Review of the use of Underpasses for Northern Quoll in the Ashburton Infrastructure Project

Northern Quoll *Dasyurus hallucatus;* a typical image on a motion-sensitive camera (Bamford Consulting Ecologists; near Pannawonica, October 2021)

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1 Introduction

1.1 Project area and description

Onslow Iron Pty Ltd is a wholly owned subsidiary of Mineral Resources Limited, and is undertaking planning for the Ashburton Infrastructure Project (AIP) to service iron ore mining and export developments in the West Pilbara region of Western Australia. The AIP proposal is located in the Pilbara region of Western Australia within a development envelope of 20,821 ha and clearing no more than 1,564 ha.

The AIP is being referred under Section 38, Part IV, of the WA Environmental Protection Act 1986 (EP Act). The referral will also be submitted for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Mineral Resources Limited (MRL) is undertaking planning for the AIP, which will include a fully sealed private haul road approximately 150 km in length that will begin at the boundary of the approved Bungaroo South haul road, and will continue west to the Port (Onslow). The haul road will include waterway crossing infrastructures such as low-profile floodway crossings, culverts and bridges to minimise impacts to these habitats (MRL 2021).

The construction of the haul road may have impacts on local fauna populations. Of particular concern is the Northern Quoll (*Dasyurus hallucatus*), which is Endangered at a State and Federal level. The initial fauna survey commissioned by MRL (360 Environmental 2021) identified stony hills and slopes, and mesas and breakaways, as ideal/likely habitat used by Northern Quoll. Where these occur close to the AIP haul road, they have been mapped (**Figure 1** and **Figure 2**). The 360 Environmental (2021) report also identified several of these habitat areas where there were multiple records of Northern Quoll, recorded via targeted live-trapping and targeted camera traps (**Figure 2**). The report concluded that the mesas at sites KBT02 and KBT05 were likely to be strongholds for the Northern Quoll populations, as critical habitat was relatively isolated in these areas (**Figure 2**). There was more connectivity between critical habitat, and more widespread habitat near sites KBT01, KBT03, and KBT04 (**Figure 2**). The Haul Road Development Envelope (DE) (see **Figure 2**) was therefore designed to limit disturbance by avoiding mesas and breakaway habitat.
While no Northern Quolls were recorded within the Haul Road DE, subsequent to the 360 Environmental (2021) fauna survey, the Haul Road DE was specifically designed to avoid all recorded locations of Northern Quoll, as well as any potential Northern Quoll denning habitat (mesa and breakaway habitat) (MRL 2021). However, the alignment passes between areas of suitable habitat and therefore animals may enter the DE when foraging or dispersing. As a result, it has been proposed by the Department of Agriculture, Water and the Environment (DAWE) for MRL to investigate the possible value of constructing underpasses for Northern Quoll to use if crossing over the haul road.

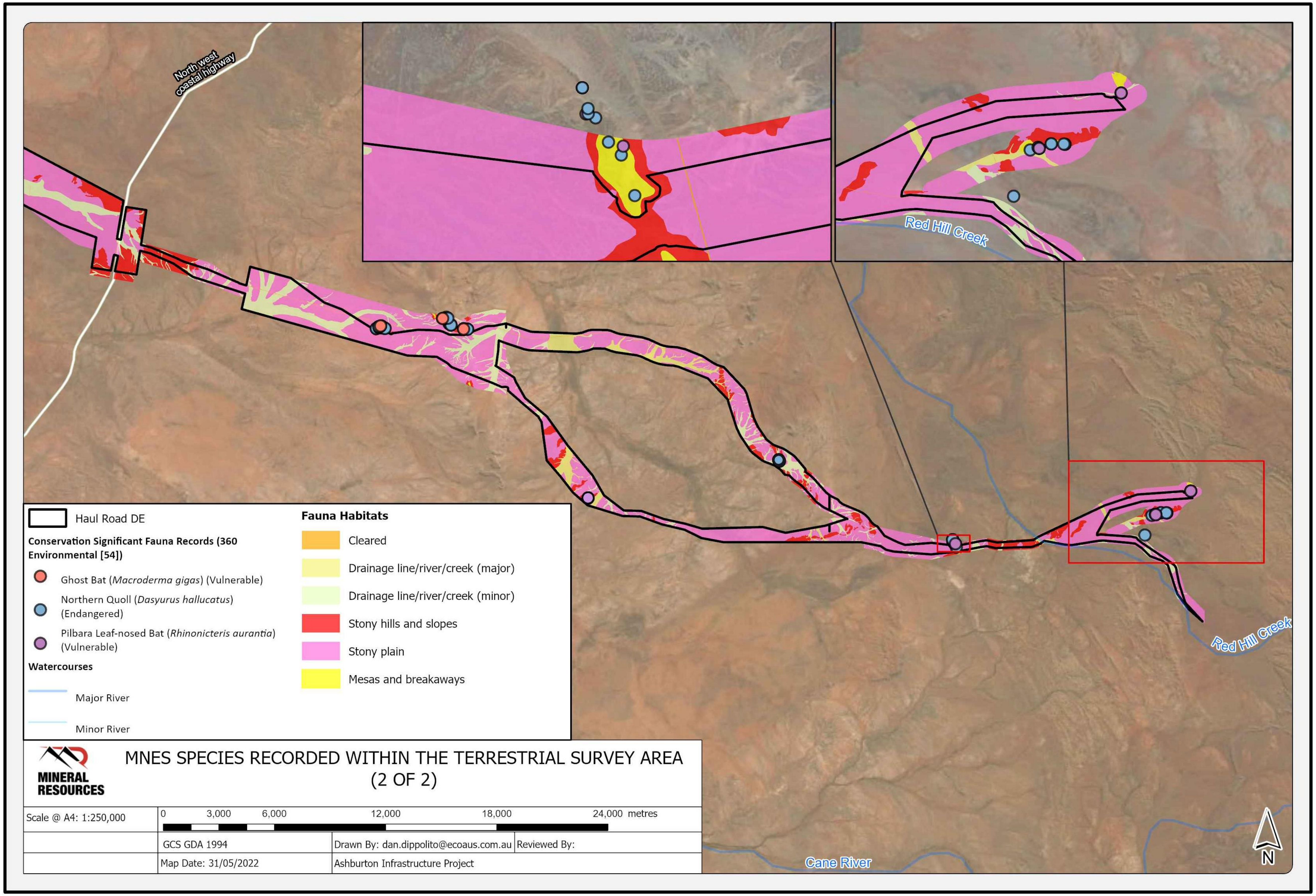

Figure 1: Map of known MNES records and habitats (including Northern Quoll) in relation to the proposed new Haul Road Development Envelope (DE) and Indicative Footprint (IF).

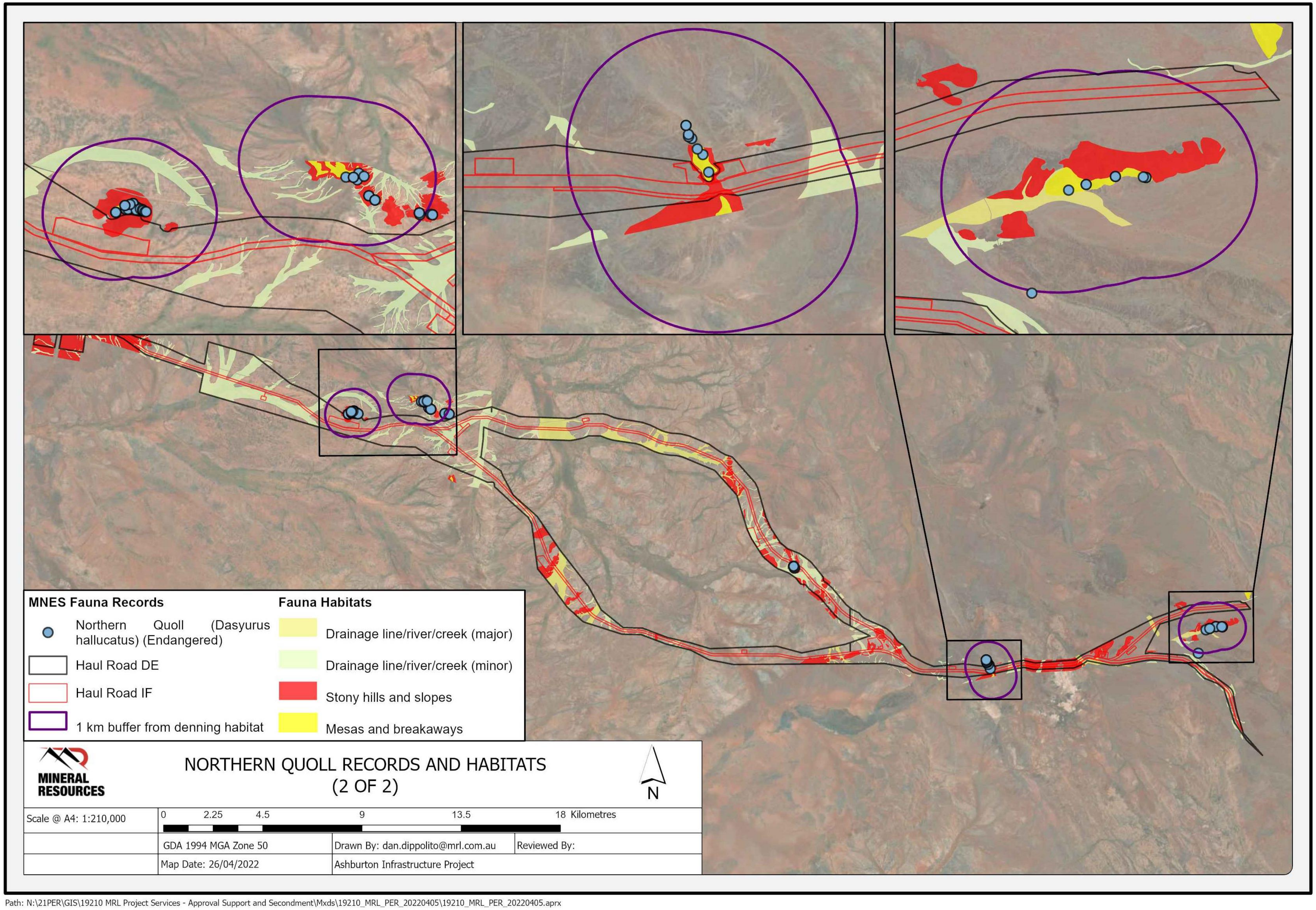

Figure 2: Map of known Northern Quoll records and habitats in relation to the proposed new Haul Road Development Envelope (DE) and Indicative Footprint (IF).

1.2 Scope of report

As it has been proposed by DAWE for MRL to investigate the possible value of constructing underpasses for use by Northern Quolls to safely cross the AIP haul road, MRL engaged Bamford Consulting Ecologists (BCE) to undertake a desktop study to investigate the possible impacts of the haul road on existing populations of the Endangered Northern Quoll (*Dasyurus hallucatus*), and how underpasses may be used to reduce these risks.

There are limited data available concerning the use of underpasses by Northern Quoll, and the effectiveness of such underpasses in terms of mitigating impacts of linear infrastructure on this species. This report summarises what data exist specifically about Northern Quoll, but also discusses general considerations about fauna underpasses and puts these in the context of Northern Quoll ecology and biology, in order to advise on the likely benefits of fauna underpasses for this species in relation to the AIP haul road.

2 Northern Quoll biology and ecology

2.1 Distribution and habitat associations

The current range of the Northern Quoll is significantly less than the former range, which occurred across northern Australia from Western Australia to south-east Queensland. Now only extant populations are found in the Pilbara and Kimberley (WA), parts of the Northern Territory and Queensland (Threatened Species Scientific Committee 2005). Northern Quoll populations in the Pilbara are of high conservation priority due to separation/isolation from other populations of Northern Quoll in the north of Australia, distinct genetics, and the fact they are threatened by different threatening processes and occupy unique habitats compared to other Northern Quoll populations in Australia (Dunlop *et al*. 2019).

It appears that the Northern Quoll exists at high densities in the mesa and breakaways habitat surveyed by 360 Environmental (2021). During these targeted surveys, ~11 individuals per 100 camera trap nights were recorded, compared with the average of 3.6 individual per 100 camera trap nights for the Pilbara region in general (Dunlop *et al*. 2019). While it is not clear if the density of cameras was similar, and therefore whether or not the recording rates can be directly compared, the species was clearly abundant in the mesas and breakaways targeted by 360 Environmental (2021). High density populations are considered to be important for the long-term survival of the Northern Quoll (Commonwealth of Australia 2016), so the populations of Northern Quoll that have been recorded in proximity to the AIP haul road are likely to be considered important populations for the survival of the species.

In the Pilbara region, the Northern Quoll tends to prefer the Rocklea, Macroy and Robe land systems (Biota Environmental Services 2008), which comprise of basalt hills, mesas, high and low plateaux, lower slopes, occasional tor fields and stony plains supporting either hard or soft spinifex grasslands (van Vreeswyk *et al*. 2004). These rocky areas provide shelter, and animals forage into adjacent land systems. The Northern Quoll has also been recorded in other land systems which comprise sandstone and dolomite hills and ridges, shrublands, sandy plains, clay plans and tussock grasslands and coastal fringes including dunes islands and beaches (Biota Environmental Services 2008). They will also follow drainage lines where large trees, under-cut banks and patches of exposed rock provide shelter (M. Bamford pers. obs.)

Critical habitat is considered to be habitat within the broad distribution of the Northern Quoll that provides shelter for breeding, and refuge from fire, predation, and poisoning from cane toads (Commonwealth of Australia 2016). The most critical habitats for long-term survival of the population are likely to be those that are preferred by females for den sites, and the attributes of these habitats are not yet well understood (Dunlop *et al.* 2019).

Based on current genetic information, it is believed that all Pilbara populations of Northern Quoll are genetically linked, indicating that a high level of dispersal and therefore genetic mixing occurs between populations that are geographically distant from each other (Dunlop *et al.* 2019 and references therein). This is important as it indicates that large scale movements of individuals across the landscape are important and common, and this may be impacted by linear infrastructure.

2.2 Ecological and life-history traits

In the Pilbara, Northern Quolls are most commonly found in dissected rocky escarpment habitat. The dissected nature of the rocky habitat helps to create more areas for females to den (Oakwood 2008). They can be terrestrial and arboreal, using a variety of den sites, which they don't share and usually change every night. Dens can be found in a variety of different habitats, including rock crevices, tree hollow, logs and termite mounds. The Northern Quoll is predominantly nocturnal but is occasionally active during the day, particularly in mating season (Oakwood 2008).

Home ranges are overlapping; on average 35 ha for females and 100 ha for males (Oakwood 2008; Herdandez-Santin *et al.* 2021). Male home ranges were found to be reduced during pre-mating and mating season, contrary to expectations (Herdandez-Santin *et al.* 2021), but robust statistical analyses were not done due to low sample size.

The diet of Northern Quolls is varied and described as opportunistic omnivores (Oakwood 2008), consuming invertebrates, fruits, small vertebrates (e.g. bandicoots, rats, birds, reptiles, frogs), bird eggs, nectar from native flowers, as well as found to scavenge on road-kills and in rubbish bins.

Northern Quolls have short lifespans (Commonwealth of Australia 2016); usually one year although most females survive two breeding seasons (Oakwood 2008; Commonwealth of Australia 2016). What contributes to this short lifespan is that males undergo an intense physical effort in roving during the annual breeding in June to September, leading to physiological decline and near-complete annual male die-off (Commonwealth of Australia 2016). Females can produce on average seven young, and then typically wean 2-3 young each year by 6 months old, which are then reproductively mature by 11 months old (Oakwood 2008; Commonwealth of Australia 2016).

The most common direct causes of death in Northern Quolls are predation by dingoes, feral Cats, snakes, owls, and kites, as well as domestic dogs, pesticide poisoning, Cane Toads and vehicle strike (Oakwood 2008).

2.3 Threats to Northern Quoll

Threats to Northern Quolls include predation by feral Cats, reduction of ground cover (shelter) through extensive hot fires and grazing, being poisoned by Cane Toads, and loss of habitat from agriculture, mining and urban development (Threatened Species Scientific Committee 2005). Although populations of Northern Quoll in the Pilbara are not currently threatened by Cane Toads, it is predicted that Cane Toads will invade this area between 2026-2064 (Dunlop *et al.* 2019 and references therein), so this will be a threatening process in the future. Mining infrastructure, such as the proposed AIP haul road, can also threaten Northern Quoll populations. This may be via vehicle strike, creating a barrier that may fragment existing populations and making them more susceptible to extinction, and reducing the amount and quality of available habitat through road construction and clearing (Rytwinski and Fahrig 2015).

Research into the impacts of disturbances from industry and development is one of the current priorities for the Department of Biodiversity, Conservation and Attractions (DBCA), after key directions for research were determined in 2013 (Cramer *et al.* 2016). The most recent progress report (2018) from the Pilbara Northern Quoll Research Program recognises that the impact of habitat fragmentation from linear infrastructure on distribution and population densities of Northern Quoll is not well understood, and represents an important knowledge gap (Dunlop *et al.* 2019).

3 Effects of roads/linear infrastructure on terrestrial fauna

One of the main concerns with the construction of a large road, such as the one proposed in the AIP, is that the road will lead to fragmentation of fauna populations and fauna habitat. The effect of fragmentation on wildlife has been well researched, and the main concerns are an increase in the risk of roadkill as fauna move between fragments (Dufty 1989, Jones 2000, Klocker *et al*. 2005, Shepherd and Bamford 2019), or that the fragments of habitat are not able to support viable populations (How and Shine 1999, How and Dell 2000, Dell and Banyard 2000, Bamford 2008, Bamford and Calver 2012, Shepherd and Bamford 2019). It is often larger fauna that are recorded as being at risk of fragmentation (Bamford and Calver 2012), however this can also depend on density and reproductive strategy.

Roads and traffic can affect fauna populations by directly causing mortality of individuals (due to vehicle strike), creating a barrier that divides populations into smaller populations that are more susceptible to extinction, and decreasing the overall amount and quality of available habitat (as some of it is replaced by the road and associated land clearing) (Rytwinski and Fahrig 2015). Importantly, when considering conservation of a particular species, how a road impacts the viability of the population as a whole is more important than impacts on single individuals (Rytwinski and Fahrig 2015). The combined effects of the main impacts of roads discussed above (mortality, habitat fragmentation, habitat loss) depends on the behavioural traits and ecological traits of the species in question. For example, species that avoid open areas (a behavioural trait) would avoid a road and therefore be less impacted by direct mortality due to vehicle strike. However, this same species would be more heavily impacted in terms of habitat loss and fragmentation of the population, as they would be much less likely to approach and/or cross a road or railway. In this case, the linear structure would effectively reduce the amount of habitat available as well as splitting a population into smaller sub-populations. A species that was willing to approach and cross the road would not be as affected in terms of habitat loss and fragmentation, assuming the loss of individuals due to direct mortality from vehicle strike was not excessively high (the threshold for this would depend on the reproductive rate and population size of the species in question).

Behavioural traits that are considered important in predicting how a road will affect a species are as follows (from Rytwinski and Fahrig 2015):

- Species that are attracted to roads (e.g. for roadkill, or to bask on warm ground) will be more likely to suffer direct mortality due to vehicle strike;
- Species that avoid the road surface and disturbances due to light/noise/chemicals will be less likely to suffer direct mortality, but more likely to suffer from the loss of habitat and the fragmentation of the population; and
- Species that can move out of the way of oncoming traffic will be less likely to suffer direct mortality than those that are less behaviourally responsive or less physically capable of manoeuvring out of the way (e.g. slow moving reptiles).

Ecological traits are characteristics of the species that determine the sort of habitat and resources that are required to support a population. Ecological traits that are important when considering how roads affect a species are as follows (from Rytwinski and Fahrig 2015):

- Species with a low reproductive rate and a long generation time are likely to be negatively affected by roads;
- Species that exist at low densities will be more vulnerable to the impacts of roads (as even a low rate of mortality will have a high proportional impact on the local population);
- Species that have a large home range (large area requirement) will be more vulnerable to the impacts of roads (many individuals will encounter roads); and
- Species that are very mobile (move around a lot) are more likely to encounter roads and therefore be impacted by road mortality.

3.1 Likely effects of road infrastructure on Northern Quoll

There is little literature and data on the impacts of roads on Northern Quolls in the Pilbara (or elsewhere in the species' range). However, the behavioural and ecological traits of the Northern Quoll can be compared with the characteristics that make species more or less vulnerable to impacts from roads (listed above).

With respect to behavioural traits, Northern Quolls are adaptable and accept novel environments, so they are unlikely to avoid the road. They may even be attracted to roads in search of food. There are many anecdotal reports of the species visiting mine camps and out-buildings in search of food, and they are recorded as roadkill. Ecoscape (2019) found that Northern Quoll readily crossed a rail line and used preferred habitat close to the rail alignment. In Tasmania, Jones (2000) found that Eastern Quolls (*Dasyurus viverrinus*) used roads for long-distance travel and appeared not to be disturbed by the open road and cars approaching. The Northern Quoll is a fast-moving and agile animal, so it may be able to take some evasive action on roads, but the records of roadkill indicate that individuals are at least occasionally vulnerable to being struck by vehicles.

With respect to ecological traits, the species has some characteristics that reduce its vulnerability not to roadkill *per se*, but to population impacts from roadkill. For example, it is short-lived and with a fairly high reproductive rate, and it also occurs at moderately high densities. Populations will therefore be tolerant of some level of mortality (as discussed by Rytwinski and Fahrig 2015). However, individuals have moderately large home ranges (35 to >100ha), so many animals will be likely to encounter roads and thus be exposed to risk of roadkill.

Based on behavioural and ecological traits, it would appear that Northern Quoll populations would be at a low to moderate risk from roads and other linear infrastructure; they do not avoid and will cross such structures, and their populations can be expected to have some tolerance of mortality from roadkill. Moore *et al*. (2022a), however, found that construction of mining infrastructure, such as roads and rail lines, can compound already fragmented habitat (isolated rocky habitats), adding to the increased levels of predation in these fragmented landscapes. This suggests that at least in some situations, perhaps when preferred denning habitat (rocky areas/mesas) are widely scattered, roads and other liner infrastructure my contribute sufficiently to landscape fragmentation that there is a detrimental impact on Northern Quoll occurrence and abundance.

3.2 Mitigation of effects of road infrastructure on Northern Quoll

The Northern Quoll has some vulnerability to the effects of road infrastructure, with the study by Moore *et al.* (2022a) suggesting that roadkill can adversely affect populations in at least some circumstances. The EPBC Act referral guideline for the endangered Northern Quoll (Commonwealth of Australia 2016) recognises that some risk from road and other linear infrastructure exits, and lists measures that could be taken to reduce this risk.

Mitigation measures with respect to roads include:

- Design or relocate the road to avoid and protect habitat critical to the survival of the species
- Avoid activities such as heavy machinery operation during the breeding season
- Control and manage traffic levels to minimise habitat fragmentation and road kills
- Consider a 'no driving at night' policy
- Control/management of traffic during the breeding season
- Reduce and enforce speed limits in the vicinity of Northern Quoll habitat
- Educate mine site personnel about Northern Quoll ecology on site
- Report and record road kills
- Fence underpasses where appropriate to funnel movement to safer areas

Many of these mitigation measures are not possible for the AIP Haul Road, as the haul road will be used 24 hours a day with a high frequency of trucks (ca. one truck every six minutes), and while the alignment has been adjusted slightly to avoid directly impacting favoured denning habitat, it does pass through areas of such habitat. There will undoubtedly be movements of Northern Quoll across the haul road, with the greatest numbers of animals and frequency of movements close to favoured denning habitat. Roadkill is inevitable, and the primary means to reduce the level of roadkill is through the installation of fauna crossing structures, such as fenced underpasses, to allow easier movement of Northern Quolls across the haul road. This is discussed in more detail in Section 4 (below).

4 Fauna crossing structures

The main aim of fauna underpasses is to allow native animals to move between habitats that have been fragmented due to separation by linear development, such as the construction of a road or railway (Main Roads WA 2010). The benefits of constructing fauna underpasses include (Shepherd and Bamford 2019):

- Reducing road-kill by providing a safe alternate crossing;
- Providing resilience to fauna by maintaining population size in land parcels against future environmental events and changes (e.g. fire, increase in predators, pests, disease);
- Maintain genetic mixing between fragmented populations; and
- Maintain natural behaviour of fauna (e.g. dispersal of young, mating behaviour and dispersal, and localised migration).

The use of fauna underpasses to mitigate the effect of habitat fragmentation by linear construction of a road can also have negative outcomes. Habitat fragmentation can lead to an increase in numbers of feral predators such as feral Cats and Foxes, who have been shown to also use fauna underpasses and prey on native fauna using the underpasses (Main Roads WA 2010, Shepherd and Bamford 2019).

4.1 Different types of fauna crossing structures

Shepherd and Bamford (2019) present a comprehensive description of the different types of connecting structures that can be used by fauna to overcome fragmentation by construction of roads, railways, etc. These include:

- Corrugated steel pipes
- Concrete pipes
- Box culverts
- Buried Arch Tunnels
- Vegetated Underpass Bridges
- Rope Bridges
- Vegetated overpass bridges

Underpasses have been used for many years in Europe and North America, mainly to help avoid collisions between vehicles and large wildlife species that can be harmful to both the animals and humans (Goosem *et al*. 2001). The use of underpasses can help threatened fauna species, especially when combined with road-side exclusion fencing and are of sufficient dimensions to enable animals to see habitat on the other side of the underpass (Goosem *et al*. 2001). Underpasses for fauna are often constructed in areas where there is high road mortality or environmental impact assessment has identified existing fauna paths that will be impacted (Goosem *et al*. 2001; Groot Bruinderink and Hazebroek 1996).

Australian and overseas research suggest that larger species prefer underpasses with larger dimensions and more open structures (see studies quoted in Goosem *et al*. 2001). There does appear to be a general preference by fauna for underpasses that are open structures, short and/or provide clear lines of sight to native vegetation from entrance to exit (Australian Museum Business Services

2001a, b, c, d). There are also, however, examples of fauna using narrow and long underpasses, with usage possibly increasing with time an underpass has been in place (Chacelle *et al.* undated).

4.2 Alternatives to fauna crossing structures

To date there is little evidence to support the benefit of alternatives to fauna crossing structures for native species in general, and even more so for the Northern Quoll. Alternatives can include:

- Virtual fences (Englefield *et al*. 2019; Fox *et al*. 2019);
- Noise generators to frighten animals away from a certain area (e.g., an airport runway);
- Devices that can be attached to vehicles that make an irritating whistling noise to deter animals from coming closer to the vehicle/road (commercially available but apparently not tested for effectiveness);
- Placement of road posts at regular intervals with wildlife reflectors which work by deflecting light from vehicle headlights into the surrounding bush, creating an 'optical fence' (e.g. Jones 2000); and
- Providing structures to encourage escape off the road where there are deep gutters and steep embankments – for example ramps off the road with sections of drainage pipes nearby for animals to use to run off the road and use the pipe for shelter (Jones 2000).

5 Use of underpasses by Northern Quoll

There is little research on the use of underpasses by Northern Quolls. In fact, there have been only six studies that have investigated the effect that mining/resource development has had on Northern Quolls in the Pilbara (Moore *et al*. 2022b), despite there being a great overlap between Northern Quoll habitat and mining activity in the region). Only two studies from the Pilbara investigated the impact on Northern Quolls from mining-related habitat clearing, which found that this species persisted at two rocky sites that were close to a mining rail line (Dunlop *et al*. 2015; Henderson 2015). Other potential threats in the Pilbara region include the risk of death from collision with a vehicle (Oakwood 1997; Moore *et al*. 2022b).

One study that did look at the use of underpasses by Northern Quoll is Ecoscape (2019) for Roy Hill. This study monitored the use of fauna-friendly culverts installed under the Roy Hill railway (344 km) that links Roy Hill mine (approximately 115 km north of Newman) to Port Hedland. The monitoring program used wildlife cameras which were placed in culverts and in nearby habitat, and were operated for two periods during the year (May-July and October-December) to record the presence of fauna, including Northern Quolls, and their use of the culverts to cross the rail corridor (Ecoscape 2019).

Ecoscape (2019) confirms that Northern Quoll will use culverts to cross underneath a railway line, and that there was no evidence that the railway line was a barrier to dispersal of fauna in general over the 4-year monitoring period. It is not possible to determine whether or not the rail acted as a barrier for Northern Quoll specifically as there were not enough data on Northern Quoll (and therefore other more common species were used as a proxy for determining the effect of the railway line and culverts on fauna in general).

Northern Quoll were most often detected near culverts of size class 3 – diameter of 1500-2300 mm. However, there was insufficient data (only eight records; many more records of Feral Cat) to determine if Northern Quolls (as well as Greater Bilby and Brush-tailed Mulgara) actually used culverts regularly, or to demonstrate any preference for culverts of a certain size (Ecoscape 2019). Northern Quoll used culverts near granite habitats more than drainage or sandplain habitats; however, this was attributed to monitored culverts near granite habitat being located near known population of Northern Quoll. In addition, there are not much data specific to Northern Quoll which makes it difficult to make any conclusive assessment of preference.

Formal statistical analysis of whether culvert size or habitat type influence use of culverts by Northern Quoll was not possible (due to the majority of Northern Quoll events being detected at one location and only one detection occurring inside a culvert). Therefore, what can be concluded is that Northern Quoll have been observed using culverts to cross a railway line, but it is not well understood whether habitat characteristics or culvert size influence the amount of use by Northern Quolls.

5.1 Studies on similar species use of underpasses

Monitoring of underpasses constructed under the Pacific Highway in a range of habitats in New South Wales found that a variety of mammals from small rodents, small marsupials (*Antechinus* spp.) and bandicoots to large wallabies all commonly used underpasses (Australian Museum Business Services 2001a, b, c, d). Less frequent users of underpasses included possums, Koala, Echidna, birds, lizards, frogs and feral species including Red Fox, Cat, Dog, House Mouse and Cane Toad. Many of these same species, as well as Eastern Pygmy-possum (*Cercartetus nanus*), Wombat (*Vombatus ursinus*) and Tiger Quoll (*Dasyurus maculatus*) were recorded using three underpasses on the freeway between Sydney and Newcastle (Australian Museum Business Services 1997). Goosem *et al*. (2001) suggests that underpass use by native species in both of these studies appeared to relate to proximity of native vegetation to the entrance of the underpass, as well as underpass dimensions, location and adjoining habitat. Chambers and Bencini (2014) found that the frequency that Quenda and Western Bobtail lizards used underpasses in Perth was related to the length of the underpass – the shorter the underpass, the more it was used. In contrast, Bond and Jones (2008) found that even small-medium native species (e.g. rodents, possums, bandicoots) did not seem deterred by the 48 m long (2.4 m high, 2.5 m wide) underpass under a Brisbane major road. Hayes and Goldingay (2009) also found high levels of use by bandicoots, rodents and macropods for two underpasses under the Pacific Highway in NSW (3 x 3 m reinforced concrete box culverts, 42.3 m and 62.5 m long).

Some studies (see studies listed in Bond and Jones 2008) have found that many species take a long time to feel comfortable about using a road underpass, and may take months or years for regular use. However, Bond and Jones (2008) found that fauna species such as rodents, possums, bandicoots were regularly using underpasses from 6 months post-construction, and continued throughout the 2-year study.

Overall, studies on other species indicate that underpasses are widely-used by species broadly similar in size to the Northern Quoll, with use favoured by large internal dimensions, presence of nearby habitat, short (as opposed to long) length, and period of time that an underpass has been in place.

There is likely to be interaction between these factors. For example, a short, narrow underpass may be as well-used as a wide, long underpass.

Some studies have raised the concern that wildlife underpasses funnel species into a 'trap' and expose them to increased levels of predation. This is discussed by Little *et al.* (2002) who concluded: "*We review the literature and conclude that evidence for the existence of prey-traps is scant, largely anecdotal and tends to indicate infrequent opportunism rather than the establishment of patterns of recurring predation. Most passage studies record no evidence of predation in or around passages. Conversely, there is some evidence that predator species use different passages than their prey*." Despite this, Harris *et al.* (2010) recorded the severe decline of Quenda (*Isoodon (obesulus) fusciventer*) due to predation by Red Foxes at underpasses. The provision of shelter at the entrance to and within underpasses is widely recommended to encourage use of underpasses and to provide protection for fauna. Fencing to guide fauna to underpasses is also often recommended (Main Roads WA 2010).

6 Conclusions and Recommendations

Interpretation of the literature and the biological characteristics of the Northern Quoll suggest that it is a species that may be at some population risk from roadkill along roads, but it is not a species that is highly vulnerable (at the population level) to roadkill. The AIP haul road does pose a risk of roadkill, and purely on a precautionary basis, minimising roadkill where the risk is greatest is recommended. This is where the road passes between favoured rocky outcrop/mesa habitat, as that is where the road will intersect the highest number of home ranges, and where dispersing animals will regularly cross the road. However, it should be noted that this is an assumption. It is not known if it is possible to investigate the level of Northern Quoll activity in these areas to determine if there is indeed the sort of movement that would warrant concern. This would require deployment of large numbers of motion-sensitive cameras and would be especially effective if there is an existing track close to the proposed alignment.

Assuming that no change to the speed and frequency of trucks is possible, the primary option for the reduction of roadkill is to install underpasses (some secondary options are discussed below). Northern Quolls will use underpasses, but a number of factors need to be considered to make them as effective as possible.

Location. They should be placed where they are most likely to be used. Northern Quoll are likely to cross the road anywhere, but the greatest numbers will be where denning habitat is nearby. These locations have already been broadly identified as where the haul road passes between rocky hills and mesas (see Figure 3). They may also follow drainage lines, and the use of drainage lines means that culverts installed for drainage will also be used by Northern Quoll. Installation of underpasses and the availability of drainage culverts will not eliminate mortality; the intent is only to reduce it to a level that is sustainable for the population.

Dimensions. Underpasses work best for fauna if the underpass is large and short. There will clearly be other factors (i.e road design) that will determine underpass dimensions. While underpasses should be as wide and short as possible, studies have demonstrated that narrow and long underpasses will be used by fauna similar in size to the Northern Quoll. The culverts that appeared to be used by Northern Quoll in the Ecoscape (2019) study had a diameter of 1.5 to 2.3m. Culverts as narrow as

1.2m wide and 0.6m high were used by bandicoots (Chambers and Bencini 2015). This is to say that even if engineering limitations exist, even a narrow underpass is likely to be of some value.

Fencing. This is recommended to guide animals towards an underpass. While Northern Quolls are very agile, even a low fence (0.5m fine mesh) is likely to guide them, and it will also be useful for many other fauna species (large lizards, Echidna, rock-wallabies) that will use underpasses. Rocky hills and mesas close to the road are quite discrete, and the fence should extend as far as the denning habitat extends close to the road. This is likely to be around 50m. Drainage culverts should also be fenced.

Furniture. The term furniture is used to describe materials (logs, rocks, branches) placed at the entrance to and inside underpasses to provide cover for fauna. The use of furniture in drainage culverts may interfere with their primary function (drainage) but may also be possible, at least to the side.

Bamford Consulting Ecologists, in consultation with MinRes has identified the following potential locations for fauna (Northern Quoll) underpasses (**Figure 3**). The proposed locations presented in **Figure 3** show the following propose underpass location and size:

- Proposed Eastern Fauna Underpass: located within 1 km of Mesas and breakaway habitat (confirmed Norther Quoll Habitat). Underpass consists of a 600 mm corrugated steel culvert, with appropriate fencing either side of entrance and exist and appropriate furnishing. At this location the underpass has a dual purpose as both a culvert and fauna underpass.
- Indicative Western Underpass: located within 1 km of Mesas and breakaway habitat (confirmed Norther Quoll Habitat). Underpass consists of a 300 mm corrugated steel culvert, with appropriate fencing either side of entrance and exist and appropriate furnishing. At this location, the underpass has been specifically installed as a fauna underpass only.
- Proposed Western Fauna Underpass: located within 3 km of Mesas and breakaway habitat (confirmed Norther Quoll Habitat). Underpass consists of a 600 mm corrugated steel culvert, with appropriate fencing either side of entrance and exist and appropriate furnishing. At this location the underpass has a dual purpose as both a culvert and fauna underpass.

As noted above, some secondary options may be able to reduce the risk of roadkill. For example, Northern Quoll are likely to be attracted to the haul road to forage on roadkill and food waste. Roadkill (including dead Northern Quoll) should be promptly removed, and personnel using the road should be strongly advised not to throw out waste of any sort. Lighting will also attract insects and subsequently Northern Quoll, but lighting along the haul road is unlikely. The retention of cover as close as possible to the road may also be beneficial, as it means that Northern Quoll on the road have the shortest distance possible to traverse.

In addition, a register of Northern Quoll roadkills should be kept. For example, if this occurs close to an underpass or drainage culvert, it may be possible to install additional fencing to guide animals to a safe crossing.

Ongoing monitoring is strongly recommended. This can be done readily with motion-sensitive cameras to look at use of underpasses, use of drainage culverts and movements of Northern Quoll (and other fauna) along the road more generally. Monitoring will also detect issues with feral predators if this occurs. Ongoing visual monitoring of fauna underpasses is also proposed to be undertaken post significant rainfall / flow events, to ensure no blockages or other factors that may deter the Northern Quoll from using the fauna underpasses or prevent access.

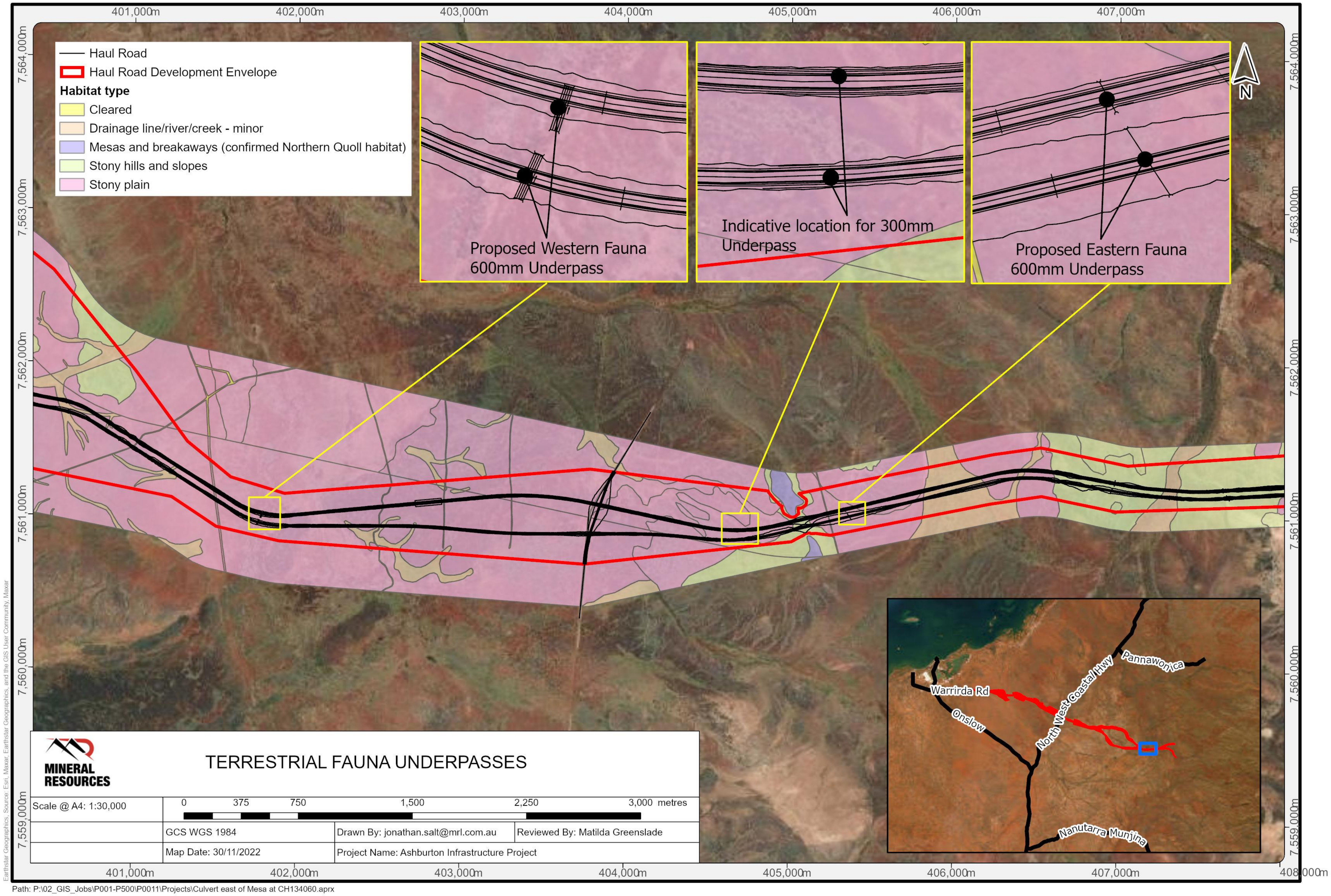

Figure 3: Map of proposed Northern Quoll, fauna underpasses in relation to the Haul Road Development Envelope (DE) and Indicative Footprint (IF).

There is some uncertainty about the need for and likely effectiveness of underpasses, and about long-term impacts of development projects in general once they are approved. In addition, it does need to be stated that the suggestion that the AIP haul road poses a population risk to Northern Quoll due to roadkill, and that underpasses provide an effective solution to this risk, is speculative. As noted above, more information on the level of Northern Quoll activity between the rocky hills and mesas would be useful in assessing the risk. Northern Quoll might not use the underpasses often enough for any real benefit, and there may be an increased impact due to feral predators. A further consideration is that the cost of underpass installation and maintenance may draw funds away from other conservation actions, such as landscape scale fire management and feral species control.

7 References

360 Environmental. (2021). Ashburton Infrastructure Project Vertebrate Fauna and Short-Range Endemic Invertebrate Fauna Assessment. Unpublished report prepared for Mineral Resources Limited by 360 Environmental Pty Ltd.

Australian Museum Business Services (2001a) Fauna Underpass Monitoring: Stage One — Final Report — Brunswick Heads. Report to New South Wales Roads and Traffic Authority. 38 pp. Australian Museum Business Services, Sydney.

Australian Museum Business Services (2001b) Fauna Underpass Monitoring: Stage One — Final Report — Herons Creek. Report to New South Wales Roads and Traffic Authority. 15 pp. Australian Museum Business Services, Sydney.

Australian Museum Business Services (2001c) Fauna Underpass Monitoring: Stage One — Final Report — Bulahdelah to Coolongolook. Report to New South Wales Roads and Traffic Authority. 47 pp. Australian Museum Business Services, Sydney.

Australian Museum Business Services (2001d) Fauna Underpass Monitoring: Stage One — Final Report — Taree. Report to New South Wales Roads and Traffic Authority. 25 pp. Australian Museum Business Services, Sydney.

Bamford, M.J. (2008). Local Extinction of Fairy-wrens due to Cat Predation? Amytornis 1(1): 25-26.

Bamford, M.J. and Calver, M.C. (2012). Cat predation and suburban lizards; a 22 year study at a suburban Australian property. The Open Conservation Biology Journal 6: 1-11.

Biota Environmental Services (2008). Hope Downs Northern Quoll Position Paper. Prepared for Rio Tinto Iron Ore on behalf of Hammersley HMS.

Bond, A. R. and Jones, D. N. (2008). Temporal trends in use of fauna-friendly underpasses and overpasses. *Wildlife Research*, **35**: 103-112.

Chacelle, P.D., Chambers, B.K., Bencini, R. and Maloney, S.K. (undated). Home range and use of underpasses by Western Grey Kangaroos on the Swan Coastal Plain. Unpubl. report by the Faculty of Natural and Agricultural Sciences, University of Western Australia.

Commonwealth of Australia. 2016. EPBC Act referral guideline for the endangered northern quoll. Accessed online: https://www.awe.gov.au/sites/default/files/documents/referral-guideline-northern-quoll.pdf

Chambers, B. and Bencini, R. (2015) Factors affecting the use of fauna underpasses by bandicoots and bobtail lizards. *Animal Conservation* **18**: 424-432.

Cramer, V.A., Dunlop, J., Davis, R., Ellis, R., Barnett, B., Cook, A., Morris, K. and van Leeuwen, S. 2016. Research priorities for the northern quoll (*Dasyurus hallucatus*) in the Pilbara region of Western Australia, *Australian Mammalogy,* 38, p 135-148.

Dell, J. and Banyard, J. (eds). (2000). Bush Forever. Vol. 2. Dept of Environmental Protection, Perth.

Dufty, A.C. (1989). Some Population characteristics of *Perameles gunnii* in Victoria. Wildlife Research: **18** (3) 355 - 365

Dunlop, J., Birch, N. and Moore, H. (2018) Pilbara Northern Quoll Research Program 2018. Annual Report. Perth, Australia. Available at: https://library.dbca.wa.gov.au/#record/150321

Ecoscape (2019). Rail Culvert Fauna Monitoring 2018, Roy Hill. Unpublished report for Roy Hill.

Englefield, B., Candy, S. G., Starling, M., McGreevy, P. D. (2019) A Trial of a Solar-Powered, Cooperative Sensor/Actuator, Opto-Acoustical, Virtual Road-Fence to Mitigate Roadkill in Tasmania, Australia. *Animals* 9: 752; doi:10.3390/ani9100752

Fox, J. M., Potts, C., Pemberton, D., and Crosswell, D. (2019) Roadkill mitigation: trialing virtual fence devices on the west coast of Tasmania. Australian Mammalogy, 41: 205–211 https://doi.org/10.1071/AM18012

Goosem, M., Izumi, Y. and Turton, S. (2001) Efforts to restore habitat connectivity for an upland tropical rainforest fauna: A trial of underpasses below roads. Ecological Management and Restoration, 2 (3): 196-202.

Groot Bruinderink G. W. T. A. and Hazebroek E. (1996) Ungulate traffic collisions in Europe. *Conservation Biology*, 10: 1059–1067.

Harris, I.M., Mills, H.R. and Bencini, R. (2010). Multiple individual Southern Brown Bandicoots (*Isoodon obesulus*) and Foxes (*Vulpes vulpes*) use underpasses installed at a new highway in Perth Western Australia. Wildlife Research 37: 127-133.

Hayes, I. F., and Goldingay, R. L. (2009). Use of fauna road-crossing structures in north-eastern New South Wales. *Australian Mammalogy*, **31**: 89-95.

Hernandez-Santin, L., Henderson, M., Molloy, S.W., Dunlop, J.A. and Davis, R.A. 2021. Spatial ecology of an endangered carnivore, the Pilbara northern quoll, *Australian Mammalogy*, 43, 235-242.

How, R.A. and Dell, J. (2000). Ground vertebrate fauna of Perth's vegetation remnants: impact of 170 years of urbanisation. Pacific Conservation Biology 6: 198-217.

How, R.A. and Shine, R. (1999). Ecological traits and conservation biology of five fossorial "sandswimming" snake species (Simoselaps: Elapidae) in south-western Australia. Journal of Zoology, London. 249: 269-282

Jones, M. E. (2000). Road upgrade, road mortality and remedial measures: impacts on a population of eastern quolls and Tasmanian devil. *Wildlife Research*, 2000, 27:289–296.

Klocker, U., Croft, D.B., and Ramp, D. (2005). Frequency and causes of kangaroo – vehicle collisions on an Australian outback highway. Wildlife Research. 33 (1): 5 – 15.

Little, S. J., Harcourt, R. G., Clevenger, A. P (2002). Do wildlife passages act as prey-traps? Biological Conservation 107 (2): 135-145).

Main Roads WA (2010) Design of Fauna Underpasses Guideline. Available from:

https://www.mainroads.wa.gov.au/technical-commercial/technical-library/road-traffic-engineering/roadside-items/design-of-fauna-underpasses/

Mineral Resources Limited (MRL) (2021). Ashburton Infrastructure Project, EPBC Referral Terrestrial Supporting Document. Available from:

http://epbcnotices.environment.gov.au/_entity/annotation/150f38a9-922f-ec11-80d0-00505684c563/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1635724800329

Moore, H. A., Michael, D. R., Dunlop, J. A., Valentine, L. E., Cowan, M. A., Nimmo, D. G. (2022a). Habitat amount is less important than habitat configuration for a threatened marsupial predator in naturally fragmented landscapes. *Landscape Ecology*, **37**: 935-949.

Moore, H. A., Dunlop, J. A., Jolly, C. J., Kelly, E., Woinarski, J. C. Z., Ritchie, E. G., Burnett, S., van Leeuwen, S., Valentine, L. E., Cowan, M. A. and Nimmo, D. G. (2022b) A brief history of the northern quoll (*Dasyurus hallucatus*): a systematic review. *Australian Mammalogy*, **44**: 185-207.

Oakwood, M. (1997). The ecology of the northern quoll, Dasyurus hallucatus. PhD thesis thesis. Australian National University, Canberra.

Oakwood, M. (2008). Northern quoll *Dasyurus hallucatus*. **In:** Van Dyck, S. & R. Strahan, eds. *The Mammals of Australia (3rd ed)*. Page(s) 57-59. Sydney, NSW: Reed New Holland.

Rytwinski, T. and Fahrig, L. 2015. The impacts of roads and traffic on terrestrial animal populations. Chapter 28, in Handbook of Road Ecology.

Shepherd, B. and Bamford, M. (2019). Yanchep Rail Extension Part 2: Fauna Underpass Assessment Statement. Unpublished report for the Public Transport Authority. Available from:

https://www.epa.wa.gov.au/sites/default/files/PER_documentation2/AppG_Yanchep%20Rail%20Extension%20Part%202%20Fauna%20Underpass%20Statement.pdf

Threatened Species Scientific Committee (2005). *Commonwealth Listing Advice on Northern Quoll (Dasyurus hallucatus)*. Available from: http://www.environment.gov.au/biodiversity/threatened/species/dasyurus-hallucatus.html.

van Vreeswyk, A.M.E., A.L. Payne, K.A. Leighton & P. Hennig (2004). An inventory and condition survey of the Pilbara region, Western Australia. Department of Agriculture Technical Bulletin No. 92.