Terratree

Phytophthora Dieback Linear Assessment

Perth Darwin National Highway Project Corridor

Prepared for Coffey

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ecological assessment
& management

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Terratree Pty Ltd

Executive Summary

Coffey Environments Australia Pty Ltd (Coffey) commissioned Terratree Pty Ltd (Terratree) to undertake a linear *Phytophthora* Dieback assessment of the Perth Darwin National Highway (PDNH) project corridor (hereafter referred to as the 'project corridor') for Main Roads Western Australia as part of the NorthLink project.

The study area is approximately 37 km in length and extends from 0.5 km south of Reid Highway along Tonkin Highway, to approximately 4 km north of Muchea along the Great Northern Highway. The assessment was conducted in accordance with the Department of Parks and Wildlife's (DPAW) *Manual for detecting* Phytophthora *Dieback disease (Procedures for DPAW managed lands)* (2013).

A nominal 200 m wide study area was determined to be appropriate because it allowed 100 m for the disturbance corridor plus an additional 50 m either side. The width of the study area was increased to assess sections that are wider than 200 m and the landscape context within which the corridor is located.

Approximately 17 km of native vegetation required assessment along the corridor which equated to 465 ha in total. Native vegetation adjacent to the disturbance corridor was mapped so that protectable areas could be identified and appropriately managed to prevent infestation.

In total 27 soil and tissue samples were taken from recently dead and dying disease indicator species, which included one canker tissue sample. Four positive results for *Phytophthora cinnamomi*, one positive result for a *Lasiodiplodia* sp. (Canker), and 21 negative samples were reported. Overall, 1,541.61 ha were assessed with 69.8% determined to be Excluded (unmappable) from the Dieback assessment, 23.5% Infested, 3.7% Uninfested and 3.0% Uninterpretable.

Dieback is spread through the movement of water and soil within the landscape. Major vectors of Dieback include, among others, wet soil adhering to vehicle tyres/tracks and earthmoving equipment. Therefore, quarantine management procedures are an effective tool to reduce the spread of Dieback as a result of earthmoving activities.

While some areas of protectable Uninfested vegetation were mapped within the corridor, the Uninfested areas adjacent to the corridor are more significant in terms of being protectable from Dieback in the longer term. While the majority of the vegetation within the project corridor will be cleared, the critical issue preventing the spread of pathogen into adjacent areas where it can vector it along watercourses, tracks and roads.

Uninterpretable areas (3%) are predominantly comprised of creeks and drainage lines intersecting the study area. Uninterpretable riparian vegetation and watercourses may, or may not be hosting the pathogen but these areas are potential vectors for the pathogen if hygiene is not adequately managed.

Terratree recommends that a Dieback Management Plan be prepared for the PDNH Project by a suitably qualified and experienced person in accordance with best practice management techniques.

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1 Introduction

Coffey Environments Australia Pty Ltd (Coffey) commissioned Terratree Pty Ltd (Terratree) to undertake a linear *Phytophthora* Dieback assessment of the Perth Darwin National Highway (PDNH) project corridor (hereafter referred to as the 'project corridor') for Main Roads Western Australia as part of the Perth to Darwin Highway project known as NorthLink. The assessment was conducted in accordance with the Department of Parks and Wildlife's (DPAW) *Manual for detecting* Phytophthora *Dieback disease (Procedures for DPAW managed lands)* (2013).

1.1 Background

Phytophthora Dieback ('Dieback') is a soil borne pathogen with a range of hosts in the southwest of Western Australia (WA). These predominantly come from the Proteaceae, Ericaceae, Myrtaceae, Xanthorrhoeaceae and Fabaceae plant families. While some plant species are resistant, others are susceptible to the disease caused by the pathogen resulting in chlorosis, dieback and usually death (Wills, R.T. and Keighery, G.J. 1994).

According to the most recent Western Australian (WA) State of the Environment Report (Environmental Protection Authority, 2007) Dieback, which is listed as a Priority 1 threat, is the third greatest threat to biodiversity after salinity and climate change. It is considered a more serious threat than weeds, clearing of native vegetation, acid sulphate soils and soil erosion. It is significant in WA because:

- Over 40% (2,300) of the native plant species and half of the endangered plant species in the south-west of WA are susceptible to the pathogen
- The changes in plant community composition and structure that Dieback causes has impacts throughout the whole ecosystem, including impacts on the indigenous fauna
- Dieback can lead to significant soil erosion as a result of the loss of susceptible vegetation

The pathogen that causes Dieback is widespread in areas with greater than 800 mm of annual rainfall, less extensive in areas that receive between 600–800 mm and mainly restricted to water-gaining sites in areas that receive 400–600 mm. The pathogen does not occur in areas that receive less than 400 mm of annual rainfall. In WA, Dieback is a significant environmental issue for projects between Geraldton in the Midwest and Esperance on the South Coast and is widespread in the Southwest region.

Three variables are required to have disease expression caused by Dieback:

1. Host- plant species present that are susceptible to *Phytophthora* spp. (i.e. *Banksia, Hakea, Leucopogon, Daviesia* spp.).

2. Pathogen - The *Phytophthora* pathogen must be present either residing in susceptible or resistant species.

3. Environment - Soil temperatures 15-30^{o} C and pH 5-6 (acidic) for *P. cinnamomi*. Some species including *P. multivora* can survive in alkaline soils (pH 7+).

The average annual rainfall for the Perth metro area (1993 -2014) is 738 mm but the disease is widespread due to and the relatively high concentration of disease vectors including uncontrolled vehicular access, surface and stormwater drainage, and rubbish dumping in areas of remnant native vegetation.

1.2 Project Location and Description

The 'study area' is comprised of the project corridor plus a nominal 50 m buffer either side which was expanded if an understanding of the broader landscape context was required for assessment. The study

area is approximately 37 km in length and extends from 0.5 km south of Reid Highway along Tonkin Highway, to approximately 4 km north of Muchea along the Great Northern Highway (**Figure 1**).

The PDNH project will require clearing remnant native and planted exotic and native verge vegetation. To manage the risks to biodiversity associated with the possible presence of the plant pathogen *Phytophthora cinnamomi* and other less virulent *Phytophthora* species, Dieback occurrence has been mapped and protectable areas were identified within, adjacent to, and downstream of the study area.

1.3 Regulatory Context

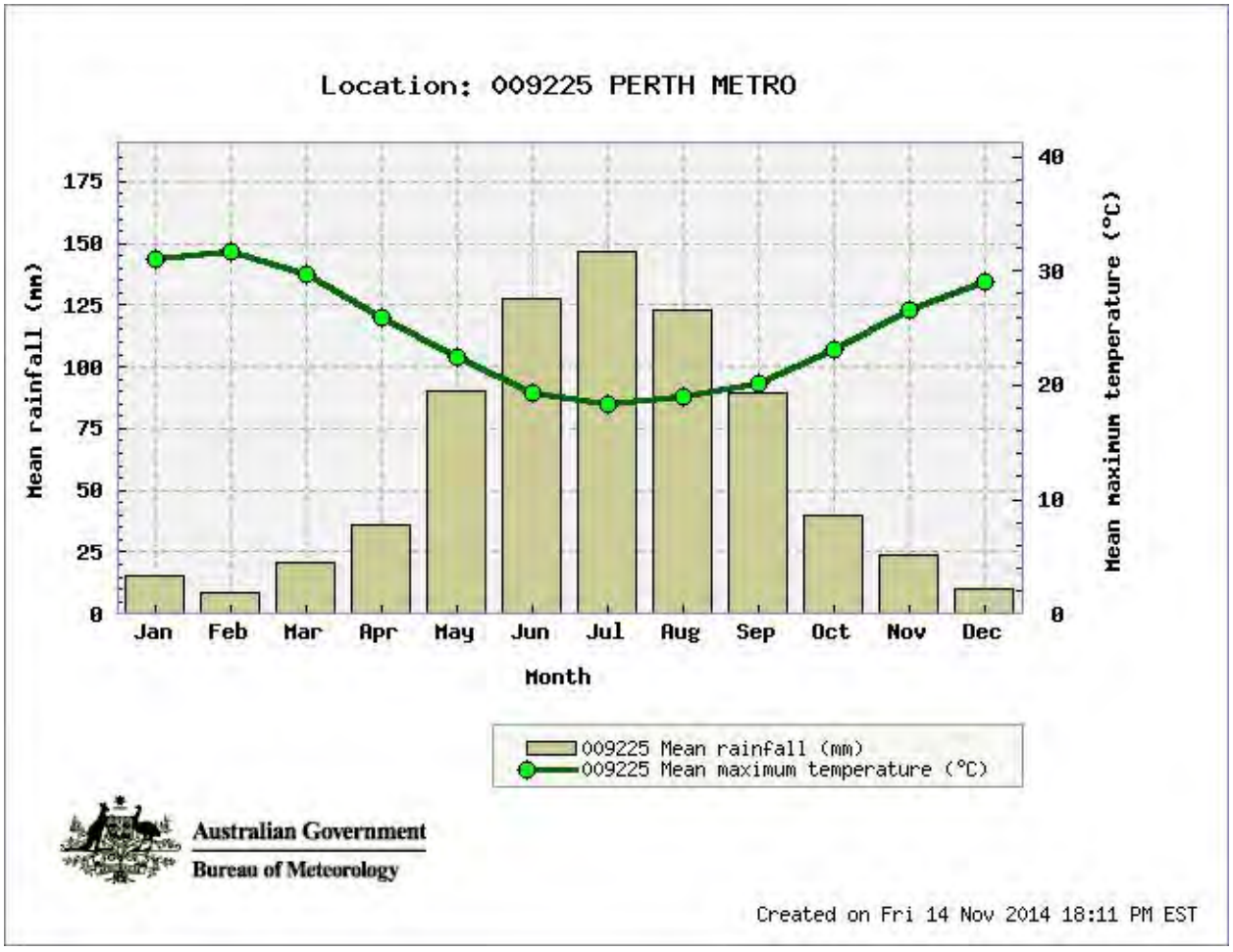
Dieback management is required under the following regulatory mechanisms in WA:

- *Phytophthora* Dieback is listed as a Key Threatening Process with the Federal Government under the *Environment Protection and Biodiversity Conservation Act* (1999).
- *Environmental Protection Act* (1986) Part V S.50A "Serious Environmental Harm" provisions.

2 Existing Environment

2.1 Climate

The Perth Metropolitan Area experiences a Mediterranean type climate with hot summers and wet winters. The average annual rainfall for the Perth metro area (1993 -2014) is 738 mm and the mean maximum temperature (1994-2014) is 24.7°C.



Graph 1: Perth Metro mean rainfall (1993-2014) and mean maximum temperatures (1994-2014) (BoM, 2014)

2.2 Flora and Vegetation

The Swan Coastal Plain is a low lying coastal plain, mainly covered with woodlands. It is dominated by Banksia or Tuart on sandy soils, *Casuarina obesa* on outwash plains, and paperbark in swampy areas. In the east, the plain rises to duricrusted Mesozoic sediments dominated by Jarrah woodland. The Perth subregion is composed of colluvial and aeolian sands, alluvial river flats, coastal limestone. Heath and/or Tuart woodlands on limestone, Banksia and Jarrah-Banksia woodlands on Quaternary marine dunes of various ages and Marri on colluvial and alluvial soils (Mitchell *et. al*, 2002).

3 Methods

The Dieback assessment was undertaken by DPAW registered Dieback Interpreter Joseph Grehan and Field Assistant Kelby Jennings from September to October 2014. The linear Dieback assessment was conducted in accordance with the *Manual for detecting Phytophthora Dieback disease (Procedures for DPAW managed lands)* (DPAW, 2013).The assessment occurred during optimal sampling conditions, after significant spring rainfall and increasing soil temperatures.

3.1 Recent Changes to Dieback Occurrence Categories

The Dieback Interpreters Guidelines (DPAW, 2013) were recently updated and now categorise land that has been cleared of native vegetation as 'Excluded' from assessment. Non-vegetated areas that are Excluded from assessment include pasture, pits, easements, development, large roads (sealed and unsealed), permanently flooded areas and parkland tree stands. Excluded areas are distinguished from 'Temporarily Uninterpretable' areas by the fact that they cannot regenerate naturally and eventually become Mappable. **Table 1** presents the assessability of vegetated and non-vegetated areas, which include the Excluded category (DPAW, 2013).

The Temporarily Uninterpretable category is allocated to areas of native vegetation which have been disturbed, but will recover over time and become Interpretable and therefore Mappable. Examples of Temporarily Uninterpretable areas include vegetation that has been impacted by fire, grazing, timber harvesting, flooding or mining and rehabilitation. Recovery in Temporarily Uninterpretable areas may take longer than 3 years (DPAW, 2013).

Table 1: Assessability of vegetated and non-vegetated areas (as cited in DPaW 2013)

	Phytophthora **occurrence category**	**Typically present**	**May be present**
Naturally vegetated areas (Phytophthora occurrence categorisation is or will be possible) Small un-vegetated areas can exist and may be included in the assessment area considering total environmental context	**INFESTED**	Dead and dying reliable indicator species	Healthy reliable indicator species. Indicator Species Deaths (ISDs) that have been killed by other agents
	UNINFESTED	Healthy reliable indicator species	ISDs that have been killed by other agents
	UNINTERPRETABLE	Very few reliable indicator species	Occasional reliable indicators, but too few for *Phytophthora* dieback interpretation
	NOT YET RESOLVED	Usually reliable indicator species in an environment not favourable to disease development	Negative sample results for all *Phytophthora* species
	TEMPORARILY UNINTERPRETABLE	Indicator species masked by disturbance. Keighery disturbance rating of 4 or greater Disturbance typically from; fire, harvesting, temporary flooding. Should recover (become interpretable) in 3 years or less	Occasional reliable indicator species, but disturbance prevents accurate placement of *Phytophthora* occurrence boundaries. Recovery time may be longer than 3 years
	DISEASE RISK ROAD	Unformed track with shoulders of interpretable vegetation	Shoulders and batters with regenerated vegetation. Incipient infestation

	Phytophthora occurrence category	Typically present	May be present
Non-vegetated areas (*Phytophthora* occurrence assessment is not possible) Can be determined by desktop assessment (aerial photo) Small vegetated areas can exist and may be Excluded from the assessment area considering total environmental context	**EXCLUDED**	Pasture, pits, easements, infrastructure, large roads (sealed and unsealed) permanent flooding, plantations, parkland tree stands	Sporadic reliable indicator species

The Keighery vegetation disturbance scale (**Table 2**) was used to determine the interpretability of remnant vegetation area. Areas that achieve a vegetation condition rating of 1-3 (Pristine - Very Good) are considered to be Mappable. In addition, there must also be enough disease indicator species present to enable a diagnosis of the disease status. An area with a vegetation condition rating of 4 (Good) is possibly Mappable however it is up to the interpreter's discretion and may be categorised as Temporarily Uninterpretable or Excluded depending on the likelihood that the area will recover and become Mappable. Areas given a condition rating of 5 or 6 (Degraded or Completely Degraded) are unmappable and therefore Excluded from assessment.

Table 2: Keighery vegetation disturbance scale and assessability (DPAW, 2013)

Interpretability	Scale		Condition
Mappable	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
Possibly Mappable, discretion required	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.
Unmappable or Excluded from assessment	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 very 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.

The vegetation of Uninterpretable areas can range from Pristine to Very Good however whether the pathogen is present in resistant hosts or as Zoospores in permanent water bodies is indeterminable. Uninterpretable areas that meet the protocols for identifying Protectable Areas (CALM, 2004) are managed as being both Infested and Uninfested so that the pathogen is neither imported into, nor exported from these areas.

3.2 Protocols for Identifying Protectable Areas

According to the *Phytophthora cinnamomi* Management Guidelines (CALM, 20003) the following primary criteria are used to define 'Protectable Areas' as those that:

- Have been determined to be free of the pathogen *Phytophthora* sp. by a registered Dieback Interpreter (all susceptible indicator plant species are healthy and no plant disease symptoms normally attributed to *Phytophthora* Dieback are evident).
- Are positioned in the landscape and are of sufficient size (e.g. > 4 ha with axis >100 m) such that a qualified Interpreter judges that the pathogen will not autonomously engulf them in the short term (a period of a few decades).
- Includes areas of high conservation and/or socio-economic value (for example, a small Uninfested area with a known population of a susceptible species of Threatened flora).
- Consists of areas where human vectors are controllable (e.g. not an open road, private property) (DPAW, 2013, pp 101 - 102).

3.3 Field Assessment

A nominal 200 m wide study area was proposed. The minimum 200 m wide study area was determined to be appropriate because it allowed 100 m for the disturbance corridor plus an additional 50 m either side. The width of the study area was increased to assess sections that are wider than 200 m and the landscape context within which the corridor is located.

Approximately 17 km of native vegetation required assessment along the corridor which equated to 465 ha. Native vegetation adjacent to the disturbance corridor was mapped so that protectable areas could be identified and appropriately managed to prevent infestation.

The first step of the field assessment was to complete a reconnaissance of the study area to determine the following:

- Access.
- Identify interpretable vegetation and disease expression if present.
- Identify possible disease vectors, e.g. tracks, utility corridors, ground disturbance, feral animals.
- Determine the location of high risk areas, e.g. areas of high disturbance and water-gaining sites.
- Identify other impacts to vegetation, e.g. drought, cankers, herbivory, *Armillaria luteobubalina,* fire.

The Dieback assessment involved traversing areas of native vegetation within the study area along 50 m wide strip-lines, recording evidence of presence or absence of Dieback and taking soil and tissue samples of recently dead or dying disease indicator species. This was followed by disease boundary mapping, including buffers of appropriate width, as prescribed in the Dieback Interpreter's Guidelines (**Section 3.6**). The samples were lodged with DPAW's Vegetation Health Services Laboratory (VHS) where diagnostic baiting was conducted. All sample point locations were recorded with a hand-held Global Positioning Satellite (GPS) device.

3.4 Sampling

Soil and tissue samples were taken from recently dead or dying disease indicator species to confirm the presence or indicate the possible absence of Dieback and inform interpretation of the area. Negative sample results do not necessarily mean that the pathogen is absent because low levels of inoculum can lead to false negative results.

Sampling strategies for the assessment of Dieback include the following:

Initial standards sampling: Initial samples were taken to determine disease behaviour. The results inform the sampling strategy and enable the testing of early hypotheses (e.g. are other factors causing the deaths of susceptible species such as *Armillaria luteobubalina* or drought).

Sampling to support infested diagnosis: Recently dead and dying indicator species were sampled to support an infested diagnosis.

Sampling to support an uninfested diagnosis: Recently dead and dying indicator species were sampled to support an uninfested diagnosis. A cautious approach must be adopted when claiming that a negative result means that an area is Uninfested because false negative results can be recorded when inoculum levels are depleted due to prolonged unfavourable environmental conditions for the pathogen.

All sampling strictly adhered to the following procedures:

- All tools used in sampling were thoroughly sterilised with a 70:30 mixture of methylated spirits and water before samples were taken. Tools were dry prior to sampling so that the results were not compromised.
- The area around the base of the plant being sampled was cleared of leaf litter and debris so that this material was not included in the sample.
- The plant sampled was excavated to a suitable depth to ensure that adequate plant tissue material can be obtained from the roots and cambium layer around the collar of the plant being sampled.
- Material from all around the plant was taken in addition to any obvious lesions to avoid missing any infected material. All the plant tissue material and a few handfuls of soil from around the roots and other places in the soil profile were placed in a polythene bag.
- Enough distilled water to moisten the soil was poured into the bag to ensure the survival of any inoculum that may be present in the sample.
- All relevant information pertaining to the plant sampled and sample location was recorded on the Sample Information Sheet.
- Two aluminium tags which provide the date, project name, sample number, species sampled and the name of the interpreter were written. One tag was placed in the sample bag and the other was tied near the sample site which was also flagged with a day-glo orange flagging banner.
- The sample hole was backfilled to prevent fauna becoming trapped.
- All tools were brushed off (to remove excess soil) and sterilised to prevent contamination of the next sample site and sample.

3.5 Mapping

Dieback occurrence maps illustrate the extent of Dieback within the study area. Areas of vegetation were classified according to their Dieback occurrence category, as defined in DPAW's draft Dieback Interpreters guidelines (**Table 1**). Field evidence and observations were used to prepare the Dieback occurrence map of the study area (**Figure 2-13**). Information used in Dieback occurrence mapping includes:

Sample results: Positive sample results for *Phytophthora* spp. confirm that a particular point is infested. Extrapolation of this is done by the Dieback Interpreter mapping disease occurrence through field observations including susceptible species deaths, biomass reduction, disease pattern and chronology. The Interpreter must also determine the disease status in low interpretability areas and areas where disease was being masked through colonisation of resistant species such as sedges (McComb *et.al* 1994) (**Plate 1**).

Interpretability of the vegetation: this is determined from the abundance and cover of susceptible species and the presence or absence of disease indicator species. The level of interpretability is also determined by the vegetation condition with areas rating five or greater (Degraded to Completely Degraded) on the Keighery scale (**Table 2**) Excluded from assessment. Vegetation may also be in Pristine or Excellent

condition and be Uninterpretable due to the composition of the plant species present and the absence of disease indicator species.

Topography and drainage: these two factors are critical in determining the likelihood of an area being infested and whether an area is protectable from disease.

Disease vectors and disturbance: these two factors are considered when determining whether an area is likely to recover and is Temporarily Uninterpretable or should be Excluded from assessment because it is not likely to recover naturally and therefore become mappable. Excluded areas may be assessed as high risk of being Infested due to uncontrolled public access, dumping and disturbance.

3.6 Buffers

The following buffers were applied during mapping of Infested areas in accordance with the Dieback Interpreter Guidelines (DPAW, 2013):

- Minimum upslope buffers 15 m depending on complexity of disease expression.
- Minimum downslope buffer of 25 m depending on degree of slope, drainage patterns, soil type and geology.

3.7 Limitations

The following limitations were encountered during the assessment:

- The Degraded or Completely Degraded condition of the majority of native vegetation within the study area meant that the majority (69.8%) of the study area had to be Excluded from assessment.
- The widespread impacts of canker made Dieback interpretation more difficult because primary disease indicator species including *Banksia* spp. were particularly affected by these pathogenic fungi.
- The widespread impact of drought made Dieback Interpretation more difficult.
- Access to some of the properties along the project corridor was initially prohibited which delayed the field assessment by several weeks resulting in some samples being taken later, during less optimal conditions.

4 Results

In total, 27 soil and tissue samples were taken from recently dead and dying disease indicator species, which included one canker tissue sample. All the samples, apart from one sample taken from a *Xanthorrhoea preissii*, were taken from *Banksia* spp. because this genus is considered the most susceptible to *Phytophthora cinnamomi*. In total, four positive results for *P. cinnamomi*, one positive result for a *Lasiodiplodia* sp. (canker), and 21 negative samples were reported (**Table 3, Appendix 2**).

Table 3: Sample Results

Sample No.	Species	Easting GDA 94 Zone 50	Northing GDA 94 Zone 50	Laboratory Results
1	*Banksia attenuata*	400799	6484596	*P. cinnamomi*
2	*Banksia ilicifolia*	399603	6482900	Negative
3	*Banksia grandis*	404845	6509570	Negative
4	*Banksia menziesii*	403463	6488149	*P. cinnamomi*
5	*Banksia attenuata*	403463	6487606	Negative
6	*Banksia attenuata*	403745	6487608	*Lasiodiplodia* sp. (canker)
7	*Banksia attenuata*	403415	6487327	Negative
8	*Banksia attenuata*	403428	6487171	Negative
9	*Banksia ilicifolia*	403303	6486895	Negative
10	*Banksia ilicifolia*	403329	6486759	Negative
11	*Banksia attenuata*	403268	6486599	Negative
12	*Banksia menziesii*	403442	6487076	Negative
13	*Banksia attenuata*	403234	6486262	Negative
14	*Banksia attenuata*	402730	648561	Negative
15	*Banksia attenuata*	402356	6485482	Negative
16	*Banksia attenuata*	402039	6485343	Negative
17	*Banksia ilicifolia*	401931	6485377	Negative
18	*Banksia attenuata*	402329	6485559	Negative
19	*Banksia menziesii*	397209	6479515	*P. cinnamomi*
20	*Banksia ilicifolia*	397523	6478527	Negative
21	*Banksia attenuata*	397376	6478222	Negative
22	*Banksia menziesii*	397166	6480700	*P. cinnamomi*
23	*Banksia menziesii*	396969	6480467	Negative
24	*Banksia menziesii*	405118	6507024	Negative
25	*Banksia menziesii*	402968	6485904	Negative
26	*Banksia attenuata*	403001	6485955	Negative
27	*Xanthorrhoea preissii*	397572	6477399	Negative

In total 1,541.61 ha were assessed with 69.8% of the area determined to be Excluded (unmappable) from the Dieback assessment, 23.5% Infested, 3.7% Uninfested and 3.0% Uninterpretable (**Table 4**).

Table 4: Proportion of each Dieback occurrence category within the study area

Dieback Occurrence Category	Area (ha)	Area (%)
Excluded (unmappable)	1,076.51	69.8
Infested (*P. cinnamomi*)	362.47	23.5
Uninfested	56.76	3.7
Uninterpretable	45.90	3.0
Total	1,541.64	100

5 Discussion

Because of the length of the study area, the following discussion considers Dieback occurrence from the northern to the southern extent of the study area (**Figures 2-13** respectively).

5.1 Figures 2-7

The northern portion of the study area from Muchea to Warbrook Road shown in **Figures 2-7** was mostly Excluded from assessment because it is not possible to map Dieback occurrence in pasture and disturbed areas where the vegetation condition is rated as Degraded to Completely Degraded according to the Keighery vegetation condition scale.

An Infested area has been mapped extending from a historical positive result for *Phytophthora cinnamomi* to the northern extent of the study area on both sides of the Great Northern Highway (**Figure 2**). Although a negative sample (NLS03) result was returned from this area, there was enough evidence, including disease indicator species deaths, disease patterns and chronology; to determine that this section of the study area is infested.

Watercourses which are dominated by species resistant to Dieback, including *Melaleuca raphiophylla* and *Eucalyptus rudis,* intersect the study area at several locations (**Figures 2-7**, **Plate 2**). One Uninterpretable watercourse is downstream of an Uninfested area (NLS24) and is therefore unlikely to be vectoring the pathogen downstream (**Figure 2**). Hygiene management within Uninterpretable areas is critically important because poor hygiene management can result in the pathogen being vectored downstream to Uninfested vegetation.

5.2 Figure 8

This section of the study area includes Infested vegetation, both north (NLS04) and south of Maralla Road, including an area within DPAW managed Nature Reserve 2066/893. Significantly, there is also an area of Protectable Uninfested vegetation which extends both west and east beyond the corridor. Vegetation in these Uninfested areas displayed symptoms of drought and canker with a positive a result for *Lasiodiplodia* sp. recovered from a recently dead *Banksia menziesii* (**Plate 3**, **Appendix 1**).

The Infested areas were commonly restricted to wetland areas where sufficient *Xanthorrhoea preissii* and fringing *Banksia* spp. deaths displaying disease pattern and chronology provided enough evidence for an infested diagnosis (**Plate 4**). The infestation within the nature reserve south of Maralla Road had been previously delineated with a positive sample site for *P. cinnamomi*. Mapping of this infestation was checked and updated. Hygiene management within this section will be critical to ensuring that the pathogen is not vectored into uninfested areas adjacent to the corridor.

5.3 Figures 9 and 10

This section of the study is located in the Ellenbrook area (**Figure 9**), within Rocla's mining tenement and also traverses the Gnangara-Moore River State Forest (**Figure 10**). Although potential disease vectors were plentiful in the bushland adjacent to Ellenbrook, including unrestricted vehicular access and rubbish dumping; the majority of this section of the study area is Uninfested. Infested areas were mainly restricted to wetland areas and immediately adjacent upland vegetation. Some areas were highly disturbed and were therefore Excluded from assessment but are considered high risk due to unrestricted vehicular access and rubbish dumping (**Plate 5**). In total, 11 samples were taken in this section with no positive results for *P. cinnamomi* or other *Phytophthora* species. These sample results, along with the vegetation condition, absence of disease pattern or chronology; support an Uninfested diagnosis for these areas. Significantly, the upland vegetation east of the study area appears to be Uninfested, with Dieback generally restricted to water-gaining sites.

The majority of the study area within Rocla's mining lease was Excluded from assessment either because it was pine plantation or cleared land that cannot be assessed for the presence of Dieback. Some areas where

the pine trees had been cleared had native species regenerating. However, the vegetation condition was Degraded and there were not enough disease indicator species present to enable assessment of these areas.

Disease expression within areas of native vegetation in Rocla's mining lease areas was obvious with multiple disease indicator species deaths, strong disease pattern and chronology (**Plate 6**). For these reasons, only two samples were taken in this area with one positive result (NLS01) for *P. cinnamomi.*

5.4 Figures 11 and 12

This section of the study area south of Gnangarra Road, which includes Cullacabardee Nature Reserve (**Figure 11**) and the western side of Whiteman Park, is mostly Infested (NLS 19 and NLS 22) with obvious disease symptoms, pattern and chronology (**Plate 7**). Several historical positive sample results for *P. cinnamomi* have been recorded both east and west of the study area, with disease vectors intersecting the project corridor in the form of drainage lines and unsealed roads (**Figure 12**). The area in between Hepburn Avenue and Cullacabardee Nature Reserve is Completely Degraded with *Xanthorrhoea preissii* the only remnant native species present. Normally an area that is Completely Degraded would be Excluded from assessment; however the evidence of disease pattern and chronology in the *X. preissii* population, in conjunction with widespread disease in the surrounding landscape has resulted in an Infested diagnosis (**Plate 8**).

There are three Uninfested areas within Cullacabardee Nature Reserve (**Plate 9**). The two smaller areas are Unprotectable due to their size (0.49 and 0.18 ha). The larger Uninfested area is 9.66 ha and located upslope of Dieback vegetation. Therefore it would meet DPAW's protocol for identifying protectable areas because more than four hectares of this Uninfested area are upslope from Dieback.

5.5 Figure 13

The most southern section of the study area between Hepburn Avenue and the Tonkin and Reid Highway interchange is a combination of Infested and Excluded areas. The Infested areas displayed obvious disease symptoms, including disease pattern and chronology. The Excluded areas include cleared areas and areas where the vegetation condition is Degraded or Completely Degraded, making these areas unmappable for Dieback (**Plate 10**).

5.6 Other Potential Impacts to Vegetation

There may be other factors causing the observed deaths of disease indicator species, including drought, other *Phytophthora* species, other pathogenic fungi and *Armillaria luteobubalina* (Armillaria or Australian Honey Fungus).

5.6.1 Drought

Impacts to vegetation as a result of prolonged drought were differentiated from impacts caused by *P. cinnamomi* by the following characteristics:

- No disease pattern or chronology in the surrounding vegetation.
- The plant had senesced gradually rather than succumbing quickly as is usually the case with deaths attributed to *P. cinnamomi.*
- No visible lesions or mycelium on the roots of the dead or dying plant.
- Re-shooting or epicormic growth visible on dying plants (**Plate 11**).

The presence of single or multiple dead branches with the remainder of the plant appearing to be healthy may be attributed to drought or pathogenic fungi. Impacts to vegetation symptomatic of drought were evident throughout the study area (**Plate 12**).

5.6.2 *Armillaria* (Australian Honey Fungus)

Armillaria luteobubalina (Armillaria) or Australian Honey Fungus is a species of mushroom which causes Armillaria root-rot in affected plants. The fungus is widespread in Jarrah (*Eucalyptus marginata*) and Karri (*E. diversicolor*) forests of the southwest of WA, but has also been recorded in coastal vegetation between Cape Arid 120 km east of Esperance to Cervantes 160 km north-west of Perth (Shearer *et al.* 1994a, 1997). Armillaria is dispersed by spores produced by the mushroom and also reproduces vegetatively through the roots of affected plants. It affects many of the same plant genera as *Phytophthora* in particular members of the Myrtaceae and Protecaceae plant families such as *Eucalyptus* and *Banksia* species (Shearer 1994a). Armillaria forms quite visible white or yellow leathery mycelial sheath which is visible beneath the bark in the roots or lower stem. Other observable factors that can be applied in the diagnosis of *Armillaria* infection include:

- Clusters of fruiting bodies around or near the base of the plant.
- A pungent mushroom smell.
- An inverted V-shaped scar at the base of the plant.
- Yellow-white stringy rot under the bark in the roots and base of affected plants (DEC, 2012).

While some of the mycelium observed in this study may be as a result of Armillaria, the assessment was undertaken at the wrong time of the year to observe fruiting bodies and therefore confirm the presence of the fungus. It is possible that *Armillaria luteobubalina* is present within the study area and contributing to the destruction of the vegetation.

5.6.3 Other Pathogenic Fungi

In addition to the impact of drought the possibility also exists that cankers caused by aerial fungi are having an impact on *Banksia* species in particular. Crane and Burgess (2013) studied the effect of cankers caused by pathogenic fungus on Proteaceous species. The study examined the impact that aerial cankers are having on coastal vegetation between Esperance and Cervantes and demonstrated pathogenicity in seven *Banksia* species over a wide geographic range. The pathogenic fungus was identified as a new genus and species within the Cryphonectriaceae (Diaporthales) and is described as *Luteocirrhus shearii* gen. sp. *nov*. The fungus causes the death of single branches; however it can lead to multiple branch deaths or cause complete crown dieback as occurred with some of the *Banksia baxteri* and *B. verticillata* sampled (Crane and Burgess 2013).

Only one canker sample was taken from a *Banksia attenuata* to confirm that it was having an impact on the proteaceous species being assessed for symptoms of Dieback. The sample returned a positive result for *Lasiodiplodia* sp. This species of canker has a host range which includes species from the Protecaceae, Myrtaceae and Ericaceae plant families. *Lasiodiplodia* sp. along with other genera in the Botryosphaeriales, are commonly isolated from stem and twig cankers of *Eucalyptus, Hakea* and *Banksia* spp. of south-western Australia (Shearer 1994b). Crane (2014; **Appendix 1**) states that '*Lasiodiplodia* sp. are sometimes parasitic and often exist as benign endophytes (present in host tissues asymptomatically) causing disease only when the host is compromised in some way. Plants affected by drought, insect attack, defoliation by fungi, sunscald, herbicides or mechanical injury are predisposed to infection and disease development'.

6 Conclusion and Recommendations

The Dieback assessment determined that the majority of the study area (69.8%) is unmappable due to being cleared and/or farmland and is therefore Excluded from assessment. Mappable areas are a mosaic of mainly Infested (23.5%) and Uninfested (3.7%) native vegetation. While some areas of Protectable Uninfested vegetation were mapped within the corridor, the Uninfested areas adjacent to the corridor between Maralla Road and Gnangara Road are more significant because they are Protectable from Dieback in the longer term. While the majority of the vegetation within the project corridor will be cleared, the critical issue is that the pathogen is not introduced into areas that can vector it along watercourses, tracks and roads.

Uninterpretable areas (3%) are predominantly comprised of creeks and drainage lines intersecting the study area. Uninterpretable riparian vegetation and watercourses may, or may not, be hosting the pathogen but these areas are a potential vector for the pathogen if hygiene is not adequately managed.

Dieback is spread through the movement of water and soil within the landscape. Major vectors of Dieback include, among others, wet soil adhering to vehicle tyres/tracks and earthmoving equipment. Therefore, quarantine management procedures are an effective tool to reduce the spread of Dieback as a result of earthmoving activities.

Terratree makes the following recommendations for managing *Phytophthora* Dieback during the PDNH project:

- A Dieback Management Plan should be prepared for the project by a suitably qualified and experienced person in accordance with best practice management techniques described in the following publications:
  - Management of *Phytophthora* Disease; Policy Statement 3. Department of Parks and Wildlife (2014).
  - "*Phytophthora cinnamomi* and Disease Caused by it" Volume 1 Management Guidelines, Department of Environment and Conservation (2004).
- The management plan should include:
  - A comprehensive risk assessment of potential disease vectors and proposed activities within project corridor.
  - Recommendations for hygiene management locations that consider the level of risk to biodiversity in the surrounding landscape.
  - A program to monitor and report on compliance with the hygiene protocols prescribed in the management plan.
  - A communication program to make personnel aware of the risk to biodiversity associated with spreading Dieback and the importance of adhering to hygiene protocols.

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8 Glossary of Terms

Assessment – (*Phytophthora* occurrence) any combination of activities including, detection, diagnosis (interpretation), mapping and demarcation of *Phytophthora* Dieback disease in natural ecosystems.

Assessment Area – an area where *Phytophthora* occurrence assessment is possible, or will be possible in the short to medium term. This area may be larger or smaller than the proponent's project area.

Buffer – the intervening area reducing the danger of interaction. In dieback mapping this refers to the area between the visible disease symptoms and the demarcation.

Chlorosis – the loss of the normal green colouration of leaves of plants, caused by mineral deficiency, disease or lack of light.

Disease – The combination of a pathogen, host and correct environmental conditions, which results in disease symptoms or death of a host.

Environment - The sum of all external factors which act on an individual organism during its lifetime.

Excluded Area – An area of high disturbance in which native vegetation is unlikely to recover.

Host - means the plant which is invaded by a pathogen and from which the pathogen derives its energy.

Indicator species – Plant species that area more susceptible to Phytophthora disease and reliably show symptoms earlier than other species.

Infection – The invasion of a host organism's bodily tissue by disease causing organisms. In relation to Dieback this refers to an individual plant and not the population.

Infested – The state of being invaded or overrun by pests or parasites. In relation to Dieback it refers to a population of plants and not individual plants.

Inoculum – Cells, tissue, or viruses that are used to inoculate a new culture

Lesion- any abnormality in the tissue of an organism (damage), usually caused by disease or trauma.

Mycelium – The mass of hyphae that for the vegetative part of a fungus

Pathogen – Any organism or factor causing disease within a host

Pathogenic – Causing or capable of causing disease

***Phytophthora* Dieback –** A term referring to the disease symptoms caused by *Phytophthora* species in susceptible vegetation.

Protectable area- an area of vegetation that can be protected by the application of hygiene controls to prevent infestation.

Susceptible – Likely to be influenced or able to be harmed by particular pathogen

Symptom – A phenomenon that arises from, and accompanies a particular disease or disorder and serves as an indication of it

Uninfested – An area that does not contain infected plants or show visible signs of disease

Uninterpretable – a natural area where there are inadequate visible symptoms present to make a diagnosis

Unmappable – A naturally vegetated area that has had disturbance and from which is likely to recover in the short term

Unprotectable – A disease free area that is likely to become Infested within a given time

Vector – any agent that acts as a carrier or transporter

Figures

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Gnangara-Moore River State Forest
Un-named Nature Reserve
Bullsbrook Nature Reserve
Neaves Road Nature Reserve
Neerabup National Park
Un-named Conservation Park
Un-named Miscellaneous Reserve
Jandabup Nature Reserve
Lake Joondalup Nature Reserve
Woodvale Nature Reserve
Twin Swamps Nature Reserve
Walyunga National Park
Ellen Brook Nature Reserve
2066/893
2650/480
Gnangara-Moore River State Forest
Talbot Road Nature Reserve
Parkerville Nature Reserve
John Forrest National Park
Un-named 5(1)(g) Reserve
1014/836
Greenmount National Park
Beelu National Park
Un-named 5(1)(h) Reserve

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LEGEND

- Swan Valley Bypass
- Tonkin Highway Grade Seperation
- DPaW managed lands
- Watercourse

NORTHLINK - PROJECT LOCALITY

Linear Phytophthora Dieback Survey

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Kilometers

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

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Date: 19/11/2014	Checked: J Botterill	
Project No: TW14013	Reviewed: N King	Terratree
Figure: 01	Revision: Rev A	

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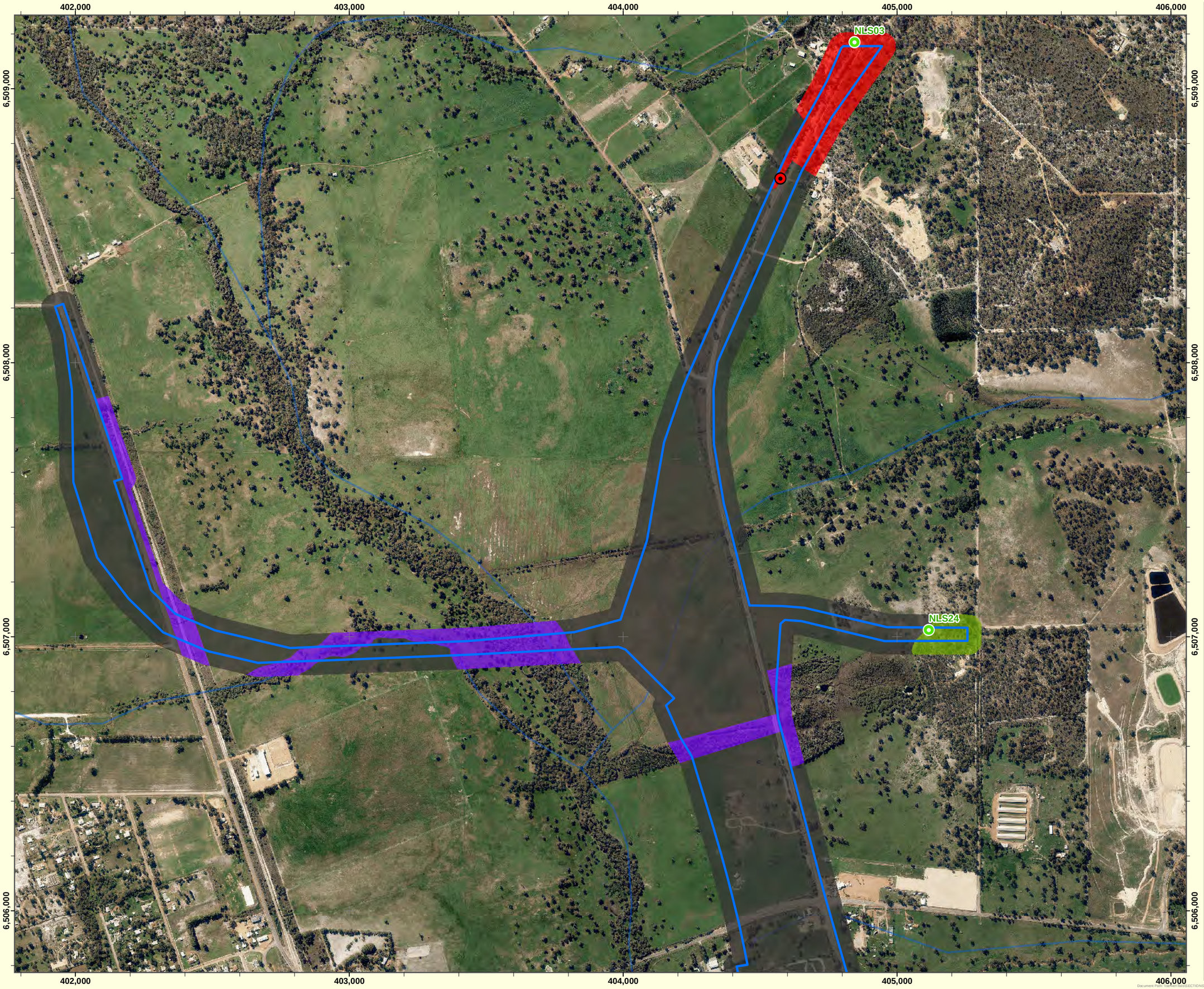


LEGEND

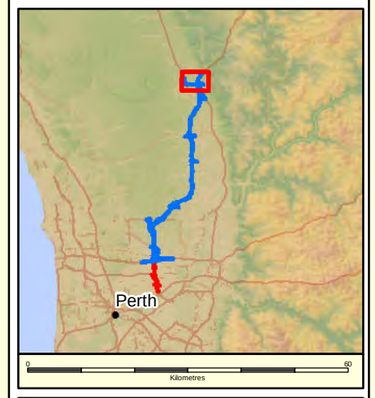
- Swan Valley Bypass
- Tonkin Highway Upgrade
- DPaW managed lands
- Watercourse

Dieback Occurence Category

- Excluded
- Infested
- Uninfested
- Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative
- *P. cinnamomi* (Historical)



NORTHLINK - SWAN VALLEY BYPASS PROJECT

Linear Phytophthora Dieback Survey

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Revision:	Rev B
Project No:	TW14001
Prepared:	B Jones
Checked:	J Botterill
Reviewed:	N King

Figure 2

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Un-named Nature Reserve

LEGEND

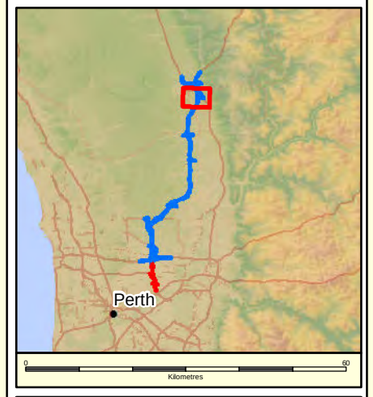
- Swan Valley Bypass
- Tonkin Highway Upgrade
- DPaW managed lands
- Watercourse

Dieback Occurence Category

- Excluded
- Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative



NORTHLINK - SWAN VALLEY BYPASS PROJECT

Linear Phytophthora Dieback Survey

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Checked:	J Botterill
Reviewed:	N King

Figure 3

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LEGEND

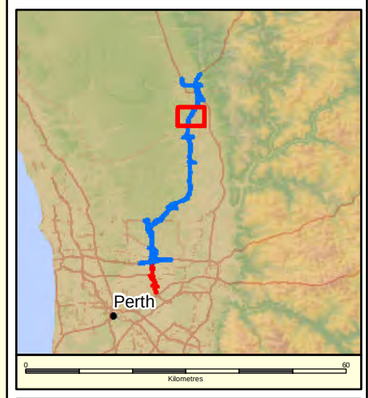
- Swan Valley Bypass
- Tonkin Highway Upgrade
- DPaW managed lands
- Watercourse

Dieback Occurence Category

- Excluded

Dieback Sample Results

- *P. cinnamomi*
- Negative



NORTHLINK - SWAN VALLEY BYPASS PROJECT

Linear Phytophthora Dieback Survey

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Project No:	TW14001
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Checked:	J Botterill
Reviewed:	N King

Figure 4

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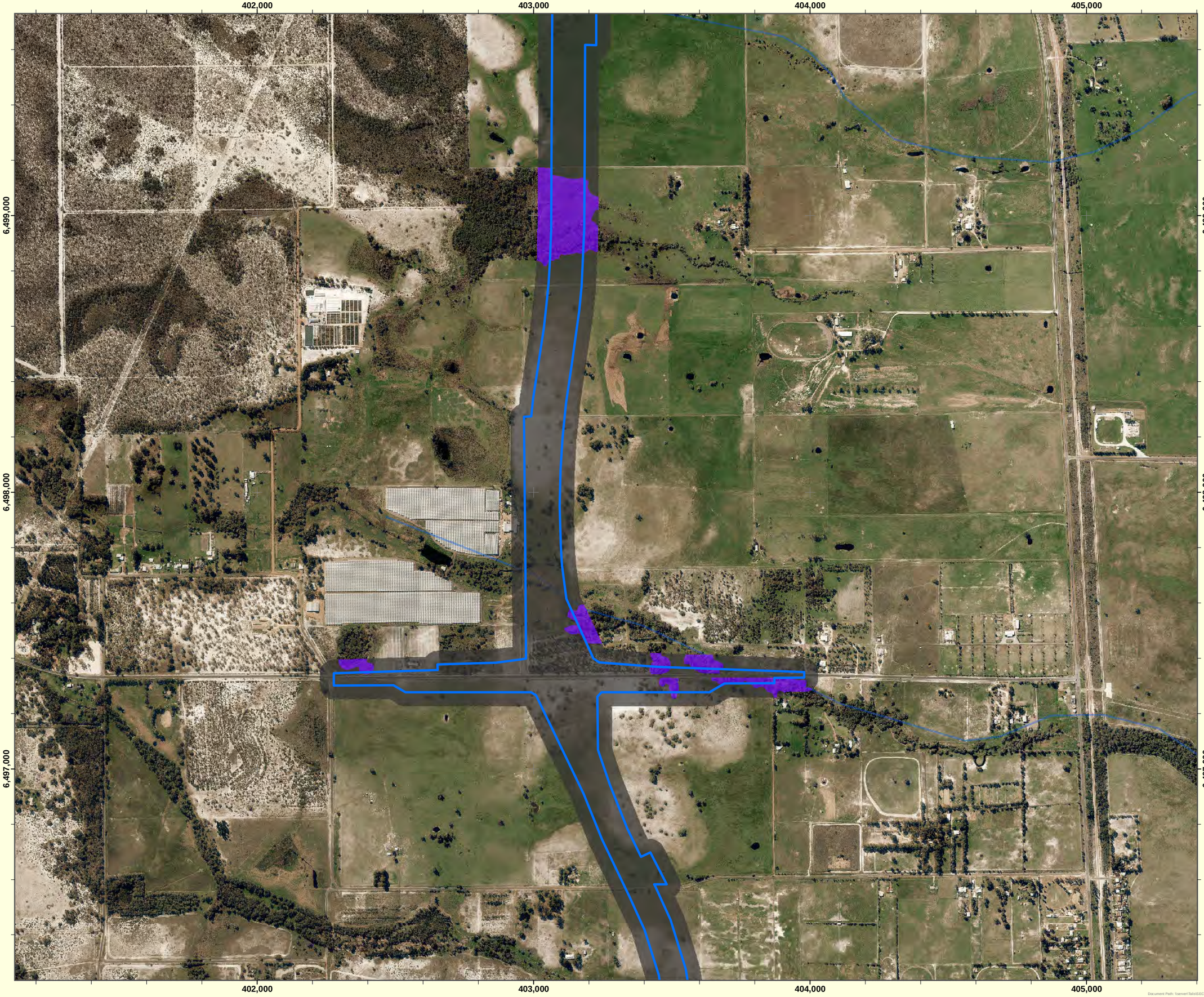


LEGEND

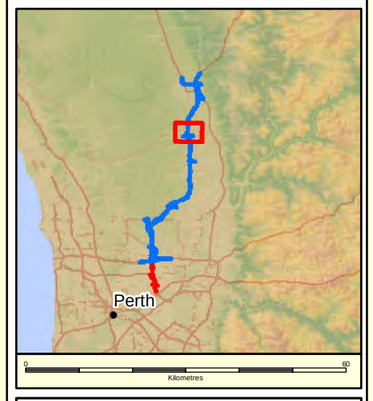
- Swan Valley Bypass
- Tonkin Highway Upgrade
- DPaW managed lands
- Watercourse

Dieback Occurence Category

- Excluded
- Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative



NORTHLINK - SWAN VALLEY BYPASS PROJECT

Linear Phytophthora Dieback Survey

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Figure 5

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LEGEND

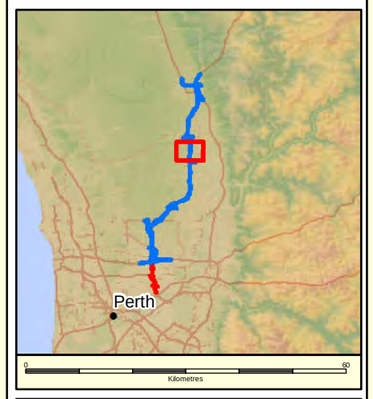
- Swan Valley Bypass
- Tonkin Highway Upgrade
- DPaW managed lands
- Watercourse

Dieback Occurence Category

- Excluded
- Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative



NORTHLINK - SWAN VALLEY BYPASS PROJECT

Linear Phytophthora Dieback Survey

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Revision:	Rev B
Project No:	TW14001
Prepared:	B Jones
Checked:	J Botterill
Reviewed:	N King

Figure 6

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