards achieving the completion criteria. Following monitoring, areas that fail to meet completion criteria are risk assessed and scheduled for remediation based on risk and appropriate timeframes to address quality issues. Remediation works may include:

- Seeding of additional legume;
- Planting of additional eucalypt tube stock;
- Planting of additional species; and
- Re-work (re-establishing soil profile, contour ripping, seeding and planting) in response to erosion utilising the smallest earthmoving equipment possible to minimise disturbance.

Alcoa follows an agreed regulatory approach to rehabilitation area certification and relinquishment of management responsibility.

Table 6-3: Overview of Rehabilitation Activities for current prescription

Rehabilitation Component	Elements
Landscaping	• Topsoil and overburden are mechanically stripped to be used directly in rehabilitation or stored for future use. Topsoil contains native seed, nutrients and beneficial organisms that support successful revegetation, providing approximately 60% of species diversity in the 'recipient' rehabilitation area. Overburden and topsoil greater than 3-months old are used to reconstruct the soil profile. • Pre-ripping of compacted pit floors with a winged tine to at least 1.2 m, excluding batters and waste islands. • Vertical faces re-shaped to achieve acceptable grades that blend in with the surrounding natural forest landscape (< 18º slope). • Long-term forest access tracks reinstated as agreed with DBCA and located as low in the profile as possible with surface water runoff directed into the rehabilitated area. • Pits are landscaped to retain surface water runoff and sediment.
Soil return	• Topsoil and overburden returned from stockpiles to an area of the same *Phytophthora* dieback category. • Fresh topsoil is sourced from an area (donor site), cleared nominally from late spring to mid-summer of the commencing rehabilitation season. • Where practicable topsoil and overburden depth is applied to replace what was stripped from the area. Reduced depth may be applied subject to limited soil availability across the mine. • Topsoil handling scheduled to avoid damage to the structure during high moisture.
Fauna habitats	• Constructed fauna habitats established at a target rate of one per hectare. • Habitats constructed with woody material, rocks and soil to support re-establishment of fauna populations within rehabilitated areas. • If pits are designed to retain water, habitat structures should not be placed at the base of the pit to avoid being surrounded by water.
Contour ripping	• Ripping carried out on contour with a multi-tyne. • Some batters and banks need not be deep ripped, but must be scarified or shallow ripped, to avoid bringing up rocks. • Interceptor banks constructed during contour ripping on steeper areas to assist in erosion control. • Cleared, un-mined areas scarified on contour to avoid bringing up rocks.
Seeding	• Seed collection from approved provenance zones which have been informed by genetic analysis. • Apply seed mix including understorey and overstorey species. • Standard prescription for Upland Forest is to establish 80% *Eucalyptus marginata* and 20% *Corymbia calophylla*. • Standard prescription for Streamzones is to establish *Eucalyptus patens*, *Eucalyptus megacarpa* and *Eucalyptus rudis* used in proportions relating to density in surrounding areas, calculated from permanent monitoring plots in streamzones. • Mixed understorey seed sown at the rate of 1-2 kg/ha. Seeding soon after contour ripping operations (preferably within seven days). • Seed applied mechanically at time of contour ripping or by hand.
Planting	• Planting recalcitrant seedlings, following significant autumn/winter rains. • Use of *Phytophthora* dieback (and other relevant pathogen) free nursery stock.

Rehabilitation Component	Elements	
Fertilising	• Fertiliser generally spread in early spring of the following year.	
Monitoring	• Rehabilitation monitoring program will be in place to evaluate rehabilitated areas against approved rehabilitation completion criteria (RCC) which incorporates performance criterion for: ○ plant densities, plant species richness, erosion and weeds in the early establishment phase. ○ longer-term ecosystem development and integration with standard forest management. • Monitoring of rehabilitation completed post 2016 (inclusive of disturbance and rehabilitation undertaken as part of this proposal) is undertaken at the following intervals:	
	○ 9 Months:	Monitoring at nine months evaluates rehabilitated areas for tree and legume densities as well as the presence of erosion and the presence of weeds against completion criteria standards.
	○ 15 Months:	Monitoring at 15 months assesses the species richness of the rehabilitated area in comparison to the surrounding remnant (i.e., unmined) forest. The RCC stipulates that all rehabilitated areas achieve a minimum of 60% species richness.
	○ 24 Months:	Monitoring at 24 months is undertaken using an unmanned aerial vehicle (UAV) to assess rehabilitated areas for erosion and measure specific metrics for comparison against completion criteria.
	○ Five Years	Monitoring through aerial imagery and GIS tools is undertaken to ensure that the completed rehabilitation remains on trajectory to achieve RCC, with a focus on areas that have insufficient tree density.
	○ 12 years:	Final assessment of rehabilitation can be undertaken once rehabilitation >12 years of age to assess the area and confirm resilience criterion has been met and is on trajectory to a self-sustaining jarrah forest ecosystem.

6.2.2 Rehabilitation Completion Criteria

Alcoa's rehabilitation practices have evolved since the 1960s, and during this time, its rehabilitated areas have been measured against the RCC developed in consultation with and approved by the MMPLG. The RCC have evolved over time – informed by improvements in research, technologies and shifting community expectations – and have been subject to periodic review.

Rehabilitated areas established up to 1987 reflect the agreed Post Mining Land Use (PMLU), which at that time was to support the establishment of a non-jarrah forest ecosystem, with species chosen for their resilience to the soil-born pathogen *Phytophthora cinnamomi*. These are collectively termed *Early Era rehabilitation*.

Since 1988, key RCC have been related to the establishment of native species overstorey, which is the primary indicator of vegetation cover and primary productivity in a forest ecosystem, and understory species, which are the predominant floristic diversity in the Jarrah Forest. The RCC have been further developed over four iterations, with the fifth currently under development in consultation with DBCA. The relevant RCC is applied to when the rehabilitation occurs, Alcoa does not apply subsequent revised RCC to areas rehabilitated under previous versions of the RCC.

Each criterion has an associated standard, including targets against which Alcoa monitors and reports the rehabilitation performance. The assessment of rehabilitation against the RCC is applied throughout the stages of rehabilitation operations and during the early years of ecosystem development. This ensures adaptive management can be carried out while operations are nearby.

Alcoa's rehabilitation approach for this era is to restore a self-sustaining jarrah forest ecosystem planned to enhance or maintain water, timber, recreation, conservation and/or nominated forest values. The current RCC was developed in 2015 and applied in 2016 onwards and are published on the Alcoa website[13] and provided in Appendix 69.

Alcoa's next iteration of RCC is currently under development. In consideration of Ministerial Statement 728 and the *Pinjarra Alumina Refinery (Pinjarra) Agreement Act (1969)*, the agreed RCC will be further reviewed in consultation with the BSEC before public consultation period.

6.2.3 Rehabilitation Monitoring and Reporting

Alcoa's rehabilitation quality monitoring program evaluates rehabilitated areas against the Alcoa WA Mining RCC developed in consultation with the PMLU manager, the DBCA and other key stakeholders and endorsed by the MMPLG in 2016.

As well as long term rehabilitation monitoring, Alcoa conducts monitoring in rehabilitation areas at nine and 15 months after establishment to provide early feedback on performance and allow for timely remediation and procedural improvements. At nine months, Alcoa monitors the density of Jarrah, Marri, total Eucalypts, and legumes. At 15 months, Alcoa assess species richness over 80 m^2 in each area and monitors the density of 'recalcitrant' obligate re-sprouter species (Stantec, 2023).

[13] www.alcoa.com/australia/en/pdf/mining-operations-rehabilitation-program-completion-criteria.pdf

The monitoring methodology employs a combination of traverses along transects and floristic sampling within quadrats, using both temporary transect and a combination of temporary and permanent plots. Temporary plots are used during 9-month monitoring and consist of 4 m x 4 m quadrats positioned along transects to record legumes, with a sampling intensity covering 5% of rehabilitated areas. Permanent plots are established during the 15-month botanical monitoring at an intensity of one plot every five hectares.

Alcoa has established 151 permanent vegetation monitoring plots in unmined forest areas around its Huntly and Willowdale operations, serving as reference sites for comparison.

At 24 months, erosion monitoring is undertaken after the second wet season following the establishment of rehabilitation using an external company which provides photogrammetric services. This company conducts the UAV photography across Alcoa's rehabilitation estate and derives secondary products including Digital Elevation Models and Orthomosaics of the rehabilitated landscape. Careful interpretation of these products by the supplier helps identify erosion using specific metrics, including depth, length, and width, ensuring they meet the completion criteria.

Additional vegetation monitoring is undertaken at five years using aerial imagery and Geographical Information Systems (GIS) tools to identify rehabilitated areas with insufficient tree density. Rehabilitation >12 years of age is monitored utilising a combination of LiDAR, Real Time Kinematic (RTK) enabled UAV imagery, aerial photography, permanent plot monitoring and research trials are utilised to assess rehabilitation performance against resilience completion criteria.

Alcoa has also established 12 long-term vertebrate fauna monitoring sites consisting of unmined habitat and areas rehabilitated five, 10, and 15 years ago. Vertebrate fauna at these sites are periodically monitored to ensure rehabilitated areas are progressing on a trajectory towards unmined forest.

An Environment and Rehabilitation checklist has been developed to record the status of rehabilitation in the field. Historic rehabilitation records and aerial photographs are also used to assist with the assessment. The assessments indicate whether the site is exhibiting sustained growth and development. If a site is recorded as not meeting one of the criteria, it is recorded within Alcoa's corrective action management system to inform rework planning.

6.2.4 Rehabilitation Area Certification

Since rehabilitation practices and procedures have evolved over time and RCC are subject to periodic review, Alcoa's rehabilitation areas are assessed against differing criteria and expectations depending on the year of establishment.

There is an ongoing process prior to proposed handback of rehabilitated areas for Alcoa to internally monitor and confirm achievement of completion criteria prior to submission of applications for certificates of acceptance. This takes place at the various stages of completion, supported by monitoring data and self-audit checklists. DBCA reviews Alcoa's rehabilitation checklists, and monitoring data are provided to DBCA annually to allow field audits of the rehabilitation and timely feedback to Alcoa where appropriate. Where the relevant completion criteria are not met or other mitigating/corrective actions are required, Alcoa will remediate accordingly. This process is undertaken in partnership and is not mandated.

The formal acceptance of rehabilitated areas by the State is achieved through the issue of a Certificate of Acceptance to Alcoa by the DBCA on behalf of the State.

6.2.5 Rehabilitation Status

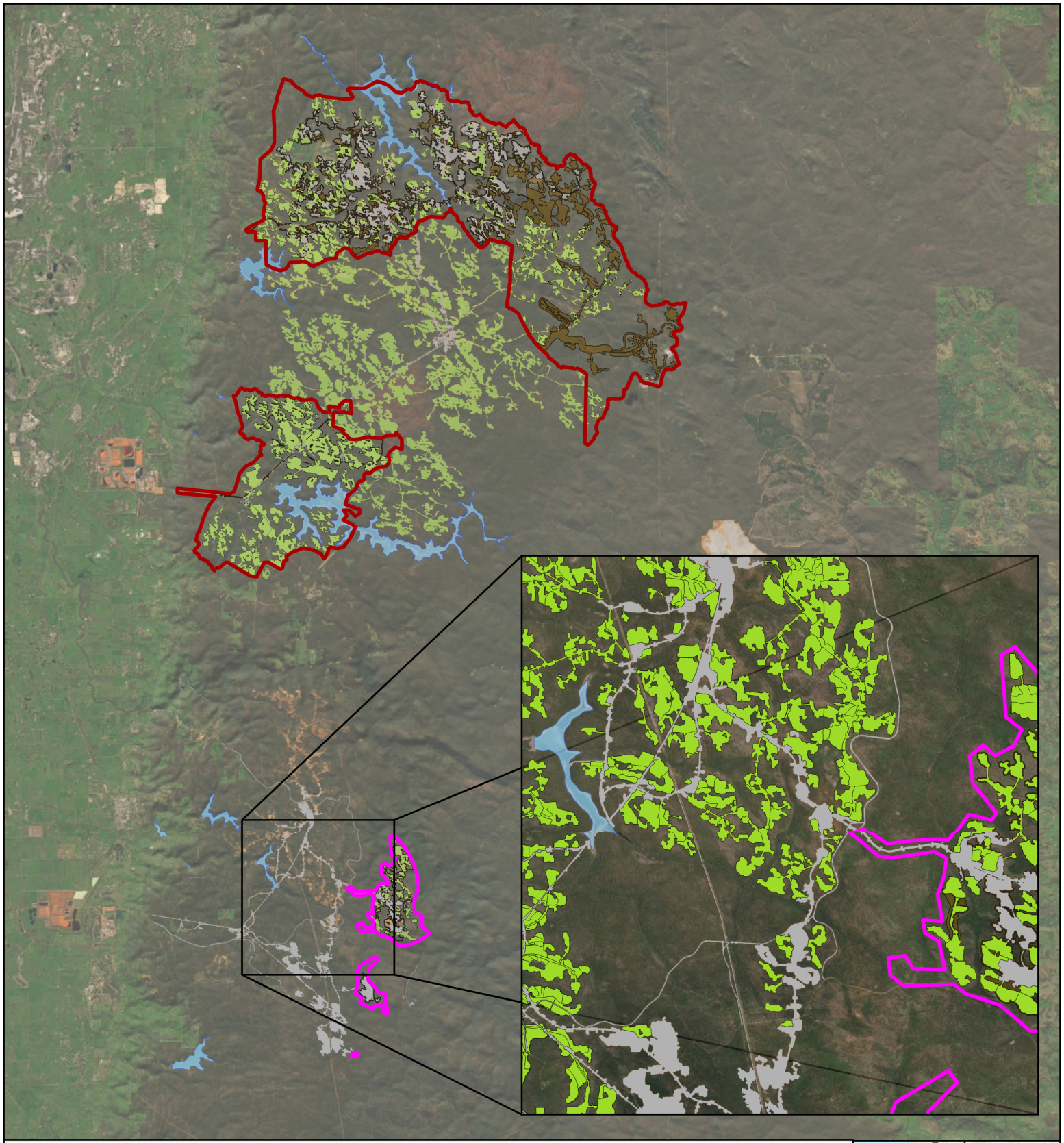
As of June 2023, 18,459 ha had been rehabilitated at the Huntly and Willowdale mines. Alcoa has rehabilitated 77% and 74% of the existing mining areas in the Huntly and Willowdale regions. While not included in the Proposal, Alcoa has rehabilitated 100% of the Jarrahdale mining disturbance and received a Certificate of Acceptance 1,355 ha to the DBCA. Alcoa's rehabilitation efforts are shown in Table 6-4, which breaks down the rehabilitation completed based on the years since rehabilitation was undertaken and the corresponding completion criteria at the time. Rehabilitation undertaken as of June 2023 across Alcoa's Operational Footprint in relation to open areas (existing and proposed) are shown on Figure 6-1.

Table 6-4: Rehabilitation Status (to June 2023)

Region		Huntly Rehabilitation / Disturbance (ha)				Willowdale Rehabilitation / Disturbance (ha)				Jarrahdale[1] Rehabilitation / Disturbance (ha)	
Applicable Completion Criteria		1976 – 1987	1988 – 2004	2005 – 2015	> 2016	1984– 1987	1988 – 2004	2005 – 2015	> 2016	1966 – 1987	1988 – 2004
Rehabilitation Age (years)	35+	1,768	169	-	-	100	70	-	-	1,706	132
	19 – 34	-	3,553	351	-	-	1,770	142	-	-	2,193
	15 – 18	-	-	1,580	-	-	-	672	-	-	-
	9 – 14	-	-	2,687	-	-	-	965	-	-	-
	3 – 8	-	-	-	2,293	-	-	-	796	-	-
	1 – 2	-	-	-	746	-	-	-	344	-	-
	<1	-	-	-	271	-	-	-	182	-	-
Total Rehabilitated		13,418				5,041				4,031[2]	
Total Cleared		17,416				6,728				4,031	
Percentage Rehabilitated		77%				75%				100%	

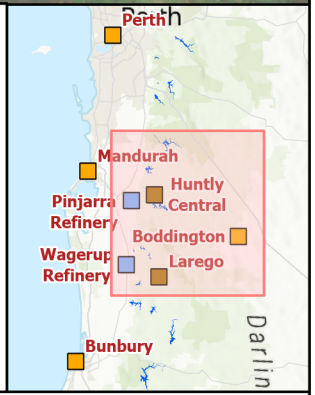
[1]Note, Jarrahdale is not included in the Proposal. Jarrahdale rehabilitation has been included to further demonstrate Alcoa's commitment to rehabilitation.

[2]1,355 ha has received a Certification of Acceptance



Legend

- Huntly Mine DE
- Willowdale Mine DE
- Proposed Disturbance Footprint
- Previously Cleared Areas
- Rehabilitation Footprint
- Reservoirs



Bauxite mining on the Darling Range in the Southwest of WA - 2023 to 2027

Figure 6-1 Rehabilitation undertaken (as of June 2023) across Alcoa's Operational Footprint in relation to open areas (existing and proposed)

Kilometres

0 5 10 15 20 25

Scale: 1:350,000 at A4

Date Printed: 28/02/2025

N

Alcoa

6.2.6 Independent Peer Review of Rehabilitation Methods and Success to Date

Continuous improvements in rehabilitation are identified and investigated by implementing focused research involving in-house trials, field studies, and collaborating with experts from a range of research providers including universities, consultants, and industry partners. An additional facet is independent peer reviews which are undertaken from time to time at the direction of Alcoa or regulatory agencies.

Alcoa's direct involvement in research on environmental management issues related to its operations in Western Australia commenced in 1972 with the appointment of a scientist to work on mine site rehabilitation. Alcoa has sponsored a considerable amount of research by universities, government departments, CSIRO, and consultants.

Stantec Australia (2023) conducted an independent peer review of Alcoa's rehabilitation. Their purpose was to assess the:

- Rehabilitation success to date, based on vegetation units, efficacy, and stability both now and in the context of climate change;
- Alignment of rehabilitation methods and success with proposed Northern Jarrah Forest post-mining land use; and
- Consistency with ongoing ecological integrity of the Northern Jarrah Forest.

The peer review was conducted consultants which are very familiar with Alcoa's operations in WA, particularly in relation to rehabilitation of mined areas, and bauxite residue. In addition to direct relevant experience with Alcoa, the team has broad experience in rehabilitation approaches, monitoring, and development of completion criteria with major clients across the WA resources sector. As a complement to that on-ground experience, the consultants were involved in the development of the recent DEMIRS-endorsed framework for developing mine-site completion criteria in Western Australia (WABSI 2019), being a co-author on the publication.

Outcomes and performance of Alcoa's rehabilitation is more thoroughly described in Section 6.1. Stantec (2023) surmised Alcoa's rehabilitation practices after bauxite mining in the NJF, together with a substantial program of related research published in peer-reviewed journals, remain as sophisticated and comprehensive as any mining operation globally. In addition, the process of development and sequential refinements of publicly-available completion criteria, commencing more than 30 years ago, exceeds that of other mining operations in WA, if not globally. Despite this, rehabilitation standards and practices, and stakeholder expectations have increased over time such that continuing improvements in biodiversity outcomes and ecological integrity are required. Several areas of improvement were identified (Stantec, 2023):

- Species richness targets have generally been met; however, where remedial works have been undertaken, monitoring will occur again;
- The peer review did not identify or review any monitoring data for understory cover;
- The monitoring and self-certification process relies on Alcoa's internal data tracking which is subject to a level of inaccuracy and reliant on DBCA identifying errors during the sign-off process which has not always been successful.
- Alcoa places a reliance on the creation of fauna habitat in absence of studies on recolonisation of fauna in current era rehabilitation; however, recent studies highlight the

need for caution when assuming that revegetation will lead to the establishment of appropriate faunal communities;
- Further research is required to understand the long-term implications of differences in community composition in rehabilitation compared to unmined forest and the impacts posed by climate change, fire regimes, *Phytophthora* dieback, and drought.

Stantec concluded that Alcoa will require a more holistic landscape-scale assessment of rehabilitation performance over time and needs to continually examine how rehabilitation practices can be adapted to support both the sustainability of rehabilitation and the ecological integrity of the surrounding forest matrix (Stantec, 2023).

Alcoa also undertakes monitoring as required by the commitments outlined in the 2023–2027 MMP Ministerial Approval and Division 3 of the Exemption Order. As per the 2023–2027 MMP Approval Condition 27, Alcoa is required to obtain the services of an independent qualified person to monitor and report compliance. Condition 32 necessitates Alcoa to submit an annual CAR to the Minister of State Development. This report must detail compliance with monitoring requirements for each condition of the MMP Approval, as stipulated by Condition 35.

Ramboll (2024) completed an independent CAR, involving both desktop checks and field verification. Field monitoring began on 8 February 2024, with frequency increasing weekly to thrice weekly in May. The Exemption Order and MMP Approval conditions necessitate weekly compliance monitoring until April 2024, increasing to three times per week in May, and five days per week in June. Both Huntly and Willowdale mining sites were monitored during the reporting period from December 2023 to 20 June 2024. The findings from the assessment are found in the Compliance Assessment Plan in accordance with Ministerial Approval Condition 36 (Alcoa, 2024b).

Alcoa remains committed to achieving its rehabilitation goal. This is evident in various awards that have been awarded to Alcoa in relation to rehabilitation efforts and environmental contributions, such as:

- Department of Mines, Industry Regulation and Safety Golden Gecko Merit Award (2018) for Environmental Excellence Alcoa of Australia (in partnership with Murdoch University);
- Landcare Australia – WA Landcare Awards (2017) Australian Government Partnerships for Landcare Swan Alcoa Landcare Program (Alcoa of Australia, Department of Biodiversity, Conservation and Attractions and Perth Natural Resource Management);
- Australian Nursery and Garden Industry Association Various Best Propagation; Best Training; Best Community; Best Medium Production Nursery Awards (2014, 2012, 2011, 2010);
- Western Australian Environment Awards Bush, Land and Waterways Category Award (2009) Alcoa of Australia, Greening Australia and Harvey River Restoration Taskforce won for the Nell's Block Project in Yarloop;
- Western Australian Department of Mines and Petroleum Golden Gecko Award (2007) for Environmental Excellence Western Australian Mining Operations (for closure, remediation and rehabilitation of the company's first bauxite mine at Jarrahdale, comprising 4,090 hectares);
- Society for Ecological Restoration International Award for Outstanding Contribution to the Field of Ecological Restoration (2003) Alcoa of Australia (for leadership in mine rehabilitation in Western Australia);

- Western Australian Department of Mines and Petroleum Golden Gecko Award (2002) for Environmental Excellence Alcoa of Australia (for mine rehabilitation and restoring the botanical diversity of the Jarrah Forest);
- Wildlife Habitat Enhancement Council (1992) Portland Aluminium Smelter (two awards for Smelter in the Park; this was the first time the Council had awarded any organisation outside the United States); and
- United Nations Environmental Program Global 500 Honour Roll (1990) Alcoa of Australia (first mining company in the world to be recognised for mine rehabilitation excellence).

6.3 Rehabilitation Performance

This section has been compiled to demonstrate Alcoa's rehabilitation performance utilising quantitative and qualitative data gathered from Alcoa's internal monitoring program and conclusions drawn from the peer review completed by Stantec (2023).

As of June 2024, Alcoa had rehabilitated approximately 79.6% of its operational footprint. Rehabilitation has been identified as a primary mitigation measure across the potentially impacted environmental factors. This section expands on the information provided in Section 2.2.4 regards the rehabilitation program.

Alcoa's rehabilitation is subject to completion criteria developed with and approved by the BSEC (previously approved by the MMPLG). The current agreed rehabilitation objective is to restore a self-sustaining jarrah forest ecosystem planned to enhance or maintain water, timber, recreation, conservation and/or other nominated forest values (Alcoa, 2015) (Section 6.2.2). The completion criteria have evolved over time, being informed by interactions in research and practice and are applied to the relevant rehabilitation establishment year. The assessment of rehabilitation against the completion criteria occurs at various stages of the rehabilitation execution and establishment. This is discussed in Section 2.2.4.

This section examines the quality of the rehabilitation completed to date, concluding from Alcoa's internal monitoring program and the peer review completed by Stantec (2023) which is provided in Appendix 70.

6.3.1 Flora and Vegetation

In rehabilitation, the return of flora and vegetation is the foundation for many other ecological processes. Indeed, within the Jarrah Forest, at least 300–400 plant species assemble to constitute the vegetation typically mined (Koch, 2007). This vegetation attracts herbivores (and other fauna), like the emu, which benefit from the food vegetation provides and, in turn, contribute to seed dispersal and nutrient cycling. At the same time, soil is one of the critical ingredients supporting vegetation; however, biotic processes within vegetation also influence the soil. For example, plant roots stabilise against erosion (Hubble, Docker, & Mickovski, 2012), detritus from plant decomposition reduces water runoff and increases infiltration (Doerr, Shakesby, & Walsh, 2000), and plant microbial activity assist in replenishing soil nutrients (Jasper, 2007).

Alcoa has botanical monitoring data, dating from 1990 onwards, demonstrating vegetation establishment in rehabilitation. Alcoa measures the success of rehabilitation using several indices and their associated thresholds established within four discreet rehabilitation eras. For example, species richness is one commonly applied index of success which has

appeared in the Completion Criteria of the three most recent rehabilitation eras and has generally been met for most rehabilitated areas. The species richness recorded within rehabilitation is at a level which is considered acceptable according to the conditions agreed upon by the government in the corresponding Completion Criteria eras. Species richness and other measures related to density and recalcitrant species are discussed in the following sections.

In lieu of the progressive nature of the Completion Criteria and striving to keep up with best research practices, Alcoa continue to develop rehabilitation and monitoring practices. For example, Alcoa's rehabilitation seeding program returns 78–113 native Jarrah Forest species from local provenance collected within approximately 20 km of the mine (Koch, 2007). Using local provenance seeds is supposed to ensure that the genetic diversity of the restored areas is maintained and matched to surrounding native vegetation (McKay, Christian, Harrison, & Rice, 2005). Still, other progress in the use of remote sensing technologies to measure the Leaf Area Index (LAI) to demonstrate vegetation is present (related to Completion Criteria around bare areas assessment), growing at rates similar to those observed in the unmined forest are still in development (but see more on LAI in Section 6.3.1.4.

6.3.1.1 Native Plant Species Richness

Species richness refers to the total number of different species present in a specific ecological community, ecosystem, or defined area. It is a fundamental measure of biodiversity, providing insight into the variety of life forms within a particular habitat (Rafferty, 2023). Alcoa has adopted species richness as a leading performance indicator, whereby early adaptive management can be implemented based on performance against this rehabilitation criterion.

From 2004 onwards, Alcoa has adopted a mean species richness target of 60% of analogue sites. Alcoa utilises analogue reference ecosystems, which are adjacent or nearby sites from which the necessary ecological attributes can be quantified to develop completion criteria (Young, O'Connell, & Roper, 2019). These analogue sites are termed 'permanent forest plots' by Alcoa and are 20 m × 20 m plots (containing quadrats) which have been established in unmined forest adjacent to mining areas in the same Havel Site Vegetation Types (SVTs).

The current Completion Criteria requires that all rehabilitated areas achieve a minimum of 60% species richness. If a rehabilitation pit does not achieve the minimum 60% species richness target, remediation will be undertaken to meet the Completion Criteria standard.

The average species richness for rehabilitated areas in 2020 was 101.7%, in 2021 was 91%, and in 2022 was 86% (Plate 6-1). Plot richness mean at each site for rehabilitation undertaken in 2020–2022 is outlined in Table 6-5.

Table 6-5: Plot richness means at Huntly and Willowdale 2020–2022

Rehabilitation Year	Year Monitored	Huntly	Willowdale	Total WA Mining
2020	2021	103.1%	96.8%	101.7%
2021	2022	104.4%	81.3%	91.0%
2022	2023	88.3%	79.8%	86.0%

Of the 2022 rehabilitation season, 47 out of 48 pits at Huntly and 13 out of 14 pits at Willowdale met or exceeded the 15-month botanical monitoring Completion Criteria target of 60% species richness. The two isolated pits spread across Huntly and Willowdale that did not meet the Completion Criteria target, are likely attributed to the flow-on effects of underperforming topsoil, as a growth medium for broadcast seed and plants. Remediation involving broadcast planting within these pits was undertaken in 2024, to elevate species richness to meet the Completion Criteria standard.

As highlighted in Plate 6-1 below, Huntly's 2020 results demonstrated an increase in species richness, which exceeded Alcoa's internal target of 100% species richness return. Since 2020, Huntly's and Willowdale's species richness average has seen a downward trend, which is still on average, exceeding the 60% species richness Completion Criteria target by 37% at Huntly and 27% at Willowdale.

The reduction in species richness across locations is attributed to short-term weather patterns exhibiting consistently low precipitation coupled with the quality of donor soil material. The reduction in species richness at Willowdale, is likely a result of the onflow effect of the 2015 and 2016 fires, which has reduced the soil seed bank contribution to the species richness tally. Further investigations into donor site quality across WA Mining operations are required to understand the declining trend in species richness.

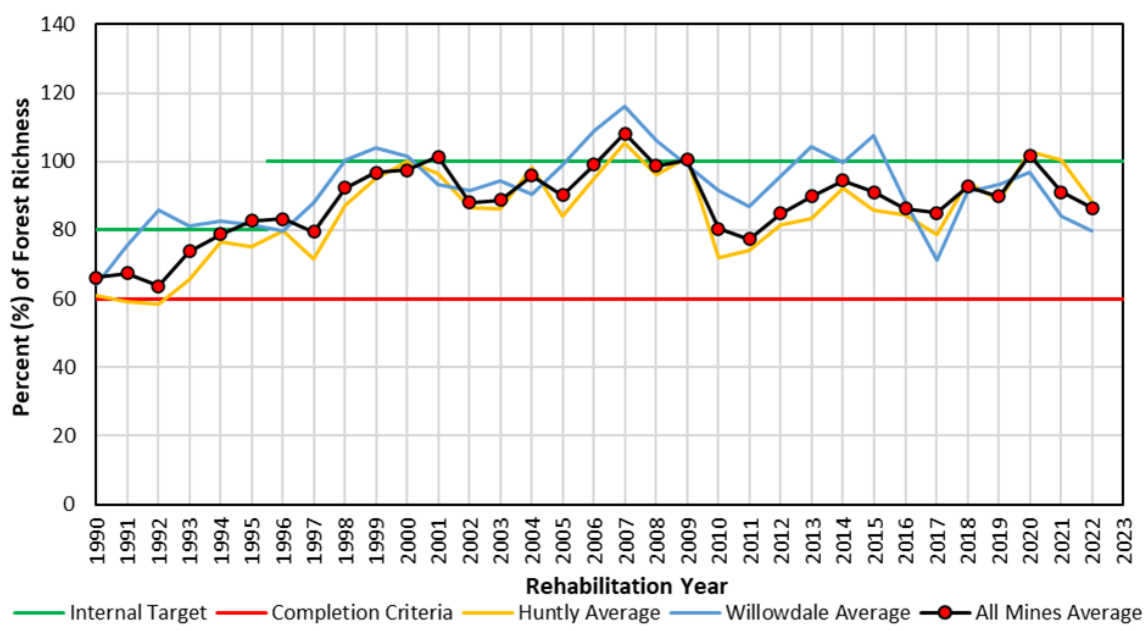


Plate 6-1: Trends in plant richness from 1990 to 2022 averaged across the rehabilitation at Huntly and Willowdale

From 1992 to 2022, on average 99% of the total rehabilitated area (15,989 ha) was deemed to have met the species richness target at 15 months of age (Plate 6-2). Rehabilitation covering 106.7 ha established during this period did not achieve the richness criterion at 15 months. Remedial works have either been completed or scheduled, which includes in-fill planting and seeding. The success of these works will be verified through reassessment botanical surveys.

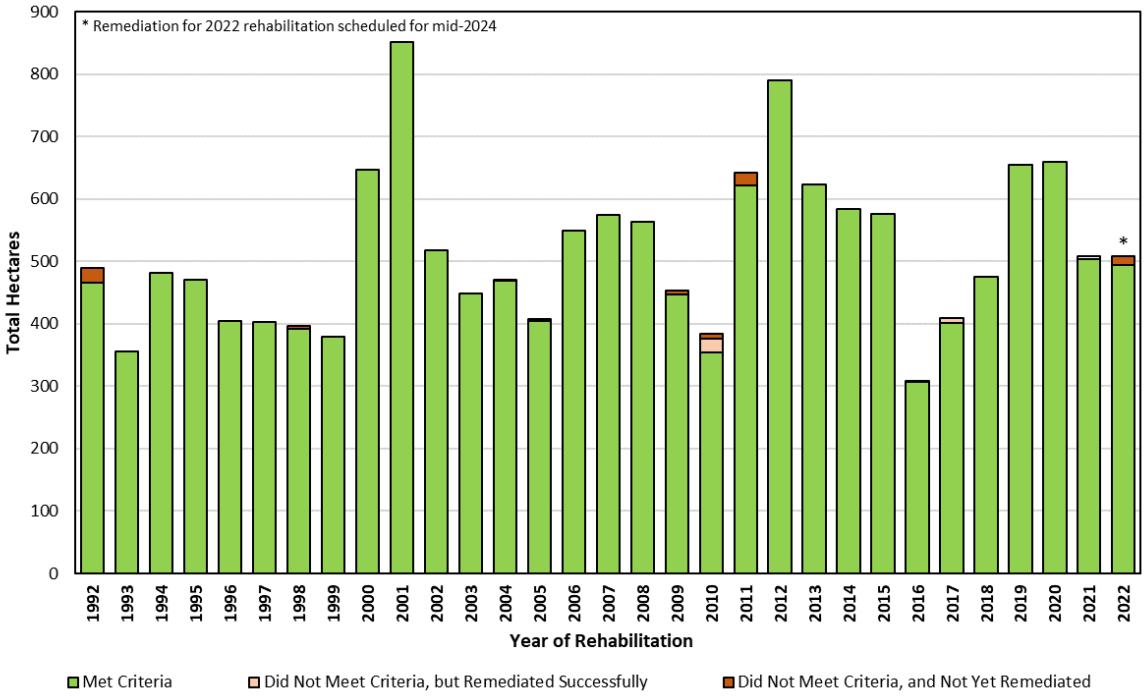


Plate 6-2: Rehabilitation Assessed at 15 months as meeting the critera for species richness

There has been substantial variability in species richness between the forest reference plots monitored within these SVTs from 1992 to 2023; however, the mean species richness was similar at around 40 to 42 species. When comparing the rehabilitated area species richness to the corresponding SVT, there was little variability between P, S and T type rehabilitation compared to forest completion criteria targets, with a mean of 80-82% species richness return. Therefore, it appears that the success in rehabilitation, in terms of returning species richness, is correspond well with each of these forest types (Stantec, 2023).

Analyses of species richness trajectories in Alcoa's rehabilitation performed by Standish et al. (2020) demonstrate that species richness declines along with the age of restored sites. This pattern is likely due to the reduction in early-colonising plants like weeds and short-lived plants, especially in the short term, followed by the progressive reduction of legumes (Daws et al., 2021). This pattern appears consistent with research from other temperate forests, which demonstrate a U-shaped model for forest succession predicated on the general observation of higher richness in the early and late stages of forest succession (Hilmers et al., 2018). If we apply this model to the regenerative stages of the Jarrah forest, postulated by Bradshaw (2015), we might expect that early-colonising plants would progressively decline during younger ages (0–15 years), with reduced richness detected in the juvenile–immature age classes (15 – ~120 years). While Alcoa's oldest rehabilitation is ~ 40 years, fire (an enforced standard built into the last four completion criteria eras) has acted as a disturbance mechanism, effectively resetting this model in older areas; subsequently, the oldest age in Standish et al.'s (2021) research was around 25 years of age, corresponding with species decline phase of the trajectory. Still, Bradshaw (2015) posits that Jarrah and Marri trees begin to die off at around 250 years of age – with larger trees living up to 450 years. Corresponding with this degenerative phase (~120 – 250 years), where natural decay would lead to canopy gaps and the formation of microhabitats, we might expect to see an increase of habitat specialist species, effectively increasing species richness. While ongoing

research is necessary, the trajectory remains promising despite the relatively short (post-fire effective rehabilitation age of 25 years) timeframe, given that these forests require approximately 120 years to reach the stage in which increasing richness is hypothesised.

6.3.1.2 Native Plant Density

Plant density refers to the number of individual plants per unit area. Monitoring plant density helps assess the success of rehabilitation by providing insights into how well a plant community is establishing and whether the ecosystem is recovering as projected. Understanding and monitoring plant density allows for adaptive management strategies to improve plant density (where required) or take remediation measures to reduce the density where establishment is too successful and will lead to resource competition.

Plant density is monitored for Jarrah, Marri and Legumes at 9-months, as a leading indicator. The density of all living vascular plant species (excluding moss, lichen, and fungi) is also recorded at all permanent monitoring plots established at 15 months.

Jarrah densities have been recorded since the early 1990s, with the inclusion of a minimum Jarrah target criterion introduced from 2015. From 2015 to 2022, 98% of the total rehabilitated area was assessed as meeting the Jarrah target density (150 stems/ha) at nine months of age, using on-ground monitoring plots (Plate 6-3).

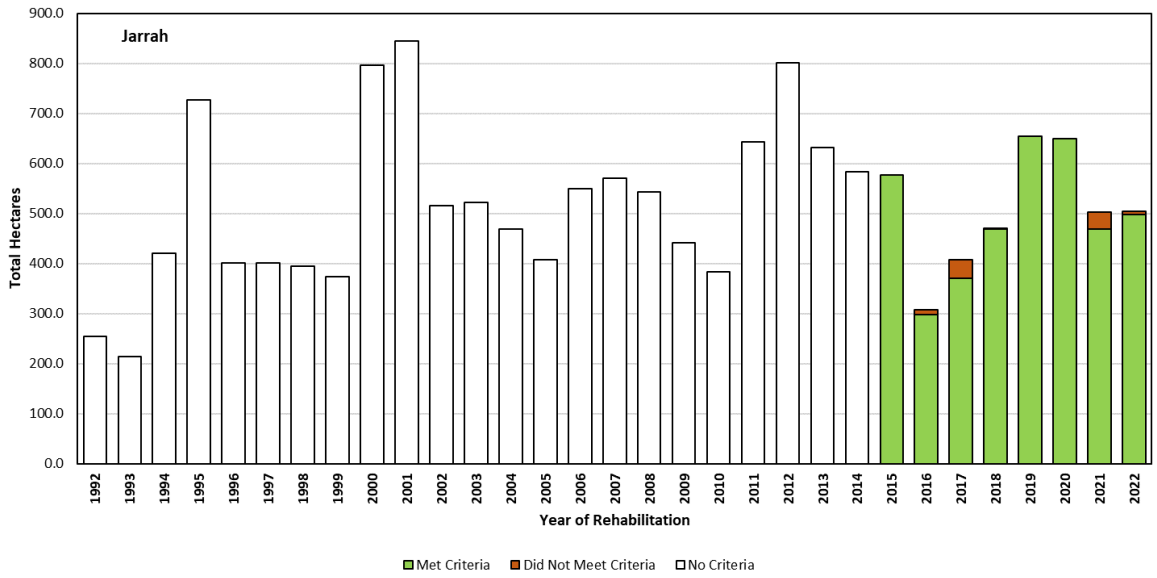


Plate 6-3: Rehabilitation by area for Jarrah density and areas that met the target of 150 stems/ha from 2015 onwards

Marri density has been less successful with 63% of the total rehabilitated area meeting the marri tree density criteria (200 stems/ha) from 2015 onwards (Plate 6-4). From 2019 to 2022, data indicated that marri establishment has not been as successful as the longer-term average, with between 22% and 58% of pits meeting the 200 stems/ha target, equating to a total area of 1099 ha over four years that did not meet the marri density target at nine months of age (Stantec, 2023).

The investigation into the declining trend in marri establishment has not yielded definitive conclusions regarding the reduced success rates observed in recent years. Alcoa has undertaken several proactive measures to enhance marri establishment in light of this trend.

In 2021, Alcoa increased marri seeding rates to improve germination success. Concurrently, Alcoa is engaged in active research and trials focused on various aspects of marri seed establishment. This research includes a reassessment of the timing for evaluating marri establishment efficacy. Preliminary findings suggest that marri germination may occur beyond the initial two-year period post-seeding, indicating that traditional 9-month monitoring might not adequately capture the full scope of marri establishment success. All areas not meeting the marri density target at nine months have undergone remediation efforts, including in-fill planting and seeding and are subject to further monitoring to confirm achievement of required density. Further remediation will be completed if required.

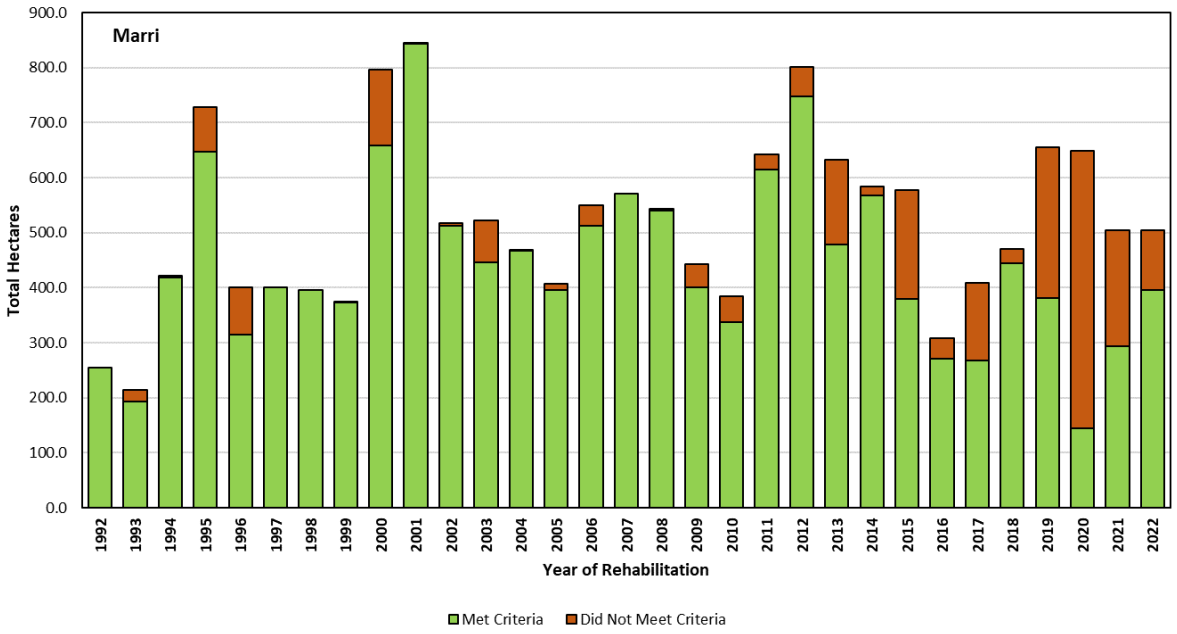


Plate 6-4: Rehabilitation by area that met the marri density target of 150 stems/ha (2005–2014) or 200 stems/ha (1988–2004 and 2015 onwards)

The criteria for total Eucalypt density have been updated over the years and embedded within the four rehabilitation Completion Criteria eras. Before to 2004, the criterion specified an average of 1,300 stems/ha over 65% of the pit and was updated to a target range of 600–2,500 stems/ha. In 2015 this target range was reduced to 600–1,400 stems/ha. Tree stocking rates have progressively decreased as research has demonstrated that high tree stocking rates are a tradeoff for species richness understory strata and run off to the catchment. Changes in State policy have effectively removed future timber harvesting potential as a consideration for these areas (Conservation and Parks Commission, 2023; Koch, 2007), with future aims of further shifting the focus from tree establishment towards a more balanced outcome for forest diversity and resilience. The reduction also reflects the application of this Criterion at Completion (i.e., 12 years of age) compared to previous versions applied at the establishment (i.e., in the first year after completing rehabilitation activities), which allows for natural tree mortality.

As articulated in the Stantec peer review, the total Eucalypt density was met at over 80% of the total rehabilitated area between 2004 and 2021 (Plate 6-5), with obvious deficiencies between 2019 and 2021 reflective of the poor marri densities (Stantec, 2023). As a standard action, all areas that did not meet the criteria were remediated, with in-fill planting assumed to be successful, based on the expected survival rate of seedlings.

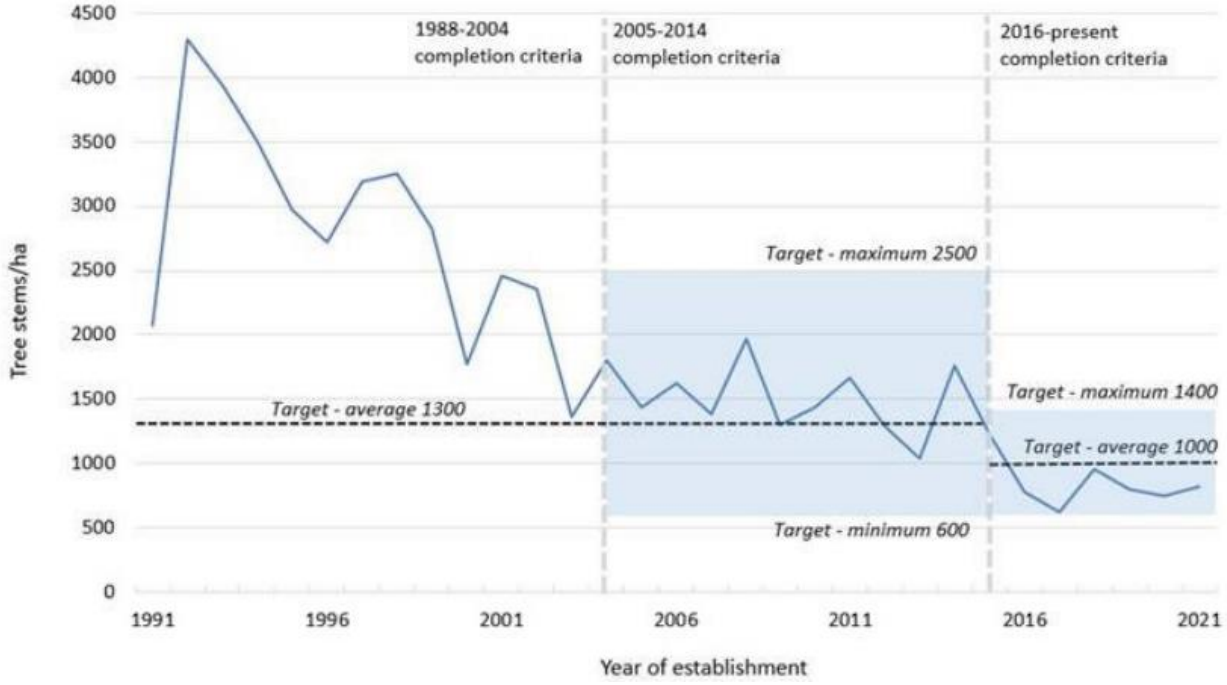


Plate 6-5: Mean total Eucalypt stem densities in relation to changing completion criteria targets (Alcoa, 2022a)

Legumes play a role in nitrogen cycling by fixing atmospheric nitrogen. This role is reflected by their inclusion as species functional group in the Completion Criteria. Legumes generally form a persistent soil seed bank due to having water impermeable 'physically dormant' seeds. While legumes are included in the applied seed mix most species come from seeds within the Fresh Topsoil applied during rehabilitation.

From 1992 to 2022, approximately 79% of the total rehabilitated area was assessed as meeting the relevant legume density target (Plate 6-6). The target was decreased from ≥1 plant/m^2 to ≥ 0.5 plant/m^2 in 2004 (with remediation and re-monitoring occurring), which equates to a decrease from 10,000 to 5,000 plants/ha (Stantec, 2023). High densities legume species may negatively impact the diversity and cover of other understorey species including native perennial herbs and resprouter species (Daws & Koch, 2015). In seeking to better balance the benefits and disadvantages of the legume understorey, and in doing so enhance the similarity of restored forest to the reference forest, a minimum density target was reduced.

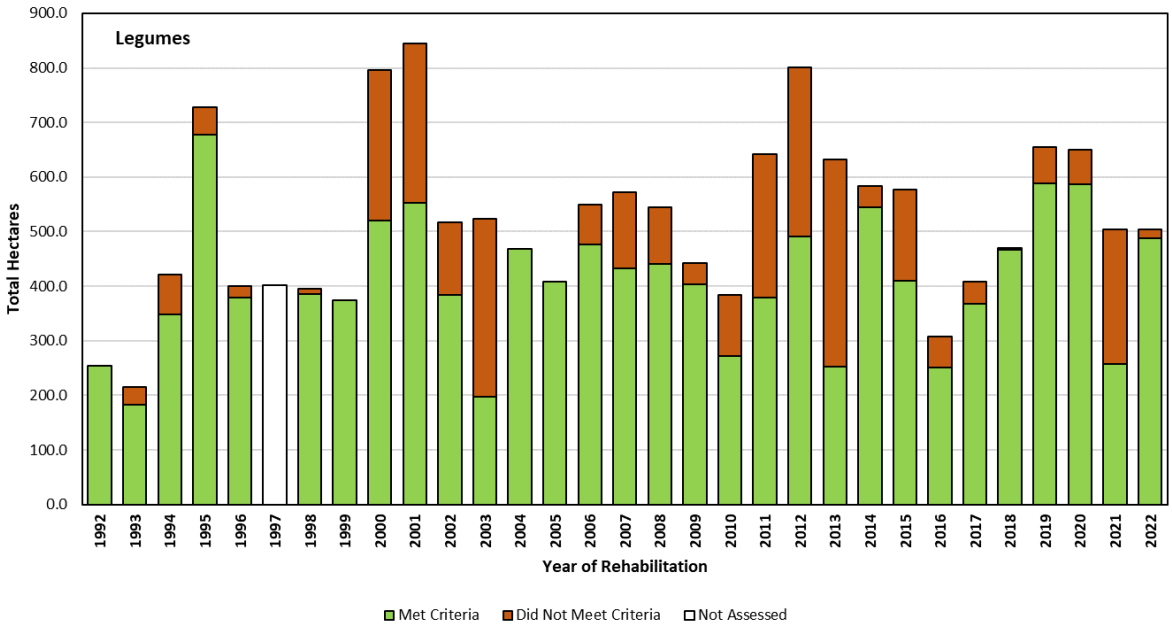


Plate 6-6: Proportion of rehabilitation meeting legume density targets

From 1999-2005, obligate re-sprouter species were propagated and nursery-grown seedlings planted in rehabilitation at densities of approximately 200 to 300 plants/ha, comprising 15 to 28 species (Koch, 2007). Most of these are graminoids, from the sedges (*Cyperaceae*), rushes (*Restionaceae*), and certain species of lily (*Anthericaceae*) and lomandras (*Dasypogonaceae*) (Koch, 2007). Currently, approximately 15 species are propagated and planting rates, in place since 2006, are approximately 800 plants/ha for all species combined (Alcoa, 2022a). The completion criteria for 2016 onwards consists of a minimum of 200 plants/ha in the 'Early establishment, monitored in rehabilitation at 15 months of age. Alcoa (2022a) indicates rehabilitation has been broadly successful at meeting this target.

6.3.1.3 Recalcitrant Species

Recalcitrant species are under-represented in the rehabilitated mined areas when compared to the surrounding Jarrah forest. Recalcitrant species are often difficult or impossible to re-establish using conventional direct seeding application methods and require propagation by tissue culture, cuttings or seeds. Table 6-6 shows the total number of recalcitrant plants planted in rehabilitated mine pits between 2021 and 2023. The number of plants produced is on an upward trend as external suppliers become more experienced in propagating and new species are introduced. Research and development are ongoing in an effort to further increase the richness and density of these species in mine rehabilitation.

Table 6-6: Mine recalcitrant planting 2021 to 2023

Year of Planting	Number Planted	Target
2021	490,328	551,040
2022	556,123	427,560
2023	439,046	426,720

6.3.1.4 Leaf Area Index

Leaf area, defined as the surface area of a single leaf, is a crucial measure of leaf size. This measure is influenced by various factors, including climate, geology, altitude, latitude, and different types of stress, such as heat, cold, drought, and nutrient deficiencies (Pérez-Harguindeguy, et al., 2017). The Leaf Area Index (LAI) is used when scaling up from individual leaves to quantify the total leaf area in a canopy relative to the ground area beneath it (Fang, et al., 2019).

LAI is a valuable metric for understanding ecosystem functions and is relatively easy to measure on a large scale. It provides insights into photosynthesis, which stores carbon while using water, affecting forest water dynamics (Fang, et al., 2019). LAI is typically measured remotely using satellite imagery and other remote sensing technologies (Macfarlane, Grigg, & Evangelista, 2007; Macfarlane, Grigg, & Daws, 2017). The remote sensing capability allows for large-scale monitoring and assessment of forest ecosystems with minimal fieldwork, requiring only ground truthing of specific areas. LAI provides essential data for ecological modelling and the environmental management of rehabilitation projects.

Research studies have used LAI as an indicator of combined overstorey and understory vegetation cover and shown that historic LAI of rehabilitation was higher than the unmined forest range, as a result of higher stem densities, consistent with the assumption regarding development of long-term cover (Bradshaw F. , 2015; Alcoa, 2022a). While for contemporary rehabilitation with lower tree density targets, even the oldest sites of the current prescription (rehabilitated in 2016) are too young to verify that current prescriptions result in a lower equilibrium LAI than rehabilitation established under earlier prescriptions.

LAI summary data for rehabilitation at Huntly and Willowdale since 2016 indicates that the LAI of contemporary rehabilitation (2016 onwards) is trending towards that of non-mined forest but on average remains substantially lower at 6 to 7 years of age; however, at this age it will be dominated by understory rather than trees. At 12 years of age rehabilitated areas have a greater coverage than that of non-mined forest; however, understory cover decreases (notable exception 17 years of age) such that at 25 years old understory cover of rehabilitation is approximately half that of the average understory cover recorded in non-mined forest areas. Peaks and subsequent decreases in understory between 12 and 17 years of age are likely related to the growth and then senescence of ‘seeder’ species (including longer-lived, nitrogen-fixing legumes) (Daws, et al., 2021).

6.3.1.5 Floristic Compositional Similarity

When comparing the composition of flora between two areas, such as rehabilitated sites and forest reference plots, we might consider how closely they resemble one another. In this context, many different ‘resemblance coefficients’ have been used to quantify the similarity or dissimilarity between the two objects (Podani, 2002). The colloquial use of the term ‘similarity’ has caused confusion in the field of ecology. It has been applied in various ways, often describing how alike two objects are in terms of species richness or density (both described above) rather than directly addressing how they resemble each other according to their composition of species. Perhaps the Euclidean, Sørenson, and Bray-Curtis indexes are the most common and easily understood coefficients which directly describe how two objects resemble each other by using the number (or abundance) of species which are shared,

missing in one object but present in another, or missing from both objects (= floristic composition).

Standish *et al.* (2021) and Daws *et al* (2021) provide perhaps the most comprehensive assessments of how the floristic composition of rehabilitation resembles unmined forests. Using 131 permanent plots established across rehabilitation and forest reference sites, Standish et al. (2021) demonstrate that the Bray-Curtis similarity coefficient (i.e., composition) of rehabilitation is progressing towards the forest reference state. Similarly, Daws *et al.* (2021), using a different subset of permanent plots, applied Sørensen's similarity coefficient to a comparable effect. Their study found that the similarity between rehabilitation and forest reference sites ranged from approximately 30% to 70%, showing improvement with rehabilitation age. It is especially interesting because Bray-Curtis incorporates both species abundance and presence, while Sørensen focuses on species presence and absence. The convergence of results from these two different coefficients indirectly suggests that both the abundance and diversity of species in the rehabilitation areas are shifting towards levels comparable to the forest reference plots.

Stantec (2023) found that recent works derived richness targets from unmined forest reference plots inclusive of all species present (with the majority of species coming from understory and midstory strata), specific compositional targets are only considered within the completion criteria for plant density. These plant density targets are for selected species or functional groups, namely jarrah and marri overstorey species, leguminous species and from 2016 onwards 'recalcitrant species', which may comprise 15 to 28 species (Koch, 2007). Other species that may be abundant in unmined forest but do not fall within these categories are therefore not represented by a specific target.

Despite inconsistency between studies, Alcoa is confident that completion criteria targets relating to establishment of a biodiverse understorey have been successfully met, as monitored in 80 m^2 plots in rehabilitation pits. This includes species richness, which has averaged over 80% of un-mined forest control plots, well above the target of 60%, and has met targets for legumes (Alcoa, 2022a).

6.3.2 Fauna Recovery

Alcoa's long history of mining, rehabilitation and monitoring has provided many opportunities to study the recolonisation of vertebrate fauna following the rehabilitation of mining disturbed areas in the NJF. In regard to vertebrate fauna colonisation following the rehabilitation of Alcoa's mining areas, Nichols and Grant (2007) found:

- Mammal recolonisation varies between species depending on species' food and shelter requirements and their distribution and abundance in the surrounding forest. Despite this, all mammal species recolonised mined areas within 10 years of restoration. Some species, like Grey Kangaroos, Mardos, and Chuditch (zero two years) recolonised rapidly, while others, such as Brushtail Possums and Brush-tailed Phascogales, took longer (eight to 10 years).
- Birds rapidly recolonize and 95% of species have been recorded in restoration. Bird community structure changes with restoration type and age, and in current restoration, it is similar to that of unmined forest by the age of 10 years.
- Reptile recolonisation varies between species with some species consistently occur in lower densities in rehabilitated areas compared to unmined forest. Of the species

compared studies showed that 21 out of 24 reptile species successfully recolonized to rehabilitated areas.

More recently Baseline Monitoring of Rehabilitation Programs in Alcoa's Bauxite Mining Areas has been undertaken by Terrestrial Ecosystems, with separate studies being undertaken in Summer (Appendix 41) and Winter (Appendix 42) of 2023. The baselines established 12 long-term monitoring sites for vertebrate fauna. Three of the sites are in unmined habitat, and three of the sites are in areas rehabilitated five, 10 and 15 years ago. It is proposed that the vertebrate fauna at these sites would be periodically monitored (e.g., every 5 years) to enable judgements to be made about the extent to which rehabilitated areas were progressing on a trajectory towards the recreation of functional ecosystems, as determined by the terrestrial vertebrate fauna assemblage, like that in the unmined areas (Terrestrial Ecosystems, 2023a). The baseline survey data indicated that the three unmined sites selected as analogue climax communities for the rehabilitation areas are not similar, and there are appreciable differences among the fauna assemblages within aged classes of rehabilitation. Further the preliminary data collected in this survey would suggest that conservation significant species are in the unmined areas, but not the rehabilitated areas (Terrestrial Ecosystems, 2023a).

The winter survey (undertaken June to July 2023) arrived at similar conclusions to the summer baseline with Terrestrial Ecosystems (Terrestrial Ecosystems, 2023b) reporting the current monitoring program requires adjustment, as the analogue sites for the rehabilitated areas appear not to be appropriate given the spatial variability in the vertebrate fauna assemblages in the unmined, and possibly older rehabilitated sites of the northern Jarrah forest. Many of the fauna recorded in the winter survey are common, widespread, and abundant, and given the mosaic disturbance pattern undertaken by Alcoa to mine bauxite in the northern Jarrah forest, the mining program is unlikely to threaten any of these common species. The camera and cage trapping program in June-July 2023 provided useful information about the abundance of these threatened species in selected areas, but the pit, funnel and aluminium box trapping program caught too few animals to be a useful monitoring tool (Terrestrial Ecosystems, 2023b).

The results of the winter survey showed that the pit, funnel and aluminium box trapping program predominantly caught frogs, in particular *Crinia georgiana* (Quacking Frog), with most of these captures in the rehabilitation sites (Terrestrial Ecosystems, 2023b). The increase in captures from summer was likely due to the cooling climate. Conversely, *Cercartetus concinnus* (Western Pygmy Possum) was more frequently recorded in summer probably due to the abundance of nectar producing plants that are flowering at the time and the ambient temperature. In cold weather, *C. concinnus* enters torpor and if found it is typically curled up in a ball and immobile. Similar observations were made for reptiles (Terrestrial Ecosystems, 2023b). Species trapped were generally typical of early coloniser species.

Cage and camera traps generally showed to be consistent to more successful in winter then summer. Many more *D. geoffroii* (Chuditch) were caught in June-July, with 13 of the 17 females caught having pouch young. The number of Quenda and Echidna caught was consistent (Terrestrial Ecosystems, 2023b). Chuditch, Quenda and Quokka were all recorded in greater numbers in the winter camera trapping than the summer.

Terrestrial Ecosystems (2023b) made several distinct recommendations to improve reliability in the future:

- The analogue sites for the rehabilitation areas should be relocated to the unmined areas adjacent to the rehabilitated areas that are being monitored.
- The summer (i.e., January) surveys should utilise pit, funnel and aluminium box traps monitoring techniques.
- The cage trapping program targeting Chuditch be replaced with camera trapping and a spot recognition analysis to determine relative abundance across the areas.

Alcoa has undertaken or supported many long-term studies into the recolonisation of fauna within the NJF. Survey methodologies, the location surveyed, and species of interest have varied greatly. Given the large volume of literature available, the data deficiency lies with the access, collation and review of the works undertaken.

6.3.3 Post-mining Land Use

In consultation with DBCA, the current era of completion criteria's agreed Post Mining Land Use (PMLU) is to re-establish a self-sustaining jarrah forest ecosystem, planned to enhance or maintain water, timber, recreation, conservation and other nominated forest values (DAFF, 2016). Rehabilitated areas must become amenable to similar management practices employed in the surrounding jarrah forest. Due to the evolving nature of Alcoa's rehabilitation aims and practices, rehabilitation is undertaken to meet the completion criteria of the time which has not always sought to achieve this PMLU. Where completion criteria targets are not met, remediation must be undertaken.

Alcoa is broadly achieving its conservation value targets (further defined below); however, it is noted that rehabilitated areas will require considerable time to return all habitat values removed during mining to support the diverse range of fauna of the NJF.

6.3.3.1 Conservation Values

Alcoa's rehabilitation object prior to 1987 was to establish tree plantations (not indigenous to the area) with no requirement to establish an understory, as was consistent with the approach adopted by the government of the time. Rehabilitation conducted between 1978 -1987, has a broader range of floristic characteristics established by seeding understory species (mostly legumes) but still with few overstorey Eucalyptus species native to the Darling Range (Stantec, 2023).

After 1988, direct seeding of indigenous species was introduced, with jarrah as the dominant *Eucalyptus* species. Genetic diversity is maintained through use of local provenance seed for rehabilitation, based on provenance zones established in 1991. The provenance zones are considered conservative given the relative uniformity of jarrah forest vegetation (Stantec, 2023).

Despite the sequential improvements in rehabilitation methods, differences in compositional similarity between rehabilitation and unmined forest remain (see Section 6.3.1). Furthermore, rehabilitation does not aim to reinstate the specific upland SVTs that were cleared (P, S and T), as the subtle differences in soil profile and landscape that defined the vegetation types are lost with the mining and rehabilitation process (Koch, 2007). Accordingly, while rehabilitation achieves comparable species richness and cover, it is

expected to cause a partial loss in the diversity of vegetation types compared to native jarrah forest (Stantec, 2023). Alcoa continues to strive for continuous improvement of flora and vegetation biodiversity outcomes through ongoing refinement of elements such as fertiliser inputs (specifically with respect to phosphorus), tailored seed mixes and continued focus on the return of species that remain poorly represented in rehabilitation compared to unmined forest.

The completion criteria relating to the re-establishment of fauna have varied slightly over time but have remained focused on creating habitat structures during initial rehabilitation works. For rehabilitation completed since 2005, at least one constructed habitat is required to be installed per two hectares. While completion criteria have not required monitoring of recolonisation by fauna, Alcoa have an established Long Term Fauna Monitoring Program and associated research programs. Synthesis studies conducted in both 2003 (Nichols & Nichols, 2003) and 2007 (Nichols & Grant, 2007) indicated that all mammal species re-colonize mined areas within 10 years of rehabilitation, though the rate of recolonisation varied, with some species returning relatively quickly (Grey kangaroo, mardo) and others, dependent on larger trees for example, taking longer (Brushed-tailed Phascogale, Forest red-tailed black cockatoos). Previous research has also indicated that the recovery of floristic diversity (>80 percent) in past prescriptions of rehabilitation was likely a key attribute supporting recolonisation of fauna including invertebrates, mammals (e.g., woylie) and reptiles (Glen, et al., 2008).

Based on survey and research programs on past prescriptions, Alcoa have concluded with a high level of confidence that the effectiveness of rehabilitation under past prescriptions (e.g., 1980s-1990s) has been demonstrated in relation to fauna return (Alcoa, 2022a). However, only a moderate level of confidence has been assigned to the ability of contemporary rehabilitation prescriptions to improve fauna habitat values which is expected given the lack of studies on recolonisation of fauna in current era rehabilitation, given the young age of rehabilitation. This risk is partially offset by the expectation that current era rehabilitation will establish a floristic diversity and vegetation structure closer to that of un-mined forest relative to earlier prescriptions (Alcoa, 2022a).

The final element considered for conservation value is the soil profile in rehabilitated areas. Suitable growth medium is essential to facilitate successful rehabilitation. This is achieved by removing the two top layers of the soil profile (topsoil and overburden) separately prior to mining (termed double stripping). Following ore extraction, the area is landscaped to blend in with the surrounding forest and the two soil layers are replaced in order. In this way, the original topsoil and overburden (subsoil) serve as a suitable growth medium.

Soil physical, chemical and biological properties all influence species richness and plant density in rehabilitation. To improve water infiltration, support plant growth, and alleviate compaction, the pit floor is ripped. The soil profile is then returned, firstly overburden is replaced, then stockpiled topsoil and finally fresh topsoil is returned. The final landform is then ripped on contour to facilitate rapid infiltration of rainfall to minimise any pooling or overland flow. Rehabilitated areas are fertilised to replace some of the nutrients lost through vegetation removal. Biological activity is replaced through seeds and microbial communities in the fresh topsoil. Measuring soil fertility and drainage by ensuring the presence of a suitable growth medium is standard practice throughout industry (Young, O'Connell, & Roper, 2019).

Plant-soil feedback and below-ground biotic processes during vegetation growth led to further soil development. For instance, roots stabilise soil and prevent erosion (Hubble, Docker, & Mickovski, 2012). Increased soil organic content reduces water runoff and increases infiltration (Doerr, Shakesby, & Walsh, 2000) and plant microbial activity replenishes soil nutrients (Jasper, 2007).

Fixing atmospheric nitrogen through the symbiotic relationship between legumes and rhizobia is key in post-mining rehabilitation as it enriches the potentially depleted soil with essential nutrients, promoting the recovery of healthy ecosystems.

Species also differ in how they access and use nutrients. Legumes can fix nitrogen from the air (Hansen, Russell, & Rind, 1987), plants with fungal associations can absorb nutrients and water by accessing larger areas of soil (Hingston, O'Connell, & Grove, 1989), and some plants have roots that release acids to unlock nutrients in the soil (Jasper, 2007; Lambers, 2014). A diverse range of species leads to a greater genetic diversity, which helps species adapt to changing climates and promote soil health (O'Brien, 2007).

Studies indicate that soil fertility and profile increasingly resemble unmined forest permanent plots as rehabilitation establishes over time (Tibbett, 2010). By age 12 soil microbial function is on a trajectory towards full recovery (Liddicoat, et al., 2021; Banning, et al., 2011) and is resilient to fire (Cookson, Murphy, & Roper, 2008). Additionally at this age, topsoil seedbanks have been replenished (Smith, Smith, & Johnson, 2000) enabling recruitment following future disturbances.

Measuring soil fertility is challenging, but early indicators like soil nutrient levels and initial plant establishment can be utilised to predict future rehabilitation success (Young, O'Connell, & Roper, 2019). Measuring soil health via stocking rates of eucalyptus, legumes, and species richness, provide a measure for soil health (Young, O'Connell, & Roper, 2019).

Alcoa (2022a) indicates that the current rehabilitation practices in relation to recreation of the soil profile provides a comparable, stratum to support root growth as prior to mining. Alcoa has identified that a substantial proportion of the rehabilitation completed at Huntly in 2018 had not had pit floor ripping to the required standard and that this had in some areas led to erosion in rehabilitated areas (e.g., Manning 15 pit), and importantly, has potential to constrain vegetation growth over the long term (Stantec, 2023). Further investigation into 2018 rehabilitation following the Stantec's review has confirmed areas were ripped but not to the agreed prescription. To date botanical monitoring has not identified any constraints on vegetation establishment or growth; however, the area is subject to erosion. These areas will continue to be monitored and remediation will be undertaken to ensure completion criteria are achieved, including criterion in relation to tree growth and establishment and erosion.

Alcoa have undertaken a series of research programs to understand the recovery of soil processes in rehabilitation at various stages of succession along with assessments of resilience to disturbances such as prescription burning and thinning in comparison to non-mined jarrah forest. Broadly, these studies have demonstrated that soil organic matter and microbial biomass re-establishes over time in rehabilitated sites, although recovery of organic matter (as measured by total organic C) is slower than the recovery of microbial biomass and in 18–26 years old rehabilitation remains below that of the non-mined forest mean (Banning & Murphy, 2008), (Jasper, 2007).

6.3.3.2 Water Catchment

Alcoa's long-term research into water quality monitoring and numerical modelling indicates that mining and rehabilitation is unlikely to substantially increase salinity or turbidity, nor substantially reduce inflows into drinking water reservoirs.

Bauxite mining causes an initial rise in groundwater levels and where groundwater is close to the valley surface a temporary increase in stream flow. This is followed by declines in groundwater and stream flow back towards pre-disturbance conditions as rehabilitation establishes (Croton & Reed, 2007), vegetation water use increases and a hydrological equilibrium is re-established (Macfarlane C. , Grigg, McGregor, Ogden, & Cilberstein, 2018; Grigg A. H., 2017). A study of streamflow response in the Lewis catchment, mined in the late 1990s, showed mining resulted in an initial increase in streamflow, peaking approximately four years after mining, followed by a return to pre-mining streamflow after around 11 years (Grigg A. H., 2017). Catchment responses to mining are equivalent to other forest disturbances such as timber harvesting. Therefore, the primary goal for the protection of surface water and groundwater values within mined catchments is the achievement of rehabilitation surface stability and vegetation establishment, and additional ecosystem resilience aspects.

Observations of continuing declines in flows in some catchments where density of rehabilitation exceeded that of pre-mining forests have led to trials of various rehabilitation prescriptions to reduce competition between trees and also developing rehabilitation approaches that result in less plant-available water within the soil profile in mine pits (Grant & Koch, 2007) (Grigg A. H., 2012).

Permanent tracks and roads can be a significant source of sediment and increased stream turbidity but the mitigating effects of riparian zone buffers, stream bank revegetation and stream channel vegetation on erosion and turbidity are well documented (Borg, Hordacre, & Batini, 1988; Harper & Lacey, 1997; Croke & Hairsine, 2006). Removal of haul road stream crossings and successful rehabilitation of streamzones are also expected to contribute to the protection of surface water quality.

Completion criteria recognise the fundamental importance of landscape design and accurate implementation (e.g., Slopes must always be less than 18 degrees, no landscaped pit is to have a slope greater than 15 degrees for more than 20 m unless it is on contour of the surrounding forest floor) for effective management of surface water and limiting the potential for erosion (Stantec, 2023). Holding water within the mined pit through the use of in-pit sumps and contour ripping minimises sediment transport and turbid drainage that could compromise water quality. However, while there are requirements relating to initial design and implementation in each pit, the requirement to monitor water quality has not been stipulated in completion criteria but rather is outlined in the Water Working Arrangements.

6.3.3.3 Visual Amenity

The visual amenity of rehabilitation can be different to non-mined forest as mine rehabilitation typically results in fast growing, single age stands in former mine pits that are clumped but scattered within a matrix of non-mined forest (Wardell-Johnson, Calver, Burrows, & De Virgilio, 2015). This contrasts with surrounding non-mined forest where silviculture and disturbances have resulted in a mosaic of different ages and structures (Wardell-Johnson, Calver, Burrows, & De Virgilio, 2015). It is to be noted the tree density

criterion established by Alcoa ensure appropriate stocking densities are met to reflect the forest reference ecosystem. Alcoa's rehabilitation objectives are aligned with DBCA, local government and BSEC to ensure that rehabilitated areas meet future land use requirements.

6.3.3.4 Resilience to Further Disturbance, Regional Pressures, and Climate Change

Climate change is expected to be a persistent, escalating stressor on all ecosystems in the Northern Jarrah Forest with the main anticipated or predicted changes over the coming decades expected to be drier and warmer conditions (Conservation and Parks Commission, 2023). These drier and warmer conditions will interact with other pressures affecting south-west forests, such as fire, disease, weeds and pest animals.

Completion criteria over time have focused on the requirement of rehabilitation to be as resilient to fire as the non-mined jarrah forest, and able to be integrated with existing forest management practices such as prescribed burning (Grant & Koch, 2003). Following a wildfire event in 2007, Alcoa monitored the re-establishment of vegetation (using LAI) to compare the recovery of rehabilitation completed in 1990 and 1992 to an unmined area. Results indicated by the LAI that the rehabilitated areas responded in the same manner as the unmined forest, with the LAI returning to pre-fire levels by 2010 (Plate 6-7). LAI values of the rehabilitated areas recorded for the years following the fire exhibited similar trends to those of the unmined area.

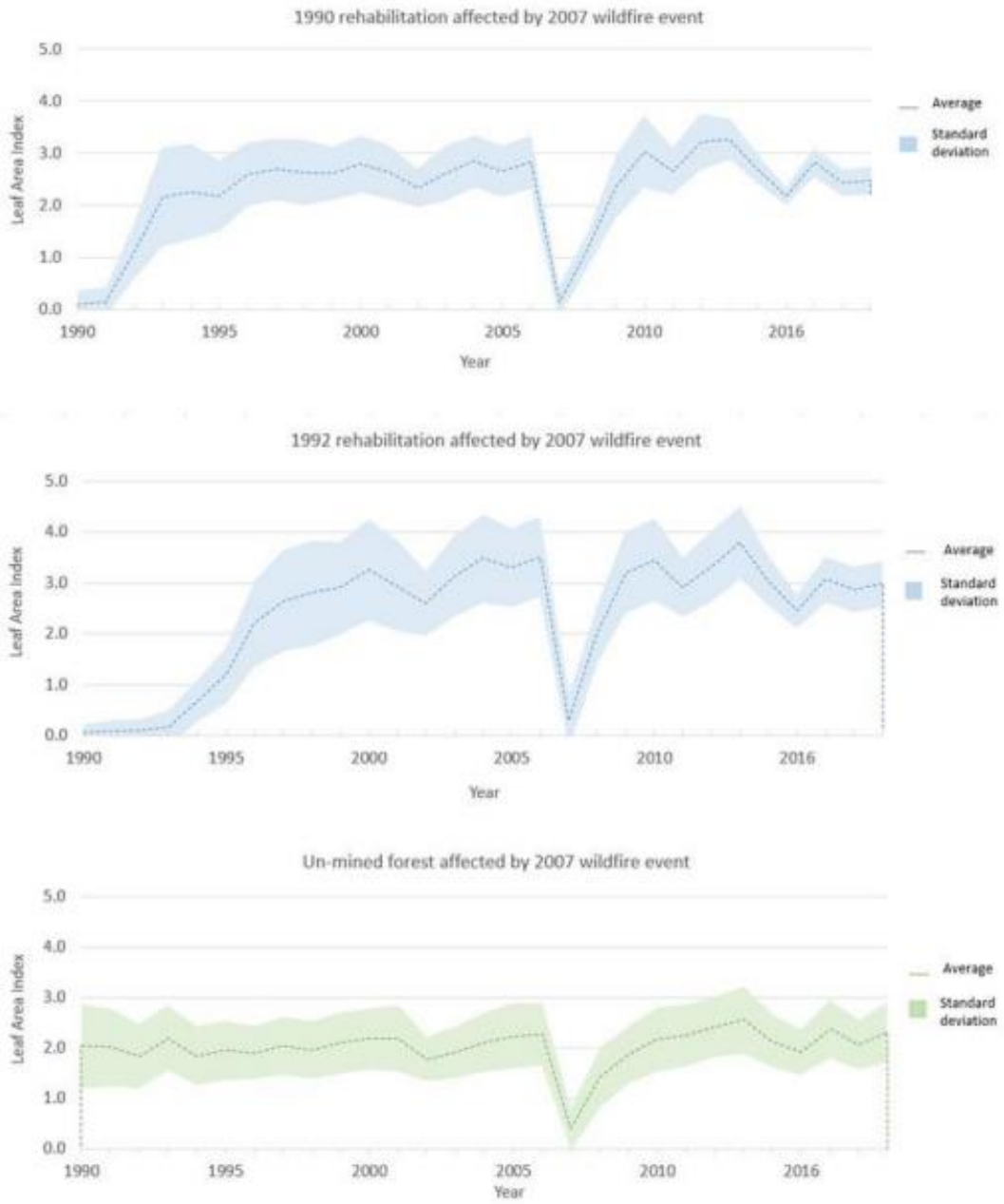


Plate 6-7: Recovery of rehabilitation following a wildfire event (Alcoa, 2022a)

A review of early monitoring of survival of 5- and 16-year-old rehabilitation (1979 to 1990 rehabilitation) and effectiveness of the *Phytophthora* dieback management procedures completed in 2000 revealed tree mortality coincided with areas of water ponding, and that the use of soil infested with *Phytophthora* dieback did not significantly decrease species richness, particularly in comparison to stockpiling of topsoil which had a larger effect (Colquhoun & Hardy, 2000). Marri is known to be less susceptible to *Phytophthora* dieback than jarrah (Colquhoun & Hardy, 2000) and is also likely to be increasingly important in the context of climate change as research suggests it has a physiology more resistant to drought (Szota, Farrell, Koch, Lambers, & Venklaas, 2011) and is a preferred foraging tree for Forest red-tailed Black Cockatoos.

Over the past 40 years, groundwater levels in the NJF have declined at rates up to 0.5 m year (Macfarlane C. , Grigg, McGregor, Ogden, & Cilberstein, 2018). To understand the

impact of a falling water table on the persistence (survival and growth) of rehabilitated forest, Alcoa have supported studies to quantify the physiological response of vegetation to water stress and use of available water (soil and groundwater) relative to non-mined forests. Species richness and assemblage composition were relatively consistent each year, and the study concluded 15-month rehabilitation demonstrated resistance to climatic variations and attributed this in part to the reliability (as opposed to the amount) of winter rainfall (Standish, et al., 2015).

In additional studies on water stress, field observations and aerial reconnaissance after the 2010/11 drought and heatwaves recorded tree deaths in both non-mined forest and in rehabilitation (Davidson, 2011). Many of the dying trees in non-mined forest had insect borers, while trees in some rehabilitation sites had obvious fungal cankers, both indicating that the trees had been under moisture stress for several months before the foliage had died (Davidson, 2011). Matusick et al. (2013) noted that tree death after drought was more prevalent close to rock outcrops and higher in the landscape and in soils with low water holding capacity; however, rehabilitation is typically situated mid slope.

Macfarlane *et al* (2018) investigated whether depth to groundwater and altered hydrology after mining affect overstorey transpiration rates of 8- and 30-year-old rehabilitation and post-harvest (logged) non-mined forests. They concluded that jarrah forests are likely to be facultative phreatophytes, meaning they will use groundwater where it is available but are not reliant on it, particularly where groundwater is within 10 m of the surface.

Based on increased confidence in seedling survival and rehabilitation practices that aim to improve water retention and root penetration, Alcoa suggest that rehabilitation in the current era is likely to exhibit reduced competition for water resources and hence demonstrate greater resilience to drought than in previous eras (Alcoa, 2022a). The ongoing trend of less trees established in rehabilitation, and thus an emphasis towards the understory, is likely to improve the water balance at the sub-catchment level (Wardell-Johnson, Calver, Burrows, & De Virgilio, 2015).

6.4 Ongoing and Future Research

Alcoa recognises the dynamic nature of ecosystems and the opportunities for improvement through research programs and advancements in technology. Since 1975 Alcoa has delivered, contributed to and supported a broad range of research including over 260 refereed journal papers and book chapters and 80 technical studies. Alcoa's Forest Research Centre, established in January 2025, builds on some 50 years of research and development with a focus on five main research pillars being:

- **Fauna protection and return** – Understanding and enhancing fauna management through improved surveys and monitoring, use of technology and feral species control.
- **Enhancing forest flora knowledge** – Developing knowledge of rehabilitated ecosystems, ecological communities, and impacts of climate, fire and dieback on forest plants.
- **Leading practice rehabilitation** – Building understanding of landscaping practice, topsoil management, seed germination and growth, and plant cultivation.
- **Water stewardship** – Ongoing protection of waterways and drinking water catchments, and furthering research of long-term trends in stream flow and climate impacts on surface and groundwater.

- **First Nations two-way science** – Partnering to enhance understanding of forest management, fire, culturally significant species, and health and wellbeing benefits found in the forest.

Alcoa has committed $15m of research funding to the Forest Research Centre for the next five years (Alcoa, 2024d), to undertake research internally plus also bolster our collaborative ability to with universities, state government, and other research institutions. The research centre is currently undertaking projects on a number of topics, including:

- Black cockatoos
- Threatened mammals
- Feral species
- Short range endemics
- Topsoil seedbanks
- Direct seeding technology
- Rehabilitation trajectories
- Erosion prediction
- The impact of fire in forest and rehabilitation
- Seed germination

Research undertaken by Alcoa is used internally to inform management and offset strategies as well as often externally published to improve the knowledge pertaining to the NJF.