To: Vladimir Rios Vera
Fortescue
87 Adelaide Terrace
East Perth WA 6004

From: Stuart Halse
Bennelongia
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Memo No. 677

The Environmental Protection Authority (EPA), through EPA Services, has requested further information regarding troglofauna habitat in relation to an s38 application for the North Star Mine Extension.

The background to the EPA request is the review comment that:
"*There is uncertainty regarding whether habitat modelling has accurately predicted and identified suitable troglofauna habitat. Appendix 50 (p. 40 and Figure 18) indicates that potentially suitable troglofauna habitat extends along strike that hosts the orebody and through low lying areas to the east and west. However, Section 5.1 in Appendix 5 of Appendix 50 states that "all sampled drill holes intersect possible troglofauna habitat, but only select holes yielded troglofauna. There may be additional factors controlling troglofauna habitat that cannot be determined from the available data*."'

Consequently, EPA Services advice was:
'The ecological and physical characteristic requirements of troglofaunal species are unknown, and other lines of evidence should be used to corroborate the conclusion on page 40, Appendix 50.'
Action

> *f) Revise the ERD to include discussion on the uncertainty related to troglofauna habitat modelling and provide additional evidence to corroborate the conclusion on page 40, Appendix 50, e. g. distributions of closely related species if possible.*

Appendix 50 is the 2023 report by Bennelongia entitled 'North Star subterranean fauna desktop and survey report'. It includes the AQ2 (2022) habitat modelling report as Appendix 5.

Troglofauna habitat
Weathering and mineralization lead to the formation of a variety of different sized spaces or voids in subterranean rock. These voids provide habitat for troglofauna in areas above the water table. The factors controlling the density of troglofaunal animals in an area such as the North Star Mine have not been studied but can be reasonably inferred from studies of troglofauna in caves. First, there is a requirement for subterranean voids with close to 100% relative humidity and an ultimate connection to the ground surface (to allow colonization). Second, it must be possible for some carbon and other nutrients to enter the void network by leaching or some other mechanism. As a first approximation, the abundance of troglofaunal animals per cubic metre of the subterranean matrix or rock and voids is determined by a combination of the proportion of habitat that is near-saturated voids and the amount of carbon available.

Modelling troglofaunal habitat
In Appendix 5, AQ2 (2022) modelled the extent of habitat suitable for troglofauna by assuming troglofauna will occur thoughout the above-water table oxidized zone, which is defined at North Star by

the weathered/transition zone (occurring at depths of up to 60-70 m), and in fractured bedrock.

Uncertainty in habitat modelling

EPA Services perceived uncertainty in habitat modelling on the basis of the AQ2 (2022) comments that "*the distribution of troglofauna intersections from Bennelongia sampling [in relation to modelled habitat] are arbitrary in nature*" and "*all sampled drill holes intersect possible troglofauna habitat, but only select holes yielded troglofauna*".

AQ2's (2022) comment that troglofauna occurrence is arbitrary with respect to modelled habitat was rather casual. It is arbitrary only because the scale at which troglofauna habitat is available and the scale of information supporting the mapping are several orders of magnitude different. Both two main determinants of troglofauna abundance (the proportion of matrix that are voids and the area of downwards movement of carbon and nutrients) show spatial variation. This is clearly shown in stygofauna habitat (Figure 1), where stygofauna are collected abundantly from high conductivity pathways (large interstitial spaces) and rarely from low conductivity areas (infilled or small interstitial spaces). Within the high conductivity areas, there are pathways of preferential flow (Figure 1B). The patterns in Figure 1A are analogous to above water table occurrence of voids and troglofauna (Halse 2018a), with adjacent areas in the same formation containing good or bad habitat for troglofauna according to relatively small geological differences. Within the good areas there are also sites of greater abundance (Figure 1B).

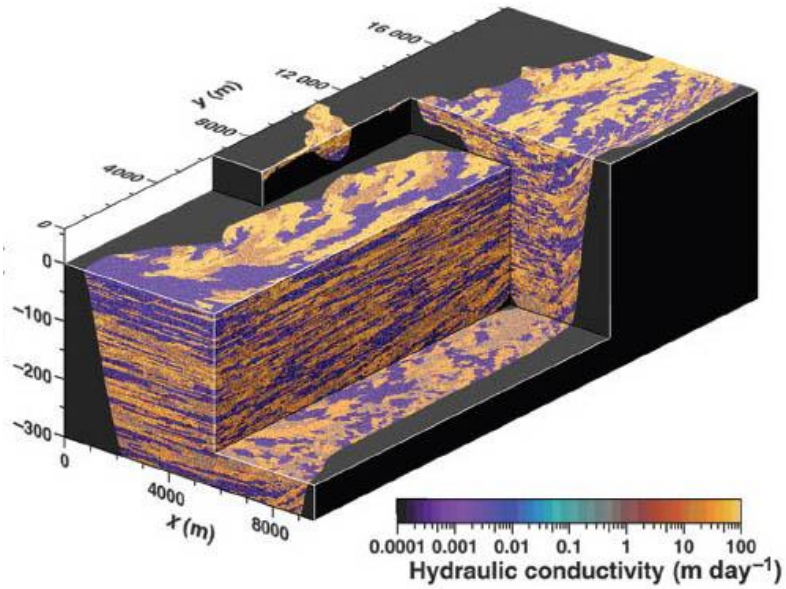

Figure 1A. High-conductivity pathways (orange and yellow shades) used by stygofauna within overall low-conductivity sediment matrix (violet-to-blue shades) that is not used. Taken from Larned (2012).

Figure 1B. Permeable flow path coated with iron in claybound, low permeability gravel (Larned 2012).

As the above paragraph highlights, an area classified as uniformly prospective for troglofauna based on overall analysis of drilling data will almost always contain substantial variability in prospectivity at a fine scale. Troglofauna will not be collected from patches of habitat that lack voids or sufficient carbon but will have at least moderate probability of being collected from those with plentiful voids and adequate carbon. Thus, the pattern of holes yielding troglofauna reflects more information about habitat than was available for modelling.

Do species occur outside impact?

In most cases, if a geology is broadly prospective for troglofauna, then suitable habitat for troglofauna species will be found from one side of the habitat to the other, irrespective of whether some patches within it lack voids. This is because there will usually be snake-like connection of various patches with voids. The two factors more likely to limit a species range than patchiness of habitat are geological/topographical barriers and the biology of the species itself (Halse 2018b). Barriers include geological faults and dolerite dyke that prevent movement between different sections of prospective habitat (Harms *et al*. 2018). Species biology includes breeding patterns, population structure, dispersal capacity and extent of natal philopatry.

When inferring the range of a potentially restricted troglofauna species, the first issue is whether the geology in which it was collected extends outside the impact area (EPA 2021). This was the case for all seven restricted species at North Star.

EPA (2021) states that the habitat-based inferences about the extent of species ranges "may be further informed by the biological and ecological attributes of [the] taxon". The most important attribute is whether species are troglophiles, expected to have a wide distribution; or troglobites, expected to be relatively restricted in distribution. All seven species at North Star are likely to be troglobites. A second attribute is the size of the ranges of related species. This information was used for the seven species at North Star (likely linear ranges from 4-22 km, depending on type of species). Third, information about the distribution of other species collected at the same sites as restricted species may be used to inform the distribution of restricted species, provided the co-occurring species are ecologically similar and are not troglophiles (EPA 2021). Four of the seven restricted species at North Star co-occurred with other troglofauna species but these species were ecologically different. There was no basis for inferring distributions of the restricted North Star species, all of which were collected from single holes, from the patterns of co-occurring species.

A fourth criterion for assessing whether restricted species are likely to occur outside the impact area is the distance of the collection site from boundary of impact. This is not discussed by EPA (2021) but a species found at site A will most likely occur at site B if the geology is the same and distance between A and B is substantially less than half the linear range of related species with similar biology. This criterion was used in the Bennelongia (2023) report. AQ2 (2023) modelled habitat inside and outside the impact area as the same.

North Star species

Four troglofauna species are currently known only from the approved mine pits at the North Star mine. These are the spider *Prethopalus* BAR135' (sometimes referred to as *Prethopalpus* sp. in Bennelongia 2023), palpigrad *Eukoenenia* 'BPAL048', pseudoscorpion *Tyrannochthonius* 'BPA439' and isopod Armadillidae gen. indet. 'BIS438'. These pits are already approved for disturbance and are currently under development.

Three troglofauna species are known only from North Star Mine Extension. These are the isopod Armadillidae gen. indet. 'BIS416', dipluran Japygidae 'BDP187' and the silverfish Atelurinae sp.

The habitat modelling provided in Appendix 5 shows that there is continuous completely weathered (prospective) habitat around the North Star mine pits (Figure 2). Bennelongia (2023) used the fourth criterion discussed above (distance from collecting site to pit boundary) to provide supporting

evidence that all seven restricted species are likely to also occur in un-mined habitat (Table 10). The distance most species were away from undisturbed prospective habitat was only a few per cent of their likely ranges (as represented by the median linear range of the group to which they belong, Halse and Pearson 2014). Even for the isopods, which tend to have very small ranges, the distances represent no more than 10% of the median linear range of an isopod.

Table 1. Calculation of the likelihood the ranges of restricted troglofaunal species at North Star will extend into undisturbed areas. Extension is likely if the percentage of linear range is substantially less than 50%.

Species	Median linear range (km)	Distance to pit boundary (km)	Percentage of linear range
Prethopalpus `BAR135`	3.7[1]	0.2	5%
Eukoenenia `BPAL048`	16.5[2]	0.3	2%
Tyrannochthonius `BPS439`	22[1]	0.12	0.5%
Armadillidae `BIS416`	2.5[1]	0.25	10%
Armadillidae `BIS438`	2.5[1]	0.24	10%
Japygidae `BDP187`	16[1]	0.35	2%
Atelurinae sp.	11[1]	0.24	2%

References

AQ2 (2022) Memo: Iron Bridge subterranean fauna habitat modelling. Job 432. AQ2 Pty Ltd, Perth.

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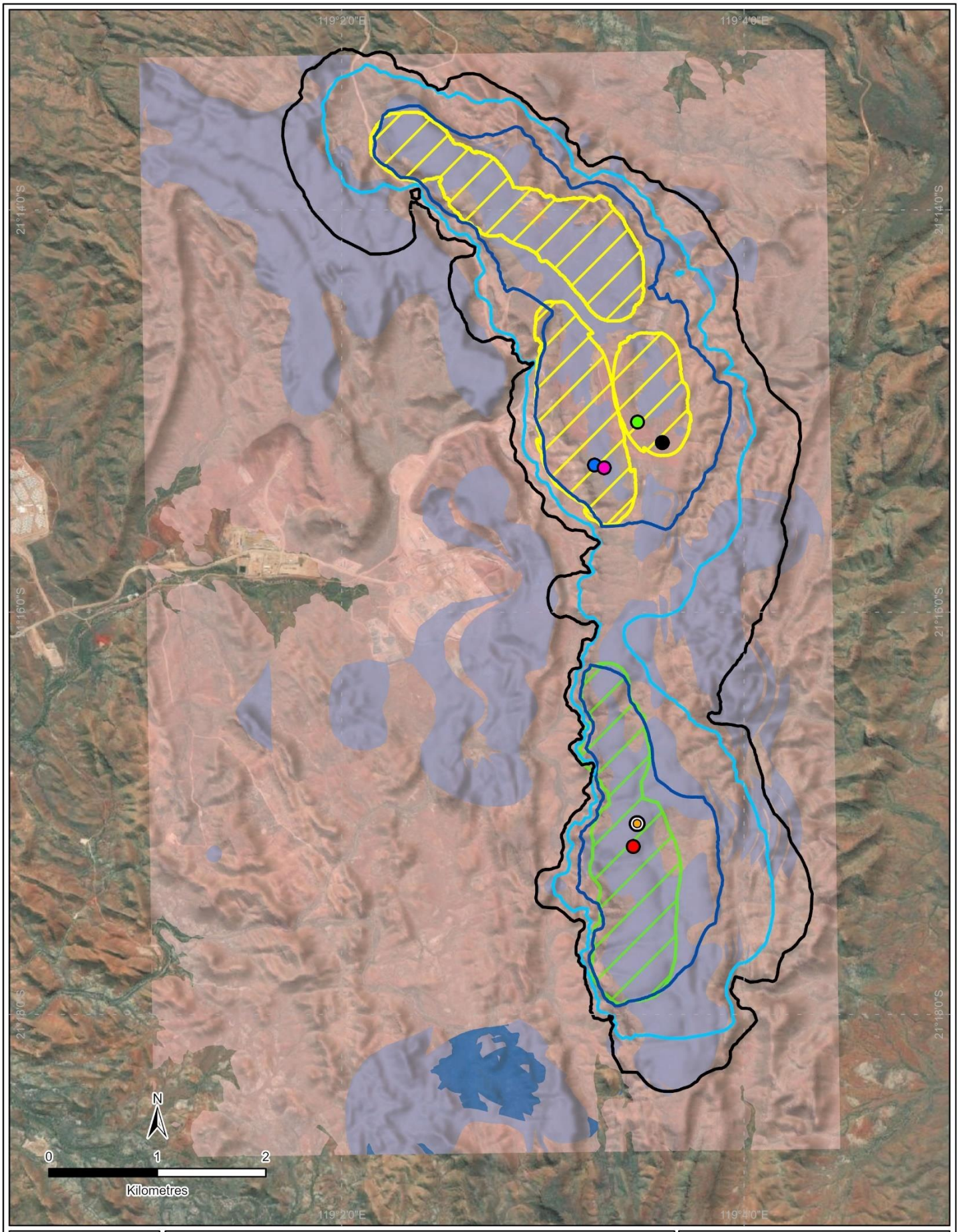

Figure 2. Troglofauna currently known only form impact areas, with associated troglofauna habitat model.

Light blue areas represent completely weathered habiat overleying transtional habitat.