South32

Worsley Mine Expansion WMDE, BTC and CBME

Phytophthora Dieback occurrence assessment – 0.144

Client	*South32*
Report name	*Worsley Mine Expansion WMDE, BTC and CBME*

This report has been prepared following the scope of work agreed between South32 and Glevan Consulting and contains results and recommendations specific to the agreement. Conclusions and advice in this report should not be referenced for other projects without the written consent of Glevan Consulting.

Procedures and guidelines stipulated in various manuals, particularly Phytophthora Dieback Interpreters Manual for lands managed by the Department (DBCA), are applied as the base methodology used by Glevan Consulting in the delivery of the services and products required by this scope of work. These guidelines, along with overarching peer review and quality standards, ensure that all results are presented to the highest standard.

Glevan Consulting has assessed areas based on existing evidence presented at the time of assessment. The Phytophthora pathogen may survive in the soil as an incipient disease. Methods have been devised and utilised that compensate for this phenomenon; however, very new centres of infestation, that do not present any visible evidence, may remain undetected during the assessment.

Executive Summary

As a part of the Worsley Alumina (Worsley) operations, bauxite mined at the Boddington Bauxite Mine (BBM) is transported by overland conveyor to the Collie Alumina Refinery.

The Worsley Mine Expansion Revised Proposal is for the:

- Expansion of the existing mining areas at the BBM;
- Development of a bauxite transport corridor;
- Development of a contingency mining area and maintenance work at the Refinery; and
- Development of associated mine/support infrastructure.

The Proposal includes activities being undertaken in three different Development Envelopes, namely:

- Worsley Mining Development Envelope (WMDE);
- Bauxite Transport Corridor (BTC); and
- Contingency Bauxite Mining Envelope (CBME).

These Development Envelopes are defined as:

- The WMDE represents a revised mining envelope that encompasses the previous development envelope known as the 'Pre-existing Approval Area' (PBA) and allows for additional mining to occur at the BBM within the broader WMDE.
- The BTC is a proposed corridor where long term truck haulage and conveying routes and associated supporting infrastructure, will be developed. The BTC will provide a route between the existing operations at Marradong and future mining areas to the north and overlaps the WMDE for most of the corridor.
- The CBME is a proposed development envelope within the existing Refinery Lease Area, where contingency bauxite mining activities will occur. The CBME is within the wider Refinery Lease Area (2,500 hectares), which includes the Worsley Refinery.

The Environmental Protection Authority (EPA) has determined that the above Proposal is to be assessed under Part IV of the *Environmental Protection Act 1986* (EP Act) (Environmental Protection Authority, 2019).

The scope of this report is to address the work required as outlined in the EPA's Environmental Scoping Document

Phytophthora Dieback is the disease caused by plant pathogens from the genus *Phytophthora*, of which over forty species have been identified in Western Australia. This disease is a key threatening process for the biodiversity of southwest Western Australia. Its dramatic impact on plant communities can also result in significant declines in some insect, bird and animal species due to the loss of shelter, nesting sites and food sources. Phytophthora Dieback can cause permanent damage to ecosystems, such that once an area is infested with the pathogen, eradication is usually impossible.

The region of Western Australia vulnerable to Phytophthora Dieback is defined as native vegetation occurring west of the 400 millimetres (mm) rainfall isohyet, in the Southwest and Midwest corner of Western Australia (Department of Parks and Wildlife, 2015). The Development Envelopes are located within the vulnerable area, with the Boddington North weather station recording the annual rainfall averaging just below 500mm (2012 – 2019).

Three species of Phytophthora have been recovered from the Development Envelopes according to publicly available data on the Dieback Information Delivery and Management System (Project Dieback, 2019). These species are:

P. cinnamomi	Located in CBME, WMDE (Saddleback, Marradong, Hotham North);
P. pseudocryptogea	Located in WMDE (Hotham North); and,
P. inundata	Located in WDME (Hotham North).

As the conditions of the disease triangle (host, environment, pathogen) have been satisfied for the Development Envelopes, Phytophthora Dieback is present in varying impacts on the vegetation across the sites.

Phytophthora cinnamomi, when identified is mapped, and the extent of the infestation determined and demarcated in the field. The other species of Phytophthora are demarcated when interpreters "determine if the pathogen's impact is significant (moderate to high impact) and take a precautionary approach in deciding whether to demarcate an infested area" (Department of Parks and Wildlife, 2015). *Phytophthora cinnamomi* is the focus of

Dieback assessments as this species is most prevalent and more destructive than other Phytophthora species.

This desktop review of the occurrence of Phytophthora Dieback used in this report was based on previous assessments conducted by Glevan Consulting and the publicly available datasets. A report referring to a recent assessment of sections of Newmont's Boddington Gold Mine (NBG) was not available for this review.

WMDE - Saddleback

Five infestations of Phytophthora Dieback occur in the Saddleback mining area. These are located adjacent to the main access road from Pinjarra-Williams Road, adjacent to the old gatehouse, adjacent to Tunnel Road and adjacent to the conveyor west of Lower Hotham Road (Figure 3).

Glevan Consulting has assessed many areas of the Saddleback region before the timber harvesting stage of the mining disturbance process. Typically only areas to be cleared for mining and infrastructure are assessed. All assessed areas that have been rehabilitated will not retain the Uninfested category until re-assessed and contain the required species and densities for interpretation. When rehabilitation clearing is needed, rehabilitated soil information is kept by Worsley and provides a level of risk of impact from the potential spread of infections.

WMDE - Marradong

One infestation of Phytophthora Dieback is located in the Marradong section of WMDE (Figure 5). This infestation follows a drainage line on the southern side of Morts Road, and mainly west of Ashcroft Road. This area was last assessed in 2017 with the infested area first identified in 1996.

WMDE - Hotham North

Four polygons of Phytophthora Dieback were identified during an assessment completed by Glevan Consulting in 2013 (Figure 6). More recent assessments have been limited to re-assessing the known infestations and tracks with a higher likelihood of disease presence. As previously stated, a current assessment (2019) for NBG within Hotham North has been undertaken, but the findings were not provided for inclusion in this report.

CBME

Phytophthora Dieback is extensive throughout the CBME (Figure 7). The vegetation was assessed in 2015 with only two small polygons (totalling 12.4 hectares) remaining Uninfested.

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1 Introduction

As a part of the Worsley Alumina (Worsley) operations, bauxite mined at the Boddington Bauxite Mine (BBM) is transported by overland conveyor to the Collie Refinery.

The Worsley Mine Expansion Revised Proposal is for the:

- Expansion of the existing mining areas at the BBM;
- Development of a bauxite transport corridor;
- Development of a contingency mining area and maintenance work at the Refinery; and
- Development of associated mine/support infrastructure.

The Proposal includes activities being undertaken in three different Development Envelopes, namely:

- Worsley Mining Development Envelope (WMDE);
- Bauxite Transport Corridor (BTC); and
- Contingency Bauxite Mining Envelope (CBME).

Together these development envelopes are collectively called the Primary Assessment Area (PAA).

These Development Envelopes (Figure 1) are defined as:

- The WMDE represents a revised mining envelope that encompasses the previous development envelope known as the 'Pre-existing Approval Area' (PBA) and allows for additional mining to occur at the BBM within the broader WMDE.

  In this report, the WMDE has been segmented into smaller areas, namely:

  - Saddleback – The area covered by the current mining area south of Pinjarra-Williams Road;
  - Marradong – The area covered by the current mining area north of Pinjarra-Williams Road, and south of the Hotham River; and
  - Hotham North – The area covered by the north side of the Hotham River.
- The BTC is a corridor where a conveyor route, haul road, and other supporting infrastructure will be developed. The development of the BTC will provide a connection from the Marradong area to the Hotham North, Nullaga and Central North mining areas. The BTC will provide a route between the existing Marradong, Nullaga

and Hotham North mining areas and future Mid Central mining areas to the north and overlaps the WMDE for most of the corridor.

- The CBME is a proposed development envelope within the existing Refinery Lease Area, where contingency bauxite mining activities will occur. The CBME is within the wider Refinery Lease Area (2,500 ha), which includes the Worsley Refinery.

The Environmental Protection Authority (EPA) has determined that the above Proposal is to be assessed under Part IV of the *Environmental Protection Act 1986* (EP Act) (Environmental Protection Authority, 2019).

Concerning the EPA's objective for the 'Flora and Vegetation' factor *"To protect flora and vegetation so that biological diversity and ecological integrity are maintained"*, the required work outlined in the EPA's Environmental Scoping Document is to *"Analyse risk of Phytophthora cinnamomi and Armillaria luteobubalina within the development envelope, undertake surveys (if relevant) and describe management actions to prevent introduction to protectable areas within the proposal area and adjacent conservation areas"*.

The scope of this document is to address, therefore the required work outlined in the EPA's Environmental Scoping Document.

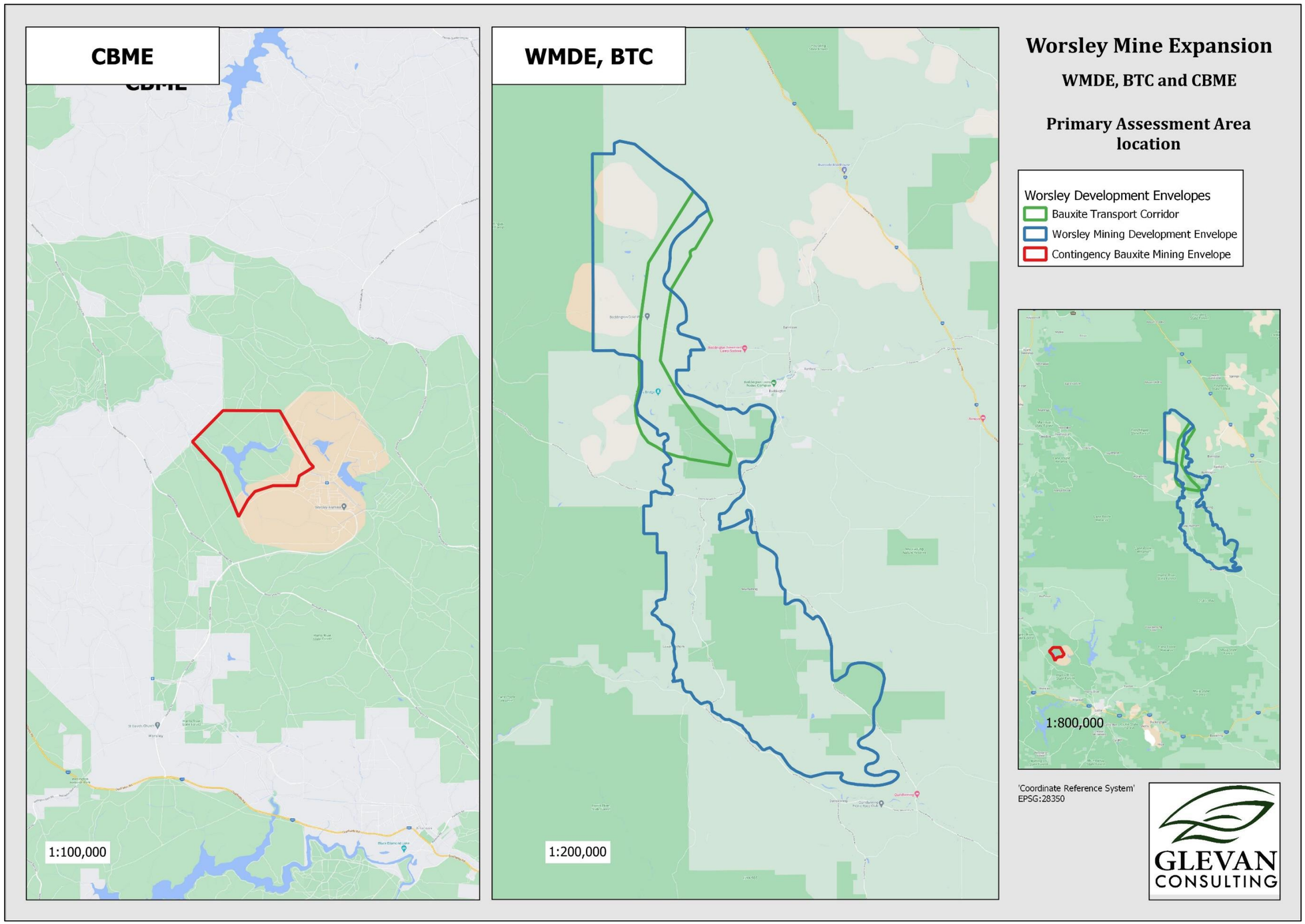

Figure 1 - Primary Assessment Area Location

2 Phytophthora Dieback

Phytophthora Dieback is the disease caused by plant pathogens from the genus *Phytophthora*, of which over forty species have been identified in Western Australia. This disease is a key threatening process for the biodiversity of southwest Western Australia. Its dramatic impact on plant communities can also result in significant declines in some insect, bird and animal species due to the loss of shelter, nesting sites and food sources. Phytophthora Dieback can cause permanent damage to ecosystems, being that once an area is infested with the pathogen, eradication is usually impossible.

Phytophthora is a microscopic water mould that belongs to the class Oomycetes. Oomycetes organisms are filamentous and absorptive and reproduce both sexually and asexually. *Phytophthora* species are considered parasitic. It behaves mainly as a necrotrophic pathogen causing damage to the host plant's root tissues because of infection and invasion (Department of Parks and Wildlife, 2015). The pathogen infects a host when it enters at a cellular level and damages the cell structure.

Phytophthora Dieback is the result of interaction between three physical components forming a 'disease triangle': the pathogen (*Phytophthora species*), the environment and the host. All three elements are needed for the disease to develop over time.

The relationship between the presence of *Phytophthora* and the development of Phytophthora Dieback disease is variable based on the susceptibility of native plant species and the different environmental characteristics, landform types and rainfall zones across bioregions.

2.1 Phytophthora Dieback Hosts

Not all species are susceptible to Phytophthora Dieback, and those that are susceptible and die allow the field interpretation for the presence of Phytophthora Dieback. These species are known as 'Indicator Species'.

The vegetation structure may include mostly susceptible species, in which Phytophthora Dieback may be obvious, to vegetation with little susceptible species where any Phytophthora Dieback present will display subtle symptoms.

Accepted Phytophthora Dieback indicator species that are known to be present in the Development Envelopes are shown in the following Table 1 (Department of Parks and Wildlife, 2015).

Table 1 - Susceptible Species Present in Development Envelopes

Family	Genus	Species
Cycadaceae	***Macrozamia***	***riedlei***
Ericaceae	***Leucopogon***	***capitellatus***
Ericaceae	***Leucopogon***	***nutans***
Ericaceae	***Leucopogon***	***propinquus***
Ericaceae	***Leucopogon***	***pulchellus***
Ericaceae	***Leucopogon***	***verticillatus***
Ericaceae	***Styphelia***	***tenuiflora***
Fabaceae	***Bossiaea***	***aquifolium* subsp. *aquifolium***
Fabaceae	***Daviesia***	***decurrens***
Fabaceae	***Pultenaea***	***reticulata***
Iridaceae	***Patersonia***	***occidentalis***
Iridaceae	***Patersonia***	***rudis***
Myrtaceae	***Eucalyptus***	***marginata***
Proteaceae	***Adenanthos***	***barbiger***
Proteaceae	***Adenanthos***	***cygnorum***
Proteaceae	***Adenanthos***	***obovatus***
Proteaceae	***Astroloma***	***ciliatum***
Proteaceae	***Banksia***	***grandis***
Proteaceae	***Banksia***	***littoralis***
Proteaceae	***Banksia***	***nivea***
Proteaceae	***Banksia***	***sessilis***
Proteaceae	***Banksia***	***squarrosa***
Proteaceae	***Persoonia***	***longifolia***

Family	Genus	Species
Proteaceae	*Xylomelum*	*occidentale*
Xanthorrhoeaceae	*Xanthorrhoea*	*gracilis*
Xanthorrhoeaceae	*Xanthorrhoea*	*preissii*

The vegetation must be of a suitable condition to allow the interpretation of Phytophthora Dieback. The condition is defined using the scale in Table 2.

Table 2 – Keighery (1994) Vegetation Condition Scale

Scale		Vegetation Condition
1	Pristine	Pristine or nearly so; no obvious signs of disturbance.
2	Excellent	Vegetation structure intact; disturbance affecting individual species and weeds are non-aggressive species.
3	Very good	Vegetation structure altered; obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
4	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
5	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
6	Completely degraded	The structure of the vegetation is no longer intact, and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Vegetation that can be interpreted will be segmented into Phytophthora Dieback occurrence categories based on Table 3.

Table 3 - Phytophthora Dieback Assessment for Vegetation Condition

Vegetation Condition	Phytophthora Occurrence Category
Naturally vegetated areas. Keighery (1994) disturbance rating of 3 or less, Phytophthora Dieback occurrence categorisation is possible	**Infested - Determined to have plant disease symptoms consistent with the presence of *P. cinnamomi,* or other Phytophthora species if determined by Interpreter during assessment.**
	Uninfested - Determined to be free of plant disease symptoms that indicate the presence of Phytophthora Dieback.
	Uninterpretable - Undisturbed areas where susceptible plants are absent, or too few to make a determination of the presence or absence of Phytophthora Dieback.
	Not yet resolved.
Vegetation structure temporarily altered.	**Temporarily Uninterpretable - Areas of disturbance where natural vegetation is likely to recover.**
Vegetation structure severely altered. Keighery (1994) disturbance rating 4 or greater. Phytophthora Dieback occurrence assessment is not possible	**Excluded.**

Note: The DBCA changed some nomenclature of Phytophthora Dieback occurrence categories with the release of the current manual *"FEM047 Phytophthora Dieback Interpreter's Manual for lands managed by the department".* The category 'Unmappable' which may appear in historic reporting has now been split into 'Temporarily Uninterpretable' and 'Excluded', as per the definitions in Table 3.

The condition of the vegetation in the PAA, as mapped by Mattiske Consulting (Table 4), shows that approximately 40% of the total area can be assessed for the presence of Phytophthora Dieback.

Table 4 - Summary of Vegetation Condition in PAA

Vegetation Condition	Hectares	% of the total
Completely degraded	13,016.63	44.35%
Degraded	4,211.05	14.34%
Good	119.32	0.41%
Very good	710.18	2.42%
Excellent	11,299.16	38.48%
TOTAL	29,356.33	

2.2 Environment

The region of Western Australia vulnerable to Phytophthora Dieback is defined as native vegetation occurring west of the 400 millimetres (mm) rainfall isohyet, in the Southwest and Midwest corner of Western Australia (Department of Parks and Wildlife, 2015). Within this area, Phytophthora Dieback ranges from being barely perceptible to full-scale environmental destruction. A significant factor determining the impact of the disease is the average annual rainfall with the trend of impact reduction correlating with rainfall reduction is generally applicable (Department of Parks and Wildlife, 2015).

The PAA is within the vulnerable area, with the Boddington North weather station recording the annual rainfall averaging just below 500mm.

Table 5 - Annual Rainfall - Boddington North

Year	Annual Rainfall (mm)
2012	510.6
2013	517.2
2014	424.6
2015	370.0
2016	497.4
2017	671.2
2018	572.8
2019	387.0

2.3 Phytophthora Species in the Primary Assessment Area

Three species of Phytophthora have been recovered from the PAA according to publicly available data on the Dieback Information Delivery and Management System (Project Dieback, 2019). These species are:

P. cinnamomi Located in CBME, WMDE (Saddleback, Marradong, Hotham North);

P. pseudocryptogea Located in WMDE (Hotham North) (**Error! Reference source not found.**); and,

P. inundata Located in WDME (Hotham North) (**Error! Reference source not found.**).

Phytophthora cinnamomi when present is mapped, and the extent of the infestation determined and demarcated in the field. The other species of Phytophthora are demarcated when interpreters "determine if the pathogen's impact is significant (moderate to high impact) and take a precautionary approach in deciding whether to demarcate an infested area" (Department of Parks and Wildlife, 2015). *Phytophthora cinnamomi* is the focus of this Dieback assessment as this species is most prevalent and more destructive than other Phytophthora species.

This desktop review of the occurrence of Phytophthora Dieback used in this report was based on South32 implemented hygiene prescriptions developed from previous assessments conducted by Glevan Consulting (Figure 2) and the publicly available datasets. Some areas assessed and mapped as Excluded by Glevan Consulting have been extended by South32 to incorporate adjacent private property of the same vegetation condition (degraded or completely degraded) to the relevant property boundary, dependant on the level of risk of occurance. A report referring to a recent assessment of sections of Newmont's Boddington Gold Mine (NBG) was not available for this review.

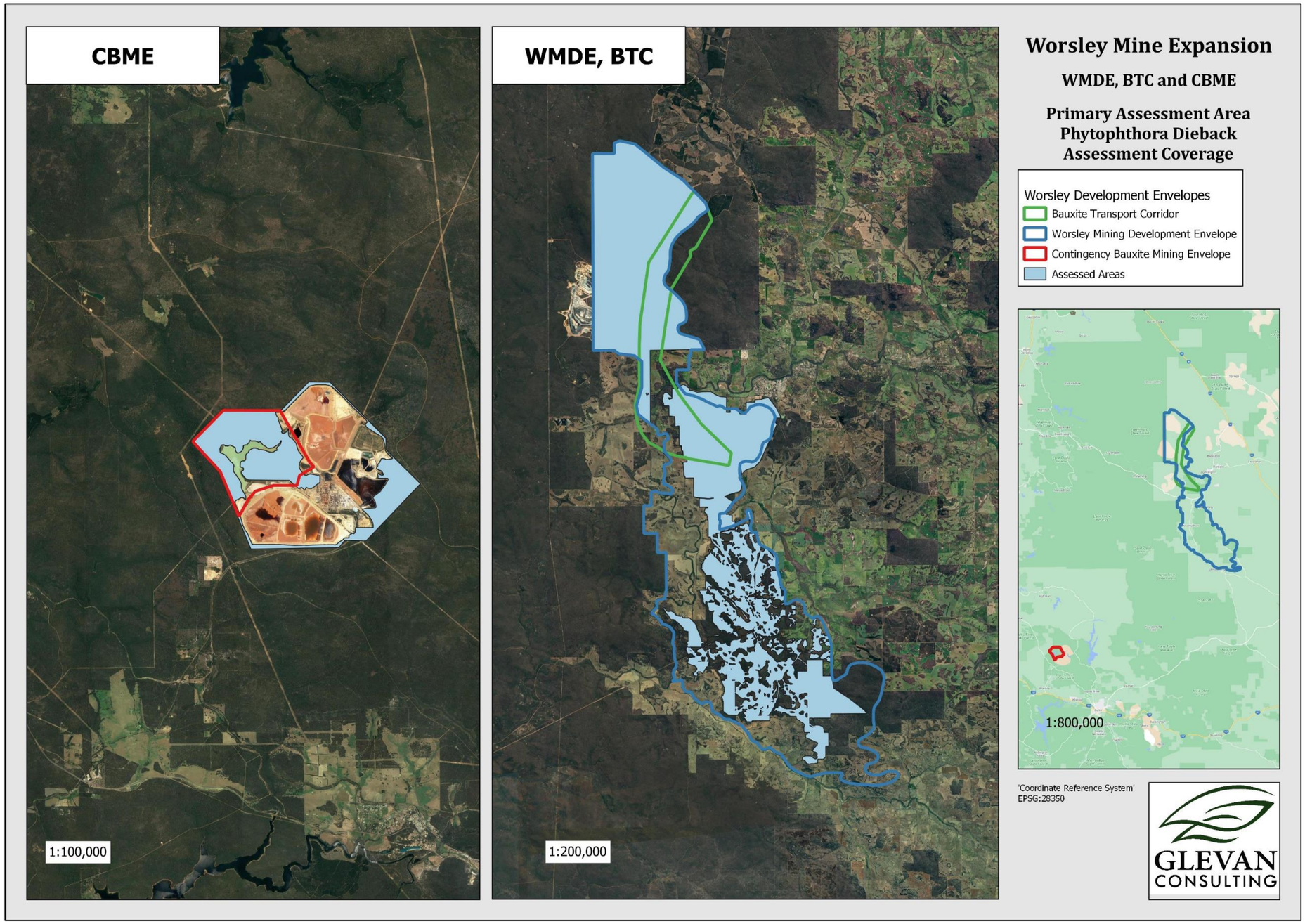

Figure 2 - Interpretation History in Development Envelopes

2.4 Phytophthora Dieback in the Primary Assessment Area

As the conditions of the disease triangle (host, environment, pathogen) have been satisfied for the Development Envelopes, Phytophthora Dieback is present in varying impacts across the sites. The occurrence of Phytophthora Dieback used in this report is based on previous assessments conducted by Glevan Consulting between 2007 and 2019 (Figure 2).

All Phytophthora Dieback detection, diagnosis and mapping have been performed to standards and procedures defined in *FEM047 Phytophthora Dieback Interpreter's Manual for lands managed by the department* – Chapter 6 (Department of Parks and Wildlife, 2015). These procedures are grounded on the presence in the vegetation of Indicator Species, and the observance of deaths in these plants. Indicator species deaths alone do not necessarily indicate disease presence, and it was necessary to consider all environmental and ecological factors that were present. These other factors (as listed in FEM047) include:

- Chronology of deaths;
- A pattern of deaths;
- Topographical position;
- Vectoring – causal agencies, and;
- Biomass and biological diversity reduction.

Other possible causes of plant deaths that needed to be considered when determining the presence of Phytophthora Dieback, included (from FEM047):

- *Armillaria luteobubalina* (commonly known as Australian Honey Fungus);
- various cankers;
- insects;
- drought, wind scorch and frost;
- salinity and waterlogging;
- fire and lightning;
- senescence and competition;
- physical damage, and;
- herbicides and chemical spills.

WMDE

Saddleback

Five infestations of Phytophthora Dieback occur in the Saddleback mining area. These are located adjacent to the main access road from Pinjarra-Williams Road, adjacent to the old gatehouse, adjacent to Tunnel Road and adjacent to the conveyor west of Lower Hotham Road (Figure 4).

Glevan Consulting has assessed many areas of the Saddleback region before the timber harvesting stage of the mining disturbance process. As typically only areas to be cleared for mining and infrastructure are assessed. All assessed areas that have been rehabilitated will not retain the Uninfested category until re-assessed and contain the required species and densities for interpretation. When rehabilitation clearing is needed, rehabilitated soil information is kept by Worsley and provides a level of risk of impact from the potential spread of infections.

Marradong

One infestation of Phytophthora Dieback is located in the Marradong section of WMDE (Figure 5). This infestation follows a drainage line on the southern side of Morts Road, and mainly west of Ashcroft Road. This area was last assessed in 2017 with the infested area first identified in 1996.

Hotham North

Four polygons of Phytophthora Dieback were identified during an assessment completed by Glevan Consulting in 2013 (Figure 6). More recent assessments have been limited to re-assessing the known infestations and tracks with a higher likelihood of disease presence. A current assessment (completed in 2019) for NBG within Hotham North has been undertaken, however the findings were not available for inclusion in this report.

CBME

Phytophthora Dieback is extensive throughout the CBME (Figure 7). The vegetation was assessed in 2015 with only two small polygons totalling 26.08 ha (3.49% of CBME by area) remaining Uninfested.

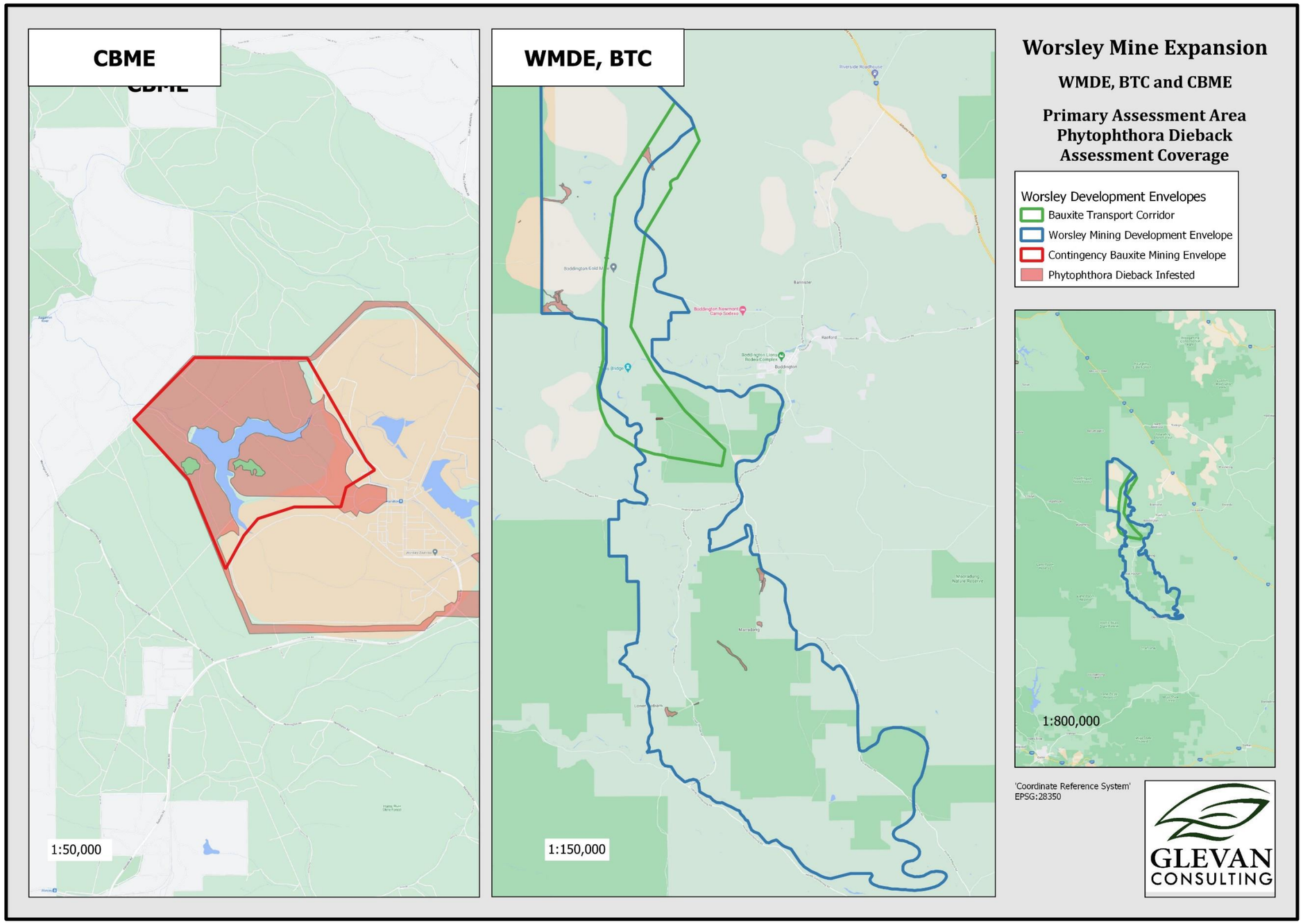

Figure 3 - Phytophthora Dieback occurrence across PPA

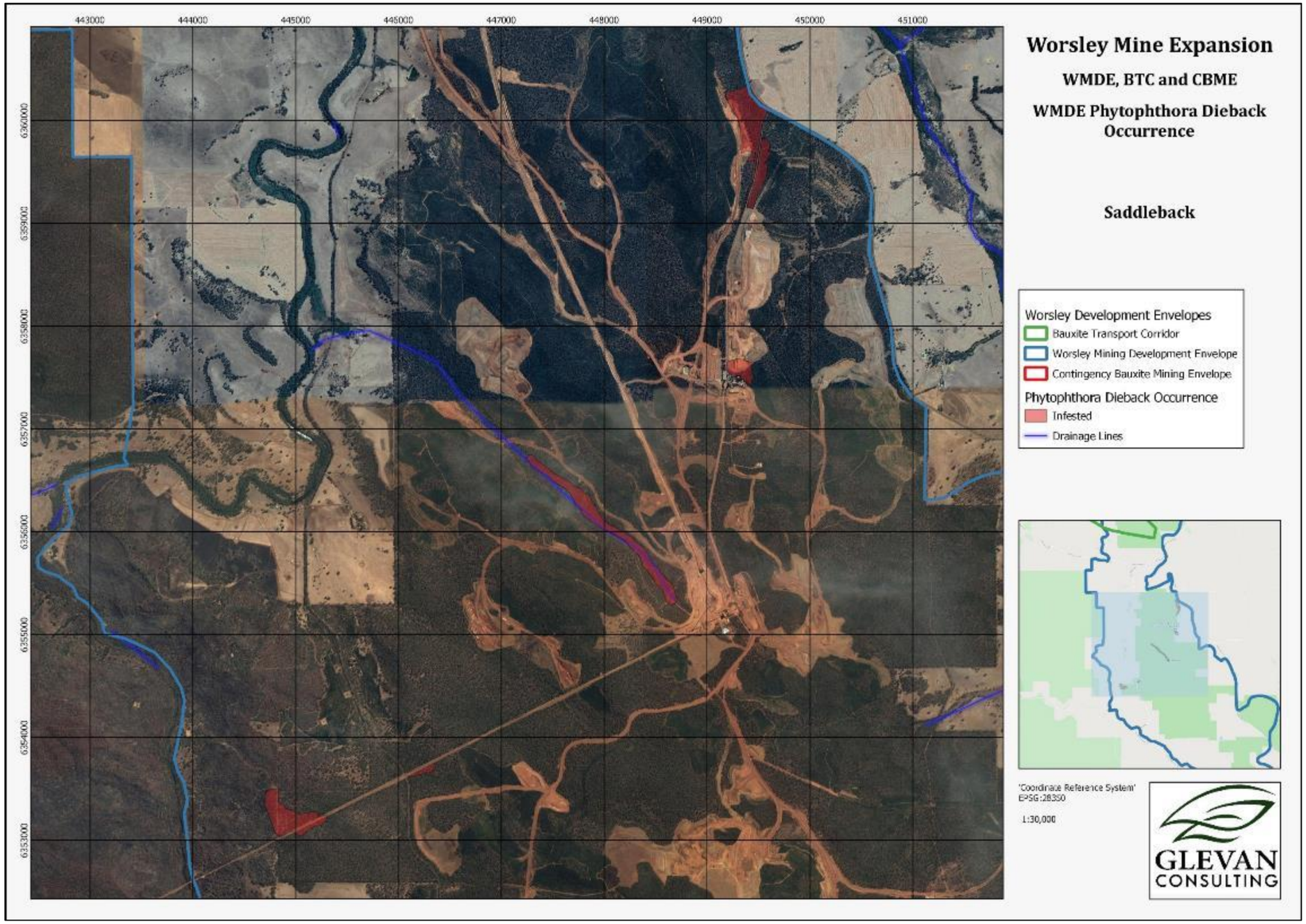

Figure 4 - Saddleback Dieback Occurrence

Figure 5 - Marradong Dieback Occurrence

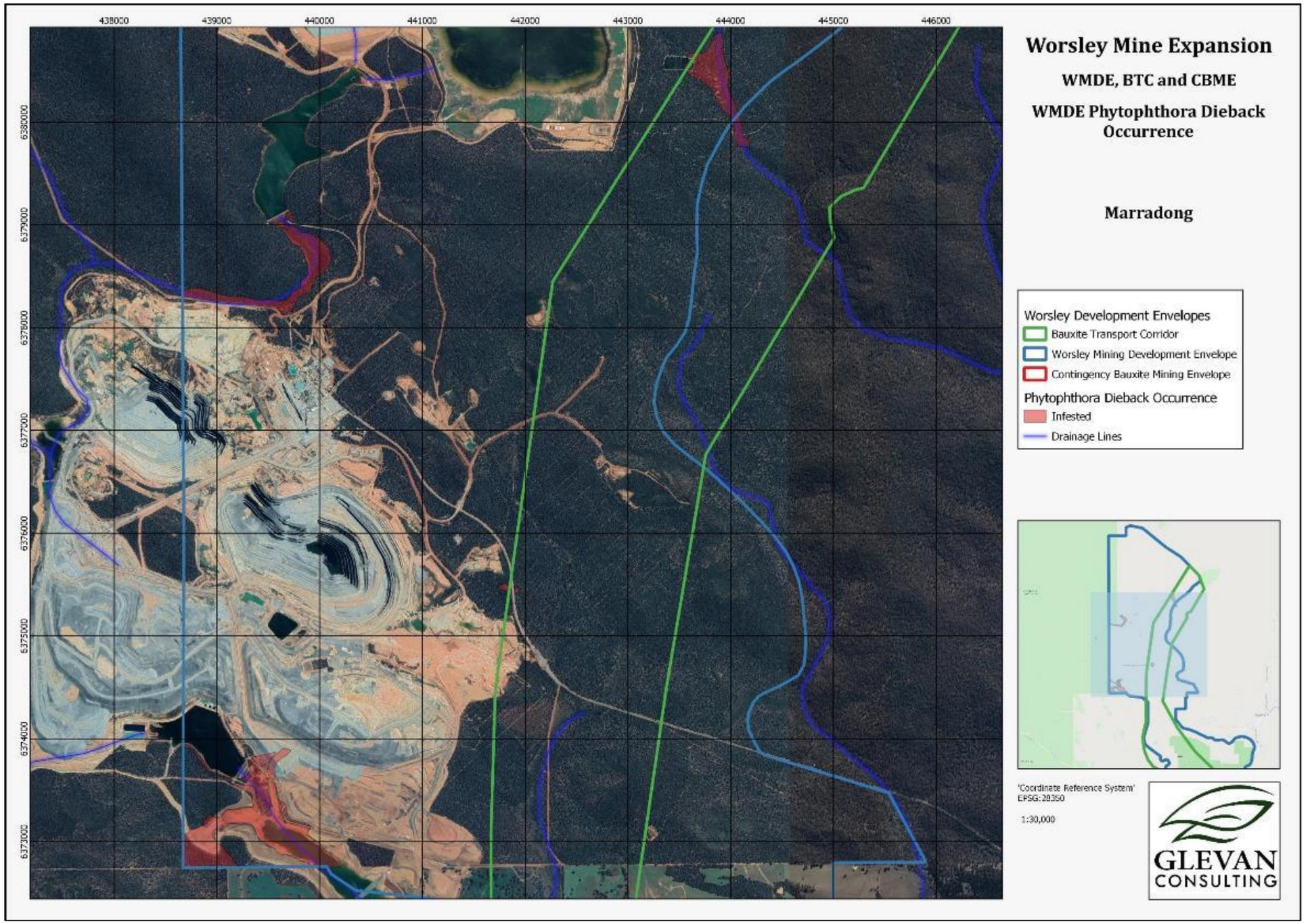

Figure 6 - Hotham North Dieback Occurrence

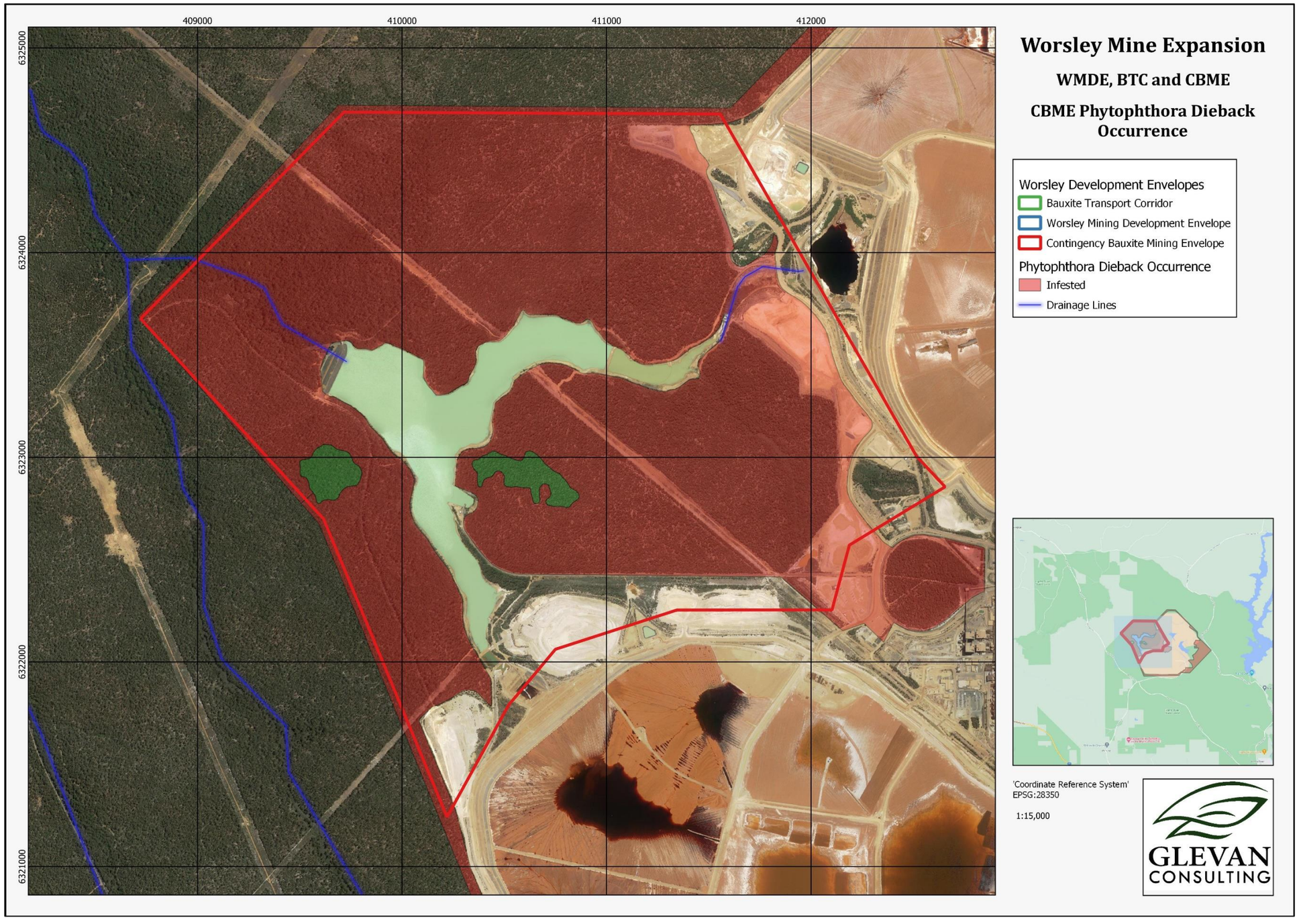

Figure 7 - CBME Dieback Occurrence

2.5 Determining areas protectable from Phytophthora Dieback

The remaining Uninfested (or not mapped) vegetation is considered protectable from Phytophthora Dieback based on the following criteria:

- Determined to be Uninfested, Uninterpretable or Temporarily Uninterpretable;
- Situated in areas receiving more than 600 mm rainfall a year or those that are water-gaining sites in the 400- to 600-mm a year rainfall range;
- Both positioned in the landscape and of sufficient size such that it is adjudged that the pathogen will not autonomously engulf them in the short term (greater than four hectares with an axis greater than 100 metres);
- Areas of high conservation or socio-economic value (for example, areas with a known population of a susceptible species of threatened flora), and;
- Areas where human vectors are controllable (Department of Parks and Wildlife, 2015).

3 *Armillaria luteobubalina*

Armillaria luteobubalina, the Australian honey fungus, is a widespread, endemic pathogen of native forest, woodland and coastal shrub communities in the southwest of Western Australia. In Australia there are 6 known species of *Armillaria*. *Armillaria luteobubalina* is the only species known to occur in Western Australia (Robinson, 2011).

The impact of the fungus ranges from single dead plants to complete devastation of understorey and overstorey species.

The life cycle of the fungus consists of a parasitic phase during which the host is infected and killed followed by a saprophytic phase during which the root system and stump of the dead host is used as a food base. In this manner *Armillaria luteobubalina* has the ability to persist in an infected root system for decades during which surrounding regrowth may also be susceptible to infection (Robinson, 2011). Within infected plants, *A. luteobubalina* appears as white or yellow-white leathery mycelial sheaths which may be visible beneath the bark in the roots and lower stem. Other features that may be present in an area affected by the fungus include:

- an inverted vee-shaped scar at the base of the plant;
- clusters of fruiting bodies at or near the base of the plant;
- wet, stringy yellow-white rot in roots and base of the plant, and;
- a strong mushroom smell (Department of Parks and Wildlife, 2015).

3.1 Armillaria luteobubalina hosts

A. luteobubalina is a primary pathogen of more than 50 different plant families and more than 200 plant species. The majority of susceptible native plant species are in the Proteaceae, Myrtaceae, Papilionaceae, Epacridaceae and Mimosaceae (APPS, 2007). It is and is associated with deaths of karri (*Eucalyptus diversicolor*), wandoo (*E. wandoo*) and jarrah (*E. marginata*), *Banksia* spp. in coastal woodlands, as well as exotic eucalypts planted on mine-sites and in plantations (Robinson, 2011).

Because *A. luteobubalina* is an endemic pathogen, it may not be possible to detect all infested areas (Department of Parks and Wildlife, 2015).

3.2 *Armillaria luteobubalina in the Primary Assessment Area*

Armillaria luteobubalina is having a significant impact on vegetation in sections of WMDE and BTC, in some areas alongside Phytophthora Dieback. The known extent of this disease within the WMDE and BTC are mapped in Figure 8 (PAA), Figure 9 (Hotham North) and Figure 10 (Saddleback).. Occurrences of Armillaria have not been identified within the CBME.

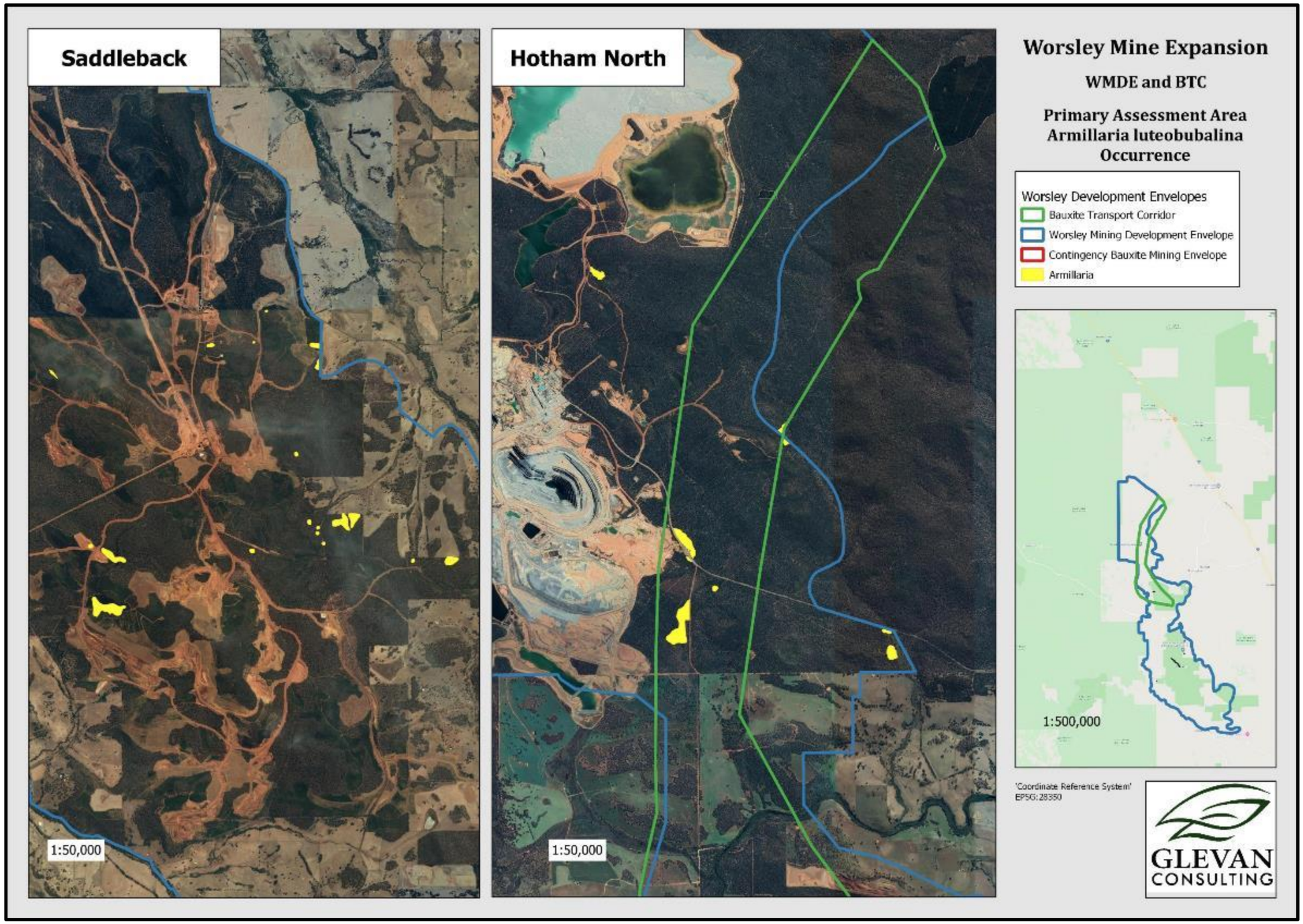

Figure 8 - Armillaria luteobubalina with the PAA

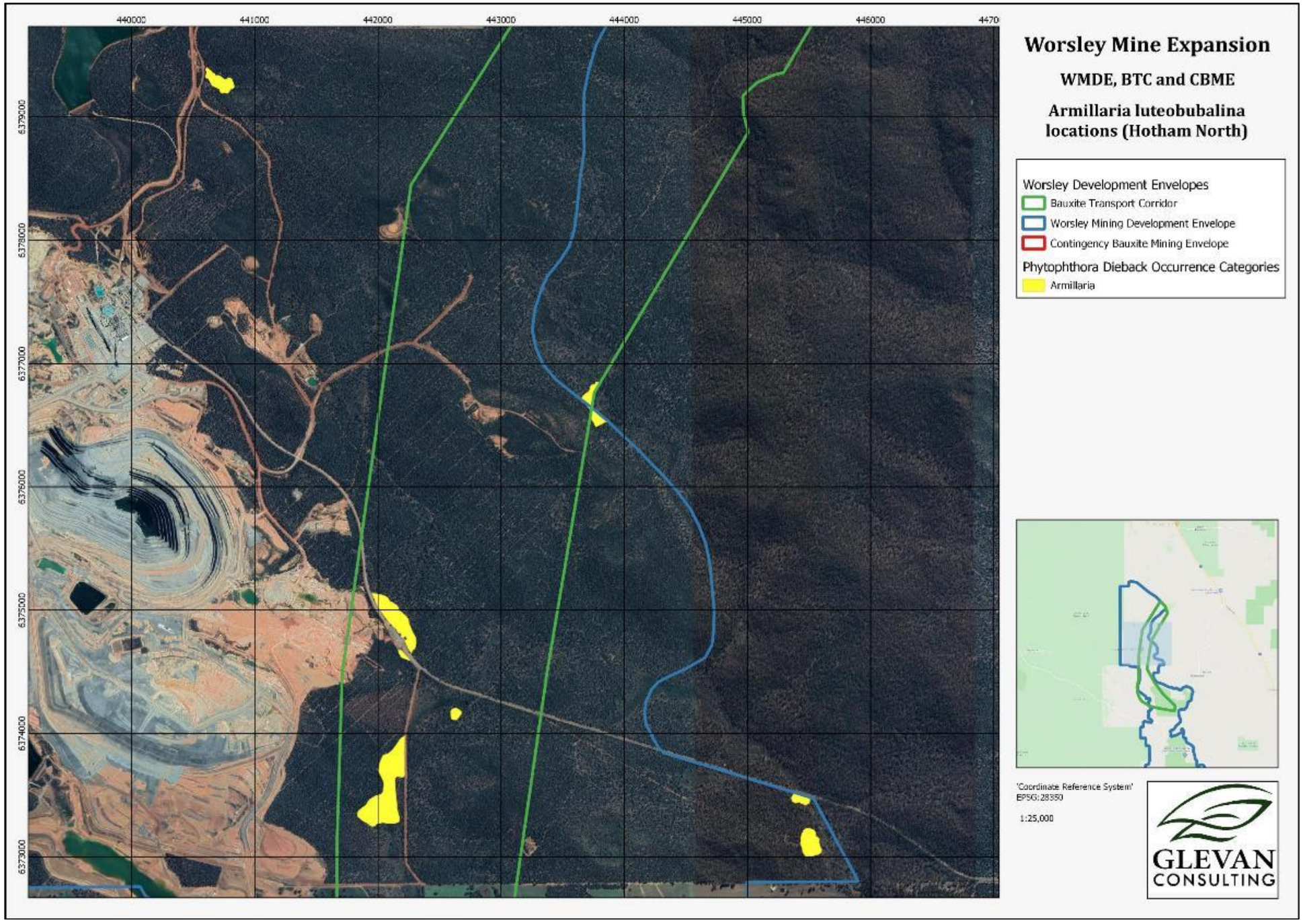

Figure 9 - Armillaria luteobubalina occurrence in Hotham North

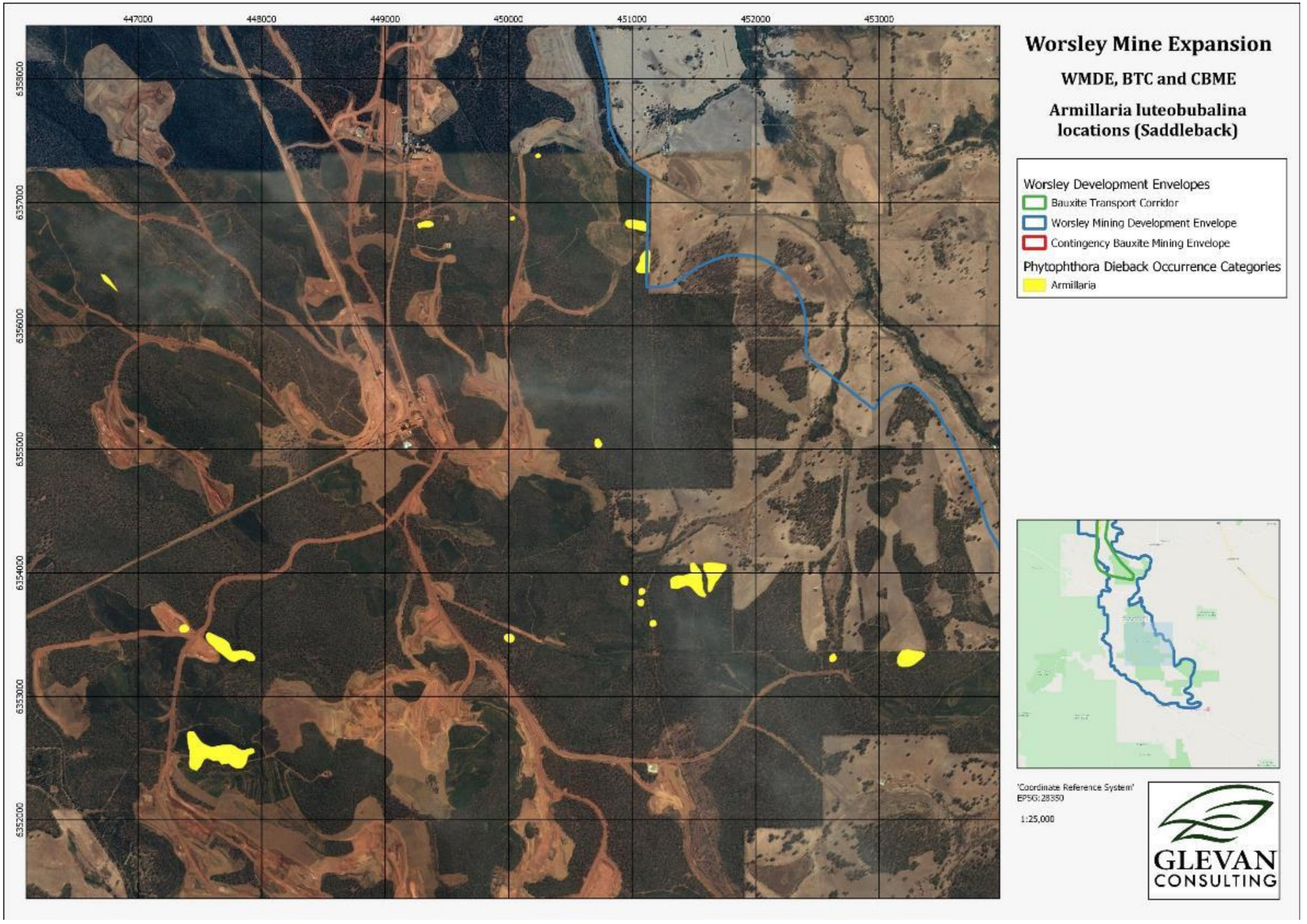

Figure 10 - Armillaria luteobubalina occurrence in Saddleback

4 Discussion

4.1 Phytophthora Dieback

Phytophthora Dieback has been recorded in the PAA and shown by hectare (Table 6) and by the percentage of vegetated areas (Table 7). These infestations occur on a variety of site-vegetation types as mapped by Mattiske Consulting (2020). The following Table 8, displays the susceptibility to the disease of each vegetation type (over 77% by area), and Table 9, the predicted impact of the disease (based on ratings used by DBCA). This result does not suggest that the remaining vegetation is not affected by Phytophthora Dieback, but that infestations have not yet been found in these site-vegetation types.

Table 6 - Phytophthora Dieback Occurrence, Development Envelopes and PAA, by Hectare

Development Envelope	Infested	Uninterpretable	Uninfested, Not Mapped	Total
WMDE	167.86	260.26	15022.60	15450.72
BTC	23.20	185.19	3969.44	4177.82
CBME	563.98	0.00	26.08	590.06
PAA	731.84	298.67	15227.15	16257.66

Table 7 - Phytophthora Dieback Occurrence, Development Envelopes and PAA, by Percentage

Development Envelope	Infested	Uninterpretable	Uninfested, Not Mapped	Total
WMDE	1.09%	1.68%	97.23%	100%
BTC	0.56%	4.43%	95.01%	100%
CBME	95.58%	0.00%	4.42%	100%
PAA	4.50%	1.84%	93.66%	100%

Table 8 - Site-Vegetation Types Known to be Infested with Phytophthora Dieback

Site-Vegetation Type	Development Envelope						Primary Assessment Area		Known Phytophthora Dieback in Site-Vegetation Type and Predicted Impact Rating[1]	
	BTC (ha)	% of BTC Area	CBME (ha)	% of CBME Area	WMDE (ha)	% of WMDE Area	PAA (ha)	% of PAA Area	Known infestations	Impact
A	39.79	0.96%			121.40	0.44%	130.06	0.44%		Low
A1					2.88	0.01%	2.88	0.01%		Low
A2					1.66	0.01%	1.66	0.01%		Low
AC					34.15	0.12%	34.15	0.12%		Low
AD	0.89	0.02%			4.74	0.02%	5.62	0.02%		Low
AX	98.18	2.37%			195.96	0.70%	223.94	0.76%		Low
AY	153.96	3.71%			404.70	1.46%	434.45	1.48%	YES	Low
AY/D	5.35	0.13%			5.35	0.02%	5.35	0.02%		Low
B					0.47	0.00%	0.47	0.00%		High
CQ			9.62	1.29%			9.62	0.03%	YES	Low-High
CW			17.90	2.40%			17.90	0.06%	YES	Low-High
D	147.63	3.56%			390.36	1.40%	399.62	1.36%		High
DG	5.06	0.12%			7.93	0.03%	8.72	0.03%	YES	High
E			0.00	0.00%			0.00	0.00%		High
G1	6.51	0.16%			69.29	0.25%	69.29	0.24%		No data
G2					12.24	0.04%	12.24	0.04%		No data
G3	3.28	0.08%			75.53	0.27%	75.53	0.26%	YES	No data
G4	2.07	0.05%			12.07	0.04%	14.14	0.05%		No data
H	501.51	12.10%			1590.05	5.72%	1812.48	6.17%	YES	Low-Moderate
H1					138.04	0.50%	138.04	0.47%		Low-Moderate
H2	2.21	0.05%			577.43	2.08%	579.64	1.97%		Low-Moderate
HG					50.65	0.18%	50.65	0.17%		Low-Moderate
L	27.02	0.65%			32.90	0.12%	32.90	0.11%		Low
M	334.06	8.06%			1538.59	5.54%	1669.15	5.69%	YES	Low
M2	1.38	0.03%			45.43	0.16%	45.53	0.15%		Low
MG	28.35	0.68%			218.53	0.79%	220.47	0.75%	YES	Low
P	259.08	6.25%			1476.86	5.31%	1476.86	5.03%	YES	High
PS	453.01	10.93%			1248.05	4.49%	1272.87	4.34%		High
PW	2.54	0.06%			2.54	0.01%	2.54	0.01%		High
Q			63.64	8.52%			63.64	0.22%	YES	Low
R					1.29	0.00%	1.29	0.00%		Moderate-High
S	301.2	7.27%	79.76	10.68%	1649.51	5.93%	1747.14	5.95%	YES	Moderate-High
SP	28.93	0.70%	5.72	0.77%	90.59	0.33%	96.31	0.33%	YES	Moderate-High

Site-Vegetation Type	Development Envelope						Primary Assessment Area		Known Phytophthora Dieback in Site-Vegetation Type and Predicted Impact Rating[1]	
	BTC (ha)	% of BTC Area	CBME (ha)	% of CBME Area	WMDE (ha)	% of WMDE Area	PAA (ha)	% of PAA Area	Known infestations	Impact
ST	20.65	0.50%	229.34	30.70%	378.87	1.36%	608.20	2.07%	YES	Moderate-High
SW			17.68	2.37%	9.17	0.03%	26.85	0.09%	YES	Moderate-High
T			14.04	1.88%			14.04	0.05%	YES	Low-Moderate
TS			68.94	9.23%			68.94	0.23%		Low-Moderate
W					0.82	0.00%	0.82	0.00%		Moderate
Y	194.47	4.69%			623.79	2.24%	720.56	2.45%	YES	Low
YG	20.71	0.50%			11.95	0.04%	31.15	0.11%		Low
Z	217.92	5.26%			806.48	2.90%	842.63	2.87%	YES	Low-Moderate
Not vegetated or rehab	8010.26	31.12%	225.64	32.18%	12959.23	57.44%	13212.9	55.83%		
Total hectares	12197.52		746.54		28404.34		29356.39			

[1] The predicted impact rating is based on the impact prediction tables developed by the Department of Parks and Wildlife. The impact prediction classifications are as follows;

Low (No overstorey trees dead or dying because of *P. cinnamomi*):

On low impact sites, many species will be resistant to the pathogen; fewer susceptible plant species will be present. After sites have become infested, symptoms may be evident in a few scattered herb and shrub layer or middle storey deaths. There will be no noticeable impact on the overall structure of the site. Jarrah will be tolerant or resistant on such sites; overstorey impact will not be discernible. The overstorey on low impact sites will often have a lesser proportion of jarrah and more significant proportions of marri, blackbutt or karri. Low impact sites are usually well-drained or fertile.

Moderate (less than 10 per cent overstorey trees dead or dying because of *P. cinnamomi*):

On moderate impact sites some resistant, less susceptible understorey species will be present (Acacia, Bossiaea, Calothamnus species, for example). After sites have become infested, overstorey deaths are likely to be scattered, not grouped. Most susceptible understorey species will die over time, but less than 10 per cent of the overstorey will be affected. These sites often have average soil drainage, which could be impeded in parts. Fertility is moderate; soils are typically gravelly sandy loams, such as found on Havel or Strelein S types.

High (greater than 10 per cent overstorey trees dead or dying because of *P. cinnamomi*):

On high impact sites, many species present will be highly susceptible to the pathogen. After sites have become infested most susceptible understorey species and more than 10 per cent, but less than 50 per cent of overstorey trees will die[6]. The vegetative structure of the site will collapse, which will lead to ecological collapse. Over time, the site will be recolonised with resistant species. These sites will have shallow and infertile soils, often with impeding clay, hardpan or cap-rock layer.

Very high (greater than 50 per cent overstorey trees dead or dying because of *P. cinnamomi*):

On very high impact sites, most species will be highly susceptible to the pathogen. After sites have become infested, most susceptible understorey species and more than 50 per cent of overstorey will die. The entire ecological structure of the site will collapse. Re-colonisation by resistant species can occur on sites that have progressed past an epidemic state[7]. Very high impact sites will have shallow and infertile soils, often with impeding clay, hardpan or cap-rock layer (Department of Parks and Wildlife, 2015).

The impact of Phytophthora Dieback on the site-vegetation types within the PAA has been estimated based on impact prediction tables (Department of Parks and Wildlife, 2015). Those vegetation types not currently infested with Phytophthora Dieback, but which are susceptible to the disease, in the Development Envelopes are shown in the following Table 9.

Table 9 - Predicted Impact of Phytophthora Dieback by Vegetation Type

Site-Vegetation Type	Description	Present within the PAA	Predicted Impact Rating
B	Open woodland of *Eucalyptus marginata* and *Corymbia calophylla* over *Mesomelaena tetragona, Adenanthos obovatus* and *Babingtonia camphorosmae* on lower sandier soils on fringes of	**WMDE**	High
D	Open forest of *Corymbia calophylla* and *Eucalyptus marginata* over *Hakea lissocarpha, Macrozamia riedlei, Acacia alata, Babingtonia camphorosmae, Hypocalymma angustifolium* and *Phyllanthus*	**WMDE BTC**	High
R	Open woodland of *Eucalyptus marginata* and *Corymbia calophylla* over *Trymalium ledifolium, Phyllanthus calycinus* and *Hypocalymma angustifolium* on sandy-gravels associated with	**WMDE**	Moderate-High
W	Open forest of *Corymbia calophylla, Eucalyptus marginata* and *Eucalyptus patens* over *Hakea lissocarpha, Hypocalymma angustifolium, Acacia*	**WMDE**	Moderate
L	Open woodland of *Eucalyptus patens* with some *Eucalyptus wandoo* over *Xanthorrhoea preissii, Macrozamia riedlei, Trymalium ledifolium, Acacia saligna* and *Hakea prostrata* on clay and clay loam	**WMDE BTC**	Low

It is therefore expected that the introduction of Phytophthora into any section of susceptible vegetation within the PAA has the potential to cause significant consequence to the vegetation.

The risk to the vegetation will be dependent on the likelihood of introduction of the pathogen to those vegetation types identified that would be impacted by the disease. This likelihood is predicted by current Phytophthora Dieback locations and assumed spread patterns (autonomous spread) and breakdown in hygiene management during soil moving operations or general operations (non-autonomous spread). From known Phytophthora Dieback locations, adjacent vegetation is at immediate threat from the autonomous spread. This rate of movement of the pathogen is dependent on local conditions, such as topographical slope, soil moisture content and soil drainage characteristics.

The non-autonomous spread of the pathogen, and the subsequent impact on the vegetation, will be mitigated by the continuation of hygiene procedures currently being utilised by South32, and described in the internal document "Forest Hygiene Management Procedure" and relevant management plans.

4.2 Armillaria luteobubalina

Armillaria luteobubalina has been recorded in the PAA and shown by total hectares in the following Table 10. The total hectares affected will be conservative as only significant infestations are recorded and demarcated. Infestations affecting a few plants only are not mapped. Infestations that co-exist with Phytophthora Dieback (in particular adjacent to Thirty-Four Mile Brook) will not be recorded separately and will only be assigned as Phytophthora Dieback.

Table 10 - Armillaria luteobubalina in PAA

Development Envelope	Armillaria (ha)
WMDE	52.61
BTC	21.04
CBME	0
PAA	52.61

These infestations occur on a variety of site-vegetation types as mapped by Mattiske Consulting (2020). The following Table 11 shows the percentage of each vegetation type affected by the pathogen.

Table 11 - Site-Vegetation Types Known to be Infested with Armillaria luteobubalina

Site-Vegetation Type	Development Envelope				Primary Assessment Area	
	BTC (ha)	% affected by Armillaria	WMDE (ha)	% affected by Armillaria	PAA (ha)	% of PAA Area
A	39.79	1.56%	121.40	0.89%	130.06	0.83%
AX	98.18	3.43%	195.96	1.72%	223.94	1.50%
AY	153.96	9.50%	404.70	3.62%	434.45	3.47%
D	147.63	0.34%	390.36	0.49%	399.62	0.47%
H	501.87	0.00%	1590.05	0.05%	2091.92	0.04%
M	334.06	0.00%	1538.59	0.04%	1669.15	0.04%
P	259.27	0.00%	1476.86	0.11%	1736.13	0.09%
S	301.42	0.00%	1649.48	0.06%	1950.90	0.05%
Y	194.47	0.47%	623.79	1.38%	720.56	1.13%
Z	217.92	0.00%	806.48	0.07%	842.63	0.07%

5 Conclusion

This document has been prepared as a response to the EPA's objective for the 'Flora and Vegetation' factor *"To protect flora and vegetation so that biological diversity and ecological integrity are maintained"*, the required work outlined in the EPA's Environmental Scoping Document is to *"Analyse risk of Phytophthora cinnamomi and Armillaria luteobubalina within the development envelope, undertake surveys (if relevant) and describe management actions to prevent introduction to protectable areas within the proposal area and to adjacent conservation areas"*.

In summary, approximately 732 ha (Table 6) within the PAA is known to be infested with Phytophthora Dieback, with the disease currently infecting 14 mapped site-vegetation types and most of these having high predicted impact rating. A further five site-vegetation types are susceptible to Phytophthora Dieback, with the predicted impact rating being mostly high to moderate.

The risk to the vegetation within the PAA has been determined by the likelihood of Phytophthora Dieback presence, and the predicted impact on the vegetation.

Mapping for the presence of Phytophthora Dieback has been conducted across areas of the PAA either before activities or for general planning purposes. Whilst, the entire PAA has not been mapped, the data are available for areas that have been assessed providing sufficient information to determine the potential impact and therefore consequence of the disease in the different vegetation types (Table 8). Phytophthora Dieback mapping has a currency of one year from assessment for disease boundaries, and three years from assessment for Uninfested areas if no operations have been conducted in the area. Vegetation within the boundaries of construction activities will be assessed for the presence of Phytophthora Dieback when required before operations.

The likelihood of the disease presence was determined from previously identified Phytophthora Dieback infestations, expected spread from these infestations, and opportunities for new infestations from unhygienic operations. Current hygiene procedures

detailed in the internal South32 soil hygiene documents offers processes to mitigate and manage the introduction and spread of Phytophthora Dieback.

6 Bibliography

APPS. (2007, February). Armillaria luteobubalina. *Pathogen of the Month*.

Bureau of Meteorology. (n.d.). *Average annual, seasonal and monthly rainfall*. Retrieved from Average annual, seasonal and monthly rainfall

Department of Parks and Wildlife. (2015). *FEM047 Phytophthora Dieback Interpreter's Manual for lands managed by the department.* Unpublished.

Environmental Protection Authority. (2019). *Draft Environmental Scoping Document - Worsley Mine Expansion – Revised Proposal.*

Keighery, B. (1994). *Bushland Plant Survey: a Guide to Plant Community Survey for the Community.* Wildflower Society of WA (Inc.).

Project Dieback. (2019, December 20). *DIDMS*. Retrieved from https://didms.gaiaresources.com.au/

Robinson, R. (2011). *Recognising the symptoms of Armillaria root disease.* Manjimup: Department of Environment and Conservation.