Appendix 9

Conservation Significant Flora Species Recorded within 50 km of the Study Area

Species	Habit	Habitat	Source of Historic Records														Rio Tinto Database Additional Records	Likelihood of Occurrence in the Study Area
			P&W search	Biota (2007a)	Biota (2007b)	Biota (2008)	Biota (2009c)	Biota (2010c)	Biota (2010b)	Biota (2010d)	Biota (2012)	Biota (2013a)	Biota (2013b)	Biota (2013d)	Biota (2013e)	Biota (2013f)		
Threatened Flora																		
Lepidium catapycnon	Low shrub.	Skeletal soils of hill slopes.	✓									✓					✓	Likely to occur; populations known from 14 km northwest and 10 km southeast of the study area, associated with the AHs (Mount McRae Shale and Mount Sylvia Formation) and AHm (Marra Mamba Iron Formation), and also from 12 km southeast in the AFj (Jeerinah Formation) geological unit; not recorded during the field survey, however suitable habitat is present (including hills in geological units AHm and AFj, and some less prospective stony plains in AHs).
Priority 1																		
Bothriochloa decipiens var. *cloncurrensis*	Perennial grass.	Stony clay plains, creeklines.	✓														✓	May potentially occur; one record from 8.5 km southeast, from a creekline that continues through the study area.
Brachyscome sp. Wanna Munna Flats (S. van Leeuwen 4662)	Annual herb.	Open woodland on clay flats.	✓															Unlikely to occur; only one record in the locality, which is over 24 km north; no suitable habitat in the study area.
Calotis squamigera	Annual herb.	Clay, creeklines.															✓	Unlikely to occur; only two records from the locality, the closest of which is 28 km northwest.
Eucalyptus lucens	Mallee.	Mountain tops and rocky slopes at high elevation.	✓															May potentially occur; recorded at elevations between 850 m and 1,100 m from Mt Nameless, 8.9 km southeast of the study area; some suitably tall hills occur in the eastern section of the study area.
Euphorbia inappendiculata var. *queenslandica*	Annual herb.	Clay plains.	✓															Unlikely to occur; only one record from the locality, from 32 km north of the study area; no suitable habitat in the study area.
Helichrysum oligochaetum	Annual herb.	Alluvial plains.	✓															Unlikely to occur; only one record from the locality, from 39 km north of the study area.
Hibiscus sp. Mt Brockman (E. Thoma ET 1354)	Tall shrub.	Steep hill slopes, gullies, rocky areas.	✓									✓						Known to occur; recorded during current and previous field surveys.

Species	Habit	Habitat	Source of Historic Records													Rio Tinto Database Additional Records	Likelihood of Occurrence in the Study Area
			P&W search	Biota (2007a)	Biota (2007b)	Biota (2008)	Biota (2009c)	Biota (2010c)	Biota (2010b)	Biota (2010d)	Biota (2012)	Biota (2013a)	Biota (2013b)	Biota (2013d)	Biota (2013e)	Biota (2013f)		
Josephinia sp. Marandoo (M.E. Trudgen 1554)	Low upright shrub.	On plains in mixed shrubland of Senna and *Acacia.*	✓															Unlikely to occur; only one record from the locality, from 31 km northeast.
Sida sp. Hamersley Range (K. Newbey 10692)	Shrub.	Skeletal stony soils; rocky hills, breakaways.	✓									✓					✓	Likely to occur; frequently recorded in the locality, particularly from high elevations (700 m to 1,050 m); closest known record is 5 km south of the study area; considerable suitable habitat, particularly in the eastern section of the study area.
Teucrium pilbaranum	Low shrub.	Cracking clay plains.									✓							Unlikely to occur; no suitable habitat; only two records from the locality, both over 35 km northeast of the study area.
Potential Priority 1 species																		
Goodenia sp. aff. *pedicellata*	Cryptic herb.	Calcareous soils on stony plains.										✓	✓			✓		Known to occur; recorded during previous field surveys.
Priority 2																		
Euphorbia australis var. *glabra*	Annual herb.	Cracking clay plains.									✓							Unlikely to occur; only two records from the locality, both over 28 km north of the study area; no suitable habitat in the study area.
Indigofera ixocarpa	Shrub.	Skeletal soils over ironstone on hills.	✓					✓									✓	Likely to occur; numerous records in the vicinity of Mt Nameless, the closest of which is 8 km southeast of the study area; most records at elevations between 750 m and 1,050 m; suitable habitat exists in the eastern section of the study area.
Ipomoea racemigera	Annual creeper.	Moderate-sized to major creeklines.												✓			✓	Likely to occur, particularly in the Hardey River system; recorded from several moderate-sized to major creeklines in the locality, both east and west of the study area; closest record is 6.6 km west of the study area in a tributary of the Beasley River.
Pentalepis trichodesmoides subsp. *hispida*	Shrub.	Stony hills.	✓									✓						May potentially occur; records from hills habitat to the west and east, the closest of which is 13 km west of the study area.

Species	Habit	Habitat	Source of Historic Records														Rio Tinto Database Additional Records	Likelihood of Occurrence in the Study Area
			P&W search	Biota (2007a)	Biota (2007b)	Biota (2008)	Biota (2009c)	Biota (2010c)	Biota (2010b)	Biota (2010d)	Biota (2012)	Biota (2013a)	Biota (2013b)	Biota (2013d)	Biota (2013e)	Biota (2013f)		
Scaevola sp. Hamersley Range basalts (S. van Leeuwen 3675)	Low shrub.	Skeletal soils over basalt, often on summits of hills.	✓		✓													May potentially occur; only two records in the locality, both of which are over 15 km east of the study area; these known records are at 800-900 m elevation; there would be suitable habitat in the study area.
Spartothamnella puberula	Low shrub.	Most records from the Pilbara are from gullies.	✓		✓							✓					✓	Likely to occur; some suitable habitat in the study area; records known from 1.8 km east of the study area.
Stylidium weeliwolli	Annual herb.	Sandy clay along major watercourses.			✓													May potentially occur; two records in close proximity in a creekline 14.8 km southeast of the study area.
Vigna sp. central (M.E. Trudgen 1626)	Creeper.	Red-loam on edge of flats and drainages.	✓														✓	Unlikely to occur; only a few records in the locality, all over 23 km north or east of the study area.
Priority 3																		
Astrebla lappacea	Tufted perennial grass.	Clay plains.	✓			✓				✓	✓						✓	Unlikely to occur; no particularly suitable habitat; closest record is 8.9 km northeast of the study area.
Calotis latiuscula	Annual herb.	Rocky hillsides, rocky creeks, riverbeds and floodplains.	✓								✓						✓	Unlikely to occur; only two records in the locality, the closest of which is 24.8 km northeast.
Dampiera anonyma	Low shrub.	Skeletal soil over banded ironstone on hill crests and slopes at high elevation (typically >800 m).	✓									✓					✓	Likely to occur; several records in the locality from areas northwest, west and southeast of the study area; the closest records are 8.8 km southeast of the study area; there is suitable habitat in the eastern section of the study area.
Eremophila magnifica subsp. *velutina*	Shrub.	Skeletal soils over ironstone on summits and breakaways.	✓									✓					✓	Known to occur; recorded during current and previous field surveys.

Species	Habit	Habitat	Source of Historic Records														Rio Tinto Database Additional Records	Likelihood of Occurrence in the Study Area
			P&W search	Biota (2007a)	Biota (2007b)	Biota (2008)	Biota (2009c)	Biota (2010c)	Biota (2010b)	Biota (2010d)	Biota (2012)	Biota (2013a)	Biota (2013b)	Biota (2013d)	Biota (2013e)	Biota (2013f)		
Geijera salicifolia	Tall shrub to low tree.	Skeletal soils on steep scree slopes, rockpiles, gorges.	✓		✓												✓	May potentially occur; records known from approximately 1 km east of the study area (Biota 2007b); some suitable habitat (steep scree slopes), much of which was not traversed during the current field survey (note that a fly-over of the area was conducted as part of Biota 2007b).
Glycine falcata	Perennial herb.	Clay plains.	✓								✓						✓	Unlikely to occur; nearest record is approximately 7 km east, but there is no particularly suitable habitat in the study area.
Goodenia sp. East Pilbara (A.A. Mitchell PRP 727)	Annual to biennial herb.	Low undulating plains, usually calcrete.															✓	Apparently recorded from the study area, however we consider that this taxon is likely to be the same entity as *Goodenia* sp. aff. *pedicellata.*
Grevillea saxicola	Tall shrub to low tree.	Moderate to steep scree slopes, usually with Mulga.										✓					✓	Known to occur; recorded during current and previous field surveys.
Gymnanthera cunninghamii	Tall shrub.	Drainage lines.										✓						Known to occur; recorded during the current field survey.
Indigofera sp. Bungaroo Creek (S. van Leeuwen 4301)	Shrub.	Drainage lines.	✓				✓		✓			✓		✓	✓		✓	Likely to occur, particularly in the Hardey River system; relatively common in the locality; records known from the south, west and north of the study area, the closest of which is 2.6 km south in the Hardey River.
Iotasperma sessilifolium	Annual herb.	Cracking clay plains.	✓								✓							Unlikely to occur; no suitable habitat; the closest record is 19 km north.
Nicotiana umbratica	Annual herb.	Gullies, caves, rocky areas.	✓									✓						May potentially occur; suitable habitat is present, however this species is very infrequently recorded; the closest known record is 9.5 km west of the study area.
Oldenlandia sp. Hamersley Station (A.A. Mitchell PRP 1479)	Annual herb.	Cracking clay plains.	✓				✓				✓						✓	Unlikely to occur; no particularly suitable habitat; scattered records to the west, north and south of the study area, the closest of which is 14.8 km north.

Species	Habit	Habitat	Source of Historic Records													Rio Tinto Database Additional Records	Likelihood of Occurrence in the Study Area
			P&W search	Biota (2007a)	Biota (2007b)	Biota (2008)	Biota (2009c)	Biota (2010c)	Biota (2010b)	Biota (2010d)	Biota (2012)	Biota (2013a)	Biota (2013b)	Biota (2013d)	Biota (2013e)	Biota (2013f)		
Olearia mucronata	Low shrub.	Hills and drainage channels at high elevation (>700 m).	✓														✓	Likely to occur; numerous records from the vicinity of Mt Nameless, the closest of which is 10.3 km southeast; records mainly from 750-950 m elevation; there is suitable habitat in the eastern section of the study area.
Polymeria distigma	Prostrate herb.	Pilbara records are from cracking clay.	✓														✓	Unlikely to occur; very infrequently recorded in the Pilbara; there is no suitable habitat in the study area, and the closest record is 15.3 km north.
Ptilotus subspinescens	Low shrub.	Calcareous silty soils on stony plains.	✓	✓	✓		✓		✓			✓					✓	Known to occur; recorded during current and previous field surveys.
Rhagodia sp. Hamersley (M. Trudgen 17794	Shrub.	Mulga (*A. aneura*) and Snakewood (*A. xiphophylla*) vegetation.	✓						✓	✓							✓	May potentially occur; some suitable habitat, but all records from the locality are north of the study area, the closest being 14.8 km away.
Rostellularia adscendens var. *latifolia*	Herb or low shrub.	Creeks, rocky hills.	✓	✓							✓	✓		✓			✓	Likely to occur; suitable habitat in the study area, and there are records known from all directions surrounding the study area, the closest of which is 1.3 km north.
Sida sp. Barlee Range (S. van Leeuwen 1642)	Low spreading shrub.	Skeletal soils on steep slopes.	✓					✓				✓					✓	Known to occur; recorded during current and previous field surveys.
Solanum kentrocaule	Low shrub.	Tall stony hills.	✓															Known to occur; recorded during the current field survey.
Swainsona thompsoniana	Prostrate annual herb.	Cracking clay plains.	✓								✓						✓	Unlikely to occur; no suitable habitat; closest record is 26 km northeast.
Themeda sp. Hamersley Station (M.E. Trudgen 11431)	Perennial tussock grass.	Usually on clay plains, however there are two records from creeklines east of the study area.	✓							✓	✓						✓	May potentially occur; no clay plains are present (these are the main habitat for this species), however there is a record from a creekline 3.5 km east of the study area.

Species	Habit	Habitat	Source of Historic Records														Rio Tinto Database Additional Records	Likelihood of Occurrence in the Study Area
			P&W search	Biota (2007a)	Biota (2007b)	Biota (2008)	Biota (2009c)	Biota (2010c)	Biota (2010b)	Biota (2010d)	Biota (2012)	Biota (2013a)	Biota (2013b)	Biota (2013d)	Biota (2013e)	Biota (2013f)		
Priority 4																		
Acacia bromilowiana	Tree or tall shrub.	Skeletal loam soils on rocky hills, scree slopes, breakaways, gorges.	✓									✓					✓	May potentially occur; records are known from locations to the west, northwest and southeast of the study area, the closest of which is 9.3 km southeast; there is suitable habitat in the eastern section of the study area.
Eremophila magnifica subsp. *magnifica*	Shrub.	Rocky hillslopes, breakaways.	✓									✓					✓	Known to occur; recorded during current and previous field surveys.
Goodenia nuda	Annual herb.	Creeklines, drainage areas, low-lying plains.	✓					✓		✓	✓	✓					✓	Likely to occur; there is considerable suitable habitat in the study area, and the species is recorded relatively frequently in the locality from areas to the northwest, north, east and southeast; the closest record is from 7.9 km southeast of the study area.
Ptilotus mollis	Low shrub.	Stony hills.	✓		✓							✓					✓	May potentially occur; recorded from scattered locations to the northwest, west and southeast of the study area, with the closest location 9.3 km west.
Ptilotus trichocephalus	Prostrate annual herb.	Sandy soils on colluvial plains.	✓				✓										✓	Unlikely to occur; this species is thought to have a more southern distribution, and there are no records closer than 25 km southwest of the study area.

P&W = Department of Parks and Wildlife.

Appendix 10

Vascular Flora List

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Acanthaceae	*Dicladanthera forrestii*		✓				
	Dipteracanthus australasicus subsp. *australasicus*		✓				
Amaranthaceae	*Achyranthes aspera*		✓				
	Alternanthera nana		✓		✓		
	Amaranthus undulatus		✓				
	Gomphrena cunninghamii		✓	✓	✓		✓
	Gomphrena kanisii		✓		✓		✓
	Ptilotus aervoides		✓		✓		
	Ptilotus astrolasius		✓		✓		✓
	Ptilotus auriculifolius		✓				✓
	Ptilotus calostachyus		✓		✓		✓
	Ptilotus clementii				✓		✓
	Ptilotus fusiformis		✓				✓
	Ptilotus gomphrenoides var. *gomphrenoides*		✓				
	Ptilotus helipteroides				✓		
	Ptilotus nobilis subsp. *nobilis*		✓	✓	✓	✓	✓
	Ptilotus obovatus var. *obovatus*		✓	✓	✓		✓
	Ptilotus rotundifolius		✓		✓		✓
	Ptilotus schwartzii var. *schwartzii*		✓	✓	✓		✓
	Ptilotus subspinescens	Priority 3	✓	✓			
Apocynaceae	*Cynanchum floribundum*		✓				
	Cynanchum pedunculatum		✓				
	Gymnanthera cunninghamii	Priority 3	✓				
	Rhyncharrhena linearis		✓	✓			✓
	Sarcostemma viminale subsp. *viminale*		✓				
Araliaceae	*Astrotricha hamptonii*		✓				✓
	Trachymene oleracea subsp. *oleracea*		✓	✓	✓		✓
Asteraceae	**Bidens bipinnata*	Weed	✓	✓	✓		
	**Flaveria trinervia*	Weed					✓
	Olearia xerophila		✓				
	Peripleura arida			✓	✓		
	Peripleura obovata						✓
	Peripleura virgata						✓
	Pluchea dentex		✓	✓			
	Pluchea rubelliflora		✓				✓
	Podolepis capillaris		✓				

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Asteraceae	*Pterocaulon sphacelatum*		✓	✓			✓
(continued)	*Pterocaulon sphaeranthoides*		✓		✓		✓
	Pterocaulon sp. (insufficient material)		✓				
	**Sonchus asper*	Weed	✓				
	**Sonchus oleraceus*	Weed					✓
	Streptoglossa bubakii		✓				✓
	Streptoglossa decurrens		✓				✓
Boraginaceae	*Heliotropium chrysocarpum*		✓				
	Heliotropium cunninghamii		✓				
	Heliotropium glanduliferum						✓
	Heliotropium heteranthum		✓				
	Heliotropium inexplicitum						✓
	Heliotropium pachyphyllum					✓	✓
	Heliotropium tenuifolium		✓				
	Trichodesma zeylanicum var. *zeylanicum*		✓	✓	✓		✓
Brassicaceae	*Lepidium pedicellosum*						✓
	Lepidium phlebopetalum				✓		
	Lepidium pholidogynum				✓		✓
	Lepidium platypetalum		✓				
Capparaceae	*Capparis lasiantha*		✓	✓	✓		✓
	Capparis spinosa var. *nummularia*		✓				
	Capparis umbonata		✓	✓			✓
Caryophyllaceae	*Polycarpaea corymbosa* var. *corymbosa*		✓	✓			✓
	Polycarpaea holtzei			✓			✓
	Polycarpaea longiflora		✓				✓
Celastraceae	*Stackhousia intermedia*				✓		✓
	Stackhousia muricata						✓
Chenopodiaceae	*Dysphania kalpari*			✓			
	*Dysphania rhadinostachya (*subsp. not determined)			✓			✓
	Dysphania rhadinostachya subsp. *rhadinostachya*				✓		✓
	Enchylaena tomentosa var. *tomentosa*		✓		✓		✓
	Maireana georgei		✓		✓		✓
	Maireana melanocoma				✓		✓
	Maireana planifolia		✓		✓		✓
	Maireana planifolia x villosa			✓			
	Maireana ? thesioides/melanocoma (insufficient material)		✓				

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Chenopodiaceae	*Maireana ? trichoptera* (insufficient material)				✓	✓	
(continued)	*Maireana triptera*		✓		✓		
	Maireana villosa			✓			✓
	Maireana sp. (insufficient material)		✓				
	Rhagodia eremaea		✓	✓	✓		✓
	Salsola australis		✓		✓		✓
	Sclerolaena cornishiana		✓				
	Sclerolaena eriacantha		✓		✓		
	Sclerolaena minuta		✓				
Cleomaceae	*Cleome viscosa*		✓		✓		✓
Convolvulaceae	*Bonamia* sp. Dampier (A.A. Mitchell PRP 217)						✓
	Duperreya commixta		✓	✓	✓		✓
	Evolvulus alsinoides var. *decumbens*		✓		✓		
	Evolvulus alsinoides var. *villosicalyx*		✓	✓	✓		✓
	Ipomoea plebeia		✓				
	Polymeria ambigua		✓		✓		
Cucurbitaceae	*Cucumis variabilis*		✓	✓	✓		✓
Cyperaceae	*Bulbostylis barbata*		✓	✓	✓		✓
	Cyperus cunninghamii subsp. *cunninghamii*		✓				
	Cyperus vaginatus		✓				✓
	Fimbristylis dichotoma		✓		✓		✓
	Fimbristylis simulans		✓				✓
Dilleniaceae	*Hibbertia glaberrima*		✓				
Euphorbiaceae	*Euphorbia australis* (var. not determined)			✓	✓		
	Euphorbia australis var. *hispidula*		✓				
	Euphorbia australis var. *subtomentosa*		✓				
	Euphorbia biconvexa		✓		✓		✓
	Euphorbia boophthona		✓				✓
	**Euphorbia hirta*	Weed	✓				
	Euphorbia tannensis subsp. *eremophila*		✓	✓			
	Euphorbia trigonosperma		✓				
	Euphorbia sp. (insufficient material)		✓				
Fabaceae	*Acacia adoxa* var. *adoxa*		✓				
	Acacia ancistrocarpa		✓				✓
	Acacia aneura (sens. lat.)		✓	✓	✓		✓
	Acacia aptaneura		✓				

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Fabaceae	*Acacia aptaneura x ?* (insufficient material)		✓				
(continued)	*Acacia arida*		✓				
	Acacia atkinsiana		✓				✓
	Acacia ayersiana			✓			✓
	Acacia ayersiana (narrow phyllode variant)		✓				
	Acacia ayersiana x A. aptaneura		✓				
	Acacia bivenosa		✓				✓
	Acacia bivenosa (wispy/weeping form)		✓		✓	✓	✓
	Acacia citrinoviridis		✓				✓
	Acacia coriacea subsp. *coriacea*		✓				
	Acacia coriacea subsp. *pendens*		✓				
	Acacia dictyophleba						✓
	Acacia ? eriopoda (insufficient material)		✓				
	Acacia exilis		✓				✓
	Acacia hamersleyensis		✓				✓
	Acacia inaequilatera		✓		✓		✓
	Acacia incurvaneura x ? (insufficient material)		✓				
	Acacia kempeana		✓				✓
	Acacia ligulata		✓				
	Acacia macraneura		✓				
	Acacia maitlandii		✓			✓	✓
	Acacia marramamba		✓				✓
	Acacia monticola		✓				✓
	Acacia orthocarpa		✓				✓
	Acacia pruinocarpa		✓	✓	✓		✓
	Acacia pyrifolia (var. not determined)						✓
	Acacia pyrifolia var. *pyrifolia*		✓				
	Acacia rhodophloia		✓		✓		✓
	Acacia rhodophloia x sibirica		✓				
	Acacia sclerosperma subsp. *sclerosperma*		✓				
	Acacia sibirica		✓	✓			✓
	Acacia synchronicia		✓	✓	✓	✓	✓
	Acacia tenuissima		✓		✓		
	Acacia tetragonophylla		✓		✓		✓
	Acacia trudgeniana		✓				✓
	Acacia xiphophylla		✓		✓		✓

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Fabaceae	*Acacia* sp. (insufficient material)		✓				
(continued)	*Crotalaria dissitiflora* subsp. *benthamiana*		✓				
	Crotalaria medicaginea var. *neglecta*		✓				
	Glycine canescens		✓				✓
	Gompholobium oreophilum		✓				✓
	Indigofera linnaei		✓				
	Indigofera monophylla		✓		✓		✓
	Indigofera sp. Fractiflexa (S. van Leeuwen 3773)		✓				
	Isotropis atropurpurea		✓				✓
	Neptunia dimorphantha		✓				
	Petalostylis labicheoides		✓				✓
	Rhynchosia minima		✓		✓		✓
	Senna artemisioides subsp. *x artemisioides*		✓				
	Senna artemisioides subsp. *helmsii*		✓	✓			✓
	Senna artemisioides subsp. *oligophylla*		✓				✓
	Senna artemisioides subsp. *oligophylla x* subsp. *helmsii*		✓	✓			✓
	Senna artemisioides subsp. *? oligophylla x*				✓		
	Senna ferraria		✓				
	Senna ferraria x S. ? glutinosa subsp. *glutinosa*		✓				
	Senna glaucifolia		✓				
	Senna glaucifolia x S. artemisioides subsp. *oligophylla*		✓				
	Senna glutinosa subsp. *glutinosa*		✓		✓		✓
	Senna glutinosa subsp. *glutinosa x* subsp. *x luerssenii*		✓				
	Senna glutinosa subsp. *glutinosa x S. stricta*		✓				
	Senna glutinosa subsp. *x luerssenii*		✓	✓	✓	✓	✓
	Senna glutinosa subsp. *x luerssenii x S. stricta*		✓				
	Senna glutinosa subsp. *pruinosa*		✓		✓		✓
	Senna glutinosa subsp. *pruinosa x*						✓
	Senna glutinosa subsp. *pruinosa x* subsp. *x luerssenii*		✓				
	Senna notabilis		✓	✓	✓		✓
	Senna stricta		✓	✓	✓		✓
	Senna sp. Karijini (M.E. Trudgen 10392)				✓		
	Senna sp. (insufficient material)						✓
	Sesbania cannabina		✓				✓
	Swainsona sp. (insufficient material)		✓				
	Templetonia egena		✓				

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Fabaceae	*Tephrosia clementii*		✓				
(continued)	*Tephrosia rosea* var. Fortescue creeks (M.I.H. Brooker 2186)		✓				✓
	Tephrosia supina						✓
	Tephrosia sp. Fortescue (A.A. Mitchell 606)		✓				✓
	**Vachellia farnesiana*	Weed	✓			✓	
Goodeniaceae	*Dampiera candicans*		✓				✓
	Goodenia cusackiana		✓				
	Goodenia forrestii		✓		✓		
	Goodenia microptera		✓	✓	✓		✓
	Goodenia muelleriana		✓		✓		✓
	Goodenia sp. aff. *pedicellata*	Potential Priority species					✓
	Goodenia stobbsiana		✓				✓
	Goodenia tenuiloba			✓	✓		✓
	Scaevola acacioides		✓				✓
	Scaevola spinescens		✓				
Gyrostemonaceae	*Codonocarpus cotinifolius*		✓				✓
Haloragaceae	*Haloragis gossei* (var. not det.)						✓
	Haloragis gossei var. *inflata*						✓
Lamiaceae	*Clerodendrum floribundum* var. *angustifolium*		✓				✓
	Prostanthera albiflora		✓				✓
Lauraceae	*Cassytha capillaris*		✓				
Loranthaceae	*Amyema fitzgeraldii*		✓				
	Amyema gibberula var. *gibberula*		✓				
	Amyema hilliana		✓				✓
	Amyema preissii		✓				
	Diplatia grandibractea		✓				
	Lysiana casuarinae		✓				
Malvaceae	*Abutilon cryptopetalum*		✓		✓		
	Abutilon cunninghamii		✓				
	Abutilon fraseri subsp. *fraseri*		✓	✓	✓		✓
	Abutilon lepidum				✓		
	Abutilon macrum				✓		
	Abutilon otocarpum		✓		✓		✓
	Abutilon oxycarpum subsp. Prostrate (A.A. Mitchell PRP 1266)				✓		
	Abutilon sp. Dioicum (A.A. Mitchell PRP 1618)		✓				✓

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Malvaceae	*Abutilon* sp. Pilbara (W.R. Barker 2025)		✓				
(continued)	*Abutilon* sp. (insufficient material)						✓
	Androcalva luteiflora		✓			✓	
	Brachychiton acuminatus		✓				
	Corchorus crozophorifolius		✓				✓
	Corchorus lasiocarpus (subsp. not determined)		✓				✓
	Corchorus lasiocarpus subsp. *lasiocarpus*		✓		✓		✓
	Corchorus lasiocarpus subsp. *parvus*		✓	✓			✓
	Corchorus tridens			✓			
	Corchorus trilocularis		✓				
	Corchorus sp. (insufficient material)		✓				
	Gossypium australe (Burrup Peninsula form)		✓				✓
	Gossypium australe (Whim Creek form)		✓		✓		✓
	Gossypium robinsonii		✓				✓
	Hibiscus burtonii		✓	✓	✓		✓
	Hibiscus coatesii		✓		✓		✓
	Hibiscus goldsworthii		✓				
	Hibiscus sturtii (var. not determined)		✓				✓
	Hibiscus sturtii var. *campylochlamys*		✓				✓
	Hibiscus sturtii var. *grandiflorus*		✓		✓		
	Hibiscus sturtii var. *platychlamys*		✓		✓		
	Hibiscus sturtii var. aff. *truncatus*		✓				
	Hibiscus verdcourtii		✓				
	Hibiscus sp. Mt Brockman (E. Thoma ET 1354)	Priority 1	✓				✓
	Keraudrenia nephrosperma		✓				✓
	Keraudrenia velutina subsp. *elliptica*						✓
	**Malvastrum americanum*	Weed	✓		✓		
	Melhania oblongifolia		✓		✓		
	Sida arsiniata				✓		
	Sida echinocarpa		✓	✓	✓		✓
	Sida fibulifera (sens. lat.)		✓		✓		✓
	Sida sp. Barlee Range (S. van Leeuwen 1642)	Priority 3	✓				✓
	Sida sp. dark green fruits (S. van Leeuwen 2260)		✓	✓	✓		✓
	Sida sp. Excedentifolia (J.L. Egan 1925)		✓				✓
	Sida sp. Pilbara (A.A. Mitchell PRP 1543)		✓				✓
	Sida sp. Shovelanna Hill (S. van Leeuwen 3842)		✓				

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Malvaceae	*Sida* sp. spiciform panicles (E. Leyland s.n. 14/8/90)		✓		✓		✓
(continued)	*Sida* sp. verrucose glands (F.H. Mollemans 2423)		✓	✓			✓
	Triumfetta chaetocarpa		✓				✓
	Triumfetta clementii		✓				
	Triumfetta leptacantha		✓				
	Triumfetta maconochieana		✓				✓
	Waltheria indica		✓				✓
Menispermaceae	*Tinospora smilacina*		✓				✓
Molluginaceae	*Mollugo molluginea*		✓				✓
Moraceae	*Ficus brachypoda*		✓				
Myrtaceae	*Calytrix carinata*		✓				
	Corymbia deserticola subsp. *deserticola*		✓				✓
	Corymbia ferriticola		✓				✓
	Corymbia hamersleyana		✓				✓
	Eucalyptus aridimontana		✓				
	Eucalyptus camaldulensis subsp. *refulgens*		✓				
	Eucalyptus gamophylla		✓	✓			✓
	Eucalyptus kingsmillii subsp. *kingsmillii*		✓				
	Eucalyptus leucophloia subsp. *leucophloia*		✓				✓
	Eucalyptus repullulans		✓				
	Eucalyptus socialis subsp. *eucentrica*		✓			✓	✓
	Eucalyptus ? socialis (insufficient material)		✓				
	Eucalyptus trivalva		✓				
	Eucalyptus victrix		✓				✓
	Eucalyptus xerothermica		✓				✓
	Melaleuca bracteata		✓				
	Melaleuca eleuterostachya		✓			✓	✓
	Melaleuca glomerata		✓				
Nyctaginaceae	*Boerhavia coccinea*		✓	✓	✓		
	Commicarpus australis		✓				
Oleaceae	*Jasminum didymum* subsp. *lineare*		✓		✓		✓
Orobanchaceae	*Striga curviflora*				✓		
Papaveraceae	**Argemone ochroleuca*	Weed	✓				
Passifloraceae	**Passiflora foetida* var. *hispida*	Weed	✓				
Phyllanthaceae	*Notoleptopus decaisnei (*var. not determined)		✓	✓			
	Notoleptopus decaisnei var. *decaisnei*		✓		✓		

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Phyllanthaceae	*Notoleptopus decaisnei* var. Orbicularis (A.B. Craig 428)						✓
(continued)	*Phyllanthus erwinii*		✓	✓	✓		
	Phyllanthus maderaspatensis		✓				✓
Plantaginaceae	*Stemodia grossa*		✓	✓			✓
Poaceae	*Amphipogon sericeus*						✓
	Amphipogon sp. (insufficient material)		✓				
	Aristida burbidgeae		✓				
	Aristida contorta		✓	✓	✓		✓
	Aristida holathera var. *holathera*		✓		✓		✓
	Aristida holathera var. *latifolia*		✓				
	Aristida latifolia		✓		✓		✓
	Aristida obscura						✓
	Aristida sp. (insufficient material)		✓				
	Astrebla sp. (insufficient material)		✓				
	Bothriochloa ewartiana		✓				
	Brachyachne convergens		✓				
	Brachyachne prostrata		✓		✓		
	**Cenchrus ciliaris*	Weed	✓		✓		✓
	**Cenchrus setiger*	Weed	✓				
	Chrysopogon fallax		✓	✓	✓		
	Cymbopogon ambiguus		✓		✓		✓
	Cymbopogon ? ambiguus (insufficient material)						✓
	Cymbopogon obtectus		✓				
	Cymbopogon procerus		✓				✓
	Cymbopogon sp. (insufficient material)		✓				✓
	**Cynodon dactylon*	Weed	✓				
	Dactyloctenium radulans		✓		✓		
	Dichanthium fecundum		✓				
	Dichanthium sericeum subsp. *humilius*			✓			✓
	Digitaria brownii		✓		✓		✓
	Digitaria ctenantha				✓		
	**Echinochloa colona*	Weed					✓
	Enneapogon caerulescens		✓		✓		✓
	Enneapogon lindleyanus		✓		✓		✓
	Enneapogon polyphyllus		✓	✓	✓	✓	✓
	Enneapogon robustissimus		✓				

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Poaceae	*Enteropogon ramosus*		✓		✓		
(continued)	*Eragrostis cumingii*		✓	✓			
	Eragrostis desertorum		✓				
	Eragrostis eriopoda		✓				
	Eragrostis setifolia		✓	✓			✓
	Eragrostis xerophila		✓				
	Eriachne aristidea			✓	✓		✓
	Eriachne flaccida		✓				
	Eriachne mucronata		✓	✓	✓		✓
	Eriachne pulchella		✓	✓	✓		✓
	Eriachne tenuiculmis		✓				
	Eulalia aurea		✓				✓
	Eulalia sp. (Three Rivers Station, B. Forsyth AQ6789133)		✓				
	Heteropogon contortus		✓				
	Iseilema dolichotrichum		✓	✓	✓		
	Iseilema eremaeum				✓		
	Panicum decompositum		✓				
	Panicum effusum			✓			
	Paraneurachne muelleri		✓	✓	✓		✓
	Paspalidium clementii		✓	✓	✓		✓
	Paspalidium constrictum		✓		✓		
	Paspalidium tabulatum		✓				
	Perotis rara			✓			
	Schizachyrium fragile		✓				✓
	**Setaria verticillata*	Weed					✓
	Sporobolus actinocladus		✓				
	Sporobolus australasicus		✓	✓	✓		✓
	Themeda triandra		✓		✓		✓
	Tragus australianus			✓			✓
	Triodia angusta		✓		✓	✓	
	Triodia brizoides		✓				✓
	Triodia epactia		✓	✓	✓		✓
	Triodia longiceps		✓		✓		
	Triodia melvillei		✓	✓			✓
	Triodia pungens						✓
	Triodia wiseana		✓	✓	✓	✓	✓

Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Poaceae	*Triodia* sp. (*epactia/pungens;* sterile material)			✓			✓
(continued)	*Tripogon loliiformis*		✓		✓		
Polygalaceae	*Polygala glaucifolia*		✓	✓			✓
Polygonaceae	**Acetosa vesicaria*	Weed	✓				
Portulacaceae	*Portulaca pilosa*				✓		
	Portulaca sp. *(oleracea/intraterranea)*		✓	✓	✓		
Proteaceae	*Grevillea berryana*		✓	✓			✓
	Grevillea pyramidalis		✓				
	Grevillea saxicola	Priority 3	✓				
	Grevillea wickhamii (subsp. not determined)						✓
	Hakea chordophylla		✓				✓
	Hakea lorea subsp. *lorea*		✓				✓
Pteridaceae	*Cheilanthes brownii*		✓				✓
	Cheilanthes sieberi subsp. *sieberi*		✓	✓	✓		✓
Rhamnaceae	*Cryptandra monticola*		✓				
Rubiaceae	*Oldenlandia crouchiana*		✓	✓	✓		✓
	Pomax rupestris		✓				
	Psydrax latifolia		✓				
	Psydrax rigidula		✓	✓			
	Psydrax suaveolens		✓		✓		✓
Santalaceae	*Anthobolus leptomerioides*		✓				
	Santalum lanceolatum		✓				✓
Sapindaceae	*Dodonaea coriacea*		✓				✓
	Dodonaea lanceolata var. *lanceolata*		✓				✓
	Dodonaea pachyneura		✓				✓
	Dodonaea petiolaris		✓				✓
	Dodonaea viscosa		✓				
Scrophulariaceae	*Eremophila ? accrescens* (insufficient material)		✓				
	Eremophila cryptothrix		✓				
	Eremophila cuneifolia		✓	✓	✓	✓	✓
	Eremophila exilifolia		✓				✓
	Eremophila forrestii subsp. *forrestii*		✓	✓			✓
	Eremophila forrestii x latrobei						✓
	Eremophila fraseri subsp. *fraseri*		✓				
	Eremophila jucunda subsp. *pulcherrima*		✓				
	Eremophila latrobei subsp. *filiformis*		✓				✓

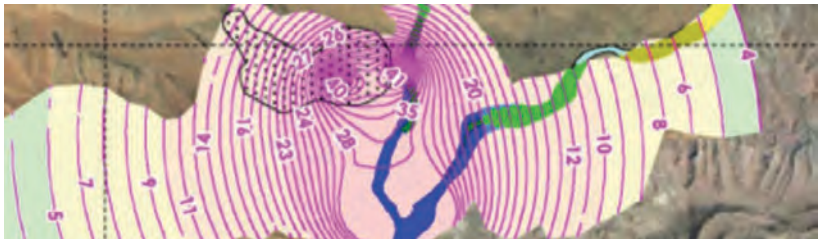
Family	Species	Weed / Priority	Current Study	Biota (2007a)	Biota (2011a)	Biota (2013b)	Biota (2013a)
Scrophulariaceae	*Eremophila latrobei* subsp. *glabra*						✓
(continued)	*Eremophila latrobei* subsp. *latrobei*		✓				
	Eremophila longifolia		✓	✓			✓
	Eremophila magnifica subsp. *magnifica*	Priority 4	✓				✓
	Eremophila magnifica subsp. *velutina*	Priority 3	✓				✓
	Eremophila petrophila subsp. *petrophila*		✓				
	Eremophila phyllopoda subsp. *obliqua*		✓	✓	✓		✓
	Eremophila tietkensii		✓				
	Eremophila sp. (insufficient material)						✓
Solanaceae	*Nicotiana occidentalis* (subsp. not determined)			✓			
	Solanum diversiflorum						✓
	Solanum horridum		✓	✓			✓
	Solanum kentrocaule	Priority 3	✓				
	Solanum lasiophyllum		✓	✓	✓		✓
	Solanum phlomoides		✓				✓
	Solanum piceum		✓				
Surianaceae	*Stylobasium spathulatum*		✓			✓	✓
Violaceae	*Hybanthus aurantiacus*		✓	✓			✓
Zygophyllaceae	*Tribulopis angustifolia*					✓	
	Tribulus hirsutus		✓		✓		✓
	Tribulus platypterus				✓		
	Tribulus suberosus		✓	✓	✓		✓
	Zygophyllum iodocarpum						✓

Biota Environmental Sciences

Western Turner Syncline Section 10 Below Water Table Groundwater Dependent Vegetation Assessment







Prepared for Rio Tinto

January 2015

Biota Environmental Sciences

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1.0 Introduction

Hamersley Iron Pty Ltd (Hamersley Iron) owns and operates Western Turner Syncline (WTS) Section 10, an active iron ore mine approximately 20 km northwest of Tom Price in the Pilbara region of Western Australia (Figure 1.1). Hamersley Iron proposes to mine below the water table at WTS Section 10 and mine a new satellite Marra Mamba pit to the northeast. The proposed WTS Section 10 expansion and mining of the satellite Marra Mamba deposit will require dewatering to facilitate below water table mining.

1.1 Scope and Objectives

This report provides an assessment of the potential impacts of groundwater drawdown on groundwater dependent vegetation (GDV) due to dewatering to enable below water table mining at WTS Section 10 (hereafter "the study area").

The objectives of this report are to:

- identify GDV in the WTS expansion locality;
- spatially relate GDV with the modelled groundwater drawdown provided by Rio Tinto;
- assess potential implications of dewatering discharge into riparian systems (where predicted hydrological changes can be identified); and
- discuss the potential impacts of groundwater drawdown on the GDV identified for the study area.

1.2 Approach and Methods

The approach adopted in this report to meet the above objectives comprised:

- a review of relevant literature;
- review of modelled groundwater drawdown and options for surplus dewatering water disposal, as provided by Rio Tinto;
- identification of GDV in the immediate vicinity and the broader locality by review of riparian vegetation units identified for the study area in Biota (2013a) Biota (2014);
- development of nominal groundwater drawdown thresholds and potential GDV response; and
- spatial intersection of GDV and modelled groundwater drawdown in MapInfo Geographical Information System (GIS) v11 to identify and quantify potentially impacted vegetation and assess the possible magnitude of the impact.

1.3 Limitations

This report provides an assessment of the impact of groundwater drawdown on GDV and associated impacts of surface discharge of surplus dewatering water. However, the following points should be taken into consideration when reviewing the assessment provided:

- Modelling of groundwater drawdown provided by Rio Tinto provides an indication of drawdown depths and behaviour. The modelling is in the preliminary stages and requires further calibration with site-specific information to improve model accuracy. Therefore, the information arising from the current models should be interpreted as indicative only.
- The groundwater drawdown thresholds determined for assessing the impact to GDV vegetation are inferred from the literature (Thorburn and Walker 1994, Thorburn et al. 1994, Halpern Glick Maunsell Pty Ltd 2000, Eamus et al. 2006). However, there is limited information available to accurately quantify tolerance limits for the species discussed in this report.
- Options for disposing of surplus water generated from groundwater drawdown are still being examined by Rio Tinto and may change as project definition improves.

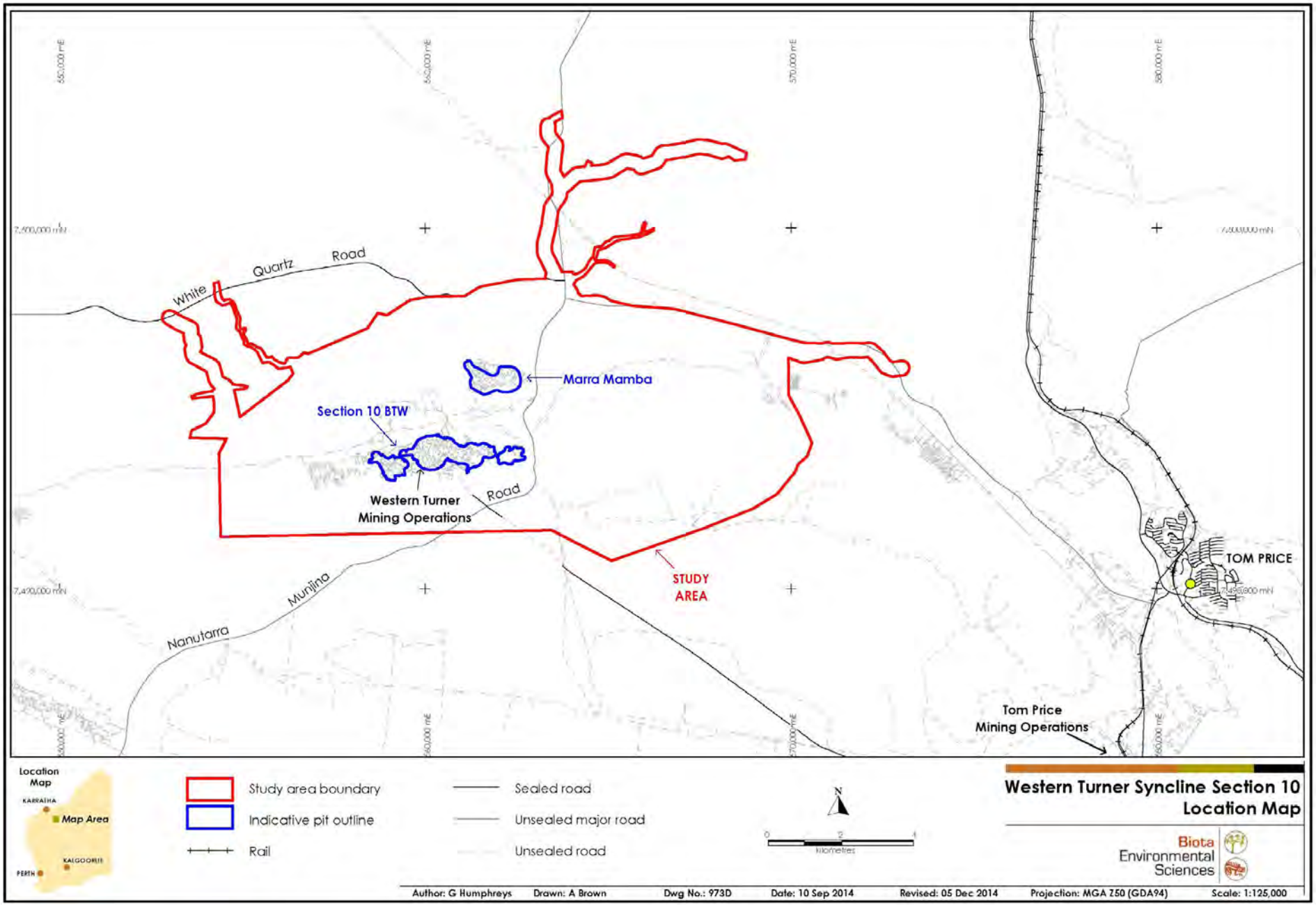


Figure 1.1: Locality map.

2.0 Background to the Issue

2.1 Plant Water Use and Categories of Groundwater Dependence

Plants obtain water from three primary sources: groundwater, surface water and soil water. Species that are primarily or totally reliant on groundwater to meet their physiological water requirements are known as phreatophytes (Kramer 1979 pp. 68–177 , 315–403). These species typically have a superficial, adventitious root system and a deeper taproot or sinker root system that penetrates the water table. It is generally accepted that the common Pilbara riparian species *Melaleuca argentea* and *Eucalyptus camaldulensis* are phreatophytic (Thorburn et al. 1993, O'Grady et al. 2005).

Mesophytes, or vadophytes, source their water primarily from the vadose zone of the soil profile above the water table, where soil capillarity provides moisture. Their water is usually derived from surface flows or direct rainfall infiltrating the soil profile and clay lenses in the stratigraphy during recharge events. These species are typically not reliant on water from aquifers, but can utilise groundwater in situations where this becomes accessible (FAO/IAEA 2008, O'Grady et al. 2009). *Eucalyptus victrix* and *Acacia citrinoviridis* are Pilbara riparian taxa that have previously been suggested as vadophytes (Muir Environmental 1995, Halpern Glick Maunsell Pty Ltd 2000, FAO/IAEA 2008). Other tree or woody shrub species that occur in floodplain or creekline environments may also be vadophytes, however this is not well established in the literature.

The floodplain species *Acacia xiphophylla* and *A. aneura* are termed xerophytes, as they are reliant on stored soil water with no access to groundwater. However, water is sourced from various soil depths, and the species can switch from deeper to shallower soil layers following rainfall and recharge events (FAO/IAEA 2008).

Processes that regulate water use within plants are complex. Soil water uptake results from interrelationships between the plant and soil and transport processes across a range of spatial and temporal scales (for example Pfautsch et al. 2011). Plant species within ecosystems may exhibit differing degrees of groundwater utilisation, from obligate dependency to facultative use. Obligate dependency describes a plant species or ecosystem that cannot survive without groundwater. Facultative use describes a species or ecosystem which accesses groundwater if it is available, but can tolerate its absence for many years. Determining both the degree of groundwater dependence and the timing of this dependency for plant species and ecosystems is complicated (Eamus et al. 2006).

2.2 Groundwater Dependent Ecosystems in the Pilbara

In the Pilbara, most watercourses are ephemeral and rainfall, flow regimes and depth to groundwater are all highly variable. Water availability is partly a function of topography and depth to groundwater, but is also variable by soil type. Water availability is a critical factor affecting the distribution of species and communities. In general, species adapted to growing in and along creeklines have access to groundwater and are less dependent on rainwater. In contrast, species growing on floodplains are typically highly dependent on rainwater (FAO/IAEA 2008).

Availability of groundwater is necessary for GDV to function and survive. There are two classes of ecosystems relevant to vegetation that are dependent on the availability of groundwater. These are (Eamus et al. 2006):

1. Ecosystems dependent of the surface expression of groundwater (i.e. wetlands, some floodplains, base flow rivers and streams and *Melalueca* swamps); and

2. Ecosystems dependent on the subsurface presence of groundwater, often accessed via the capillary fringe[1] when roots penetrate this zone. This class include terrestrial vegetation such as some riparian vegetation.

While deep-rooted, potentially phreatophytic species (such as *Eucalyptus camaldulensis* and *Melaleuca argentea*) can act as indicator species for GDVs, it is important to note that the definition of GDV does not imply that all species in this community are groundwater dependent (Eamus et al. 2006). The GDV will also comprises other tree, shrub and grass species that rely on recent precipitation, rather than groundwater, as their main water source (Grierson and Page 2012). However, removal of groundwater from these ecosystems, or a change in the timing, quantity, quality or distribution of groundwater, can influence key ecological processes such as growth, reproduction, recruitment, mortality and changes in ecosystem structure and function. Changes in groundwater regime can also impact on the ecosystem as a whole, including faunal, microbial and fungal populations (Eamus et al. 2006).

The major tree species found in riparian zones in the Pilbara differ both in their depth to groundwater ranges (DoW 2010) and in their ability to cope with fluctuating water availability and the relative availability of different water sources (Adams et al. 2005). This is important to consider when evaluating potential impacts resulting from changes in groundwater availability.

2.3 Responses to Hydrological Change

The response of flora and vegetation to groundwater drawdown and surface water discharge is a function of their water use strategies. Subject to limitations on current knowledge of individual species' responses, this can be broadly categorised as outlined in Table 2.1.

Table 2.1: Categories of plant water physiology and potential range of responses to hydrological change.

Category	Species in the Study Area	Likely response to lowered watertable	Likely response to extended flooding from surface water discharge
Phreatophyte	*Eucalyptus camaldulensis*	Decline due to prolonged water stress (dependent on duration and magnitude of drawdown)	Minimal impact (dependent on species and duration and magnitude of inundation)
Mesophyte (vadophyte)	*Eucalyptus victrix, Acacia citrinoviridis*	Impact variable (dependent on degree of facultative groundwater use)	Plant decline and possible death due to waterlogging
Xerophyte	*Acacia aneura, A. xiphophylla*	No impact	Plant death due to waterlogging

It is also important to consider the nature of changes within groundwater dependent ecosystems. *E. camaldulensis* and *E. victrix* can adapt to changes in conditions by switching water source and developing adventitious roots (Adams et al. 2005). However, if conditions change too quickly by comparison with natural patterns of changes in water availability, then problems may arise (Adams et al. 2005). Site characteristics such as, position in the landscape and routine hydrological regimes individual plants have developed in, may also affect species' ability to adapt to change and the extent to which they are dependent on groundwater. As such, some species may act as phreatophytes at some sites and not others (Grierson and Page 2012), so there is likely to be a variable dependence on groundwater across a landscape, even among trees of the same species.

1 Non-saturated zone above the saturated zone of the water table.

Quantification of water use by different plant species and how water use is partitioned between different depths and sources in groundwater dependent ecosystems is not yet fully understood, especially in arid and semi arid environments (Orellana et al. 2012). Research into groundwater hydrology and plant-water relations in the Pilbara region is ongoing, and is largely driven by advances in technology such as stable isotope techniques (used to determine sources of groundwater recharge as well as sources of water used by plants (e.g. Cullen et al. 2008, Dogramaci et al. 2012, Skrzypek et al. 2013)) and use of sapflow measurements (used to understand water use dynamics of individual trees (e.g. Pfautsch et al. 2011, 2014)).

Additionally, monitoring programs have been established, which aim to detect any changes in riparian vegetation (Biota 2012, 2013b) or changes in individual tree health or condition (Pfautsch et al. 2014) following modification of groundwater levels due to below water table mining operations. Advances in knowledge due to scientific research together with results of riparian monitoring will provide a better indication of species-specific responses and tolerance-limits of riparian flora that are subject to modification of groundwater levels.

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3.0 Below Water Table Mining at WTS

3.1 Dewatering Drawdown

Dewatering at WTS Section 10 and the satellite Marra Mamba pit is required to facilitate mining of iron ore below the water table. The WTS Section 10 ore body aquifer is located mostly in the Dales Gorge Member of the Brockman Iron Formation (Rio Tinto 2013a), which is bounded to the north and south by relatively impermeable Mt McRae Shale. The Marra Mamba ore body aquifer is located north of the WTS Section 10 ore body aquifer and the two aquifers are separated by the relatively impermeable banded iron formations (Rio Tinto 2013a). Preliminary studies indicate that the Marra Mamba ore body aquifer is likely to be connected to the Mt Lionel aquifer. Abstraction from the Mt Lionel aquifer is via the Mt Lionel borefield which is located less than 1 km to the east of the Marra Mamba pit (east). Abstraction from the borefield has been ongoing since 1976, which has contributed to a depth to groundwater under the Hardey River of 50 m (S. Shah, Rio Tinto, pers. comm. 2015). The Marra Mamba pit, while shown as a single disturbance outline in this report, will be successively dewatered and mined in the eastern and then western portions of the pit. Groundwater abstraction and dewatering have therefore been modelled separately for these two stages of the Marra Mamba pit.

The total dewatering profile at WTS Section 10 and the satellite Marra Mamba pit is currently modelled as follows:

- 2017-2018: WTS Section 10 only, abstraction rate of 6 ML/day;
- 2019-2020: WTS Section 10 and Marra Mamba pit (East), combined abstraction rate of 19 ML/day;
- 2021-2022: Marra Mamba pit (east) only, abstraction rate of 11-13 ML/day; and
- 2023-2024: Marra Mama pit (west) only, abstraction rate of 6 ML/day.

Dewatering will progressively increase the depth to the water table extending in the direction of the permeable zone, referred to as the cone of depression. Groundwater drawdown extends to areas experiencing an increase in depth to the water table. Preliminary modelling (drawdown contours provided by Rio Tinto) predicts maximum groundwater drawdown of 75 m below the current water table level for the WTS Section 10 mine and 45 m below the current water table level for the Marra Mama satellite pit (Rio Tinto 2013; Section 4.0).

3.2 Discharge of Dewatering Water

The volume of groundwater dewatered is likely to be in excess of mine process requirements, creating a water surplus. The disposal of surplus water from dewatering needs to be managed and there are currently three options being considered for disposing of surplus water (Rio Tinto 2014; Shreya Shah, pers. comm. 2014):

- Option 1: Transfer to Another Site or Industrial Use
  Dewatering water to be transferred, via pipeline, for other uses including: third party users, Hamersley Iron's other operations, the West Pilbara Water Supply Scheme and/or Tom Price town.
- Option 2: Reintroduction to Aquifer(s)
  Reintroduction to the aquifers would be achieved via: passive recharge via a disused pit, aquifer reinjection to the Hardey River Borefield (which has been in operation since 1966) and the Mount Lionel Borefield (which has been in operation since 1976), and/or reinjection into creek alluvium.
- Option 3: Discharge to Natural Watercourse(s)
  Dewatering water would be discharged in the Beasley or Hardey Rivers. There are two discharge points currently being considered for discharge into the Hardey River (see Figure 4.1 to Figure 4.3. Disposal of excess dewatering water into the Hardey River as surface flow is the

current preferred option for the project. Dewatering water would be discharged into the Beasley River via the WTS Section 10 operations, where discharge into the Beasley River has commenced. Water from the B1 deposit at WTS is currently supplied to the WTS Section 10 operations via a pipeline. When dewatering at WTS Section 10 commences, sourcing water from B1 will no longer be necessary and the pipeline could be reversed to carry water away from the WTS Section 10 operations to B1. Water can then be discharged as surface flow into a tributary of the Beasley River.

4.0 Ecological Impacts

4.1 Groundwater Dependent Vegetation in the Project Area

Vegetation mapping has been completed by Biota (2014) for the WTS Section 10 below water table study area. One of the mapped vegetation units was dominated by the phreatophytic species *Eucalyptus camaldulensis* (Section 2.1), and this vegetation type has been classified here as a GDV. In addition, one vegetation unit was dominated by *Eucalyptus victrix*, a mesophytic species that also potentially utilises groundwater (see Section 2.3). In the interests of a conservative assessment, this latter unit has also been included as GDV here. The two GDV units in this assessment are summarised in Table 4.1, along with their area of extent in the study area and the broader WTS locality.

Table 4.1: Mapped vegetation units that are dependent or partially dependent on groundwater, and their local area of extent (see Biota 2014 for more information).

Vegetation Unit	Landform	Description	Extent in the WTS below Water Table Study Area (ha)	Area in the Broader WTS Locality (ha)
EcEvAci	Major creekline	*Eucalyptus camaldulensis, E. victrix* woodland over *Acacia citrinoviridis* tall open scrub.	231.0	941.2
EvAciTeCEc	Major creekline	*Eucalyptus victrix* scattered trees over *Acacia citrinoviridis* tall shrubland over *Triodia epactia* open hummock grassland and/or **Cenchrus ciliaris* open tussock grassland	183.2	1,437.8

4.2 Impacts of Dewatering Drawdown

Groundwater drawdown modelling has been provided by Rio Tinto for WTS Section 10 and Marra Mamba satellite pit. Drawdown contours were intersected with mapping of the two GDV units for the WTS area (see Section 1.2) and four broad categories were used to estimate potential impact on the vegetation units considered (Section 2.3). These categories were as follows:

- Drawdown of less than 5 m: no impact expected for phreatophytic or mesophytic species;
- Drawdown of 5 to 10 m: within typical medium term fluctuation range in water table levels in the Pilbara region; possible stress on phreatophytic species; unlikely to be any impact on mesophytic species;
- Drawdown of 10 to 20 m: exceeds typical medium term fluctuation in water table levels in the Pilbara region; stress and potential loss of phreatophytic species, potential stress to mesophytic species, depending on duration of drawdown; and
- Drawdown of >20 m: likely loss of phreatophytic species over longer term, potential loss of mesophytic species (due to loss of hydraulic lift from phreatophytes).

These estimated impacts consider unmitigated hydrological change to the system (i.e. they do not take account of any management measures that may be implemented to offset drawdown).

The area of each GDV unit that intersects with each of these drawdown categories is outlined in Table 4.2, and shown in Figure 4.1 for WTS Section 10, and Figure 4.2 and Figure 4.3 for the two stages of the Marra Mamba pit drawdown. The overall area of each vegetation unit at risk was also conservatively calculated based on greatest potential impact. For example, if the same area of vegetation fell within the <5 m drawdown contour on the WTS Section 10 aquifer and also within the 15-20 m drawdown contour for Marra Mamba (east), its area of exposure was included in the 15-20 m drawdown in the 'overall' area calculations presented in Table 4.2 (i.e. allowing for the worst case scenario in respect of potential impact on any given area).

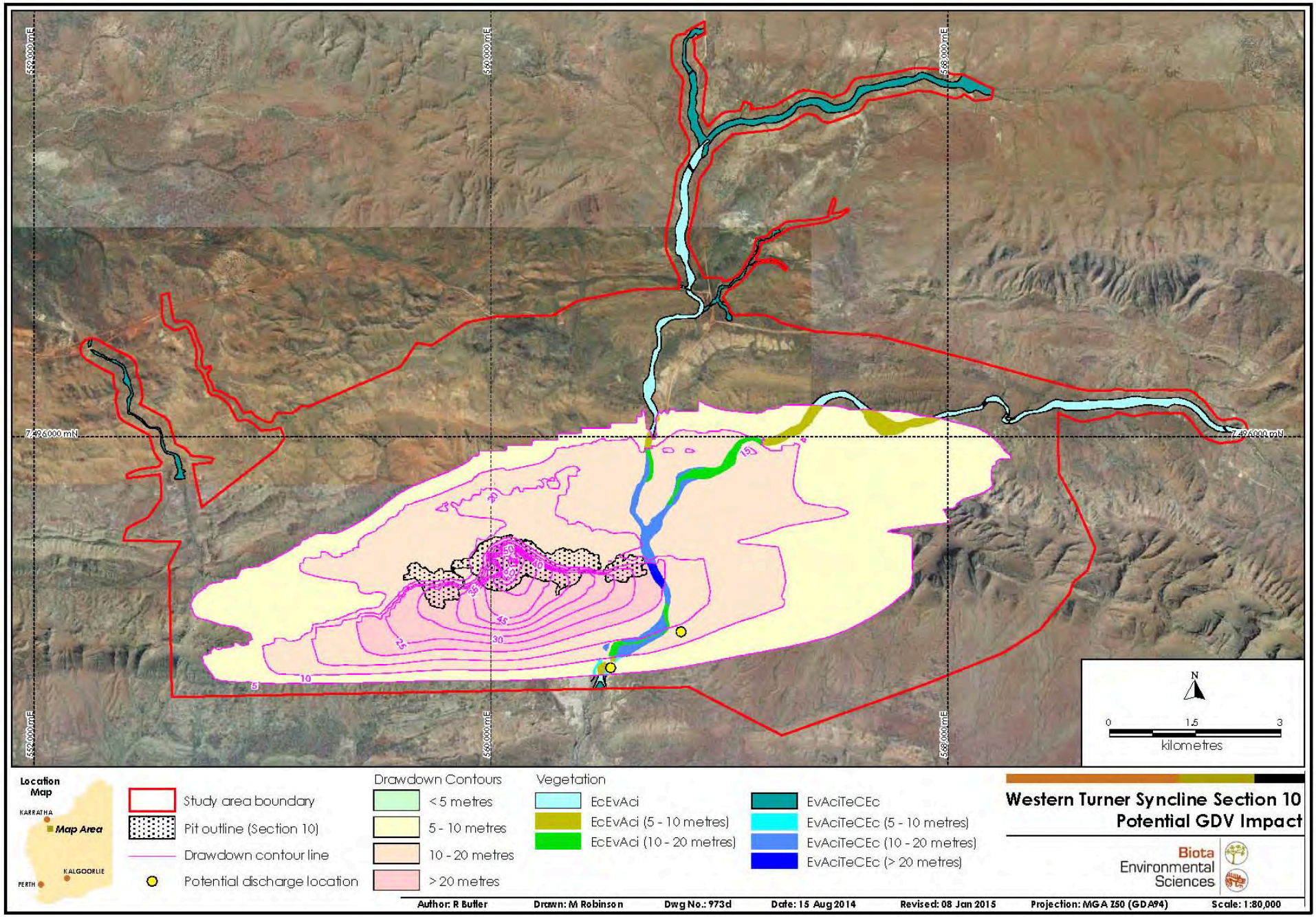


Figure 4.1: Modelled groundwater drawdown and GDV units at Section 10.

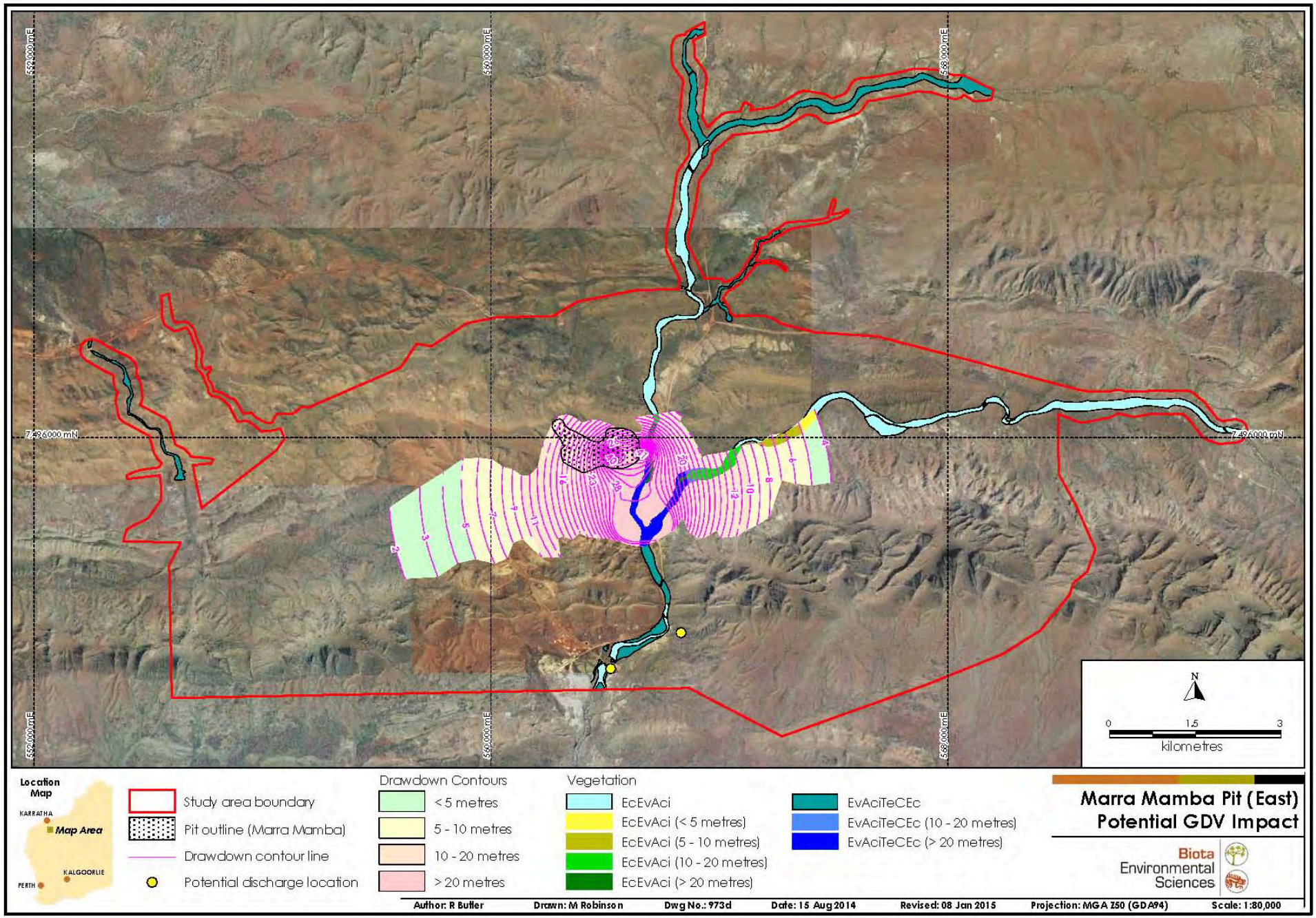


Figure 4.2: Modelled groundwater drawdown and GDV units at the Marra Mamba pit (east).

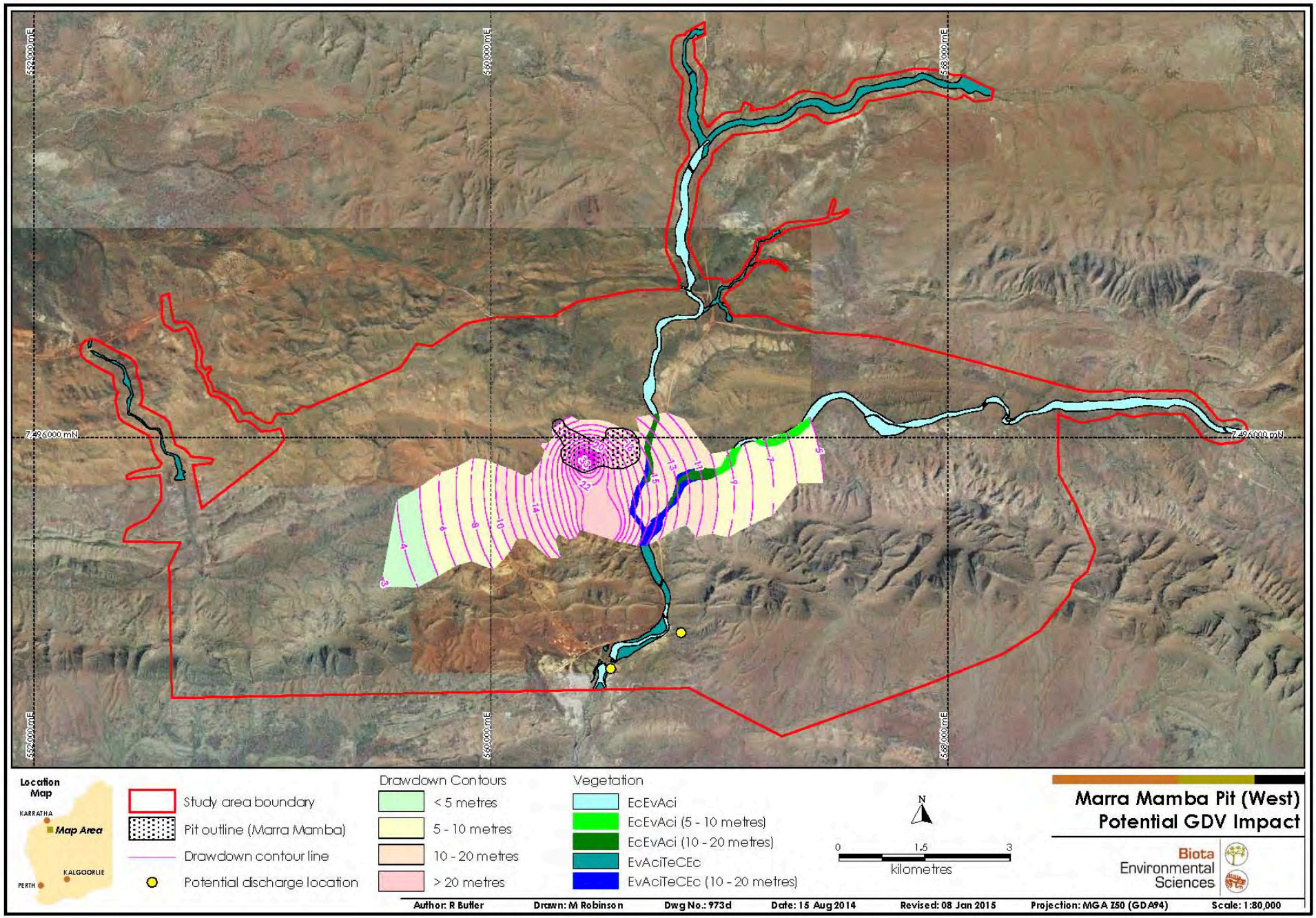


Figure 4.3: Modelled groundwater drawdown and GDV units at the Marra Mamba pit (west).

Table 4.2: Analysis of GDV units potentially affected by groundwater drawdown.

Vegetation Unit	Groundwater Drawdown (m)	Potential Impacts	Area (ha)			
			WTS S10	MM East	MM West	Overall*
Phreatophytic vegetation						
EcEvAci	<5	No impact expected	-	4.6	-	4.6
	5 - 10	Unlikely to impact phreatophytic species	46.7	8.8	23.4	43.7
	10 - 20	Stress and potential loss of phreatophytic species	36.1	16.8	15.3	30.9
	>20	Likely loss of phreatophytic species over longer term	-	10.4	-	10.4
		Total:	82.8	40.6	38.7	89.6
Mesophytic vegetation						
EvAciTeCEc	<5	No impact expected	-	-	-	-
	5 - 10	Unlikely to impact mesophytic species	1.9	-	-	1.9
	10 - 20	Potential stress on mesophytic species	52.7	1.4	28.2	25.9
	>20	Potential loss of mesophytic species	5.5	26.9	-	32.3
		Total:	60.1	28.3	28.2	60.1

* Overall impact calculated by combining the extent of the two pit drawdowns and removing overlaps by assigning worst case impact level to areas affected by both S10 and Marra Mamba (east and west) (see text at bottom of page 15).

A total of 89.6 ha of the phreatophytic vegetation unit EcEvAci falls within overall combined extent of the Section 10 and Marra Mamba drawdowns, with the majority of the overall potential impact on this unit (43.7 ha) accounted for by predicted drawdown in the 5-10 m range (Table 4.2). While monitoring would be advisable, a drop of 5-10 m is unlikely to adversely affect the GDV vegetation in these areas. Lowering of the water table by 10-20 m accounts for a further 30.9 ha of the predicted drawdown impacts on EcEvAci (Table 4.2), which may result in stress and potential loss of individual phreatophytes in these areas. Only 10.4 ha of EcEvAci falls into the highest risk category of drawdown >20 m, which is associated with the Marra Mamba pit dewatering (Table 4.2).

A total of 60.1 ha of the mesophytic vegetation unit EvAciTeCEc falls within the overall predicted drawdown, with 27.8 ha of the potential impact falling within predicted water table depression of <20 m, which may result in stress but is unlikely to lead to loss of this vegetation. The remaining 32.3 ha of potentially affected EvAciTeCEc occurs in areas of >20 m drawdown, where some loss of mesophytes could arise depending on duration of drawdown.

These predictions should be placed into context with the vegetation mapping from the broader WTS area (Biota 2013a, 2014). The percentage of each of the two vegetation units potentially impacted is compared to its total extent mapped for the broader WTS area within each of the drawdown categories in Table 4.3.

Table 4.3: Vegetation units potentially affected by groundwater drawdown and their percentage in the broader WTS locality based on the mapping completed for Biota (2013, 2014).

Vegetation Unit	Groundwater Drawdown (m)	Potential impact	Total Area (ha)	Proportion of Wider WTS Locality
Phreatophytic vegetation				
EcEvAci	<5	No impact expected	4.6	0.5%
	5 - 10	Unlikely to impact phreatophytic species	43.7	4.8%
	10 - 20	Stress and potential loss of phreatophytic species	30.9	3.4%
	>20	Likely loss of phreatophytic species over longer term	10.4	1.1%
Mesophytic vegetation				
EvAciTeCEc	<5	No impact expected	-	-
	5 - 10	Unlikely to impact mesophytic species	1.9	0.1%
	10 - 20	Potential stress on mesophytic species	25.9	1.8%
	>20	Potential loss of mesophytic species	32.3	2.2%

The wider vegetation surveys at WTS have mapped a total of 941.2 ha of the phreatophyic EcEvAci (Biota 2013a, 2014). While 30.9 ha of this vegetation type would potentially be impacted within the 10-20 m drawdown, this only represents 3.4% of the extent of this vegetation unit mapped for the broader WTS area (see Table 4.3). The highest impact risk of drawdown exceeding 20 m represents just 1.1% of the mapped extent (Table 4.3), and over 95% of the extent of this vegetation type mapped by Biota (2013a, 2014) would remain unaffected by drawdown.

Similarly, the mesophytic riparian vegetation EvAciTeCEc has a total mapped extent of 1,437.8 ha in the WTS locality (Biota 2013a, 2014). The area where potential loss of mesophytes might occur (drawdown of >20 m) represents 2.2% of the wider extent of the vegetation mapped at WTS, leaving over 1,400 ha unaffected by drawdown.

4.3 Impacts of Discharging Dewatering Water

Section 3.2 outlines the three options currently being proposed for disposing surplus dewatering water.

Options 1 (transferring dewatering water to another site or industrial use) and 2 (reintroduction to the aquifer(s)) will not result in any discharge of excess water to surface systems and would not have a detrimental effect on the vegetation of the receiving area.

Option 3 (discharge to natural watercourse(s)) would involve surface discharge of excess dewatering water into the Beasley or Hardey Rivers, with discharge into the Hardey River the current preferred option for the project.

The two proposed locations for point of discharge into the Hardey River are shown in Figure 4.1 to Figure 4.3.

Discharge into the Beasley River would entail reversing the flow of the pipeline currently supplying water to WTS Section 10 and disposal of excess water via a surface discharge point at B1, which has already been identified as part of existing approvals. The B1 operations will shortly commence dewatering and surplus water will be discharged as surface flow into a tributary of the Beasley River (Rio Tinto 2013b). Option 3 of the current assessment could potentially increase the volume of discharged water and the spatial extent of surface inundation. It is possible however, that as timing of peak discharge from Section 10 would be after the peak at B1, the additional volume may be able to be accommodated within current approval limits for B1 (Rio Tinto 2013a).

Prolonged surface flooding can be detrimental to many species that are adjusted to a seasonal cycle of wetting and drying (refer to Table 2.1). An existing riparian vegetation monitoring program is in place to monitor the effect of ongoing surface water discharge on the riparian values of the Beasley River (Biota 2013b, 2013c). The existing B1 operations has approval for the discharge water to reach up to 20 km downstream of the discharge point on the Beasley River (EPA 2013), with a maximum of 18 km downstream currently predicted (Rio Tinto 2013a). Dewatering rates, operational water needs at B1 and surface water discharge contribution from Section 10 will need to be accurately modelled and monitored to ensure that the addition of water from WTS Section 10 does not exceed the maximum discharge allowed. Provided this does not occur, no additional impacts on riparian vegetation would be predicted beyond those already identified and assessed in EPA (2013) and Rio Tinto (2013a). In the event that additional dewatering water from Section 10 will result in an increase beyond B1 approvals, the most pragmatic response to this in regards to riparian vegetation would appear to be a revision and expansion of the existing monitoring programme, which was designed to address the same potential impact from the B1 and Section 17 operations.

A similar riparian vegetation monitoring program for the Hardey River along the length of the dewatering water surface flow would need to implemented should this option proceed.

5.0 Glossary

Dominant species	The species that occur most abundantly in an area or vegetation stratum.
EPA	Environmental Protection Authority of Western Australia.
GDV	Groundwater dependent vegetation.
Mesophyte	Plant species that source their water primarily from the vadose zone of the soil profile.
Phreatophyte	Plant species that are primarily or totally reliant on groundwater.
Riparian	Vegetation associated with water and characterised by hydrophilic plants.
WTS	Western Turner Syncline.
Xerophyte	Plant species that are reliant on stored soil water and have no access to groundwater.

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Western Turner Syncline Section 10 Below Water Table and Satellite Ore Bodies Targeted Terrestrial Fauna Survey







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1.0 Summary

1.1 Background

Hamersley Iron Pty Ltd (Hamersley Iron) is proposing to mine below the water table and mine satellite pits at its operational Western Turner Syncline (WTS) Section 10 mine, located approximately 20 km northwest of Tom Price. Proposed mining includes the commencement of operational dewatering in 2017, and subsequent below water table (BWT) mining in 2018. In addition, Hamersley Iron is seeking approval to develop other Brockman/Marra Mamba prospective areas (pits and waste dumps) between Brockman 1 and Section 10.

Biota Environmental Sciences (Biota) was commissioned to carry out a targeted terrestrial fauna survey within a 6,660 ha survey area, forming part of the proposal. This report also considers an adjacent area that has been previously surveyed and forms the remainder of the proposed mining area (3,414 ha). The total 10,074 ha area is hereafter termed the study area.

The survey and reporting objectives were to:

- review previous biological reporting within the vicinity of the study area including wider-scale analysis from previous integration and WTS reports;
- determine the suitability of habitat for threatened fauna species;
- conduct targeted trapping for and recording of key threatened vertebrate fauna species, specifically the Northern Quoll (*Dasyurus hallucatus*), Orange Leaf-nosed Bat (*Rhinonicteris aurantius*), Pilbara Olive Python (*Liasis olivaceus barroni*) and Ghost Bat (*Macroderma gigas*);
- conduct targeted searches for potential Short Range Endemic (SRE) invertebrates;
- identify and assess the local and regional conservation significance of the fauna habitats in the study area; and
- highlight and discuss key biological factors specific to both the study area, and the broader WTS locality. This includes presentation of updated findings, combined mapping and calculations from the integration report (Biota 2013a) in order to place the current study area records into broader context.

1.2 Methodology

Following completion of a desktop review, the targeted field survey was conducted over a seven-day period from the 7th to the 13th of April 2014. A combination of survey techniques best suited to detecting the conservation significant target species was implemented. Work was undertaken in accordance with the relevant Environmental Protection Authority (EPA) Position Statement, Guidance Statements and Technical Guide (EPA 2002, 2004, 2009a, EPA and DEC 2010).

Systematic sampling using cage traps and large Elliott traps was conducted within the survey area at four sites located in specific targeted habitats deemed most likely to support the Northern Quoll (*Dasyurus hallucatus*). Two additional Elliott sites, six pit trapping sites and one funnel trapping site were previously established beyond the survey area, but within the broader study area. Data from these additional sites, which were surveyed in 2007 and 2008, were used in this report.

Motion cameras were deployed at seven sites within gorges and river beds with the aim of targeting Northern Quolls and Pilbara Olive Pythons. Additional non-systematic sampling focusing on recording evidence of the Pilbara Olive Python was also conducted.

Bat sampling was conducted at nine sites within gorges and river beds, primarily using echolocation call recorders. The sites were selected based on their suitability as potential flythrough habitats for the Orange Leaf-nosed Bat and Ghost Bat.

Twenty-three SRE terrestrial invertebrate search sites were surveyed within the study area. Specific invertebrate groups targeted during this survey included mygalomorph spiders, scorpions, pseudoscorpions, millipedes and terrestrial snails. Mygalomorph spiders and scorpions were targeted by visually locating and excavating burrows; pseudoscorpion searches were performed by turning over rocks and raking through soil and leaf litter; millipedes were searched for under leaf litter and logs; and aestivating land snails were targeted by collecting dead snail shells and digging under spinifex hummocks and in drainage gullies.

1.3 Results and Conclusions

1.3.1 Fauna Landforms and Habitats

Two landscapes were identified in the study area, each containing specific landforms. Of the landforms present, gorges, gullies and free faces were considered to represent the habitat of highest faunal value. These landforms have the potential to provide habitat for both the Northern Quoll and Pilbara Olive Python.

The Orange Leaf-nosed Bat was shown to be present at a single location within the study area and has the potential to forage over the majority of the study area. However, there is no evidence of any suitable roost sites for this species or the Ghost Bat.

1.3.2 Threatened Vertebrate Fauna

Of the targeted vertebrate fauna, only the Orange Leaf-nosed Bat was recorded within the study area. The Northern Quoll, Pilbara Olive Python and Ghost Bat were not recorded within the study area, although they have potential to occur.

Orange Leaf-nosed Bat (*Rhinonicteris aurantius*) (State: Schedule 1; Commonwealth: Vulnerable)
The Orange Leaf-nosed Bat was detected at a single location via two echolocation calls, most likely representing a transitory individual. There is no evidence of the existence of any suitable roost caves within the study area, or within the broader WTS area.

Northern Quoll (*Dasyurus hallucatus*) (State: Schedule 1; Commonwealth: Endangered)
The Northern Quoll typically inhabits rocky gorges and free faces. While this core habitat is present within the study area, recent and previous surveys at WTS have failed to record this species. There is therefore no evidence to suggest that a population of the Northern Quoll is currently present within the study area.

Pilbara Olive Python (*Liasis olivaceus barroni*) (State: Schedule 1; Commonwealth: Vulnerable)
Despite core habitat for this species (gorges and water holes) occurring in the study area, no individuals were recorded. However, Pilbara Olive Pythons have been recorded within the broader WTS area, and there is a high likelihood that they occur within the study area.

Ghost Bat (*Macroderma gigas*) (Department of Parks and Wildlife: Priority 4)
Although no Ghost Bats were recorded during the recent survey, one Ghost Bat has previously been detected in the broader WTS area (Biota 2013b). The species may therefore also occur in the study area periodically. However, similar to the Orange Leaf-nosed Bat, there is no evidence of the existence of any Ghost Bat roost caves within the study area, or within the broader WTS.

In regards to the above targeted fauna, impact on parts of habitat deemed "critical to the survival of the species" (DEWHA 2009) may occur within the study area during implementation of the proposed development. However, the scale, nature and context of the habitat removal during mine construction are deemed negligible both in respect to the Section 10 2014 survey area and to the total combined WTS study area, as only 3.9% and 1.1% respectively of the total core habitat has the potential to be adversely impacted.

Based on surveys of the broader WTS, the Biota (2012a) Western Turner National Environmental Significance (NES) species assessment report concluded that most significant impact criteria would not be triggered (DEWHA 2009), and the adverse affects on potential core NES habitat would be localised and minor in scale. Following the results of the current survey, this conclusion of low likelihood that the WTS development would result in a significant impact on any of the three targeted NES species remains unchanged. Similarly, no significant impact on the Priority 4 Ghost Bat is expected.

1.3.3 Potential SRE Invertebrate Fauna

Twelve mygalomorph spiders representing two families were recorded from 10 sites within the study area. Based on molecular analysis four putative species were identified; three of these represent potential SRE species, with one of these known solely from within the study area.

- *Aname mellosa* (Nemesiidae species N16) was recorded on seven occasions, at seven different locations within the study area. Individuals of this putative species have been recorded from over 200 locations in the Central Pilbara (Biota 2012 and Biota internal database) and as a result it is not considered to be an SRE taxon as defined by Harvey (2002).
- Nemesiidae sp. N13 is known from a single specimen collected approximately 22 km west of the town of Tom Price. With only a single specimen it is difficult to determine the SRE status this putative species. However, based both on the fact that is known solely from the study area and from the criteria outlined in Section 3.4.5.3 it is considered to be a potential SRE species.
- Barychelidae sp. B1 was recorded from one locations within the study area. It is known from 25 specimens collected from 23 locations in the Pilbara (Biota 2012 and Biota internal database). The current known distribution of this putative species is 6,398 km^2 and it therefore represents a potential SRE as defined by Harvey (2002).
- Barychelidae sp. B2 was recorded from two locations in the study area. It is known from 29 specimens collected from 15 locations in the Pilbara (Biota 2012 and Biota internal database). The current known distribution of this putative species is 6,730 km^2, also representing a potential SRE as defined by Harvey (2002).

Shells of dead camaenid snails were recorded from three sites within the study area. These have been preliminarily identified as *Rhagada* sp. "Mt Brockman". This species is not restricted to the study area.

Three millipedes were collected in leaf litter at a single site and were identified as *Austrostrophus stictopygus*, which is a widespread species throughout the Pilbara and not considered to be an SRE.

The landscapes and land systems represented in the study area appear relatively contiguous beyond the boundaries of this survey. There are no geomorphological or other habitat attributes that would suggest a high risk of species level distributions being restricted to the scale of the current study area.

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2.0 Introduction

2.1 Project Background

Hamersley Iron Pty Ltd (Hamersley Iron) is proposing to mine below the water table and mine satellite pits at its operational WTS Section 10 mine, located approximately 20 km northwest of Tom Price. Proposed mining includes the commencement of operational dewatering in 2017, and subsequent BWT mining in 2018. In addition, Hamersley Iron is seeking approval to develop other Brockman/Marra Mamba prospective areas (pits and waste dumps) between Brockman 1 and Section 10. These prospective areas require biological assessment and together comprise the 'study area' (Figure 2.1).

Biota has previously undertaken a series of terrestrial fauna surveys between 2007 and 2012 as part of the overall WTS development (see Section 2.5). As a result, part of the study area has previously been surveyed.

2.2 Objectives and Scope

Biota was commissioned to carry out a targeted terrestrial fauna survey within a 6,660 ha area, forming part of the proposed WTS study area, which is hereafter referred to as the 'survey area'. This report also considers the adjacent 3,414 ha area that has been previously surveyed, which forms the remainder of the 'study area' (Figure 2.2).

The field survey was planned and implemented according to the following EPA requirements:

- Position Statement No. 3 "Terrestrial Biological Surveys as an Element of Biodiversity Protection" (EPA 2002);
- Guidance Statement No. 56 "Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia" (EPA 2004);
- Guidance Statement No. 20 "Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia" (EPA 2009a); and
- Technical Guide: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA and DEC 2010).

Specific survey and reporting objectives were as follows:

- review previous biological reporting within the vicinity of the study area including wider-scale analysis from previous integration and WTS reports;
- determine the suitability of habitat for threatened fauna species;
- conduct targeted trapping for and recording of key threatened vertebrate fauna species, specifically the Northern Quoll (*Dasyurus hallucatus*), Orange Leaf-nosed Bat (*Rhinonicteris aurantius*) and Pilbara Olive Python (*Liasis olivaceus barroni*);
- conduct targeted searches for potential Short Range Endemic (SRE) invertebrates;
- identify and assess the local and regional conservation significance of the fauna habitats in the study area; and
- highlight and discuss key biological factors specific to both the study area, and the broader WTS locality. This includes presentation of updated findings, combined mapping and calculations from the integration report (Biota 2013a) in order to place the current study area records into broader context.

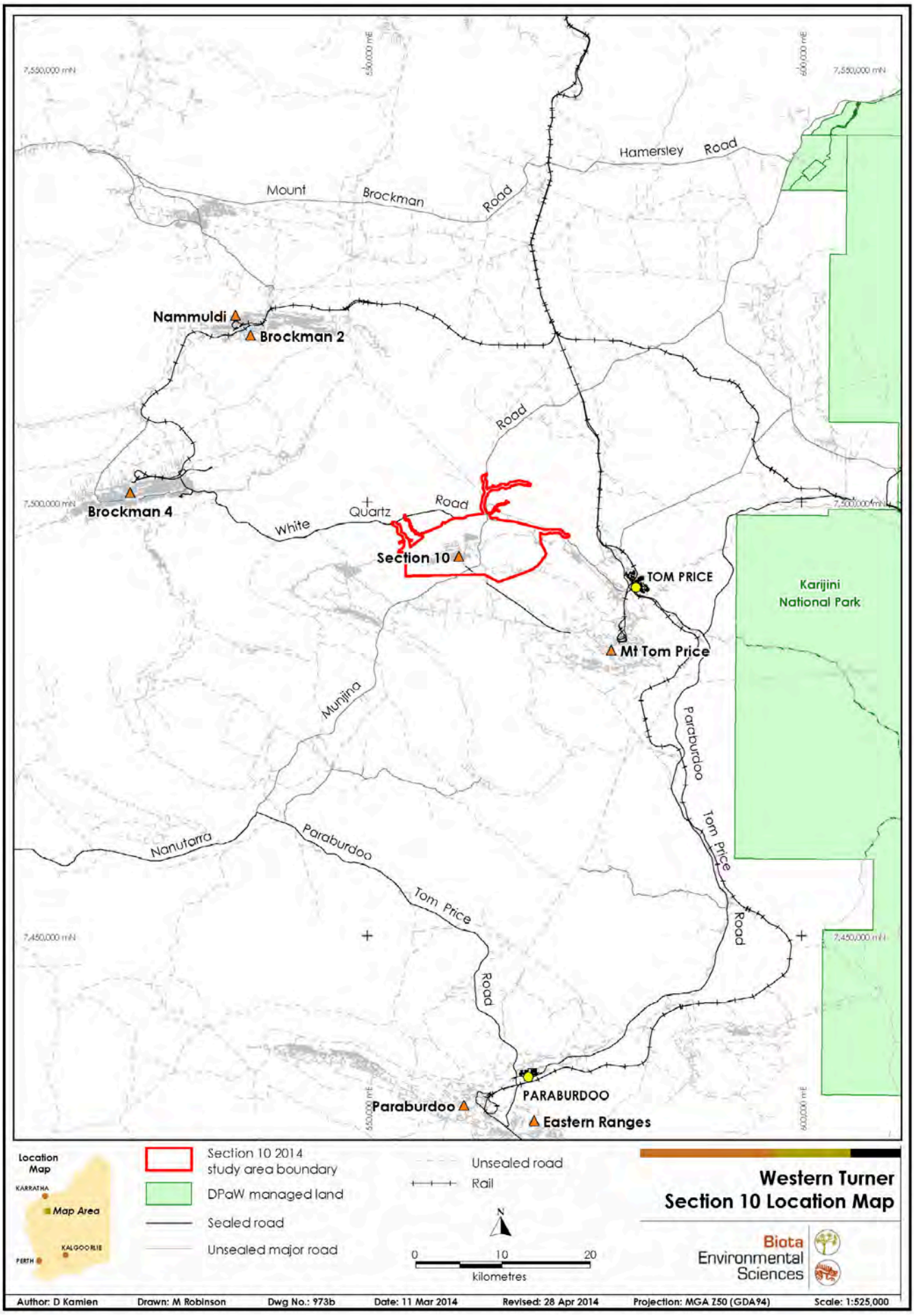


Figure 2.1: Section 10, 2014 study area location map.

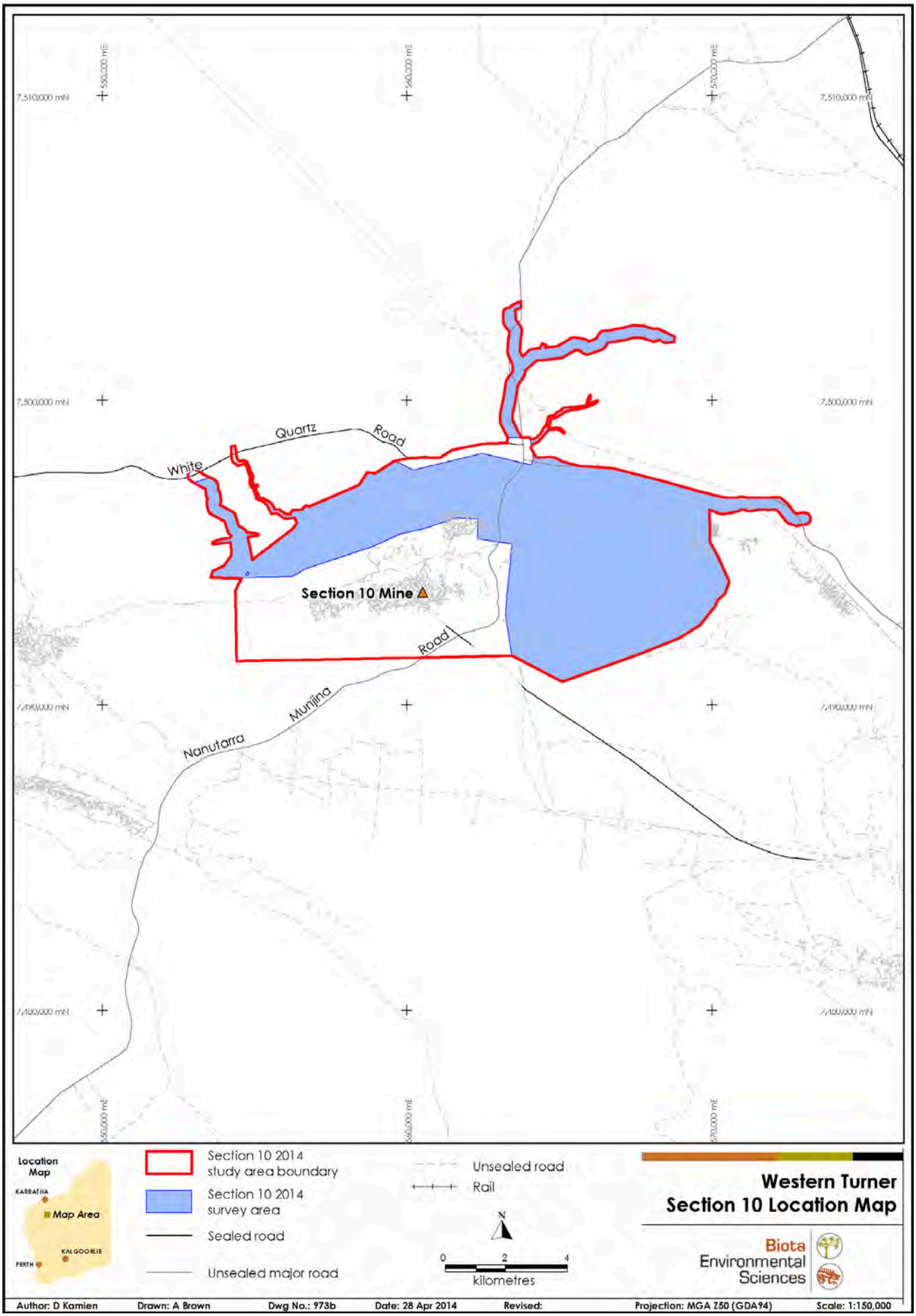


Figure 2.2: Map differentiating the 'study area' and 'survey area'.

2.3 Purpose of this Report

This report documents the methods and results of the WTS Section 10 below water table and satellite ore bodies targeted fauna survey, and discusses the conservation significance of the fauna habitats and taxa targeted in the context of the study area and the broader WTS area.

The over-arching purpose of this report is to meet relevant government policy requirements to a suitable standard to support referral under both State and Commonwealth legislation. This includes potential referral to both the State EPA under the WA *Environmental Protection Act 1986* and the Federal Department of the Environment (DotE) under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*.

Both the field survey and report are subject to specific limitations that are discussed in Section 3.5.

2.4 Targeted Taxa Overview

2.4.1 Vertebrate Fauna

2.4.1.1 Northern Quoll (*Dasyurus hallucatus*)

The Northern Quoll (Plate 2.1) is listed as Schedule 1 under the WA *Wildlife Conservation Act 1950* and Endangered under the Commonwealth *EPBC Act 1999*. It is a carnivorous dasyurid marsupial, which formerly occurred across much of northern Australia but is now considered to be restricted to six broad areas, including the Hamersley subregion in the Pilbara (DSEWPaC 2011).

The Northern Quoll favours rocky gorges, rocky free faces and hills, usually of high relief, and secondarily favours drainage lines (Biota 2009a, DSEWPaC 2011). Adjacent plains and vegetated areas provide habitats suitable for foraging and dispersal of young (van Dyck and Strahan 2008), but are considered to be of less importance for the species' conservation.



Plate 2.1: Northern Quoll, *Dasyurus hallucatus.*

2.4.1.2 Orange Leaf-nosed Bat (*Rhinonicteris aurantius*)

The Orange Leaf-nosed Bat (Plate 2.2) is listed as Schedule 1 under the WA *Wildlife Conservation Act 1950* and Vulnerable under the Commonwealth *EPBC Act 1999*. It is a relictual monotypic genus of the family Hipposideridae. An isolated population is found in the Pilbara region of Western Australia (van Dyck and Strahan 2008), although the species' wider distribution also includes the Kimberley region of Western Australia, the Northern Territory and north-western Queensland (Churchill 2008).

Occurrence of this species is influenced by the availability of suitable roost caves that offer high humidity and a stable temperature (Churchill et al. 2008). In the Pilbara, they are thought to be restricted to caves where semi-permanent or permanent water is nearby. Foraging typically occurs over open grasslands in gorges, low hills and on plains (Churchill et al. 2008).



Plate 2.2: Orange Leaf-nosed Bat, *Rhinonicteris aurantius*.

2.4.1.3 Pilbara Olive Python (*Liasis olivaceus barroni*)

The Pilbara Olive Python (Plate 2.3) is listed as Schedule 1 under the WA *Wildlife Conservation Act 1950* and Vulnerable under the Commonwealth *EPBC Act 1999*. It has a known distribution that approximately coincides with the Pilbara bioregion (Environment Australia 2000, DotE 2014). It occurs in rocky areas, showing a preference for gorges containing water in streams and rock pools (Wilson and Swan 2010).



Plate 2.3: Pilbara Olive Python, *Liasis olivaceus barroni.*

2.4.2 SRE Terrestrial Invertebrates

SRE invertebrates are groups of invertebrate fauna that display naturally small distributions (less than 10,000 km^2; Harvey 2002). These invertebrates often possess similar ecological and life-history characteristics, and are in part characterised by low fecundity, slow growth and poor dispersal capabilities (Harvey 2002). Examples exist from a range of groups including freshwater snails (Ponder and Colgan 2002), land snails (Johnson et al. 2004), and mygalomorph spiders (Main et al. 2000).

SRE invertebrates are often confined to disjunct 'refugial' habitats, having persisted from a time when moist conditions were more evenly distributed throughout the Australian landscape (Harvey 2002). Given their predisposition to restriction at small spatial scales, SRE fauna are more likely to experience population extinctions than more widely distributed taxa (Harvey 2002). The assessment of SRE taxa is therefore an important component of environmental impact assessment (EPA 2009a).

2.5 Previous WTS Surveys Overview

Prior to the current survey, Biota was commissioned by Rio Tinto to undertake a series of terrestrial fauna, flora and vegetation surveys as part of the overall WTS development. These included four stand-alone fauna surveys and reports, the results of which were subsequently presented in an integrated report (Biota 2013a). The latter report consolidated the vertebrate fauna recorded during these component surveys into an overall 24,265 ha WTS survey area.

A summary of previously conducted WTS fauna studies is provided in Table 2.1, with the spatial extents of all the supporting surveys in relation the current study area depicted in Figure 2.3.

Table 2.1: Summary of previous WTS studies.

Reference: Report Title	Survey Timing	Survey Description
Biota (2009b). West Turner Syncline Section 10 Development Two-Phase Fauna Survey.	Phase Ia: 12 – 23 July 2007; Phase Ib: 17 – 25 September 2007; Phase II: 21 – 29 July 2008.	Level 2 vertebrate and SRE fauna survey.
Biota (2009c). A Two-Phase Fauna Survey of the West Turner Syncline Area.	Phase Ia: 12 – 23 July 2007; Phase Ib: 17 – 25 September 2007; Phase II: 21 – 29 July 2008.	Level 2 vertebrate and SRE fauna survey.
Biota (2011a). West Turner Syncline Targeted Fauna Survey.	Phase I: 17 - 23 September 2011; Phase II: 4 - 10 October 2012.	Targeted vertebrate and SRE fauna survey
Biota (2013b). West Turner Syncline Stage 2 Extension Fauna Survey	Phase I: 3 – 11 October 2012.	Level 2 vertebrate and SRE fauna survey.

Data obtained from the above surveys have previously been used to assess the overall WTS development in regards to the significance of the predicted impacts of the proposed action under the terms of the *EPBC Act 1999*; specifically, relevant NES species (Biota 2012a, 2013a).

The above surveys also focussed on terrestrial SREs using results obtained from previously conducted WTS and Section 10 surveys (Biota 2009b, 2009c). A report addressing the mygalomorph spider habitat at Western Turner was compiled from these results, combined with vegetation and substrate data (Biota 2011b).

Previous survey effort at WTS comprised 73 systematic sites, utilising either pit traps, funnel traps or Elliott box traps, totalling an effort of 9,589 trap-nights. Overall, birds were censused for 84 hours at 48 sites, and bat sampling was conducted for a total of 81 survey nights at 17 sites in prospective habitat.

A combined total of 171 vertebrate fauna species were recorded during the previous four surveys. This total comprised one amphibian, 69 reptiles, 76 birds, 13 native ground-dwelling mammals, 10 bats and two introduced mammals.

Three species listed under both the Commonwealth *EPBC Act 1999* and the WA *Wildlife Conservation Act 1950* were recorded from the WTS vicinity during the previous surveys:

- Pilbara Olive Python, *Liasis olivaceus barroni* (Commonwealth: Vulnerable, State: Schedule 1): This species was recorded twice within the WTS survey area in a gully and on a rocky free face with debris slope (Biota 2009b, 2011a).
- Orange Leaf-nosed Bat, *Rhinonicteris aurantius* (Commonwealth: Vulnerable, State: Schedule 1): Two echolocation calls were detected within the Western Turner Targeted study area (Biota 2011a) and the Western Turner Stage 2 Extension study area (Biota 2013b). These calls indicate transient individuals and not the presence of a roosting colony.
- Rainbow Bee-eater, *Merops ornatus* (Commonwealth: Migratory, State: Schedule 3): The Rainbow Bee-eater is very common regionally (Burbidge et al. 2010) and was recorded 30 times from seven sites across all Western Turner surveys.

In addition, four species listed as Priority 4 by the Department of Parks and Wildlife have previously been recorded in the WTS vicinity (Department of Parks and Wildlife 2013):

- Western Pebble-mound Mouse, *Pseudomys chapmani* was trapped or detected from active mounds at 14 sites;
- Australian Bustard, *Ardeotis australis* was recorded on three occasions;
- Ghost Bat, *Macroderma gigas* was detected on a single occasion; and
- the skink *Notoscincus butleri* was recorded once.

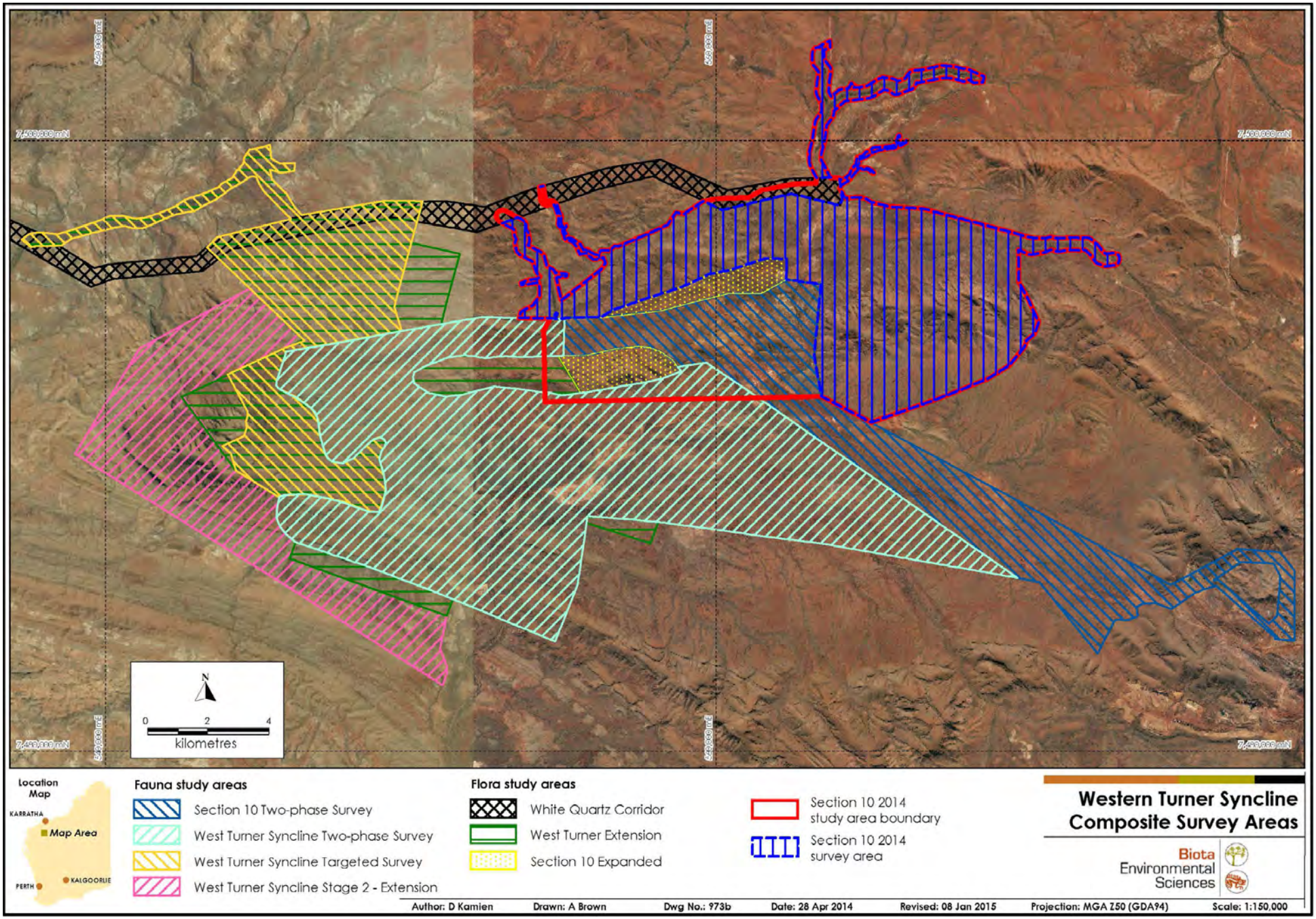


Figure 2.3: Spatial extent of individual studies at Western Turner Syncline.

3.0 Methodology

3.1 Desktop Review

3.1.1 Literature

In addition to the previous WTS surveys outlined in Section 2.5, a number of additional vertebrate and SRE fauna surveys have previously been conducted in the locality of the study area (within 40 km). Table 3.1 provides a summary of the reports reviewed to provide context to the current study.

The species recorded during these surveys and the previous WTS surveys (Section 2.5) were used in conjunction with the database searches (see Section 3.1.2) to compile a potential species list for the study area (Appendix 1).

Table 3.1: Previous studies conducted within 40 km of the study area.

Report/Survey	Survey Phase: Dates	Description of Survey
Biota (2005) Fauna Habitats and Fauna Assemblage of the Brockman Syncline Project, near Tom Price: Seasonal Survey Report.	1: 18/10/04 – 30/10/04 2: 12/04/05 – 21/04/05	Level 2 vertebrate and SRE fauna survey.
Biota (2009d). Tom Price Marra Mamba Level 1 Fauna Survey.	1: 05/09/07 – 07/09/07	SRE fauna survey and Level 1 desktop vertebrate fauna review.
Biota (2009e). Tom Price Power Line West Detritals: Two-Phase Fauna Survey.	1: 17/9/07 – 25/9/07 2: 03/9/08 – 10/9/08	Level 2 vertebrate and SRE fauna survey.
Biota (2009f). Beasley River Limonites Baseline Fauna Survey.	1: 21/05/09 – 31/05/09	Level 1 vertebrate and SRE fauna survey.
Biota (2009g). A Targeted Terrestrial Fauna Survey of the Brockman Syncline 2 Pit 7 Extension Area.	1: 07/09/09 – 11/09/09	Targeted vertebrate and SRE fauna survey.
Biota (2010). Brockman 2 Sustaining Tonnes Targeted Fauna Survey.	1: 27/04/10 – 06/05/10	Targeted vertebrate and SRE fauna survey.
Biota (2013c). Marra Mamba Targeted Fauna Survey.	1: 28/08/12 – 04/09/12	Targeted vertebrate and SRE fauna survey.

3.1.2 Database Searches

The following databases were searched to assist in determining the potential faunal assemblage of the study area:

1. NatureMap database (http://NatureMap.dec.wa.gov.au): a joint project of the Department of Parks and Wildlife and the Western Australian Museum (WAM). This database represents the most comprehensive source of information on the distribution of Western Australia's flora and fauna, and includes fauna records from the Fauna Survey Returns Database and WA Threatened Fauna Database (both managed by the Department of Parks and Wildlife), the WAM Specimen Database, and the Atlas of Australia Birds. The database search was conducted on April 29, 2014 and requested the return of records from a radius of 40 km from a central point within the study area (22°38'51"S, 117°36'48"E) (see Appendix 1)
2. The Commonwealth *EPBC Act 1999* Protected Matters database (Appendix 1). The database search was conducted on April 29, 2014 and requested the return of records from the circle radius of 40 km from a central point within the study area (22°38'51"S, 117°36'48"E).
3. The Atlas of Living Australia (http://www.ala.org.au/): a joint project between academic collecting institutions, private individual collectors and community groups. The atlas contains occurrence records, environmental data, images and the conservation status of species throughout Australia. The database search was conducted on April 29, 2014 and requested the return of records from a radius of 40 km from the central point (22°38'51"S, 117°36'48"E) (see Appendix 1).

3.2 Survey Timing and Weather

The survey was conducted over a seven-day period between the 7th and 13th April 2014. Rainfall and temperature data for the period were obtained from the nearest reliable Bureau of Meteorology (BoM) station at Paraburdoo Airport (station 7185; approximately 55 km south of the survey area). These indicate that during the survey, the minimum temperature ranged from 18.2°C to 21.0°C, while maximum temperature ranged from 30.5°C to 36.9°C. No rain fell during the survey (Table 3.2).

Table 3.2: Daily weather observations at Paraburdoo Airport for the duration of the field survey.

Date	April 7	April 8	April 9	April 10	April 11	April 12	April 13	Average
Minimum Temperature (°C)	19.7	20.1	19.4	18.2	19.5	20.9	21.0	19.8
Maximum Temperature (°C)	30.5	31.4	34.4	35.4	36.6	36.9	35.4	34.4
Rainfall (mm)	0	0	0	0	0	0	0	0

(data supplied by BOM).

Long-term and recent climatological data for Paraburdoo Airport indicate that the mean minimum and maximum temperatures for the six months leading up to the survey were in accordance with the long term average (Figure 3.1). Total rainfall for the six months leading up to the survey was also close to average, but on a monthly basis it was below average for four of the six months leading up to the survey. December and January received greater than average monthly rainfall (Figure 3.1).

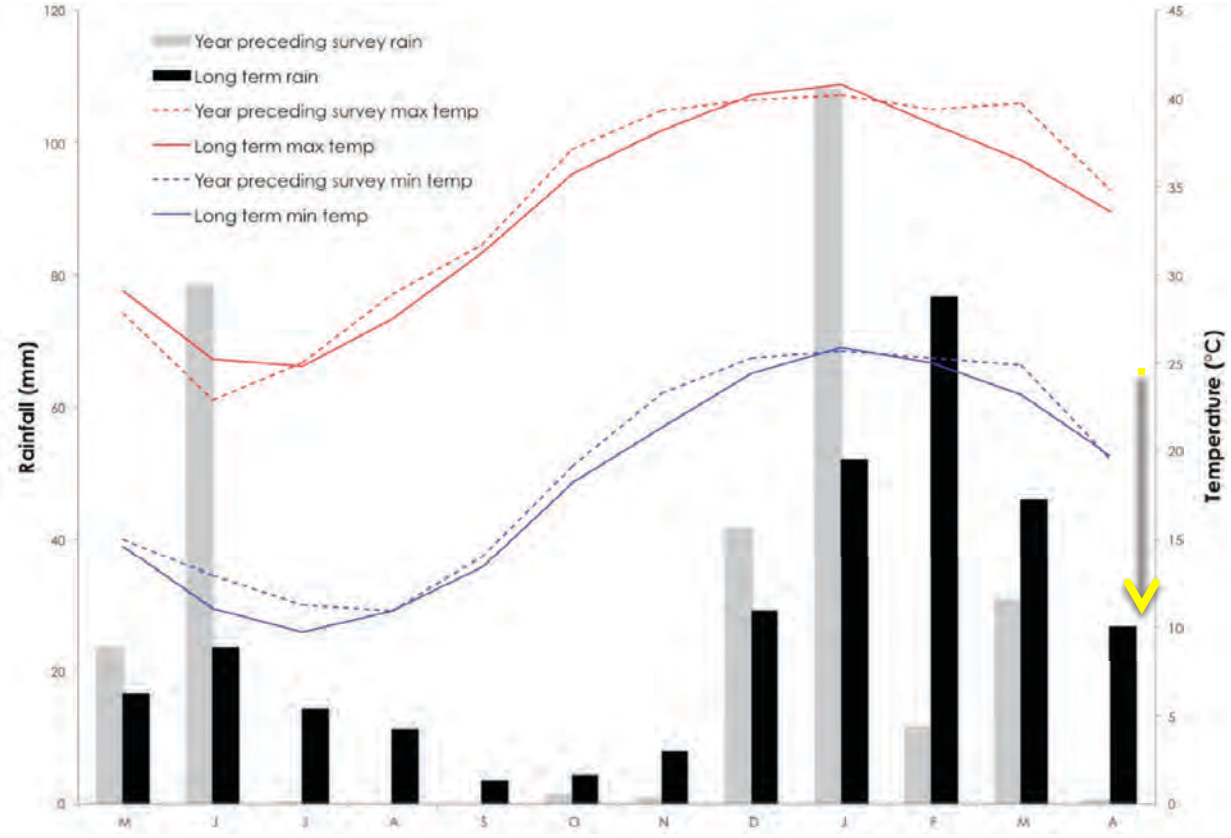


Figure 3.1: Long-term and recent climatological averages recorded at Paraburdoo Airport.
Data supplied by BOM: year preceding the survey (May 2013-March 2014); long-term rainfall data (1974-2014); long-term temperature data 1996- 2013); arrow indicates survey timing.

3.3 Fauna Survey Team

The survey was conducted under "Licence to Take Fauna for Scientific Purposes" No. SF009675 issued to Mr Dan Kamien (Appendix 2). The fauna survey team comprised Mr Dan Kamien, Mr Chris Cole and Dr Sylvie Schmidt (all from Biota).

Identification of SRE taxa was conducted by Mr Chris Cole and Dr Mieke Burger (Biota) by examination of both spider morphology and burrow characteristics.

3.4 Fauna Sampling

3.4.1 Northern Quoll Trapping

Trapping to determine the presence of the Northern Quoll (*Dasyurus hallucatus*) was conducted primarily with large Elliott traps. During the 2014 survey, systematic sampling was centred on four main trapping sites, each consisting of four cage traps (60 x 20 x 20 cm) and 30 large Elliott box traps (Table 3.3 and Figure 3.2). Two additional Elliott trapping sites were also previously completed in the wider WTS study area, each comprising 25 medium Elliott traps (Biota 2009b) (Table 3.3).

Elliott traps were spaced approximately 15 m apart and were located in specifically targeted habitats with the potential to support Northern Quoll. Traps were baited with a mixture of oats, peanut butter and bacon and were deployed for a total of 1,359 trap nights (Table 3.3).

Table 3.3: Trapping site locations and effort.

Site	Location	Landform	Date Opened	Date Closed	Number of Traps		Number of Nights	Trap Nights
					Elliott	Cage		
WTF01E	561049 mE, 7495772 mN	Narrow, rocky gorge.	7/4/2014	14/4/2014	30	4	7	238
WTF02E	566004 mE, 7493226 mN	Broad, rocky gorge.	8/4/2014	15/4/2014	30	4	7	238
WTF03E	568085 mE, 7493307 mN	Narrow, rocky gorge.	8/4/2014	15/4/2014	30	4	7	238
WTF04E	569057 mE, 7496449 mN	Broad ephemeral river bed.	8/4/2014	15/4/2014	30	4	7	238
WTS15E	562702 mE, 7493824 mN	Rocky free face	16/07/07	16/07/07	25	0	6	150
			22/07/08	28/07/08	22	0	6	132
WTC16E	562992 mE, 7493006 mN	Rocky free face	18/09/07	23/09/07	25	0	5	125
					Total Elliott trapping effort			1,247
					Total cage trapping effort			112
					Total trapping effort			1,359

Coordinates in zone 50, GDA94.
Grey shading indicates previous survey site.

Infrared motion cameras were deployed at seven locations (Table 3.4, Figure 3.2 and Plate 3.1 to Plate 3.6), for a total of 23 trap nights. Bait was placed on the ground in front of the camera to attract animals to the desired area in view of the camera.

Table 3.4: Remote camera locations and sampling effort.

Site	Location	Landform	Date Set	Date Recovered	Sampling Effort (nights)
WTF01aM	560990 mE, 7495812 mN	Narrow, rocky gorge.	8/4/2014	10/4/2014	2
WTF01bM	560992 mE, 7495901 mN	Narrow, rocky gorge.	10/4/2014	14/4/2014	4
WTF02M	565951 mE, 7493627 mN	Broad, rocky gorge.	9/4/2014	14/4/2014	5
WTF03aM	568116 mE, 7493052 mN	Stony pediment.	8/4/2014	10/4/2014	2
WTF03bM	568101 mE, 7493486 mN	Narrow, rocky gorge; camera adjacent to 40 cm wide water pool.	10/4/2014	14/4/2014	4
WTF04aM	569030 mE, 7496382 mN	Broad ephemeral river bed; camera adjacent to 10m wide water pool.	8/4/2014	11/4/2014	3
WTF04bM	568949 mE, 7496620 mN	Broad ephemeral river bed, adjacent to rock face.	11/4/2014	14/4/2014	3
Coordinates in zone 50, GDA94.			Total effort (nights)		23



Plate 3.1: Representative habitat at site WTF01aM and WTF01bM.



Plate 3.2: Site WTF02M.



Plate 3.3: Site WTF03aM.



Plate 3.4: Site WTF03bM.



Plate 3.5: Site WTF04aM.



Plate 3.6: Site WTF04bM.

3.4.2 Other Systematic Trapping Sites

Other previously sampled systematic trapping sites within the study area comprised dry pit traps and funnel traps (Table 3.5 and Figure 3.2). These were sampled within Section 10 during 2007 and 2008 (Biota 2009b).

Table 3.5: Other previous systematic trapping sites within the study area.

Site	Type	Location	Landform	Date Set	Date Recovered	Number of Traps	Number of Nights	Sampling Effort (nights)
WTS12	Pit trap	556350 mE, 7493702 mN	Plain.	16/07/2007	22/07/2007	10	6	60
				21/07/2008	27/07/2008	10	6	60
WTS13	Pit trap	558669 mE, 7494225 mN	Alluvial plain with mulga.	17/07/2007	23/07/2007	10	6	60
				22/07/2008	28/07/2008	10	6	60
WTS14F	Funnel trap	561729 mE, 7493728 mN	Rocky hill slope.	16/07/2007	22/07/2007	20	6	120
				21/07/2008	27/07/2008	20	6	120
WTS15	Pit trap	562776 mE, 7493914 mN	Ephemeral riverbed.	17/07/2007	23/07/2007	10	6	60
WTS16	Pit trap	562967 mE, 7492964 mN	Hill slope.	17/07/2007	23/07/2007	10	6	60
				22/07/2008	28/07/2008	10	6	60
WTS17	Pit trap	560531 mE, 7494746 mN	Minor drainage line.	17/07/2007	23/07/2007	10	6	60
				23/07/2008	29/07/2008	10	6	60
WTS21	Pit trap	559841 mE, 7493240 mN	Plain.	16/07/2007	22/07/2007	10	6	60
				23/07/2008	29/07/2008	10	6	60
						Total pit trap effort		660
						Total funnel trap effort		240
						Total trapping effort		900

Coordinates in zone 50, GDA94.
Grey shading indicates previous survey site.

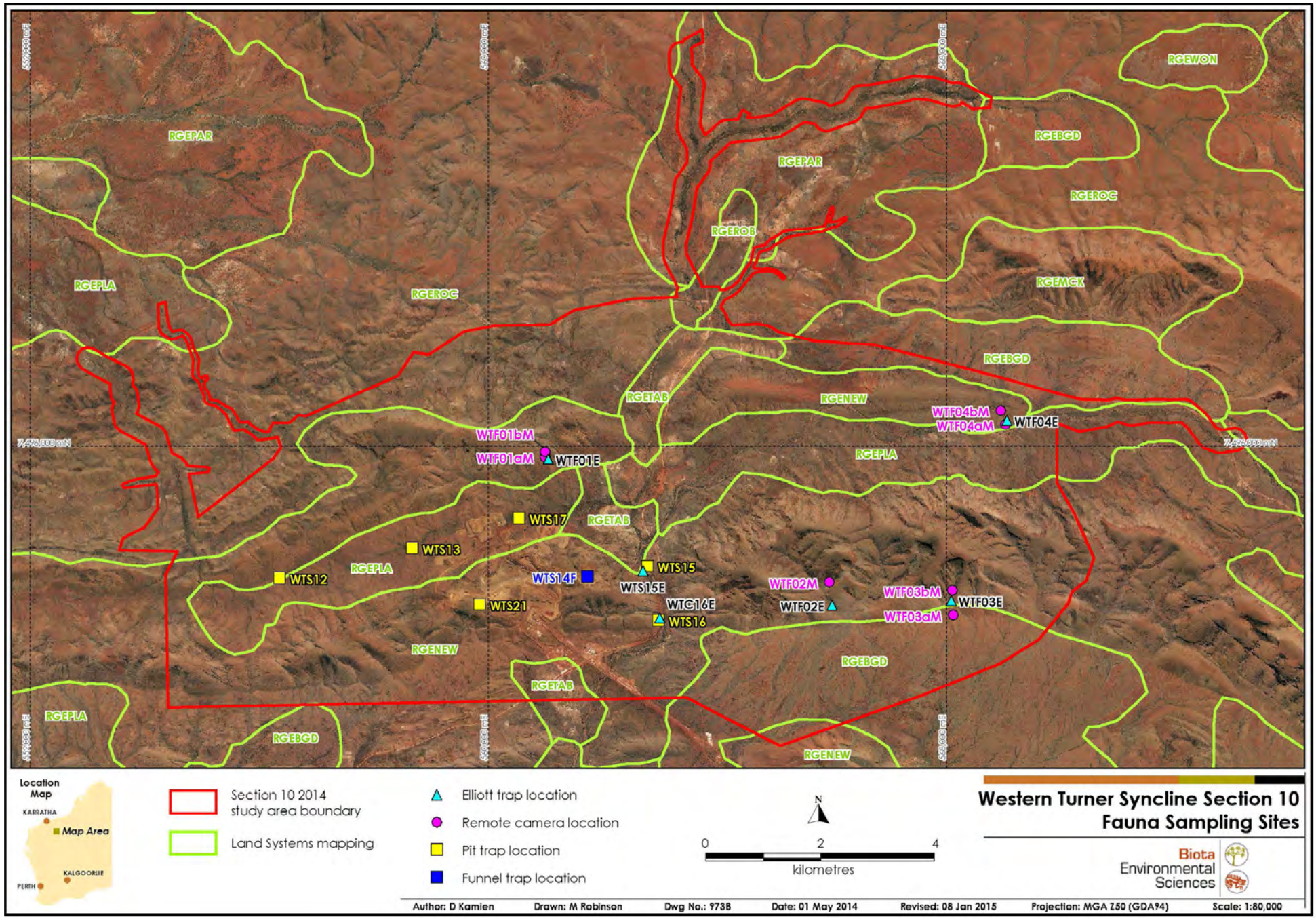


Figure 3.2: Non-volant (non-flying) vertebrate sampling sites within the study area.

3.4.3 Bats

Bat sampling within the survey area focussed on detecting the presence of the Schedule 1 Orange Leaf-nosed Bat (*Rhinonicteris aurantius*) and the Priority 4 Ghost Bat (*Macroderma gigas*). Echolocation calls were recorded using SM2BAT SongMeters, which detect and record ultrasonic echolocation calls emitted during bat flight (Wildlife Acoustics 2010). Sampling was undertaken at eight locations within the survey area at locations considered likely to provide Orange Leaf-nosed Bat or Ghost Bat records, including potential commuting and foraging routes in the vicinity of caves, at rocky free faces and gorges (Table 3.6, Figure 3.3 and Plate 3.7 to Plate 3.15). SM2BAT SongMeters and harp traps were deployed for a total of 23 trap nights (Table 3.6).

Additionally, while travelling and working within the study area the characteristics of any identified caves were assessed in regards to their suitability as roost sites for Orange Leaf-nosed Bats and Ghost Bats. Searches for Ghost Bat scats and midden piles were also conducted.

Bat call recordings were reformatted as .wav files and reviewed using Kaleidoscope software (Wildlife Acoustics Inc, USA), which displays each call sequence for identification, including information on the number and timing of calls. The settings used on each SM2 detector are provided in Appendix 3.

Orange Leaf-nosed Bat and Ghost Bat calls were confirmed by recognition of the species' distinctive diagnostic ultrasonic call characteristics (echolocation calls of 120 kHz). Orange Leaf-nosed Bat calls were analysed by Mr Dan Kamien, and Ghost Bat calls were analysed by Mr Bob Bullen (Batcall WA). Call analysis of both species used methods recommended by the Australasian Bat Society (2006), in conjunction with available reference data (McKenzie and Bullen 2009) (see Appendix 4).

One previous bat sampling site is located in the study area (Table 3.6). Here, bat echolocation calls were recorded using an Anabat II bat detector. The calls were stored on a compact flash card after being processed by an Anabat CF ZCAIM. Calls were visualised on Analook 3.3f software. Bats were also sampled using direct capture via harp traps during previous surveys (Biota 2009b) (see Table 3.6).

Table 3.6: Bat sampling locations and effort.

Site	Location	Landform	Date Set	Date Recovered	Sampling Effort (Nights)
WTFBat85-1	561028 mE, 7495805 mN	Narrow, rocky gorge.	8/4/2014	10/4/2014	2
WTFBat85-2	560980 mE, 7495800 mN	Narrow, rocky gorge.	10/4/2014	12/4/2014	2
WTFBat85-3	565884 mE, 7494997 mN	Rocky free face.	12/4/2014	14/4/2014	2
WTFBat88-1	569022 mE, 7496381 mN	Broad ephemeral riverbed; SM2 adjacent to 10m wide water pool.	8/4/2014	10/4/2014	2
WTFBat88-2	565868 mE, 7493371 mN	Broad rocky gorge.	10/4/2014	12/4/2014	2
WTFBat88-3	563971 mE, 7497195 mN	Rocky free face.	12/4/2014	14/4/2014	2
WTFBat54-1	568107 mE, 7493494 mN	Narrow, rocky gorge; camera adjacent to 40 cm wide water pool.	9/4/2014	11/4/2014	2
WTFBat54-2	563721 mE, 7495295 mN	Broad ephemeral riverbed.	11/4/2014	13/4/2014	2
WTSBat05	562635 mE, 7494143 mN	Ephemeral river; Anabat unit adjacent to water hole.	25/7/2008	28/7/2008	3
		Ephemeral river; harp trap adjacent to water hole.	24/7/2008	28/7/2008	4
Coordinates in zone 50, GDA94. Grey shading indicates previous survey site.			Total Effort (nights)		23



Plate 3.7: Site WTFBat85-1.



Plate 3.8: Site WTFBat85-2.



Plate 3.9: Site WTFBat85-3.



Plate 3.10: Site WTFBat88-1.



Plate 3.11: Site WTFBat88-2.



Plate 3.12: Site WTFBat88-3.



Plate 3.13: Site WTFBat54-1.



Plate 3.14: Site WTFBat54-2.



Plate 3.15: Site WTSBat05.

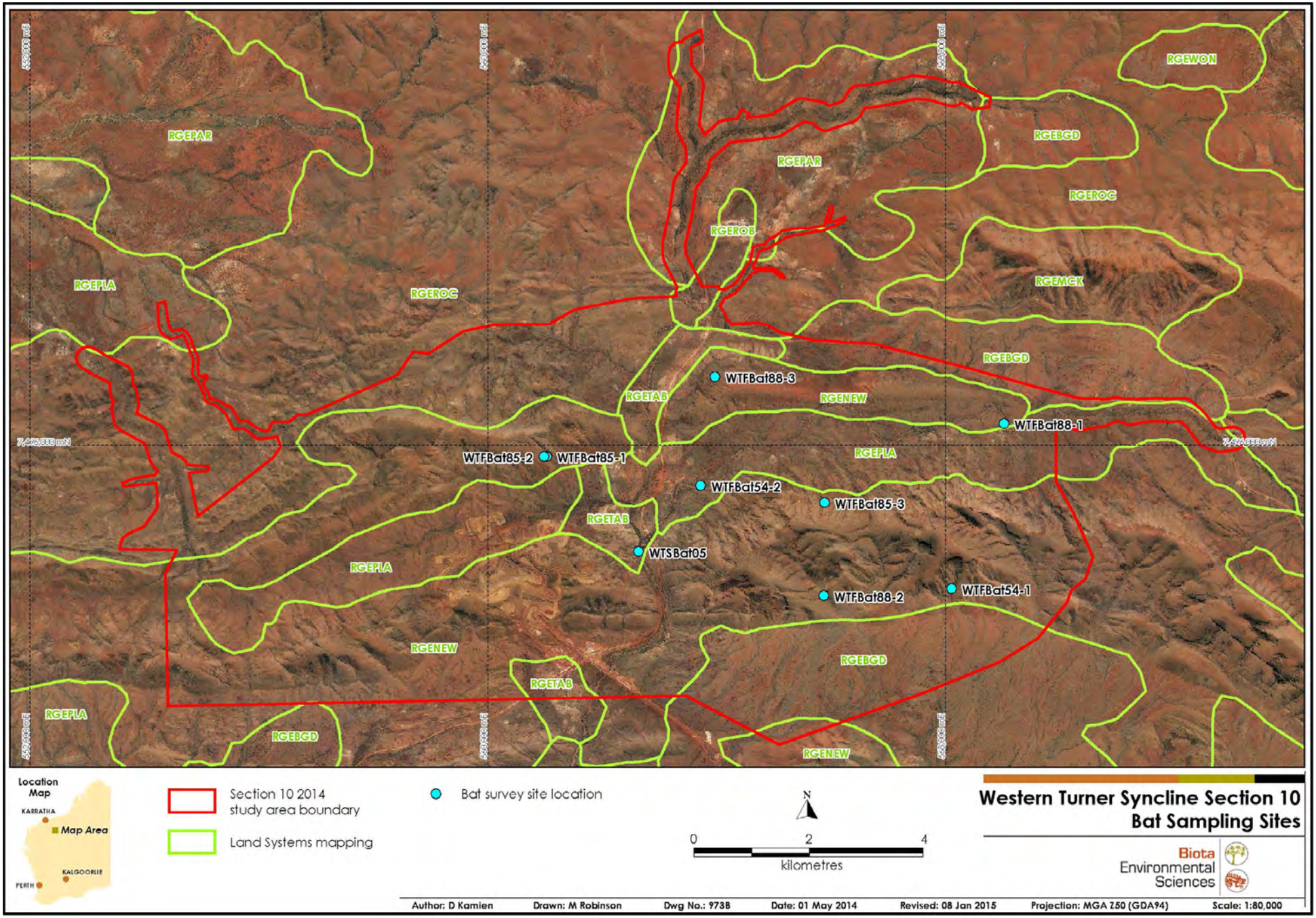


Figure 3.3: Bat sampling sites within the study area.

3.4.4 Non-systematic Searches

Non-systematic searches for evidence of the Pilbara Olive Python were conducted with a focus on trace records such as tracks, scats, burrows and skin sloughs. Searches were conducted at ephemeral pools (typical Pilbara Olive Python habitat) and while moving through the survey area during vertebrate and invertebrate sampling (see Section 3.4.4). Remote camera footage was also examined for python occurrence.

Evidence of Northern Quoll activity was also further assessed via the presence or absence of trace records (tracks and scats) throughout the study area.

3.4.5 SRE Invertebrate Sampling

3.4.5.1 Morphological identification

Collected specimens were lodged with the WAM for taxonomic identification. Tissue samples from mygalomorph spiders were lodged with the WAM for molecular analysis.

3.4.5.2 Genetic Analysis of Mygalomorph Spiders

Mygalomorph spiders are commonly recorded in the Pilbara bioregion, however very few of these have been resolved to the species level (source: Biota internal database). This report makes use of a broader genetic study into mygalomorph spiders to help infer putative species boundaries and better identify distributions.

The WAM carried out the relevant molecular analysis using sequence data derived from their collection. Specimens collected from the Yandi survey area were assigned to corresponding lineages based on Bayesian analysis of COX1 haplotypes. Previous assessments have been provided based on combining samples into species if they show less than 9.5% sequence divergence (Biota 2012b).

3.4.5.3 Determining SRE Status

The invertebrate taxa that are most likely to contain SRE fauna that were targeted during the survey included mygalomorph spiders, scorpions, pseudoscorpions, millipedes and terrestrial land snails. Table 3.7 details the criteria used to categorise the SRE status of putative species.

Table 3.7: Criteria used to classify SRE status.

SRE Status	Defining Criteria
Known SRE	• Species, morphotype or genetic type has a documented range of <10,000 km2. • Species, morphotype or genetic type is well collected with numerous specimens typed and habitat preference understood.
Potential SRE	• Species, morphotype or genetic type has a documented range of <10,000 km^2 but is poorly sampled. • Specimen may not be formally described or assigned to a morphotype / genetic type. • Short-range endemism may be common in genus or family. • May have been collected from restricted, refugial or isolated habitats
Unlikely to be an SRE	• Species, morphotype or genetic type has a documented range of <10,000 km^2 but is poorly sampled. • Specimen may not be formally described or assigned to a morphotype / genetic type. • Short-range endemism is not common in genus or family. • It was not collected from restricted, refugial or isolated habitats. • Few other individuals of the taxon collected, but records separated by long distances (>100 km).
Not an SRE	• Specimen formally described or assigned to a morphotype / genetic type. • Species, morphotype or genetic type has a documented range of >10,000 km^2.
Undetermined	• Taxa where there is insufficient taxonomic framework available to provide any informed comment on the species-level distribution of the fauna or, therefore, the risk of small-scale spatial restrictions.

3.4.5.4 Sampling Effort

Targeted searches were conducted within habitats considered likely to support SRE invertebrate fauna for a cumulative effort of over 29 person hours (Table 5.3 and Figure 3.4). SRE site descriptions are outlined in Section 5.1.

Mygalomorph spiders were targeted by visually searching for burrows, which were subsequently excavated. During excavation, a hole was dug adjacent to each burrow, allowing the burrow to be tracked below ground until the specimen was located. Specimens were collected and preserved in 70% ethanol for morphological description. Two legs were removed and each was placed in 100% ethanol to preserve DNA for molecular analysis.

Visual searches for scorpion burrows were conducted and scorpions were collected opportunistically while searching under rocks and raking through soil and leaf litter. Specimens were preserved in 70% ethanol.

Searches for pseudoscorpions were performed by turning over rocks and raking through soil and leaf litter. Specimens were preserved in 70% ethanol for morphological identification, with a sub-sample preserved in 100% ethanol for future molecular analysis.

Searches for millipedes were conducted by raking through leaf litter, bark and other debris. Specimens were preserved in 70% ethanol.

Searches for terrestrial land snails were conducted by excavating the soil and leaf litter around the base of hummock grasses, overturning rocks and raking through leaf litter and debris. Live specimens were kept and lodged with the WAM for identification.

Table 3.8: Targeted SRE search site locations and effort within the study area.

Site	Location	Landform	Targeted Taxa					No. of People	Search Time (mins)	Search Effort (mins)
			Mygalomorph Spiders	Millipedes	Snails	Pseudoscorpions	Scorpions			
WTFSRE01	567214 mE, 7491745 mN	Colluvial plain	✓					2	55	110
WTFSRE02	565779 mE, 7492062 mN	Alluvial plain with mulga	✓	✓	✓		✓	2	50	100
WTFSRE03	563581 mE, 7492118 mN	Colluvial plain with mulga	✓	✓	✓	✓	✓	2	47	94
WTFSRE04	562843 mE, 7494295 mN	Alluvial plain adjacent to ephemeral river	✓					2	35	70
WTFSRE05	568084 mE, 7493308 mN	Rocky gorge	✓					2	45	90
WTFSRE06	568084 mE, 7493308 mN	Alluvial plain	✓	✓	✓	✓	✓	2	45	90
WTFSRE07	566829 mE, 7496264 mN	Alluvial plain with mulga	✓					2	50	100
WTFSRE08	561028 mE, 7495803 mN	Narrow rocky gorge	✓					1	42	42
WTFSRE09	568119 mE, 7493133 mN	Pediment	✓					2	50	110
WTFSRE010	563327 mE, 7501823 mN	Colluvial l plain	✓			✓		3	40	120
WTFSRE011	563529 mE, 7497729 mN	Colluvial l plain	✓	✓	✓			2	63	126
WTFSRE012	568600 mE, 7497059 mN	Alluvial plain with mulga	✓					2	40	80
WTFSRE013	564725 mE, 7499461 mN	Alluvial plain adjacent to ephemeral river	✓	✓	✓	✓	✓	2	48	96
WTFSRE014	564802 mE, 7499567 mN	Alluvial plain adjacent to ephemeral river	✓					2	48	96
WTFSRE015	553298 mE, 7497398 mN	Alluvial plain	✓					2	50	100
WTFSRE016	561072 mE, 7497873 mN	Minor drainage line	✓			✓		2	83	166
WTFSRE017	572640 mE, 7496338 mN	Alluvial plain	✓					2	48	96
WTFSRE018	565871 mE, 7493373 mN	Gorge	✓	✓	✓	✓		1	65	65
WTS opp	563006 mE, 7492887 mN	Alluvial plain with mulga	✓	✓	✓	✓		4	Effort not recorded	
WTS opp	561445 mE, 7492125 mN	Minor drainage line	✓	✓	✓	✓		4	Effort not recorded	
WTS opp	554383 mE, 7493360 mN	Plain	✓	✓	✓	✓		4	Effort not recorded	
WTS13	558669 mE, 7494225 mN	Alluvial plain with mulga	✓	✓	✓	✓		4	Effort not recorded	
WTS17	560531 mE, 7494746 mN	Alluvial plain with mulga	✓	✓	✓	✓		4	Effort not recorded	
Coordinates in zone 50, GDA94. Grey shading indicates previous survey site.									Total Effort	1,751

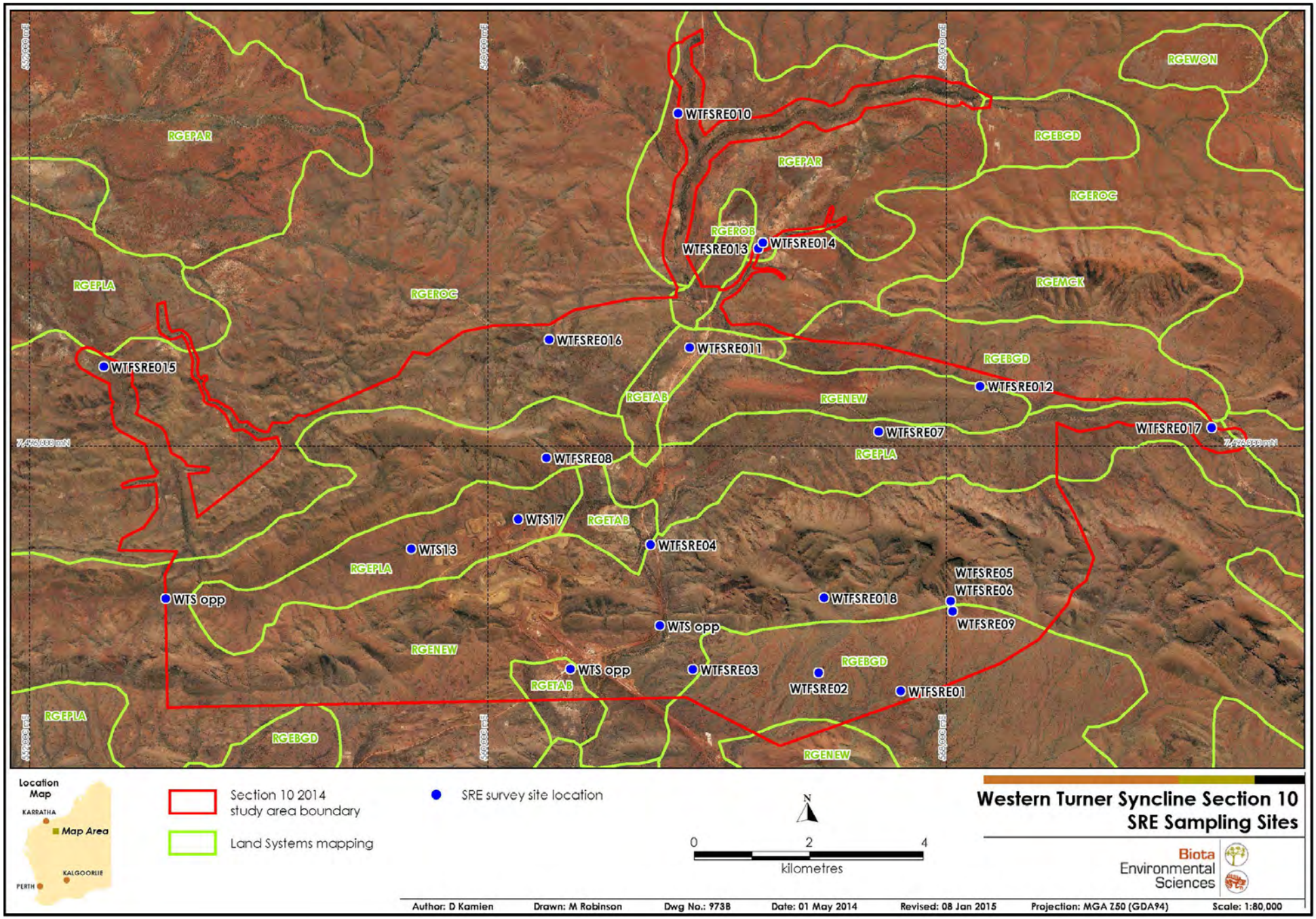


Figure 3.4: SRE sampling sites within the study area.

3.5 Survey Limitations

The following survey limitations should be recognised:

- The WTS below water table and satellite ore bodies survey comprised a single-phase targeted survey only and it is likely that additional sampling would augment the number of species recorded from the study area. Despite this, the survey was adequate in regards to effort for the target species. In addition, significant and comprehensive sampling has been conducted in the other parts of the wider WTS area (see Section 2.5). This information can be used to support the current assessment and adequate data are available to assess potential impacts of the proposed development.
- Not all sections of the study area were ground-truthed or sampled equally for fauna. Parts of the study area were inaccessible by vehicle. Fauna searches and sampling were therefore conducted in habitats readily accessible for routine access and considered most likely to support the target taxa. The areas deemed inaccessible were well represented elsewhere in the survey area in terms of land systems and habitat type, and do not represent previously unsurveyed or rare habitat.
- Terrestrial invertebrate sampling was targeted to taxonomic groups considered likely to represent SREs (EPA 2009a).
- There is only a limited taxonomic framework and ecological knowledge for the majority of terrestrial SRE invertebrates (EPA 2009a).

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4.0 Regional Context

4.1 IBRA Bioregions and Subregions

The Interim Biogeographic Regionalisation for Australia (IBRA) recognises 89 bioregions and 419 subregions in Australia (DSEWPaC 2012). The study area is located within the PIL3 (Hamersley) subregion of the Pilbara bioregion (DSEWPaC 2012).

The Hamersley subregion covers 6,215,092 ha and is described as follows:

> "*PIL3 is the southern section of the Pilbara Craton. Mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by gorges (basalt, shale and dolerite). Mulga (Acacia aneura) low woodland over bunch grasses on fine textured soils in valley floors, and Snappy Gum (Eucalyptus leucophloia) over Triodia brizoides on the skeletal soils of the ranges. The climate is Semi-desert tropical, average 300 mm rainfall, usually in summer cyclonic or thunderstorm events. Winter rain is not uncommon. Drainage into the Ashburton to the south*" (Kendrick 2003).

4.2 Land Systems

Land systems mapping of the study area has been prepared by the Western Australian Department of Agriculture (van Vreeswyk et al. 2004). Land systems are comprised of repeating patterns of topography, soils, and vegetation (i.e. a series of "land units" that occur on characteristic physiographic types within the land system).

A total of 105 land systems occur in the Pilbara bioregion. This information was obtained by combining the land system mapping for the Pilbara (van Vreeswyk et al. 2004) and Ashburton (Payne et al. 1988), and intersecting this with the Pilbara bioregion (Environment Australia 2000) in ArcView.

Eight land systems are present within the study area (Table 4.1). All the land systems occurring within the study area are relatively widespread and well represented in the Hamersley subregion. As a result, the land systems within the study area represent only a small proportion of the total occurring within the Hamersley subregion (Table 4.1).

Table 4.1: Land systems of the study area.

Land System	Description	Extent within Study Area (ha)	% of Study Area	Extent within Hamersley Subregion (ha)	% of Total within Subregion Represented in the Study Area
Boolgeeda	Stony plains adjacent to hills, hard spinifex or mulga short grass forb pastures in good to excellent condition; no erosion.	1,040.7	10.33	606,771	0.17
McKay	Hills, ridges, plateaux remnants and breakaways of metasedimentary and sedimentary rocks supporting hard spinifex grasslands.	5.0	0.05	80,718	0.01
Newman	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.	5,057.0	50.20	1,853,935	0.27
Paraburdoo	Basalt derived stony gilgai plains and stony plains supporting snakewood and mulga shrublands with spinifex and tussock grasses	393.2	3.90	106,912	0.37
Platform	Dissected slopes and raised plains supporting hard spinifex grasslands.	1,733.1	17.20	217,710	0.80
Robe	Low limonite mesas and buttes supporting soft spinifex (and	46.5	0.46	103,116	0.05

Land System	Description	Extent within Study Area (ha)	% of Study Area	Extent within Hamersley Subregion (ha)	% of Total within Subregion Represented in the Study Area
	occasionally hard spinifex) grasslands.				
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands	1,344.9	13.35	711,645	0.19
Table	Low calcrete plateaux, mesas and lower plains supporting mulga and cassia shrublands and minor spinifex grasslands.	454.0	4.51	20,645	2.20

4.3 Geology

The study area encompasses 14 major geological units (Geological Survey of Western Australia 1984) (see Table 4.2). The study area is dominated by colluvial valley-fill deposits and banded iron-formation.

Table 4.2: Geological units within the study area.

Code	Description	Area (ha)	% of Study Area	Age
Czc	Colluvium: partly consolidated quartz and rock fragments in silt and sand matrix; old valley-fill deposits, locally derived.	3,583	35.57	Phanerozoic/ Cainozoic
Czk	Calcrete: sheet carbonate, found along major drainage lines.	310	3.08	
Czp	Robe Pisolite: pisolitic limonite deposits developed along river channels.	47	0.47	
Qa	Alluvium: unconsolidated silt, sand, and gravel; in drainage channels and adjacent floodplains.	579	5.75	Phanerozoic/ Cainozoic/ Quaternary
Qc	Colluvium: unconsolidated quartz and rock fragments in soil.	315	3.13	
PLHb	Brockman Iron Formation: banded iron-formation, chert and pelite.	2,308	22.91	Proterozoic
PLHj	Weeli Wolli Formation: banded iron-formation (commonly jaspilitic), pelite and numerous metadolerite sills.	172	1.71	
PLHo	Boolgeeda Iron Formation: fine-grained, finely laminated iron-formation; pelite and chert.	3	0.03	
PLHw	Woongarra Rhyolite: metamorphosed rhyolite, rhyodacite, rhyolitic breccia and banded iron-formation.	1	0.01	
AFd	Dcite: medium- to coarse-grained metadolerite sills intruded into Fortescue Group.	514	5.10	Archaean
AFj	Jeerinah Formation: pelite, metasandstone, chert, metabasaltic pillow lava and breccia, and metamorphosed felsic volcanic rock	610	6.06	
AFu	Bunjinah Formation: pillowed and massive metabasaltic flows, metabasaltic breccia, metamorphosed volcanic sandstone, and minor chert; amygda.	46	0.46	
AHm	Marra Mamba Iron Formation: chert, banded iron-formation and pelite.	1,079	10.71	
AHs	Mount McRae Shale and Mount Sylvia Formation: pelite, chert, and banded iron-formation.	507	5.03	

4.4 Vegetation

4.4.1 Beard's Vegetation Mapping

Beard (1975) mapped the vegetation of the Pilbara bioregions at a scale of 1:1,000,000. The study area lies within the Fortescue Botanical District of the broader Eremaean Botanical Province as defined by Beard (1975). The vegetation of this province is typically open, and frequently dominated by spinifex, wattles and occasional eucalypts (Beard 1975).

The study area intersects two of Beard's vegetation units, both of which are widespread in the Pilbara region:

- Hamersley 82: *Eucalyptus leucophloia* low woodland over *Triodia wiseana* hummock grassland; and
- Hamersley 567: Mulga (*Acacia aneura*) and *Acacia pyrifolia*[1] open shrubland over soft spinifex (*Triodia epactia/pungens*) and *T. basedowii* hummock grassland.

Given the broad scale of Beard's vegetation mapping, these two units provide only limited information about the habitats occurring in the study area.

4.4.2 Vegetation of the Study Area

Vegetation mapping of the study area was completed by Biota (2014) at a considerably finer scale than Beard's mapping. A total of 46 vegetation units were identified for the study area. These units were classified into 11 broad vegetation types in four groups based on the associated landform.

No Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) were recorded within the study area (Biota 2014).

4.4.3 Conservation Reserves in the Locality

Three conservation reserves are located within 150 km of the study area:

- Karijini National Park, the nearest boundary of which is located approximately 19 km to the east;
- Mungaroona Range Nature Reserve, approximately 100 km to the northeast; and
- Millstream-Chichester National Park, approximately 108 km to the north.

In addition, the Mt Florence and Wanna former pastoral leasehold areas, currently managed by the Department of Parks and Wildlife, comprise unallocated crown land proposed for conservation. This land is located approximately 52 km northeast of the study area (Mt Florence former pastoral leasehold) and 98 km south-southwest of the study area (Wanna former pastoral leasehold).

[1] Probably intended to mean *Acacia inaequilatera*.

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5.0 Results

5.1 Landscapes and Landforms

The survey sampled two landscapes identified within the study area (Table 5.1), each containing specific landforms (Table 5.2 and Table 5.3).

Historical survey sites were selected in areas representative of the landscapes and landforms present within the study area. However, targeted investigation of conservation significant species such as the Northern Quoll, Orange Leaf-nosed Bat, Pilbara Olive Python and potential SRE invertebrates were conducted in specific landforms deemed suitable to these targeted fauna.

Table 5.1: Landscapes and landforms present in the study area.

Landscape	Landforms
LANDSCAPE 1: mountainous rugged terrain comprising ridges, plateaus, steep hills with free faces.	• Narrow rocky gorge/gully; • Broad rocky gorge/gully; • Rocky free face; • Hill slope; • Pediment; • Major drainage line/ Ephemeral river; • Minor drainage line;
LANDSCAPE 2: contemporary drainage systems and floodplains, including alluvial and colluvial deposits with gently to moderately inclined slopes to flat land, below steep hills.	• Alluvial plain; • Major drainage line/ Ephemeral river; • Minor drainage line; • Alluvial plain; • Colluvial plain.

Table 5.2: Description of targeted vertebrate fauna sites within the study area.

Site	Description	Site Photograph
LANDSCAPE 1: mountainous rugged terrain comprising ridges, plateaus, steep hills with free faces.		
WTF01E	Landform: Narrow rocky gorge. Vegetation: *Eucalyptus leucophloia* and *Acacia aneura* scattered low trees, over *Acacia* spp. open shrubland, over *Triodia* spp. hummock grassland. Land system: Newman.	
WTF02E	Landform: Broad rocky gorge. Vegetation: *Eucalyptus leucophloia* scattered low trees, over *Acacia pruinocarpa* open shrubland, over *Triodia* sp. open hummock grassland. Land system: Newman.	

Site	Description	Site Photograph
WTF03E	Landform: Narrow rocky gorge. Vegetation: *Eucalyptus leucophloia* and *Acacia aneura* scattered low trees, over scattered *Acacia* spp. shrubs, over *Triodia* spp. hummock grassland. Land system: Newman.	
WTS14F	Landform: Hill slope. Soil: Rock. Vegetation: *Eucalyptus leucophloia* scattered low trees over *Acacia* sp. open shrubland, over *Triodia* sp. hummock grassland. Land system: Newman.	
WTS16	Landform: Hill slope. Soil: Rock and scree. Vegetation: *Acacia* sp. open shrubland over *Triodia* sp. closed hummock grassland. Land system: Newman.	
WTS15E	Landform: Hill slope. Soil: Rock and scree. Vegetation: *Eucalyptus leucophloia* scattered low trees over *Acacia* sp. shrubland over *Triodia* sp. hummock grassland. Land system: Newman.	

Site	Description	Site Photograph
WTC16E	Landform: Hill slope. Soil: Rock and scree. Vegetation: *Acacia* sp. open shrubland over *Triodia* sp. hummock grassland and mixed tussock grassland. Land system: Newman.	
LANDSCAPE 2: contemporary drainage systems and floodplains, including alluvial and colluvial deposits with gently to moderately inclined slopes to flat land, below steep hills.		
WTF04E	Landform: Major drainage line. Vegetation: *Eucalyptus camaldulensis* scattered low trees, over *Acacia* spp. open shrubland, over **Cenchrus ciliaris* and *Themeda* sp. open tussock grassland. Land system: Newman.	
WTS12	Landform: Colluvial plain. Soil: Stony loam. Vegetation: *Acacia* sp. open shrubland over *Triodia* sp. open hummock grassland. Land system: Newman.	
WTS13	Landform: Alluvial plain. Soil: Clay loam. Vegetation: *Acacia aneura* open woodland over *Triodia* sp. open hummock grassland. Land system: Platform.	

Site	Description	Site Photograph
WTS15	Landform: Alluvial plain adjacent to ephemeral river. Soil: Stony clay loam. Vegetation: *Acacia* sp. shrubland over *Triodia* sp. hummock grassland and **Cenchrus ciliaris* tussock grassland. Land system: Newman.	
WTS17	Landform: Colluvial plain. Soil: Clay loam. Vegetation: *Acacia aneura* low open woodland and *Acacia* sp. open shrubland, over *Triodia* sp. hummock grassland. Land system: Platform.	
WTS21	Landform: Hill slope. Soil: Rocky loam. Vegetation: *Eucalyptus leucophloia* scattered low trees over *Acacia* sp. open shrubland over *Triodia* sp. hummock grassland. Land system: Newman.	

* indicates non-indigenous species

Table 5.3: Description of targeted SRE search sites.

Site	Site Description	Photo
LANDSCAPE 1: mountainous rugged terrain comprising ridges, plateaus, steep hills with free faces.		
WTFSRE05	Landform: Narrow rocky gorge. Soil: Rock. Vegetation: *Eucalyptus leucophloia* and *Acacia aneura* scattered low trees, over *Acacia* spp. scattered shrubs, over *Triodia* spp. hummock grassland. Land system: Newman.	
WTFSRE08	Landform: Narrow rocky gorge. Soil: Rock. Vegetation: *Eucalyptus leucophloia* and *Acacia aneura* scattered low trees, over *Acacia* spp. open shrubland, over *Triodia* spp. hummock grassland. Land system: Newman.	
WTFSRE18	Landform: Broad rocky gorge. Soil: Rock. Vegetation: *Eucalyptus leucophloia* scattered low trees, over *Acacia pruinocarpa* open shrubland, over *Triode* sp. open hummock grassland. Land system: Newman.	
LANDSCAPE 2: contemporary drainage systems and floodplains, including alluvial and colluvial deposits with gently to moderately inclined slopes to flat land, below steep hills.		
WTFSRE01	Landform: Colluvial plain. Soil: Clay loam with surface stones. Vegetation: *Eucalyptus leucophloia* and *Acacia aneura* scattered low trees, over *Acacia* spp. scattered shrubs, over *Triodia* spp. hummock grassland. Land system: Boolgeeda.	

Site	Site Description	Photo
WTFSRE02	Landform: Alluvial plain with mulga. Soil: Clay loam. Vegetation: *Acacia aneura* scattered low trees, over *Triodia* spp. open hummock grassland. Land system: Boolgeeda.	
WTFSRE03	Landform: XXX. Soil: Clay loam. Vegetation: *Eucalyptus leucophloia* and *Acacia aneura* scattered low trees, over *Acacia xiphophylla* scattered tall shrubs, over *Acacia* spp. scattered shrubs, over *Triodia* spp. hummock grassland. Land system: Newman.	
WTFSRE04	Landform: Alluvial plain adjacent to ephemeral river. Soil: Silty clay loam. Vegetation: *Eucalyptus camaldulensis* scattered low trees, over *Acacia aneura* low open woodland, over **Cenchrus ciliaris* tussock grassland and *Triodia* sp. open hummock grassland. Land system: Newman.	
WTFSRE06	Landform: Alluvial plain. Soil: Clay loam. Vegetation: *Acacia* spp. open shrubland, over **Cenchrus ciliaris* scattered tussock grasses and *Triodia* sp. open hummock grassland. Land system: Newman.	

Site	Site Description	Photo
WTFSRE07	Landform: Alluvial plain with mulga. Soil: Clay loam. Vegetation: *Acacia* spp. open shrubland, over **Cenchrus ciliaris* scattered tussock grasses and *Triodia* sp. hummock grassland. Land system: Platform.	
WTFSRE09	Landform: Pediment. Soil: Stony loam. Vegetation: *Eucalyptus leucophloia* scattered low trees, over *Acacia* sp. low shrubland, over *Triodia* spp. very open hummock grassland. Land system: Boolgeeda.	
WTFSRE10	Landform: Colluvial plain. Soil: Clay loam. Vegetation: A*cacia aneura* low open woodland, over **Cenchrus ciliaris* very open tussock grassland and *Triodia* sp. open hummock grassland. Land system: Paraburdoo.	
WTFSRE11	Landform: Colluvial plain. Soil: Loam. Vegetation: *Acacia aneura* scattered tall shrubs over *Acacia* spp. open shrubland, over *Triodia* sp. hummock grassland. Land system: Table.	

Site	Site Description	Photo
WTFSRE012	Landform: Alluvial plain with mulga. Soil: Clay loam. Vegetation: *Acacia aneura* scattered low trees, over *Acacia xiphophylla* scattered tall shrubs, over *Acacia* spp. scattered shrubs, over *Triodia* spp. open hummock grassland. Land system: Newman.	
WTFSRE13	Landform: Alluvial plain adjacent to ephemeral river. Soil: Silty clay loam. Vegetation: *Eucalyptus victrix* scattered low trees, over *Acacia* sp. low open woodland, over **Cenchrus ciliaris* tussock grassland. Land system: Paraburdoo.	
WTFSRE14	Landform: Alluvial plain adjacent to ephemeral river. Soil: Clay loam with surface stones. Vegetation: *Corymbia hamersleyana* scattered low trees, over *Acacia* spp. scattered tall shrubs, over **Cenchrus ciliaris* very open tussock grassland and *Triodia* sp. open hummock grassland. Land system: Paraburdoo.	
WTFSRE15	Landform: Alluvial plain. Soil: Clay loam. Vegetation: *Acacia* spp. shrubland, over **Cenchrus ciliaris* tussock grassland and *Triodia* sp. very open hummock grassland. Land system: Rocklea.	

Site	Site Description	Photo
WTFSRE16	Landform: Minor drainage line. Soil: Clay loam. Vegetation: *Acacia aneura* low woodland, over *Acacia* spp. tall open shrubland, over *Triodia* spp. hummock grassland. Land system: Rocklea.	
WTFSRE17	Landform: Alluvial plain. Soil: Clay loam with surface stones. Vegetation: *Acacia* spp. tall open shrubland, over *Acacia* spp. scattered shrubs, over *Senna* spp. scattered shrubs, over *Triodia* spp. hummock grassland. Land system: Platform.	

* indicates non-indigenous species

5.2 Fauna Habitats

Within recognized functional landforms (see Section 5.1), broad fauna habitats were identified on the basis of geomorphology, geology, vegetation and ecological niches that may be inhabited by specific species. On this basis, 16 terrestrial fauna habitats were identified (Table 5.4 and Figure 5.1). These fauna habitats correspond to the fauna habitats previously identified at Western Turner Syncline (Biota 2013a).

The habitats were dominated by eucalypt woodlands over *Acacia* spp. shrublands on stony plains, spurs and slopes (Habitats 7 and 8, which accounted for 73.1% of the study area; Table 5.4.

It is important to note that each habitat defined here cannot be used to map the distribution of any single species, rather they are habitats recognised as offering a suite of ecological niches generally distinct from other broad habitats.

Table 5.4: Fauna habitats of the study area and their representation.

No.	Landform	Habitat Description	Hectares in Study Area	Proportion in StudyArea (%)
2	Minor drainage	*Acacia* spp. tall shrubland over **Cenchrus ciliaris* tussock grassland in minor drainages and flowlines.	148.8	1.48
3	Plain	*Acacia xiphophylla* shrubland over *Triodia* hummock grassland on clay plains.	393.0	3.90
5	Plain	Disturbed.	563.8	5.60
6	Major drainage	Eucalypt woodland over *Acacia citrinoviridis* shrubland in major creeks.	414.3	4.11

No.	Landform	Habitat Description	Hectares in Study Area	Proportion in StudyArea (%)
7	Plain	Eucalypt woodland over *Acacia spp*. shrubland over *Triodia* hummock grassland on stony plains and slopes.	1,995.6	19.81
8	Hillslope	*Eucalyptus leucophloia* woodland over *Acacia* spp. shrubland over *Triodia* hummock grassland on spurs and hill slopes.	5,372.6	53.33
10	Minor drainage	Mixed *Acacia* spp. shrublands over *Triodia* hummock grasslands on minor flowlines on stony plains and low hills.	523.4	5.20
11	Hillslope	Mulga and *Acacia shrublands* over *Triodia* hummock grasslands on rocky hill slopes.	156.2	1.55
12	Minor drainage	Eucalypt woodland over *Acacia* spp. shrubland over tussock grassland in minor drainages.	329.3	3.27
13	Gorge/Gully	*Corymbia* spp. and eucalypt open woodland over mixed *Acacia* spp. shrubland over tussock grasslands in gullies and gorges.	79.0	0.78
15	Gorge/Gully	*Eucalyptus leucophloia* over Mulga (Acacia aneura) / *Acacia citrinoviridis* over *Triodia* hummock grassland in gullies and gorges.	1.0	0.01
16	Free Face	*Eucalyptus leucophloia* scattered trees, over *Acacia* spp. shrubland, over *Triodia* spp. hummock grassland adjacent to free faces.	97.1	0.96

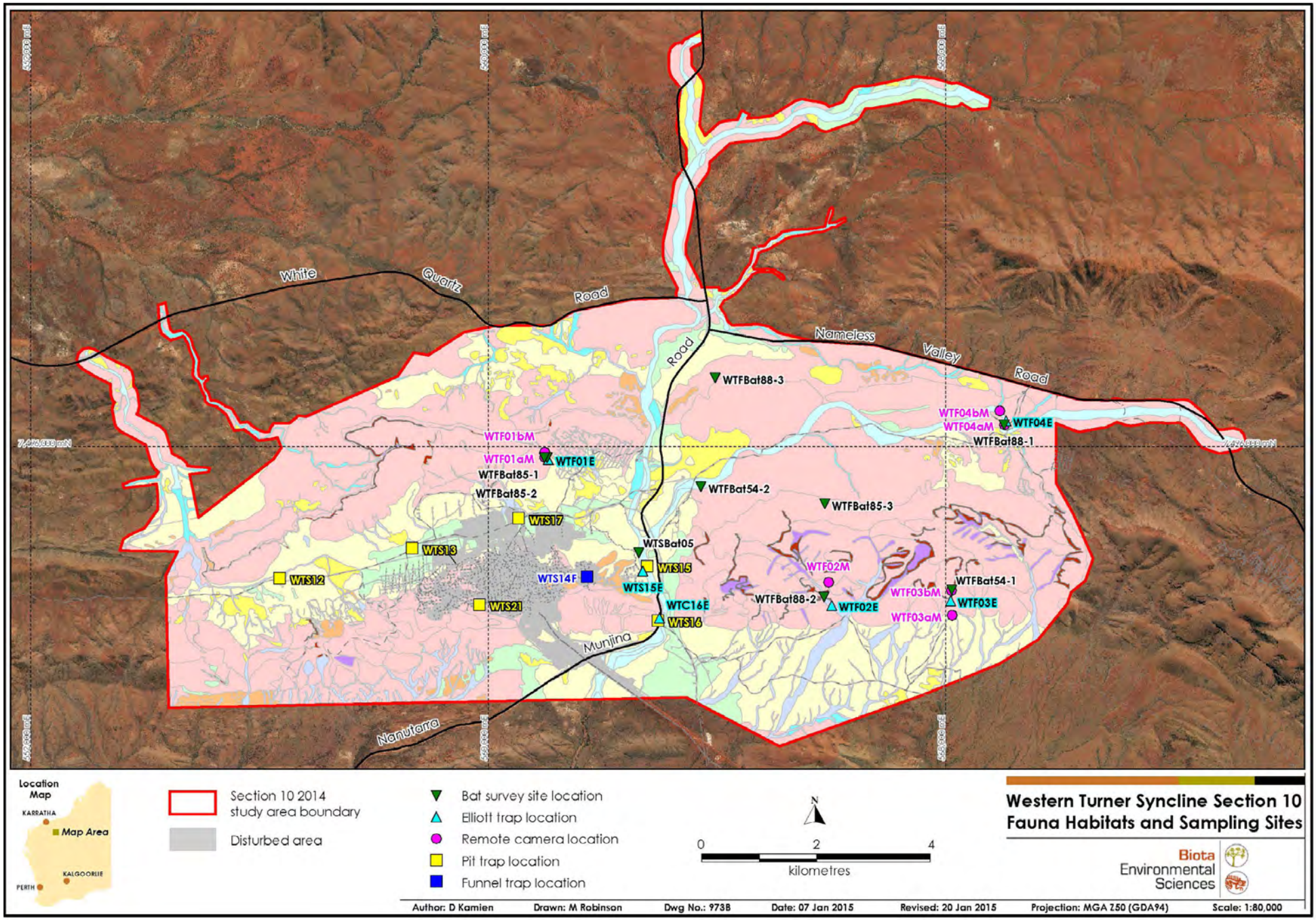
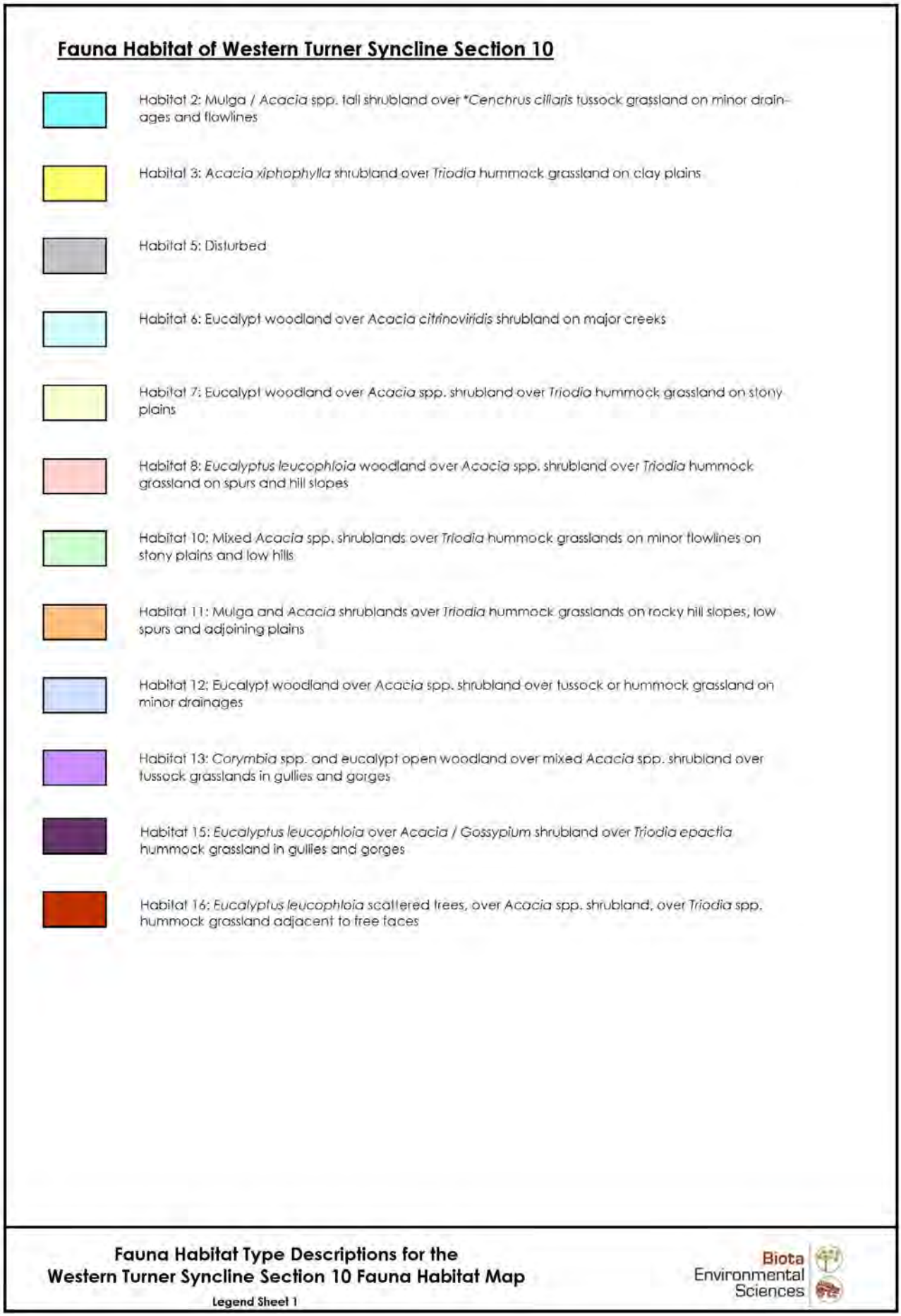


Figure 5.1: Fauna habitats of the study area


Fauna Habitat of Western Turner Syncline Section 10
Habitat 2: Mulga / Acacia spp. tall shrubland over *Cenchrus ciliaris tussock grassland on minor drainages and flowlines
Habitat 3: Acacia xiphophylla shrubland over Triodia hummock grassland on clay plains
Habitat 5: Disturbed
Habitat 6: Eucalypt woodland over Acacia citrinoviridis shrubland on major creeks
Habitat 7: Eucalypt woodland over Acacia spp. shrubland over Triodia hummock grassland on stony plains
Habitat 8: Eucalyptus leucophloia woodland over Acacia spp. shrubland over Triodia hummock grassland on spurs and hill slopes
Habitat 10: Mixed Acacia spp. shrublands over Triodia hummock grasslands on minor flowlines on stony plains and low hills
Habitat 11: Mulga and Acacia shrublands over Triodia hummock grasslands on rocky hill slopes, low spurs and adjoining plains
Habitat 12: Eucalypt woodland over Acacia spp. shrubland over tussock or hummock grassland on minor drainages
Habitat 13: Corymbia spp. and eucalypt open woodland over mixed Acacia spp. shrubland over tussock grasslands in gullies and gorges
Habitat 15: Eucalyptus leucophloia over Acacia / Gossypium shrubland over Triodia epactia hummock grassland in gullies and gorges
Habitat 16: Eucalyptus leucophloia scattered trees, over Acacia spp. shrubland, over Triodia spp. hummock grassland adjacent to free faces
Fauna Habitat Type Descriptions for the Western Turner Syncline Section 10 Fauna Habitat Map
Legend Sheet 1
Biota Environmental Sciences

5.3 Vertebrate Fauna

Eighty-seven vertebrate species were recorded within the study area (Table 5.5). One of the targeted conservation significant fauna species (the Orange Leaf-nosed Bat) was recorded during the recent survey.

Table 5.5: Vertebrate species occurring in the study area.

Fauna group	Number of Species Recorded
Native Ground dwelling Mammals	15
Introduced Ground-dwelling Mammals	0
Bats	5
Birds	50
Reptiles	17
Amphibians	0
Total	87

5.3.1 Mammals

A total of 14 mammals species have been recorded within the study area during the current and previous Biota surveys (Table 5.6). The remote cameras did not record any fauna (birds, reptiles or mammals).

The mammals included the Schedule 1 Orange Leaf-nosed Bat, which was recorded twice via echolocation calls at a single location in the study area. This species has been recorded from two other locations outside the study area during previous surveys (see Figure 5.2).

Despite the presence of the Common Rock-rat, *Zyzomys argurus* (a known prey species), no Northern Quoll were recorded.

The Priority 4 Western Pebble-mound Mouse, *Pseudomys chapmani,* has been recorded from several locations in the study area (Table 5.6) and has also been recorded in the broader WTS locality.

Table 5.6: Mammals recorded within the study area.

Family/ Species Name	Common Name	WTC 16E	WTS 12	WTS 13	WTS 14F	WTS 15	WTS 15E	WTS 16	WTS 17	WTS 21	WTS Bat05	WTF Bat88-1	WTF 01E	WTF 02E	WTF 03E	WTF 04E	Opp	Total
Dasyuridae																		
Dasykaluta rosamondae	Little Red Kaluta	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Ningaui timealeyi	Pilbara Ningaui	–	2	1	2	–	–	2	1	1	–	–	–	–	–	–	–	9
Sminthopsis macroura	Stripe-faced Dunnart	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Macropodidae																		
Macropus robustus	Euro	–	–	–	2	–	–	3	2	2	–	–	–	–	–	–	1	10
Macropus rufus	Red Kangaroo,	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	2
Hipposideridae																		
Rhinonicteris aurantius	Orange Leaf-nosed Bat	–	–	–	–	–	–	–	–	–	–	E	–	–	–	–	–	E
Vespertilionidae																		
Chalinolobus gouldii	Gould's Wattled Bat	–	–	–	–	–	–	–	–	–	4, E	ND	–	–	–	–	–	4, E
Scotorepens greyii	Little Broad-nosed Bat	–	–	–	–	–	–	–	–	–	E	ND	–	–	–	–	–	E
Emballonuridae																		
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat	–	–	–	–	–	–	–	–	–	E	ND	–	–	–	–	–	E
Taphozous georgianus	Common Sheathtail Bat	–	–	–	–	–	–	–	–	–	E	ND	–	–	–	–	–	E
Muridae																		
Pseudomys chapmani	Western Pebble-mound Mouse	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	M	1
Pseudomys desertor	Desert Mouse	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	2
Pseudomys hermannsburgensis	Sandy Inland Mouse	–	3	1	–	–	–	–	2	5	–	–	–	–	–	–	–	11
Zyzomys argurus	Common Rock-rat	28	–	–	–	–	13	–	–	–	–	–	–	13	1	–	–	55
Canidae																		
Canis lupus dingo	Dingo	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Number of Individuals		28	5	4	4	2	13	5	7	9	0	0	0	14	1	0	1	97
Number of species		1	2	4	2	2	1	2	5	4	0	0	0	2	1	0	1	14

E = echolocation call.
ND = not determined.
M = pebble mound.

5.3.2 Avifauna

A total of 50 avifauna species from 20 families have been recorded within the study area during Biota surveys (Table 5.7). This includes the Schedule 3, migratory Rainbow Bee-eater (*Merops ornatus*). The recent targeted survey did not include dedicated avifauna censusing and only avifauna of conservation significance were noted.

Table 5.7: Avifauna recorded within the study area.

Family / Species Name	Common Name	WTS 12	WTS 13	WTS 14F	WTS 15	WTS 16	WTS 17	WTS 21	WTF 03E	Total
Accipitridae										
Aquila audax	Wedge-tailed Eagle	–	–	–	–	2	–	–	–	2
Circus assimilis	Spotted Harrier	–	–	1	–	–	–	–	–	1
Falconidae										
Falco berigora	Brown Falcon	–	1	–	–	1	1	1	–	4
Falco cenchroides	Australian Kestrel	–	–	1	–	–	–	–	–	1
Falco longipennis	Australian Hobby	–	1	–	–	–	–	–	–	1
Columbidae										
Phaps chalcoptera	Common Bronzewing	–	–	–	–	1	–	–	–	1
Ocyphaps lophotes	Crested Pigeon	2	–	–	–	2	6	–	–	10
Geophaps plumifera	Spinifex Pigeon	9	–	4	–	–	–	–	–	13
Geopelia cuneata	Diamond Dove	–	1	3	2	1	39	4	–	50
Geopelia striata	Peaceful Dove	–	–	–	1	–	3	1	–	5
Cacatuidae										
Cacatua roseicapilla	Galah	–	2	–	–	2	–	–	–	4
Cacatua sanguinea	Little Corella	–	–	2	8	9	15	–	–	34
Psittacidae										
Nymphicus hollandicus	Cockatiel	2	–	–	–	–	–	–	–	2
Barnardius zonarius	Australian Ringneck	–	–	–	6	2	10	–	–	18
Melopsittacus undulatus	Budgerigar	–	–	–	–	–	6	–	–	6
Cuculidae										
Cacomantis pallidus	Pallid Cuckoo	1	–	–	–	2	–	–	–	3
Meropidae										
Merops ornatus	Rainbow Bee-eater	–	–	–	–	–	–	–	1	1
Maluridae										
Malurus lamberti	Variegated Fairy-wren	4	–	7	–	3	–	8	–	22
Malurus leucopterus	White-winged Fairy-wren	2	–	–	–	–	7	–	–	9
Stipiturus ruficeps	Rufous-crowned Emu-wren	–	–	–	–	3	–	–	–	3
Amytornis striatus	Striated Grasswren	–	–	5	–	–	–	–	–	5
Acanthizidae										
Smicrornis brevirostris	Weebill	2	11	18	12	18	4	8	–	73
Acanthiza apicalis	Broad-tailed Thornbill	–	–	–	–	–	5	3	–	8
Acanthiza uropygialis	Chestnut-rumped Thornbill	–	5	–	–	–	–	–	–	5
Meliphagidae										
Lichmera indistincta	Brown Honeyeater	–	–	–	1	–	–	–	–	1
Lichenostomus virescens	Singing Honeyeater	3	–	3	–	–	2	–	–	8
Lichenostomus keartlandi	Grey-headed Honeyeater	–	–	–	–	1	–	1	–	2
Lichenostomus penicillatus	White-plumed Honeyeater	–	–	–	11	–	–	–	–	11
Conopophila whitei	Grey Honeyeater	–	–	–	–	–	1	–	–	1

Family / Species Name	Common Name	WTS 12	WTS 13	WTS 14F	WTS 15	WTS 16	WTS 17	WTS 21	WTF 03E	Total
Manorina flavigula	Yellow-throated Miner	–	–	–	–	6	1	–	–	7
Acanthagenys rufogularis	Spiny-cheeked Honeyeater	3	–	–	–	4	–	–	–	7
Petroicidae										
Petroica goodenovii	Red-capped Robin	1	–	–	–	–	–	–	–	1
Melanodryas cucullata	Hooded Robin	–	–	–	2	1	–	–	–	3
Pomatostomidae										
Pomatostomus temporalis	Grey-crowned Babbler	3	–	–	7	–	6	5	–	21
Pachycephalidae										
Oreoica gutturalis	Crested Bellbird	1	1	1	1	1	6	3	–	14
Pachycephala rufiventris	Rufous Whistler	1	–	–	3	2	–	–	–	6
Colluricincla harmonica	Grey Shrike-thrush	–	–	1	1	–	–	–	–	2
Dicruridae										
Rhipidura fuliginosa	Grey Fantail	–	3	–	–	–	–	–	–	3
Rhipidura leucophrys	Willie Wagtail	–	1	–	3	1	1	1	–	7
Grallina cyanoleuca	Magpie-lark	1	–	–	3	4	2	–	–	10
Campephagidae										
Coracina novaehollandiae	Black-faced Cuckoo-shrike	–	1	1	–	4	–	–	–	6
Artamidae										
Artamus personatus	Masked Woodswallow	–	–	–	–	–	–	3	–	3
Artamus cinereus	Black-faced Woodswallow	–	–	3	–	2	–	–	–	5
Cracticus torquatus	Grey Butcherbird	–	–	–	–	2	–	–	–	2
Cracticus nigrogularis	Pied Butcherbird	–	1	1	1	1	1	–	–	5
Corvidae										
Corvus orru	Torresian Crow	–	7	–	–	2	4	–	–	13
Sylviidae										
Eremiornis carteri	Spinifex-bird	–	–	–	–	2	–	–	–	2
Dicaeidae										
Dicaeum hirundinaceum	Mistletoebird	1	–	2	–	–	–	–	–	3
Estrildidae										
Taeniopygia guttata	Zebra Finch	–	–	2	–	25	5	45	–	77
Emblema pictum	Painted Finch	–	–	18	–	18	–	–	–	36
Number of Individuals		36	35	73	62	122	125	83	1	537
Number of Species		15	12	17	15	28	20	12	1	50

5.3.3 Herpetofauna

Surveys have yielded a total of 17 herpetofauna species from the study area to date (Table 5.8). This total includes one gecko species (Gekkonidae), seven skink species (Scincidae), three dragon species (Agamidae), three goanna species (Varanidae), and three snake species (Elapidae). None of these records represent fauna of conservation significance. The Schedule 1 Pilbara Olive Python (*Liasis olivaceus barroni*) has been recorded from the broader WTS locality during a previous survey (see Figure 5.2).

Table 5.8: Herpetofauna recorded within the study area

Family / Species Name	WTC 16E	WTS 12	WTS 13	WTS 14F	WTS 15	WTS 15E	WTS 16	WTS 17	WTS 21	WTF 01E	WTF 02E	WTF 03	WTF 04	opp	Total
Gekkonidae															
Gehyra variegata	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
Scincidae															
Ctenotus duricola	–	2	–	–	–	–	–	–	–	–	–	–	–	–	2
Ctenotus pantherinus	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1
Ctenotus rutilans	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Ctenotus saxatilis											–	1	–		1
Ctenotus schomburgkii	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2
Egernia formosa											–	3	2		5
Menetia greyii	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Agamidae															
Ctenophorus caudicinctus	–	5	3	–	–	–	1	–	1	–	–	1	–	–	11
Ctenophorus isolepis	–	1	1	–	–	–	–	1	–	–	–	–	–	–	3
Lophognathus longirostris	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Varanidae															
Varanus acanthurus	–	–	–	–	–	–	1	–	–	–	1	–	–	–	2
Varanus gouldii	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Varanus tristis	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1
Elapidae															
Demansia rufescens	–	–	–	–	1	–	–	1	–	–	–	–	–	–	2
Furina ornata	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Parasuta monachus	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Number of Individuals	0	9	5	1	1	0	3	5	2	0	2	5	3	0	36
Number of Species	0	4	3	1	1	0	3	4	2	0	2	3	2	0	17

Opp = opportunistic record.

5.3.4 Habitat Impact Analysis

In classifying Pilbara habitats as potential core habitat for species of conservation significance, we have adopted criteria aligned with the broad criteria used by the DotE (based on DEWHA (2009) and DSEWPaC (2011)), and as inferred from previous Controlled Action decisions for Pilbara mining projects. That is, "core habitat" (equivalent to "habitat critical to the survival of the species") is identified as habitat types that are known, or are likely, to be utilised by listed species for key ecological activities such as denning, roosting, breeding, refugia and important foraging areas. It is therefore reasonable to assume that some proportion of this habitat must be maintained across the species' range in the Pilbara to ensure survival of the species in the region.

Data from the study area, in combination with previous data obtained within the broader WTS area, indicate that the three targeted NES species are either present at very low density or absent (Section 5.3 and Figure 5.2). Consistent with this finding, the majority of the habitats of the current study area would not be considered core habitats for these species.

In respect to the broader WTS extent (Biota 2013a), approximately 73.1% of the mapped area comprises open eucalypt woodland and *Acacia* spp. shrublands on stony or loamy clay plains, spurs and hill slopes, (Biota 2011c, 2013d and Table 5.4). These habitat types do not provide roosts or reliable foraging or drinking sites for the Orange Leaf-nosed Bat, or denning opportunities or key foraging habitats for the Northern Quoll, and would only be used on a transitory basis by the Pilbara Olive Python (e.g. dispersing juveniles or males searching for mates).

The potential core habitats for these three species are similar, comprising gorges, gullies, free faces, and eucalypt woodlands on major ephemeral watercourses and creeks (habitats 13, 15, 16, 10 respectively). The habitats identified as being of importance to any of the three species have been consolidated as potential core NES habit The potential core habitats present in gorges, gullies and free faces in the WTS area are, in general, likely to be of higher value to the NES species than those of the major drainage lines.
ats and mapped on Figure 5.2. Table 5.9 lists the total mapped extent of the relevant habitat types in the wider WTS area and the representative habitat loss that would arise from implementation of the overall WTS indicative project layout (including that planned within the current study area). The potential core habitats present in gorges, gullies and free faces in the WTS area are, in general, likely to be of higher value to the NES species than those of the major drainage lines.

5.3.4.1 Study Area

A total of 709.2 ha of potential NES core habitat occurs within the study area, with the majority (96.3%) occurring outside of the indicative WTS project layout. This equates to only 3.7% of the local extent of NES core habitat being potentially affected by the proposed project.

5.3.4.2 Broader WTS area

Similarly, a total of 2,168.04 ha of potential NES core habitat occur within the broad extent of the WTS area surveyed to date, representing 6.5 % of the entire WTS study area. Of this, only 23.9 ha representing 1.1 % of NES core habitat has potential to be adversely affected by implementation of the WTS project as it is currently proposed.

The above findings should also be further considered in the context of the systematic and targeted surveys (Biota 2009b, 2009c, 2011a, 2013a), which found little or no evidence that these habitats at WTS are being consistently utilised by the three focal NES species (Section 2.5). In addition, these habitat types are well represented in the wider subregion.

Table 5.9: Area of core habitats for NES species in the WTS area and predicted habitat clearing arising from the current indicative project layout.

Habitat and vegetation description	Area (ha) of Core Habitats for NES Species		
	Total WTS Area	Section 10 2014 Study Area	Total WTS Indicative Project Layout
Gorges, Gullies and Free Face			
Acacia aneura, (*A. pruinocarpa*) tall shrubland over mixed *Triodia* scattered hummock grasses	0.66	0.66	0.00
Acacia aneura, (*A. pruinocarpa*) low open forest over *Triodia brizoides* open hummock grassland	0.40	0.40	0.00
Acacia aneura, A. xiphophylla tall shrubland over *Triodia brizoides* open hummock grassland	0.35	0.35	0.00
Acacia xiphophylla, (*A. aneura*) tall shrubland over *Triodia wiseana* very open hummock grassland	0.19	0.19	0.00
Corymbia ferriticola low open woodland over *Acacia aneura, A. citrinoviridis* tall shrubland over *Triodia brizoides, T. epactia* open hummock grassland with *Eriachne mucronata* very open tussock grassland	285.25	100.56	22.00
Eucalyptus leucophloia low open woodland over *Acacia aneura* tall shrubland over *Triodia epactia* hummock grassland	184.83	0.06	0.42

Habitat and vegetation description	Area (ha) of Core Habitats for NES Species		
	Total WTS Area	Section 10 2014 Study Area	Total WTS Indicative Project Layout
Eucalyptus leucophloia subsp. *leucophloia* scattered low trees over *Acacia hamersleyensis*, (*A. maitlandii*) tall open shrubland over *Triodia brizoides*, *T. wiseana* open hummock grassland	29.36	29.36	0.00
Eucalyptus leucophloia subsp. *leucophloia* scattered low trees over *Acacia hamersleyensis* tall open shrubland over *Triodia wiseana, T. epactia* open hummock grassland	10.78	10.78	0.50
Eucalyptus leucophloia scattered low trees over *Acacia maitlandii* tall shrubland over *Triodia brizoides* hummock grassland	1.50	1.50	0.00
Eucalyptus leucophloia subsp. *leucophloia* scattered low trees over *Acacia maitlandii* tall shrubland over *Triodia wiseana* open hummock grassland	0.30	0.30	0.00
Eucalyptus leucophloia subsp. *leucophloia* scattered low trees over *Acacia pruinocarpa* tall open shrubland over *Triodia wiseana* hummock grassland	1.93	1.93	0.06
Eucalyptus leucophloia subsp. *leucophloia* scattered low trees over mixed *Acacia* spp. open shrubland over *Triodia epactia* hummock grassland	0.17	0.17	0.00
Eucalyptus leucophloia subsp. *leucophloia, Corymbia deserticola* subsp. *deserticola* scattered low trees over mixed *Acacia* scattered tall shrubs over *Triodia wiseana* open hummock grassland	1.47	1.47	0.20
Eucalyptus leucophloia, *Corymbia ferriticola* low open woodland over *Gossypium robinsonii* tall open scrub over *Triodia epactia* open hummock grassland	2.96	1.12	0.00
Eucalyptus leucophloia, Corymbia hamersleyana low open woodland over *Acacia citrinoviridis, A. pyrifolia, A. monticola* tall open scrub over *Triodia epactia* open hummock grassland	1.98	1.98	0.00
Eucalyptus leucophloia subsp. *leucophloia, Corymbia hamersleyana* scattered low trees over *Acacia inaequilatera* scattered tall shrubs over *Triodia wiseana* hummock grassland	1.05	1.05	0.00
Eucalyptus leucophloia subsp. *leucophloia* scattered low trees over *Eucalyptus gamophylla* low open mallee woodland over *Acacia hamersleyensis* tall open shrubland over *Triodia wiseana* open hummock grassland	5.70	5.70	0.00
Eucalyptus leucophloia subsp. *leucophloia, E. gamophylla* low open woodland over *Acacia pruinocarpa* tall open shrubland over *Triodia epactia, T. wiseana* hummock grassland	1.45	1.45	0.74
Eucalyptus leucophloia scattered low trees over *Triodia brizoides* hummock grassland	18.09	18.09	0.03
Eucalyptus victrix low open woodland over *Melaleuca glomerata* tall open shrubland over *Eriachne tenuiculmis* very open tussock grassland	4.35	0.00	0.00
Subtotal	552.78	177.13	23.94
Major Drainage Lines			
Eucalyptus camaldulensis subsp. *refulgens, E. victrix* woodland over *Acacia citrinoviridis* tall open scrub	618.94	231.05	0.00
Eucalyptus victrix scattered trees over *Acacia citrinoviridis* tall shrubland over *Triodia epactia* open hummock grassland and/or **Cenchrus ciliaris* open tussock grassland	996.32	183.21	0.00
Subtotal	1,615.26	414.25	0.00

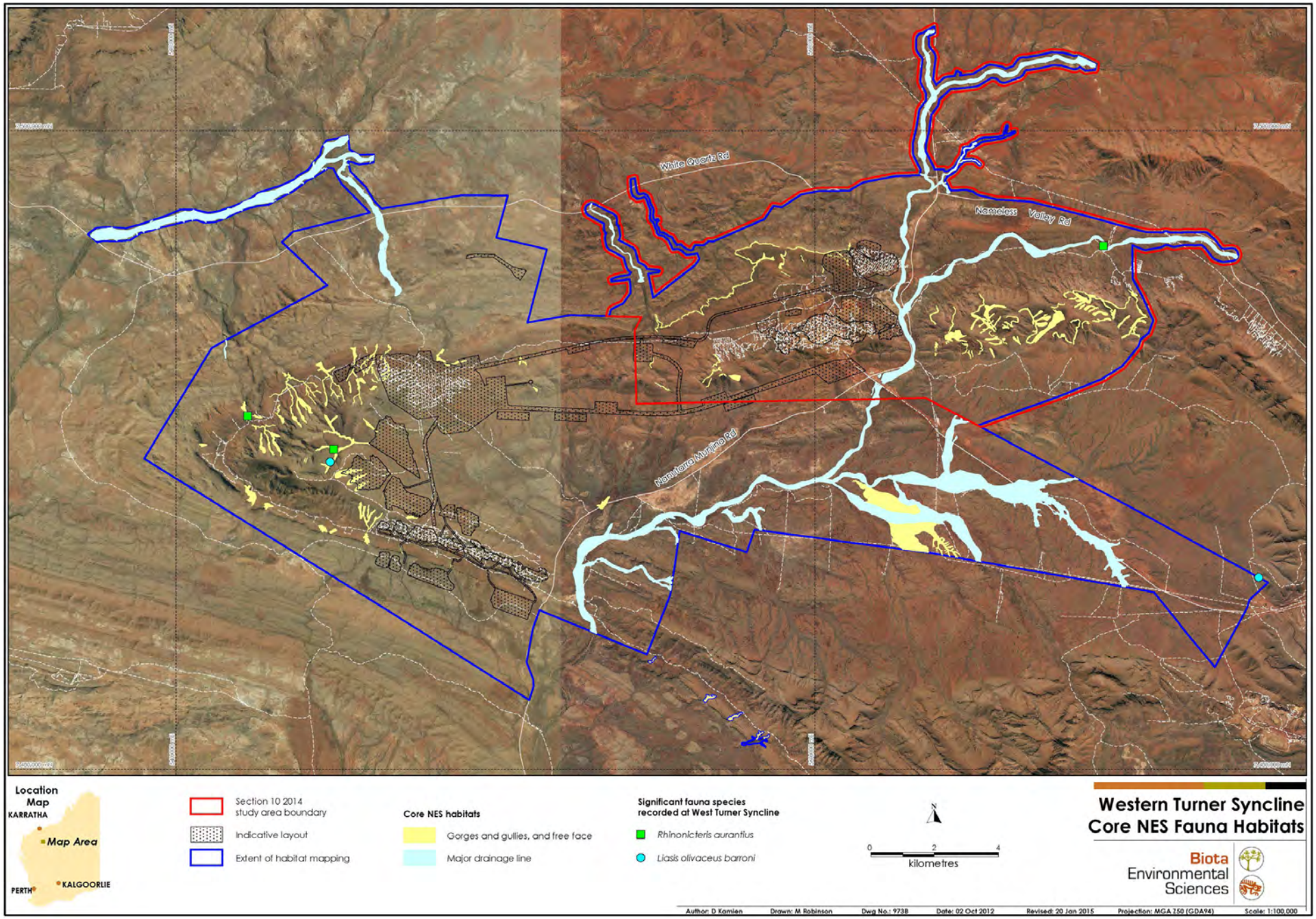


Figure 5.2: Core habitats for NES species in the WTS area, showing the Section 10 2014 study area boundary, overall indicative project layout and NES species recorded to date.

5.4 Potential Short Range Endemic Invertebrates

5.4.1 Mygalomorph Spiders

Twelve mygalomorph spiders representing two families were recorded from 10 sites within the study area (Table 5.10). Based on molecular analysis four putative species were identified (Table 5.10 and Appendix 5). Accounts and SRE status of both putative species are summarised below.

Table 5.10: Mygalomorph spiders recorded within the study area.

Site	Specimen Field Code	WAM Specimen Code	Easting (mE)	Northing (mN)	Morphological identification		SRE Status	Occurs Outside Study Area
					Family	Putative Species		
WTFSRE03	M20140410 WTFSRE03-01	T134418	563788	7492145	Nemesiidae	*Aname mellosa* (Nemesiidae sp. N16)	Not an SRE	Yes
WTFSRE05	M20140411 WTFSRE05-02	T134420	568069	7493392				
WTFSRE10	M20140412 WTFSRE10-01	T134424	563396	7501818				
WTFSRE16	M20140414 WTFSRE16-01	T134427	561086	7497895				
WTFSRE06	M20140411 WTFSRE06-01	T134421	563415	7495127				
WTFSRE15	M20140413 WTFSRE15-01	T134426	553300	7497399				
WTFSRE09	M20140412 WTFSRE09-01	T134423	568122	7493138				
WTS17	M20070723 WTS17-01	T98437	560531	7494746		Nemesiidae sp. N13	Potential SRE	No
WTS17	M20070723 WTS17-01	T89230	560531	7494746	Barychelidae	Barychelidae sp. B1	Potential SRE	Yes
WTFSRE08	M20140413 WTFSRE08-01	T134425	561021	7495799		Barychelidae sp. B2 (MYG309-DNA)	Potential SRE	Yes
WTFSRE05	M20140411 WTFSRE05-01	T134419	568066	7493394				
WTS13	na	na	558669	7494225		Barychelidae sp. (indet)	Indet.	Indet.

Coordinates in zone 50, GDA94.
Grey shading indicates site from previous survey.
indet. indicates indeterminate species.

A spider identified in the field as an araneomorph was inadvertently sequenced with the mygalomorph specimens in the laboratory (M20140411WTFSRE07-01; Appendix 5). Araneomorphae spiders are a suborder in which species do not typically represent potential SREs.

5.4.1.1 Family Nemesiidae – species N16 *(Aname mellosa*; Harvey et al. (2012)).

Distribution

Nemesiidae species N16 (*Aname mellosa*; Plate 5.1) was represented by seven individuals recorded at seven different locations within the study area (five within the survey area), (Figure 5.3). To date, 229 individuals of this putative species have been recorded from over 200 locations in the Central Pilbara (Biota 2012), with records occurring outside of the study area (Table 5.10 and Figure 5.4). The minimum spanning area (estimated known distribution) is currently known to be approximately 12,836 km^2.

Habitat
Specimens have been collected from red shallow loams or red earthy loams in narrow drainage floors, and also from adjacent landforms (e.g. low slopes and stony plains) where a suitable soil profile exists. Within the study area, it was recorded from a variety of habitats including colluvial plains with and without mulga, alluvial plains, stony pediments and drainage lines. This taxon creates either a hooded burrow entrance or a webby spoil pile, which may represent a collapsed burrow entrance (Plate 5.2).

SRE Status
The current known distribution of this putative species is greater than 10,000 km^2 and as a result it is not considered to be an SRE taxon as defined by Harvey (2002).



Plate 5.1: Nemesiidae (*Aname mellosa*): specimen M20140410WTFSRE03-01.



Plate 5.2: Nemesiidae (*Aname mellosa*) burrow: specimen M20140410WTFSRE03-01.

5.4.1.2 Family Nemesiidae – species N13

Distribution
Based on molecular analysis, the putative species Nemesiidae sp. N13 is known from a single specimen collected at site WTS17 within the study area, approximately 22 km west of the town of Tom Price (Plate 5.3 and Figure 5.3; (Biota 2008, 2011b). However, based on morphological analysis Dr Robert Raven (2011) assigned the specimen to Nemesiidae sp. MYG125 which was previously recorded on 22 occasions outside of the study area (Biota 2009e).

Habitat
As the specimen was recorded in a dry pit trap, no reliable data on habitat preference or burrow morphology is available for this putative species. However, the pit trap in which the specimen was recorded was located in a broad drainage area, mapped as part of a flora and vegetation survey completed by Biota in 2007 (Biota 2007a). The vegetation unit was mapped as:

- *Acacia* aff. *aneura* (narrow fine veined; site 1259), *A. aneura* (grey bushy form, MET 15,732), *A. pruinocarpa* tall shrubs over *A. bivenosa*, *Eremophila forrestii* subsp. *forrestii* open shrubland over *Triodia wiseana*, *T. epactia* hummock grassland.

This vegetation unit was referred to as 'C1' vegetation (Biota 2011b). Consistent with the previous EPA assessment of the original Section 10 proposal (EPA 2009b) and Guidance Statement 20 (EPA 2009a), the distribution of C1 vegetation was mapped in order to infer the potential distributional boundaries of Nemesiidae sp. N13 (known at the time as Nemesiidae sp.), (Biota 2011b). It was demonstrated that habitat for this taxon, and by inference, its distribution, extends beyond the immediate area of Section 10. As a result, it was considered a low risk that this taxon occurs only in the Section 10 area of West Turner Syncline (Biota 2011b).

SRE Status
Although Nemesiidae sp. N13 was morphologically assigned to Nemesiidae sp. MYG125 (subsequently known as molecular species Nemesiidae sp. N3 (Biota 2012b)), there is 18.4% molecular divergence between these putative taxa. Based on the 9.5% divergence threshold Nemesiidae sp. N13 and MYG125 (Nemesiidae sp. N3) are in fact different putative species.

With only a single specimen it is difficult to determine the SRE status of Nemesiidae sp. N13. However, based both on the fact that is known solely from the study area and from the criteria outlined in Table 3.7, it must be considered to be a potential SRE species.



Plate 5.3: Nemesiidae sp. N13.

5.4.1.3 Family Barychelidae – species B1

Distribution

Barychelidae sp. B1 was recorded on one occasion within the study area at site WTS17 (Plate 5.4, and Figure 5.3; Biota 2012c). This putative species also occurs outside of the study area (Table 5.10), and known from 25 specimens collected from 23 localities within the Pilbara bioregion (Figure 5.4). The minimum spanning area (estimated known distribution) is currently known to be approximately 6,398 km^2 occurring predominantly east of the study area (Biota 2012b).

Habitat

Species B1 has been recorded from Mulga (*Acacia aneura*) woodland with stony clay loam substrate. Its burrow lid is well camouflaged (Plate 5.5).

SRE Status

The current known distribution of this putative species is 6,938 km^2 and it therefore represents a potential SRE as defined by Harvey (2002).



Plate 5.4: Barychelidae sp. B1



Plate 5.5: Barychelidae sp. B1 closed burrow

5.4.1.4 Family Barychelidae – species B2

Distribution

Barychelidae sp. B2 (Plate 5.6) was recorded from two locations in the study area. Barychelidae sp. B2 also occurs outside of the study area (Table 5.10), and is known from 29 specimens collected from 15 locations in the Pilbara (Biota 2012 and Figure 5.4). It was also identified as its

alternative molecular species 'MYG309-DNA' in WAM report WAM-TS340 (see Appendix 5). Current data show that this putative species occupies a minimum spanning area of 6,730km^2.

Habitat
Previously, Barychelidae sp. B2 has been collected in areas dominated by Mulga (*Acacia aneura*), with a clay loam substrate. However, specimens collected within the study area were located in rocky gorge habitat. Its burrow is characterised by a clay lid, which is either flush to the ground or protruding above the ground on a turret shaped burrow (Plate 5.7).

SRE Status
The current known distribution of this putative species is 6,730 km^2 and it therefore represents a potential SRE as defined by Harvey (2002).



Plate 5.6: Barychelidae sp. B2: specimen M20140411WTFSRE05-01.



Plate 5.7: Barychelidae sp. B2 burrow: specimen M20140411WTFSRE05-01.

5.4.2 Scorpions

One scorpion specimen belonging to the family Urodacidae was recorded at site WTFSRE05 through rock turning during a targeted SRE search. It was determined that the specimen was unlikely to be of conservation significance and it was therefore not identified further.

5.4.3 Land Snails

Shells of dead camaenid snails were recorded from three sites within the study area (sites WTF01E, WTFSRE11 and WTFSRE16). These have been preliminarily identified as *Rhagada* sp. "Mt Brockman". This species is not restricted to the study area and has been previously recorded at Brockman Syncline 4 (approximately 30 km northwest of the study area) (Biota 2007b). As such, this taxon is not limited in distribution to the current study area and is not considered to be an SRE.

In addition, two shells of dead snails preliminarily identified as *Bothriembryon* sp. nov. were recorded opportunistically within the study area at 567079 mE, 7493636 mN. Molecular studies completed to date suggest that *Bothriembryon* sp. nov. is a single, relictual species distributed throughout the eastern Pilbara (broadly between Tom Price and Weeli Wolli Springs) (Biota 2006, Peet and Schmidt 2007). This species is not considered to represent an SRE taxon (Whisson 2012).

5.4.4 Millipede

Three millipedes were collected in leaf litter at site WTSSRE11. These represent one species, *Austrostrophus stictopygus,* of the family Trigoniulidae. This species is widespread throughout the Pilbara and is not considered to be an SRE (Harvey et al. 2011, Burger and Car 2012).

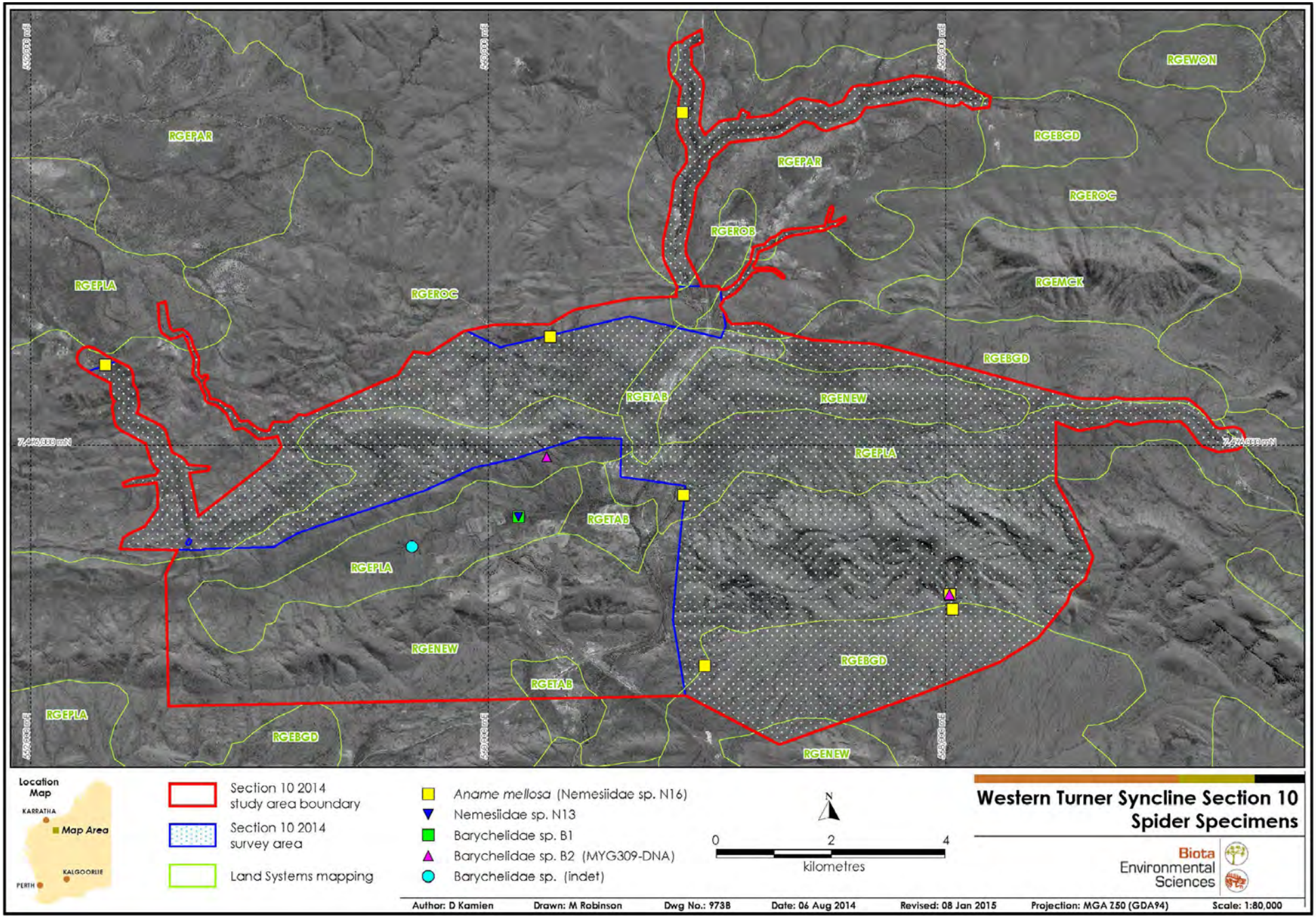


Figure 5.3: Putative mygalomorph species recorded within the study area.

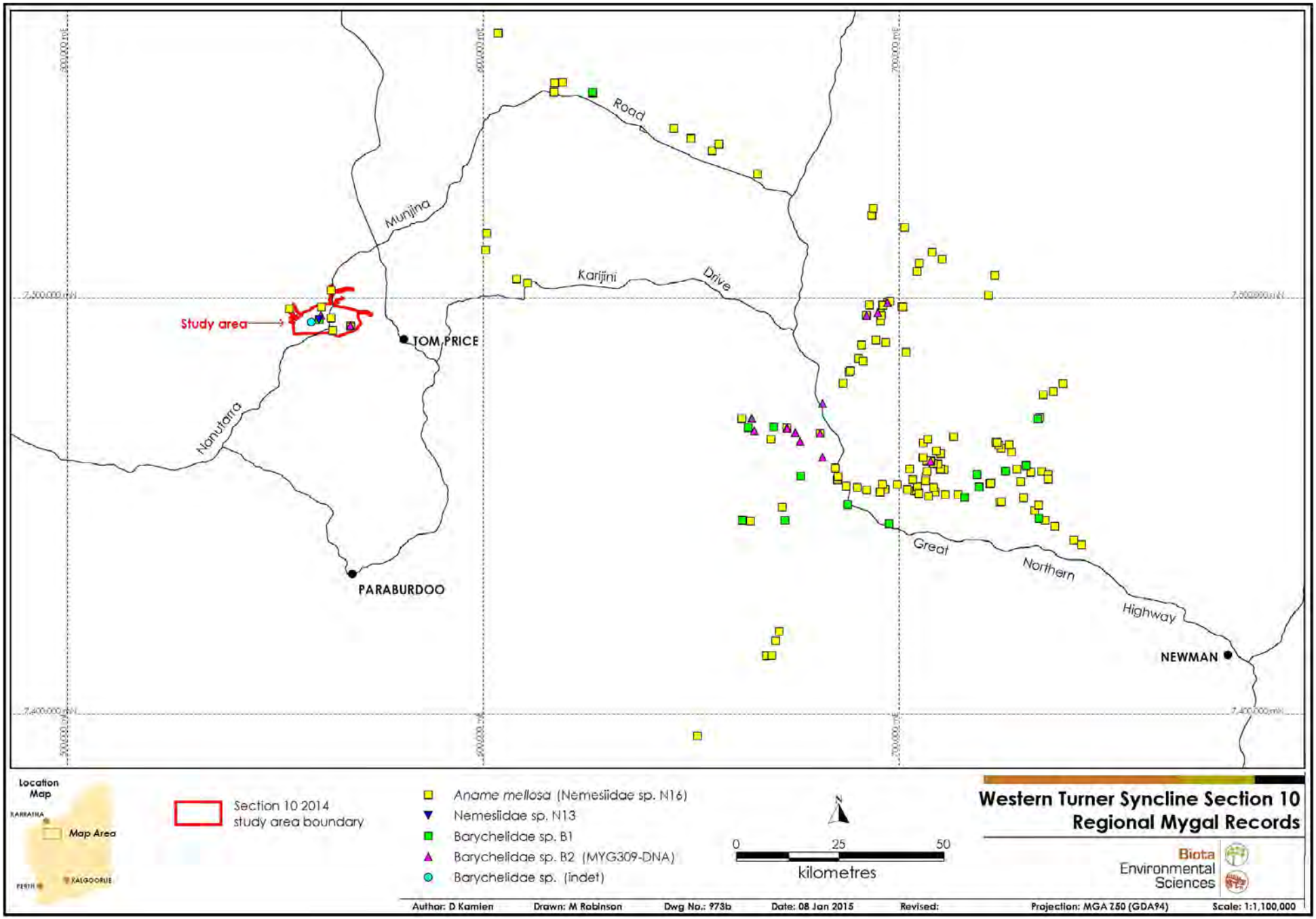


Figure 5.4: Wider distribution of putative mygalomoprh species recorded within the study area.

6.0 Conservation Significance

6.1 Faunal Value of Landforms within the Study Area

Two broad fauna landscapes encompassing numerous landforms occur in the study area, as described in Section 5.1. When considering the faunal value of the fauna habitats within the study area, the criteria were used to assess areas of higher habitat value:

- supports fauna of conservation significance;
- supports unique faunal assemblages; and
- is uncommon in the region.

Using these criteria, gorges, gullies and free faces in the study area were considered to be the landforms representing the habitat of highest faunal value. However, these are typical of similar habitat types in the wider locality.

The gorges, gullies and free faces in the study area have the potential to provide habitat for both the Northern Quoll and Pilbara Olive Python. The Orange Leaf-nosed Bat and Ghost Bat also have the potential to forage over most of the study area, but no evidence of any suitable roost sites for the species was detected.

6.2 Vertebrate Fauna of Conservation Significance

6.2.1 Conservation Significant Vertebrate Fauna Recorded from the Study Area

The Orange Leaf-nosed Bat (*Rhinonicteris aurantius*) was the only targeted conservation significant fauna species recorded in the study area, however the Priority 4 Western Pebble-mound Mouse (*Pseudomys chapmani*) was also recorded.

Orange Leaf-nosed Bat, *Rhinonicteris aurantius*
Schedule 1 under the WA *Wildlife Conservation Act 1950* and Vulnerable under the Commonwealth *EPBC Act 1999*.

Distribution: The Orange Leaf-nosed Bat is a relictual monotypic genus of the family Hipposideridae. An isolated population occurs in the Pilbara region of Western Australia, although the species' wider distribution also includes the Kimberley region of Western Australia, the Northern Territory and north-western Queensland (Churchill 2008). Populations found in the extreme northwest of Queensland are considered to be contiguous with those in the Northern Territory and the Kimberley of Western Australia. However, populations occurring in the Pilbara bioregion of Western Australia are isolated from northern populations.

Ecology: Occurrence of this species is influenced by the availability of suitable roost caves that offer high humidity and a stable temperature (Churchill 2008). In the Pilbara, they are thought to be restricted to caves where at least semi-permanent water is nearby. Foraging typically occurs over open grasslands in gorges, low hills and on plains.

Occurrence: Two Orange Leaf-nosed Bat echolocation calls were detected on a single night at site WTFBat88-1, located adjacent to a 10 m wide water pool in a broad ephemeral riverbed. Two additional calls have been recorded previously within the broader WTS area, as shown in Figure 5.2 (Biota 2011a, 2013b). Considering that these isolated calls were few in number, particularly given the extensive survey effort for bats at WTS (Biota 2013a) and due to the absence of significant caves, it is unlikely that a permanent roost supporting a colony of the Orange Leaf-nosed Bat occurs in the study area. The calls recorded were likely to represent individuals of the species foraging at a considerable distance from their roost (Biota 2012a).

Western Pebble-mound Mouse, *Pseudomys chapmani*
Listed as a Priority 4 species by Department of Parks and Wildlife

Distribution: The Western Pebble-mound Mouse is confined to the central and eastern Pilbara (Menkhorst and Knight 2011).

Ecology: The species is typically found on stony hillsides with hummock grasslands (van Dyck and Strahan 2008) and is common to very common in suitable habitat within the Hamersley and Chichester subregions of the Pilbara bioregion. The Western Pebble-mound Mouse is well known for its behaviour of constructing extensive mounds of small stones covering areas from 0.5 to 9.0 Koodaideri Western Rail Corridor Fauna Survey square meters. Mounds are most common on spurs and gentle slopes where suitably sized stones are present.

Occurrence: A single individual was recorded at WTF02E in rocky gorge habitat. Additionally, an active mound was located opportunistically at 568110 mE, 7493131 mN on a stony hillslope, which is typical habitat in which this species is commonly located.

6.2.2 Conservation Significant Vertebrate Fauna Potentially Occurring in the Study Area

Based on database searches, known fauna distributions, habitat preferences and habitat availability, the Northern Quoll, Pilbara Olive Python and Ghost Bat represent the other targeted species that may potentially occur in the study area.

Northern Quoll, *Dasyurus hallucatus*
Schedule 1 species under the WA *Wildlife Conservation Act 1950* and Endangered under the Commonwealth *EPBC Act 1999*.

Distribution: The Northern Quoll occurred formerly across much of northern Australia but is now restricted to six main areas: the north and western top end of the Northern Territory, north of Cape York, the Atherton-Cairns area, the Carnarvon Range-Bowen area of Queensland (Menkhorst and Knight 2011) and the northwest Kimberley and Pilbara regions of Western Australia (Braithwaite and Griffiths 1994). Many records from the Pilbara bioregion have come from dense vegetation along drainage areas, particularly where this is in contact with rocky free face habitats (Garth Humphreys, Biota, pers. obs.), and also from boulder tors of the Abydos-Woodstock Plain (How et al. 1991).

Ecology: The species is most abundant in open, rocky habitat and is also commonly found in gorges, breakaways and hills, which are particularly used for denning purposes (van Dyck and Strahan 2008). It also occurs near creek lines and drainage lines, where adjacent plains and vegetated areas provide habitats for foraging and dispersal of young (van Dyck and Strahan 2008). Northern Quoll populations fluctuate on both annual and inter-annual cycles. This variability is driven by both the reproductive biology of individuals and longer-term cycles in response to regional stochastic processes such as rainfall, fire and related changes in prey item populations (How et al. 2009)

Likelihood of Occurrence: While potentially suitable habitat occurs in the study area (rocky free faces, gorges and hills), no records of the Northern Quoll have been documented in the study area or surrounding areas despite extensive survey effort (Biota 2013a). There is therefore no evidence to suggest that a population of the Northern Quoll is present within the study area at this time.

Pilbara Olive Python, *Liasis olivaceus barroni*
Schedule 1 species under the WA *Wildlife Conservation Act 1950* and Vulnerable under the Commonwealth *EPBC Act 1999.*

Distribution: The Pilbara Olive Python has a known distribution that coincides roughly with the Pilbara bioregion (Environment Australia 2000).

Ecology: The Pilbara Olive Python occurs in rocky areas within the Pilbara, showing a preference for gorges containing water in streams and rock pools (Wilson and Swan 2010)

Likelihood of Occurrence: This species has been recorded in the broader WTS locality (Figure 5.2) and there is potential for individuals to occur in the current study area.

Ghost Bat, *Macroderma gigas*
Priority 4 species listed by the Department of Parks and Wildlife.

Distribution: The Ghost Bat was previously distributed across most of inland and northern Australia, but is now restricted to the tropical north of the continent (Churchill 2008). The species occurs in a broad range of habitats, with distribution being influenced by the availability of suitable caves and mines for roost sites (Churchill 2008). Populations in the Pilbara bioregion appear to be isolated from those in the Kimberley and Northern Territory.

Ecology: Ghost Bats are efficient predators of small birds, mammals, reptiles and large insects, and they have highly developed echolocation, visual and hearing systems (Churchill 2008). Bats forage over large distances (ranges of approximately 60 ha (Churchill 2008)) and the size of their foraging area is probably inversely related to the productivity of their landscape.

Likelihood of Occurrence: Although no Ghost Bats were recorded during the recent survey, one Ghost Bat has previously been detected in the broader WTS area (Biota 2013b). This species may therefore occur in the study area, most likely in a foraging capacity as no suitable roost caves were located. Ghost Bats have also been recorded at the Brockman 2 mine, approximately 30 km northwest of the study area (Biota 2010).

6.3 Synopsis of Targeted Vertebrate Fauna

Of the four vertebrate species targeted by the current survey, the Orange Leaf-nosed Bat was the only species recorded in the study area. The Pilbara Olive Python and Ghost Bat are known to occur within the broader WTS area, but the Northern Quoll has not yet been recorded in the WTS locality.

Based on the *EPBC Act* 1999 significant impact guidelines (DEWHA 2009), potential adverse affects on "habitat critical to the survival of the species" is the only significant impact criterion that may have negative consequences on the targeted Schedule 1 species occurring or potentially occurring in the combined WTS study area (Biota 2012a). However, the scale, nature and context of the proposed habitat removal during mine construction and associated works is deemed negligible, as it represents only 1.1 % of the core habitat for NES species that occurs within the total combined WTS study area.

The Biota (2012a) Western Turner NES species assessment report concluded that as most significant impact criteria would not be triggered (DEWHA 2009), and the adverse affects on potential core NES habitat are localised and minor in scale, the potential impacts from the current WTS proposal do not appear to be significant.

Results of the targeted fauna survey have not altered the conclusion outlined in Biota (2012a) that it is unlikely that the action of implementing the WTS development would result in a significant impact on any of the three targeted NES species or the Priority 4 Ghost Bat.

6.4 Short Range Endemic Invertebrates

Twelve mygalomorph spiders representing two families were recorded from 10 sites within the study area (Section 5.4.1). Based on molecular analysis, four putative species were identified. Three of these (Barychelidae sp. B1, Barychelidae sp. B2 and Nemesiidae sp. N13) represent potential SRE species, with the latter known solely from within the study area. The millipede, scorpion and land snails collected within the study area do not represent SRE taxa.

Additional searches and habitat assessments have been conducted in relation to Nemesiidae sp. N13 (Biota 2011b). The landscapes, land systems and vegetation types represented are relatively contiguous beyond the boundaries of the study area (Figure 3.4); (Biota 2011b),

indicating a high likelihood that Nemesiidae sp. N13 would occur beyond the study area. There are no geomorphological barriers or other habitat attributes that would suggest a high risk of species level distributions being restricted to the scale of the current study area.

Additionally, it was demonstrated that the habitat for this taxon, and by inference, its distribution, extends beyond the immediate area of Section 10. As a result, it was considered a low risk that this putative occurs only in the Section 10 area of West Turner Syncline (Biota 2011b).

7.0 Glossary

Biota	Biota Environmental Sciences.
DotE	Department of the Environment.
Elliott trap	A collapsible aluminium box trap.
Endemic	Unique to a defined geographic location.
EPA	Environmental Protection Authority of Western Australia.
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.
Habitat	An ecological or environmental area that is inhabited by a particular organism.
Herpetofauna	Reptiles and amphibians.
IBRA	Interim Biogeographic Regionalisation for Australia.
Landform	A geomorphological unit that is largely defined by its surface form and location in the study area.
Minimum Spanning Area	The minimum known area inhabited by a single taxon.
Non-volant mammal	Mammals that cannot fly.
NES species	Species of National Environmental Significance.
Opportunistic	A species recorded from non-systematic sampling methods.
PEC	Priority Ecological Community.
SM2	SongMeter 2 acoustic bat call recorder.
sp. (plural: spp.)	Abbreviation of 'species'.
SRE	Short Range Endemic.
Study Area	The area in which the fauna study was conducted (Figure 2.1).
Systematic sampling	Sampling using trapping transects (including pitfall traps, Elliott traps or funnel traps) and avifauna censuses in defined habitats.
Taxon (plural: taxa)	A taxonomic entity, typically at species level or below.
TEC	Threatened Ecological Community.
Volant mammal	Mammal capable of flying.

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Appendix 1

Database Search Results

NB: Conservation status codes: S = Schedule, P = Priority, En = Endangered, Vu = Vulnerable.

Avifauna

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Casuariidae							
Dromaius novaehollandiae	Emu			•		•	•
Anatidae							
Cygnus atratus	Black Swan			•			
Anas gracilis	Grey Teal			•		•	•
Anas superciliosa	Pacific Black Duck			•		•	•
Columbidae							
Phaps chalcoptera	Common Bronzewing			•		•	•
Ocyphaps lophotes	Crested Pigeon			•		•	•
Geophaps plumifera	Spinifex Pigeon			•		•	•
Geopelia cuneata	Diamond Dove			•		•	•
Geopelia striata	Peaceful Dove			•		•	•
Podargidae							
Podargus strigoides	Tawny Frogmouth			•		•	
Eurostopodidae							
Eurostopodus argus	Spotted Nightjar			•		•	•
Aegothelidae							
Aegotheles cristatus	Australian Owlet-nightjar			•		•	•
Apodidae							
Apus pacificus	Fork-tailed Swift	S3	Migratory		•		
Pelecanidae							
Pelecanus conspicillatus	Australian Pelican			•		•	
Ardeidae							
Ardea pacifica	White-necked Heron			•		•	•
Ardea modesta	Eastern Great Egret	S3	Migratory	•	•	•	
Ardea ibis	Cattle Egret	S3	Migratory		•		
Egretta novaehollandiae	White-faced Heron					•	•
Nycticorax caledonicus	Nankeen Night-Heron			•		•	
Threskiornithidae							
Threskiornis spinicollis	Straw-necked Ibis			•		•	•
Accipitridae							
Elanus axillaris	Black-shouldered Kite					•	•
Lophoictinia isura	Square-tailed Kite			•			•
Haliastur sphenurus	Whistling Kite			•		•	•
Milvus migrans	Black Kite					•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Accipiter fasciatus	Brown Goshawk			•		•	•
Accipiter cirrocephalus	Collared Sparrowhawk			•		•	•
Circus assimilis	Spotted Harrier			•		•	•
Aquila audax	Wedge-tailed Eagle			•		•	•
Hieraaetus morphnoides	Little Eagle			•		•	•
Falconidae							
Falco cenchroides	Nankeen Kestrel			•		•	•
Falco berigora	Brown Falcon			•		•	•
Falco hypoleucos	Grey Falcon	S1					•
Falco longipennis	Australian Hobby			•		•	•
Falco peregrinus	Peregrine Falcon	S4		•		•	•
Otididae							
Ardeotis australis	Australian Bustard	P4		•		•	•
Burhinidae							
Burhinus grallarius	Bush Stone-curlew	P4		•		•	•
Charadriidae							
Charadrius veredus	Oriental Plover	S3	Migratory		•		
Elseyornis melanops	Black-fronted Dotterel			•		•	•
Rostratulidae							
Rostratula australis	Australian Painted Snipe	S1	En		•		
Turnicidae							
Turnix velox	Little Button-quail			•		•	•
Cacatuidae							
Eolophus roseicapillus	Galah			•		•	•
Cacatua sanguinea	Little Corella			•		•	•
Nymphicus hollandicus	Cockatiel			•		•	•
Psittacidae							
Barnardius zonarius	Australian Ringneck					•	•
Psephotus varius	Mulga Parrot						•
Melopsittacus undulatus	Budgerigar			•		•	•
Cuculidae							
Chalcites basalis	Horsfield's Bronze-Cuckoo					•	•
Chalcites osculans	Black-eared Cuckoo					•	•
Cacomantis pallidus	Pallid Cuckoo					•	•
Strigidae							
Ninox novaeseelandiae	Southern Boobook					•	•
Tytonidae							
Tyto javanica	Eastern Barn Owl					•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Halcyonidae							
Dacelo leachii	Blue-winged Kookaburra			•		•	•
Todiramphus pyrrhopygius	Red-backed Kingfisher			•		•	•
Todiramphus sanctus	Sacred Kingfisher			•		•	
Meropidae							
Merops ornatus	Rainbow Bee-eater	S3	Migratory	•	•	•	•
Climacteridae							
Climacteris melanura	Black-tailed Treecreeper			•		•	•
Ptilonorhynchidae							
Ptilonorhynchus maculatus	Spotted Bowerbird						•
Ptilonorhynchus guttatus	Western Bowerbird					•	•
Maluridae							
Malurus leucopterus	White-winged Fairy-wren			•		•	•
Malurus lamberti	Variegated Fairy-wren			•		•	•
Stipiturus ruficeps	Rufous-crowned Emu-wren			•		•	•
Amytornis striatus	Striated Grasswren			•		•	•
Acanthizidae							
Pyrrholaemus brunneus	Redthroat			•		•	
Smicrornis brevirostris	Weebill			•		•	•
Gerygone fusca	Western Gerygone			•		•	•
Acanthiza uropygialis	Chestnut-rumped Thornbill			•		•	•
Acanthiza apicalis	Inland Thornbill					•	•
Pardalotidae							
Pardalotus rubricatus	Red-browed Pardalote			•			•
Pardalotus striatus	Striated Pardalote			•		•	•
Meliphagidae							
Certhionyx variegatus	Pied Honeyeater			•			•
Lichenostomus virescens	Singing Honeyeater			•		•	•
Lichenostomus keartlandi	Grey-headed Honeyeater			•		•	•
Lichenostomus penicillatus	White-plumed Honeyeater			•		•	•
Purnella albifrons	White-fronted Honeyeater						•
Manorina flavigula	Yellow-throated Miner			•		•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Acanthagenys rufogularis	Spiny-cheeked Honeyeater			•		•	•
Conopophila whitei	Grey Honeyeater			•		•	•
Epthianura tricolor	Crimson Chat			•		•	•
Sugomel niger	Black Honeyeater			•			•
Lichmera indistincta	Brown Honeyeater			•		•	•
Melithreptus gularis	Black-chinned Honeyeater			•		•	•
Pomatostomidae							
Pomatostomus temporalis	Grey-crowned Babbler			•		•	•
Pomatostomus superciliosus	White-browed Babbler			•		•	•
Eupetidae							
Cinclosoma castaneothorax	Chestnut-breasted Quail-thrush			•		•	•
Campephagidae							
Coracina maxima	Ground Cuckoo-shrike			•		•	•
Coracina novaehollandiae	Black-faced Cuckoo-shrike			•		•	•
Lalage sueurii	White-winged Triller			•		•	•
Pachycephalidae							
Pachycephala rufiventris	Rufous Whistler			•		•	•
Colluricincla harmonica	Grey Shrike-thrush			•		•	•
Oreoica gutturalis	Crested Bellbird			•		•	•
Artamidae							
Artamus personatus	Masked Woodswallow			•		•	•
Artamus cinereus	Black-faced Woodswallow			•		•	•
Artamus minor	Little Woodswallow			•		•	•
Cracticus torquatus	Grey Butcherbird			•		•	•
Cracticus nigrogularis	Pied Butcherbird			•		•	•
Cracticus tibicen	Australian Magpie			•		•	•
Rhipiduridae							
Rhipidura fuliginosa	New Zealand Fantail			•		•	•
Rhipidura albiscapa	Grey Fantail			•		•	•
Rhipidura leucophrys	Willie Wagtail			•		•	•
Corvidae							
Corvus bennetti	Little Crow			•		•	•
Corvus orru	Torresian Crow			•		•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Monarchidae							
Grallina cyanoleuca	Magpie-lark			•		•	•
Petroicidae							
Microeca fascinans	Jacky Winter			•			•
Petroica goodenovii	Red-capped Robin			•		•	•
Melanodryas cucullata	Hooded Robin			•		•	•
Acrocephalidae							
Acrocephalus australis	Australian Reed-Warbler			•		•	
Megaluridae							
Cincloramphus mathewsi	Rufous Songlark			•		•	•
Cincloramphus cruralis	Brown Songlark			•		•	•
Eremiornis carteri	Spinifexbird			•		•	•
Hirundinidae							
Petrochelidon ariel	Fairy Martin					•	•
Petrochelidon nigricans	Tree Martin			•		•	•
Nectariniidae							
Dicaeum hirundinaceum	Mistletoebird			•		•	•
Estrildidae							
Taeniopygia guttata	Zebra Finch			•		•	•
Emblema pictum	Painted Finch			•		•	•
Neochmia ruficauda	Star Finch	P4		•			•
Motacillidae							
Anthus novaeseelandiae	Australasian Pipit					•	•

Herpetofauna

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Hylidae							
Cyclorana maini	Sheep Frog			•		•	•
Litoria rubella	Little Red Tree Frog			•		•	•
Agamidae							
Amphibolurus longirostris				•		•	•
Ctenophorus caudicinctus	Ring-tailed Dragon			•			•
Ctenophorus isolepis	Military Dragon			•			•
Ctenophorus reticulatus	Western Netted Dragon			•		•	
Diporiphora valens				•		•	•
Pogona minor				•			•
Diplodactylidae							
Diplodactylus conspicillatus	Fat-tailed Gecko			•		•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Diplodactylus savagei	Southern Pilbara Beak-faced Gecko			•		•	•
Lucasium stenodactylum				•		•	•
Lucasium wombeyi				•			•
Oedura marmorata	Marbled Velvet Gecko			•		•	•
Rhynchoedura ornata	Western Beaked Gecko			•		•	•
Strophurus elderi				•		•	•
Strophurus wellingtonae				•		•	•
Carphodactylidae							
Nephrurus wheeleri				•			•
Gekkonidae							
Gehyra pilbara				•		•	•
Gehyra punctata				•		•	•
Gehyra variegata				•		•	•
Heteronotia binoei	Bynoe's Gecko			•		•	•
Heteronotia spelea	Desert Cave Gecko			•			•
Pygopodidae							
Delma elegans				•		•	•
Delma nasuta				•		•	•
Delma pax				•		•	•
Delma tincta				•		•	•
Lialis burtonis				•		•	•
Pygopus nigriceps				•		•	•
Scincidae							
Carlia munda				•		•	•
Carlia triacantha				•			•
Cryptoblepharus buchananii				•		•	•
Cryptoblepharus				•			•
Cryptoblepharus ustulatus				•		•	•
Ctenotus duricola				•		•	•
Ctenotus grandis				•			•
Ctenotus hanloni				•			•
Ctenotus helenae				•		•	•
Ctenotus pantherinus	Leopard Ctenotus			•		•	•
Ctenotus rubicundus				•		•	•
Ctenotus rutilans				•		•	•
Ctenotus saxatilis	Rock Ctenotus			•		•	•
Ctenotus schomburgkii				•		•	•
Ctenotus uber							

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Cyclodomorphus melanops	Slender Blue-tongue			•		•	•
Egernia formosa				•		•	•
Eremiascincus richardsonii	Broad-banded Sand Swimmer			•			
Lerista flammicauda				•		•	•
Lerista jacksoni				•			•
Lerista muelleri				•		•	•
Lerista verhmens				•		•	•
Lerista zietzi				•		•	•
Menetia greyii				•		•	•
Menetia surda				•			•
Morethia ruficauda exquisita				•		•	•
Notoscincus butleri		P4					•
Notoscincus ornatus							
Tiliqua multifasciata	Central Blue-tongue			•		•	•
Varanidae							
Varanus acanthurus	Spiny-tailed Monitor			•		•	•
Varanus brevicauda	Short-tailed Pygmy Monitor			•		•	•
Varanus bushi	Pilbara Mulga Monitor			•		•	•
Varanus caudolineatus				•		•	•
Varanus eremius	Pygmy Desert Monitor			•		•	•
Varanus giganteus	Perentie						•
Varanus gouldii	Bungarra or Sand Monitor			•			•
Varanus panoptes	Yellow-spotted Monitor			•			•
Varanus pilbarensis	Pilbara Rock Monitor			•			•
Varanus tristis	Racehorse Monitor			•		•	•
Typhlopidae							
Anilios ammodytes				•			•
Anilios ganei		P1					•
Anilios grypus				•			•
Anilios hamatus				•			
Anilio pilbarensis							•
Boidae							
Antaresia perthensis	Pygmy Python			•		•	•
Antaresia stimsoni	Stimson's Python			•			•
Liasis olivaceus barroni	Pilbara Olive Python	S1	Vu	•	•	•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Elapidae							
Acanthophis pyrrhus	Desert Death Adder						•
Acanthophis wellsi	Pilbara Death Adder					•	•
Brachyurophis approximans						•	•
Demansia psammophis						•	•
Demansia rufescens	Rufous Whipsnake			•		•	•
Furina ornata	Moon Snake			•		•	•
Parasuta monachus				•		•	•
Pseudechis australis	Mulga Snake			•		•	•
Pseudonaja mengdeni	Western Brown Snake			•			•
Pseudonaja modesta	Ringed Brown Snake			•		•	•
Pseudonaja nuchalis	Gwardar; Northern Brown Snake			•			•
Suta fasciata	Rosen's Snake			•			•
Vermicella snelli				•		•	•

Mammalia

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Tachyglossidae							
Tachyglossus aculeatus	Echidna			•			•
Dasyuridae							
Dasykaluta rosamondae	Little Red Kaluta			•		•	•
Dasyurus hallucatus	Northern Quoll	S1	En		•		
Ningaui timealeyi	Pilbara Ningaui			•		•	•
Planigale ingrami	Long-tailed Planigale			•			•
Pseudantechinus woolleyae	Woolley's Pseudantechinus			•		•	•
Pseudantechinus roryi	Rory's Pseudantechinus			•		•	•
Sminthopsis macroura	Stripe-faced Dunnart			•		•	•
Thylacomyidae							
Macrotis lagotis	Bilby, Dalgyte	S1	Vu		•		
Notoryctidae							
Notoryctes caurinus	Northern Marsupial Mole				•		
Macropodidae							
Macropus robustus	Euro			•			•
Macropus rufus	Red Kangaroo, Marlu			•		•	•

Family / Species Name	Common Name	Conservation Status		Record Source			
		State	Commonwealth	NatureMap	EPBC	ALA	Surveys within 40 km of Study Area
Hipposideridae							
Rhinonicteris aurantius	Orange Leaf-nosed Bat	P4			•		•
Megadermatidae							
Macroderma gigas	Ghost Bat	P4		•		•	•
Emballonuridae							
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat			•			•
Taphozous georgianus	Common Sheathtail-bat			•		•	•
Vespertilionidae							
Chalinolobus gouldii	Gould's Wattled Bat			•		•	•
Chalinolobus morio	Chocolate Wattled Bat						•
Nyctophilus geoffroyi	Lesser Long-eared Bat			•			•
Scotorepens balstoni	Inland Broad-nosed Bat			•			
Scotorepens greyii	Little Broad-nosed Bat			•		•	•
Vespadelus finlaysoni	Finlayson's Cave Bat			•		•	•
Molossidae							
Chaerephon jobensis	Northern Freetail-bat			•			•
Mormopterus beccarii	Beccari's Freetail-bat			•			
Muridae							
Leggadina lakedownensis	Short-tailed Mouse	P4		•		•	•
Mus musculus	House Mouse			•		•	•
Pseudomys chapmani	Western Pebble-mound Mouse	P4		•		•	•
Pseudomys desertor	Desert Mouse			•		•	•
Pseudomys hermannsburgensis	Sandy Inland Mouse			•		•	•
Zyzomys argurus	Common Rock-rat			•		•	•
Leporidae							
Oryctolagus cuniculus	Rabbit						
Canidae							
Canis lupus dingo	Dingo						•
Vulpes vulpes	Red Fox						
Felidae							
Felis catus	Cat			•			•
Bovidae							
Bos taurus	European Cattle			•			

Appendix 2

Regulation 17 Permit: Licence to Take Fauna for Scientific Purposes

DEPARTMENT OF PARKS AND WILDLIFE

Department of Parks and Wildlife

Enquiries: 17 DICK PERRY AVE, KENSINGTON, WESTERN AUSTRALIA
Telephone: 08 9334 0333
Facsimile: 08 9334 0242

Correspondence: **Locked Bag 30**
Bentley Delivery Centre WA 6983

PERSON NO. SF009675 70754

AUTHORISED PERSONS
JASON ALEXANDER
PENELOPE BROOSHOOFT
TIM SACHSE
CHRIS COLE
MICHAEL GREENHAM
DAVID KEIRLE
STEWART FORD

DATE OF ISSUE 29/01/2014
VALID FROM 01/03/2014
DATE OF EXPIRY 31/05/2014

LICENSING OFFICER

RESIDENTIAL ADDRESS:
6A WONGAN AVE
WHITEGUM VALLEY WA 6162

LICENSEE: MR D KAMIEN (DANIEL)
ADDRESS
C/- BIOTA ENVIRONMENTAL
PO BOX 155
LEEDERVILLE WA 6903

- - - - - - - - - - - - - - - - -

DEPARTMENT OF PARKS AND WILDLIFE

Department of Parks and Wildlife

Enquiries: 17 DICK PERRY AVE, KENSINGTON, WESTERN AUSTRALIA
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Correspondence: **Locked Bag 30**
Bentley Delivery Centre WA 6983

PAGE NO. 1
SF009675
PERSON NO. 70754

RECEIPT NO. **AMOUNT**
$0.00

WILDLIFE CONSERVATION ACT 1950
REGULATION 17
LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

DIRECTOR GENERAL

CONDITIONS

1 THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.

2 UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE DIRECTOR GENERAL, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.

3 NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE DIRECTOR GENERAL. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.

4 NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.

5 NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR BE HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE DIRECTOR GENERAL, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.

6 THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.

7 **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE DEPT OF SUSTAINABILITY, ENVIRONMENT, WATER, POPULATION & COMMUNITIES PH 02 6274 1111. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS DPaW'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********

8 NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE DIRECTOR GENERAL OF DPaW.

9 FURTHER CONDITIONS (NUMBERED 1 TO 9) ARE ATTACHED.

PURPOSE FAUNA SURVEYS: TARGETED VERTEBRATE (NORTHERN QUOLL (TAKE EAR TISSUE SAMPLES), ORANGE LEAF-NOSED BAT, GHOST BAT, PILBARA OLIVE PYTHON, USING ELLIOTT AND CAGE TRAPS, MOTION SENSITIVE CAMERAS, ECHOLOCATOR RECORDERS); SHORT RANGE ENDEMIC (SRE) INVERTEBRATE (ACTIVE SEARCHES / FORAGING, AND UP TO 3 INDIVIDUALS OF EACH PERCEIVED NOMINAL TAXA RETAINED FOR SPECIMENS); AND SUBTERRANEAN (STYGOFAUNA PLANKTON HAUL NETS AND TROGLOFAUNA HABITAT TRAPS) AT THE WEST TURNER SYNCLINE SECTION 10 EXPANSION PROJECT AREA, 40KM WEST OF TOM PRICE TOWN, FOR RIO TINTO.

WILDLIFE CONSERVATION REGULATIONS 1970

Regulation 17:- Licence to Take Fauna for Scientific Purposes

FURTHER CONDITIONS (OF LICENCE NUMBER SF 009675)

1. The licensee shall take fauna only in the manner stated on the endorsed Regulation 17 licence application form and endorsed related correspondence.

2. Except in the case of approved lethal traps, the licensee shall ensure that measures are taken in the capture and handling of fauna to prevent injury or mortality resulting from that capture or handling. Where traps or other mechanical means or devices are used to capture fauna these shall be deployed so as to prevent exposure of trapped animals to ants and debilitating weather conditions and inspected at regular intervals throughout each day of their use. At the conclusion of research all markers etc and signs erected by the licensee and all traps shall be removed, all pitfalls shall be refilled or capped and the study area returned to the condition it was in prior to the research/capture program. During any break in research, cage traps should be removed and pitfalls either removed, capped or filled with sand.

3. No collecting is to be undertaken in areas where it would impinge on pre-existing scientific research programs.

4. Any form of colour marking of birds or bats shall only be undertaken in accordance with the requirements of the Australian Bird and Bat Banding Scheme.

5. Any inadvertently captured specimen of fauna which is declared as likely to become extinct, rare or otherwise in need of special protection is to be released immediately at the point of capture. Where such a specimen is injured or deceased, the licensee shall contact Department of Parks and Wildlife licensing staff at Kensington (08 9219 9831) for advice on disposal. Records are to be kept of any fauna so captured and details included in the report required under further condition 6 below.

6. Within one month of the expiration of this licence, the holder shall submit an electronic return detailing the locality, site, geocode, date and number of each species captured, sighted or vouchered during the currency of the licence, into the Department of Parks and Wildlife Fauna Survey Database (FSD). A copy of any paper, report or thesis resulting from the research shall on completion be lodged with the Director General. If a renewal of this licence is required, the licensee shall submit a written progress report for activities undertaken during this licence period prior to the expiry of this licence.

7. Not more than ten specimens of any one protected species shall be taken and removed from any location less than 20km apart. Where exceptional circumstances make it necessary to take large series in order to obtain adequate statistical data the collector will proceed with circumspection and justify their actions to the Director General in advance.

8. All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this licence shall be donated to the Western Australian Museum. Duplicates (one pair in each case) of any species collected which represents a significant extension of geographic range shall be donated on request to the Western Australian Museum.

9. To prevent any unnecessary collecting in this State, all specimens and material collected under the authority of this license shall, on request, be loaned to the Western Australian Museum. Also, the unused portion or portions of any specimen collected under the authority of this license shall be offered for donation to the Western Australian Museum or made available to other scientific workers if so required.

Appendix 3

SM2 Bat Configuration

Manual Configuration for SM2Bat SongMeters

Manual Audio Configuration (Mother board, jumpers and switches)	
Mic Bias	N/A
High Pass Filter	1kHz
Gain Amplification (for left microphone)	24+ dB
Power Supply	Internal

Software Configuration for SM2Bat SongMeters

Audio Configuration (Software)	
Sample Rate	384000
Channels	Mono-L
Compression	WAC4
Gain Left (for Left Microphone)	0.00
Digital High Pass Frequency Left Microphone	Frequency of Sampling/96 (4000Hz)
Digital Low Pass Frequency Left Microphone	Off
Trigger Window Left	0.5s
Trigger Window Right	1s
Division Ratio	16

Appendix 4

Orange Leaf-nose Bat (*Rhinonicteris aurantius*) Call Parameters and Example Spectrogram

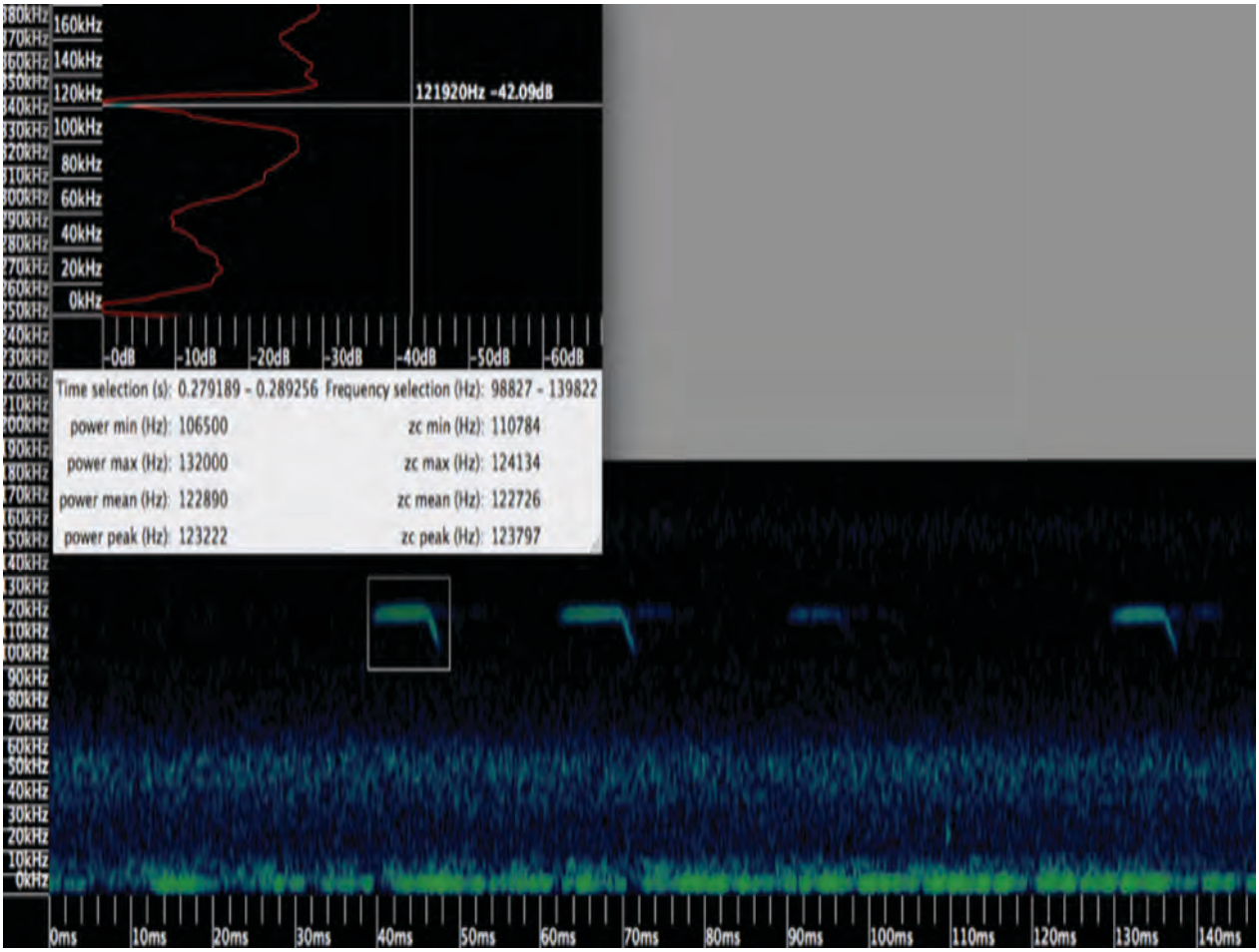


Figure 1: Spectrogram of typical Orange Leaf-nosed Bat echolocation call.

Table 1: Basic parameters of Orange Leaf-nosed Bat call signature.

Species	s,p[1]	Call Shape	Duration (ms)	Characteristic Frequency (kHz)[2]	Reference
Orange Leaf-nosed Bat, *Rhinonicteris aurantius*	56	Constant Frequency	5 to 8	120.2 ± 3.6	McKenzie and Bullen (2009)

[1] s,p: number of sequences measured, combined total number of pulses measured.

[2] Mean ± Standard Deviation; range.

Appendix 5

Mygalomorph Spider Molecular Analysis Reports

Molecular identification of Mygalomorph spiders from between ca. 17.2 km west and 28.5 km west-north-west of Tom Price, WA

(*Western Turner Syncline Section 10 expansion*)

Report to *Rio Tinto*

26 November 2014

Gaynor Dolman

Department of Terrestrial Zoology, Western Australian Museum,
Locked Bag 49, Welshpool DC, Western Australia 6986, Australia



Although identifications in this report were consistent with the best available information and current scientific thinking at the time of identification the use of this report is at the risk of the user. Any liability to users of this report for loss of any kind arising out of the use of this report or the information and identifications it contains is expressly disclaimed.

Summary

Ten specimens of spider (infra-order, Mygalomorphae) were among those collected from between ca. 17.2 km west and 28.5 km west-north-west of Tom Price, Western Australia. The specimens were lodged into the Western Australian Museum collection by *Biota Environmental Sciences (*see Appendix 1 for specimen details). As these taxa are often difficult to tell apart using morphological features alone, DNA-based identifications were sought. The main objectives of the WA Museum's Molecular Systematics Unit (MSU) were to use COI DNA barcoding to: 1) determine how many different species are present within the material, and 2) observe if the identified species have been detected anywhere else from the existing WAM records/ specimens.

Tissue was subsampled from ten specimens of Mygalomorph spiders. DNA was extracted from these subsamples using a commercially available DNA extraction kit (QIAGEN DN-easy). DNA barcoding sequences (Cytochrome Oxidase I; CO1) were amplified by PCR using Folmer's PCR primers (LCO1490, HCO2198) in the MSU and sequenced by the Australian Genomic Research Facility (AGRF) Perth node. DNA sequences were BLASTED against the Western Australian Museum DNA database and combined with DNA sequences from the WAM DNA database to generate simple distance-based trees to determine genetic relationships and species status.

A summary of specimen identifications together with their SRE status is presented in Table 1. A full explanation of the SRE categories used by the Western Australian Museum is in Appendix 2. A simple Neighbour-Joining (distance based) tree is provided in Appendix 3 for visualisation of genetic relationships. DNA sequences of queried specimens are provided in Appendix 4.

Table 1. Summary of WAMTS340 specimen identifications and SRE status

INFRAORDER	GENUS	SPECIES	# OF SPECIMENS	SRE SUB-CATEGORY
Mygalomorphae	*Aname*	*mellosa*	6	Widespread
Mygalomorphae	*Synothele*	'MYG309-DNA'	2	Potential SRE- (D) Molecular Evidence
Mygalomorphae	Indet.		1	

Results

COI DNA barcodes were amplified and successfully sequenced from 9 of ten specimens submitted by *Biota Environmental Sciences*. COI sequences from these nine Mygalomorph specimens were compared to the Western Australian Museum's DNA barcode database. A summary of the comparison (BLAST results) is provided in Table 2. Details of museum specimens that were identified in BLAST searches and contextualise the status of the queried species are provided in Table 3. DNA sequences (COI) generated from queried specimens are provided in Appendix 3.

Table 2. Summary of BLAST analysis

REG. NO.	SPECIES	SUMMARY OF BLAST RESULTS
T134418 T134420 T134421 T134424 T134426 T134427	*Aname mellosa*	Among six queried specimens there is 2.9% average sequence diversity. The average divergence between these specimens and other specimens of *Aname mellosa* is 6.9% (minimum divergence is 1.8%) *Aname mellosa* is a genetically diverse lineage with average diversity of 16.7% (360 specimens; Castalanelli et al. 2014).
T134419 T134425	*Synothele* 'MYG309-DNA'	These two specimens align with a lineage recognised through DNA barcoding, 'MYG309-DNA'. 'MYG309-DNA' has an average sequence diversity among specimens of 5.79% (diversity is from 0 to 12.21%). The average divergence between 'MYG309-DNA' and the nearest distinct lineage is 15.63%.
T134422	Indet.	No significant DNA comparisons (Blast hits).

Table 3. Details of registered WAM specimens of *Synothele* '**MYG309-DNA' according to DNA barcoding**

ORDER	Araneae									
INFRAORDER	Mygalomorphae									
FAMILY	Barychelidae									
REG. NO.	**GENUS**	**SPECIES**	**LOCALITY**	**COLLECTION METHOD**	**MALE**	**FEMALE**	**JUVENILE**	**LATITUDE**	**LONGITUDE**	**HABITAT**
T103203	Synothele	`MYG309-DNA`	Area C, 85.7 km NW. of Newman		0	0	1	-22.9483	119.025	dug from burrow
T89232	Synothele	`MYG309-DNA`	8.9 km S. of Tom Price, Tom Price Mine, site BLF# MMF100 6		0	0	1	-22.7761	117.791	leaf litter
T113657	Synothele	`MYG309-DNA`	119.1 km NW. of Newman	dug from burrow	0	1	0	-22.6337	118.87	
T113663	Synothele	`MYG309-DNA`	117.6 km NW. of Newman	dug from burrow	0	1	0	-22.6279	118.896	
T116867	Synothele	`MYG309-DNA`	Mudlark, 94 km W. of Newman	by hand	0	0	0	-23.0794	118.858	dug from burrow
T122826	Synothele	`MYG309-DNA`	127.3 km NW. of Newman	dug from burrow	0	1	0	-22.8603	118.604	Mulga woodland
T122825	Synothele	`MYG309-DNA`	111.6 km NW. of Newman	dug from burrow	0	1	0	-22.8919	118.764	Mulga woodland
T122821	Synothele	`MYG309-DNA`	111.6 km NW. of Newman	dug from burrow	0	1	0	-22.8914	118.764	Mulga woodland
T122867	Synothele	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	0	1	-22.8806	118.687	Mulga woodland
T122862	Synothele	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	1	0	-22.8808	118.688	Mulga woodland
T122860	Synothele	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	1	0	-22.8808	118.687	Mulga woodland

ORDER	Araneae									
INFRAORDER	Mygalomorphae									
FAMILY	Barychelidae									
REG. NO.	**GENUS**	**SPECIES**	**LOCALITY**	**COLLECTION METHOD**	**MALE**	**FEMALE**	**JUVENILE**	**LATITUDE**	**LONGITUDE**	**HABITAT**
T122864	Synothele	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	1	0	-22.8808	118.687	Mulga woodland
T122858	*Synothele*	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	1	0	-22.8808	118.687	Mulga woodland
T122859	*Synothele*	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	1	0	-22.8808	118.687	Mulga woodland
T122850	*Synothele*	`MYG309-DNA`	117.2 km NW. of Newman	dug from burrow	0	1	0	-22.8908	118.707	Mulga woodland
T122856	*Synothele*	`MYG309-DNA`	117.2 km NW. of Newman	dug from burrow	0	1	0	-22.8906	118.706	Mulga woodland
T122840	*Synothele*	`MYG309-DNA`	115.4 km NW. of Newman	dug from burrow	0	1	0	-22.9092	118.718	Mulga woodland
T126252	*Synothele*	`MYG309-DNA`	118.2 km NW. of Newman		0	1	0	-22.6053	118.919	
T122846	*Synothele*	`MYG309-DNA`	115.4 km NW. of Newman	dug from burrow	0	1	0	-22.9086	118.717	Mulga woodland
T122831	*Synothele*	`MYG309-DNA`	127.3 km NW. of Newman	dug from burrow	0	1	0	-22.8603	118.604	Mulga woodland
T122833	*Synothele*	`MYG309-DNA`	127.3 km NW. of Newman	dug from burrow	0	1	0	-22.8603	118.604	Mulga woodland
T122834	*Synothele*	`MYG309-DNA`	127.3 km NW. of Newman	dug from burrow	0	1	0	-22.8603	118.604	Mulga woodland
T122837	*Synothele*	`MYG309-DNA`	125.9 km NW. of Newman	dug from burrow	0	1	0	-22.8869	118.611	Mulga woodland
T122838	*Synothele*	`MYG309-DNA`	114.9 km NW. of Newman	dug from burrow	0	1	0	-22.8256	118.769	Mulga woodland

ORDER		Araneae								
INFRAORDER		Mygalomorphae								
FAMILY		Barychelidae								
REG. NO.	**GENUS**	**SPECIES**	**LOCALITY**	**COLLECTION METHOD**	**MALE**	**FEMALE**	**JUVENILE**	**LATITUDE**	**LONGITUDE**	**HABITAT**
T126249	*Synothele*	`MYG309-DNA`	118.2 km NW. of Newman		0	0	0	-22.6053	118.919	
T122282	*Synothele*	`MYG309-DNA`	Koodaideri Corridor West, 90.6 km NW. of Tom Price	burrow search	0	0	0	-21.8869	117.701	
T122871	*Synothele*	`MYG309-DNA`	118.6 km NW. of Newman	dug from burrow	0	1	0	-22.8806	118.687	Mulga woodland
T122279	*Synothele*	`MYG309-DNA`	Koodaideri Corridor West, 90.8 km NW. of Tom Price	burrow search	0	0	0	-21.8866	117.701	

Conclusions

The main objectives were to use DNA barcoding to: to: 1) determine how many different species are present within the material, and 2) observe if the identified species have been detected anywhere else from the existing WAM records/ specimens. According to currently available DNA barcoding (COI) data there are three different species among nine specimens collected from between ca. 17.2 km west and 28.5 km west-north-west of Tom Price, Western Australia.

Six specimens belong to the widespread and genetically diverse lineage, *Aname mellosa*. According to the currently available data, *Aname mellosa* is considered a single species. A seventh juvenile specimen (T134423) did not generate a high quality DNA sequence, but was also aligned to *Aname mellosa* based on morphological identification by Mark Castalanelli.

Two specimens belong to 'MYG309-DNA', a distinct lineage recognised through DNA barcoding (COI). 'MYG309-DNA' is now represented by 30 specimens in the WA Museum Collection. Currently available data reveal that 'MYG309-DNA' represents a potential SRE based on Molecular Evidence (D), with an area of distribution calculated at 6,730 Km^2. Specimen T134419, submitted as part of this project, represents the first adult male of 'MYG309-DNA' in the collection. Therefore morphological identification would have been difficult in the absence of other adult male representatives of the species. Morphological identifications carried out by Mark Castalanelli (for *Biota Environmental Sciences*) on these two specimens assigned them to 'MYG127'. 'MYG309-DNA' and 'MYG127' are among a morphologically conservative species complex of *Synothele* containing three morphologically diagnosed species and three genetically diagnosed species. The average genetic divergence between 'MYG309-DNA' and 'MYG127' is 15.86% (from 13.85% to 17.20%). Future work will be to examine the new adult male specimen (T134419) for morphologically distinguishing features.

One specimen was morphologically identified by Mark Castalanelli as 'by-catch'. As DNA work was in progress before this identity was known, a barcode was generated for this specimen. However there were no significant DNA matches (Blast hits) comparing the sequence to the WA Museum database or the publicly available DNA database, GenBank. Thus this specimen remains as species 'indetermined' until more barcoding data are available.

References

Castalanelli, M. , Teale, R., Rix, M.G., Kennington, W.J. and Harvey, M. (2014) Barcoding of mygalomorph spiders (Araneae : Mygalomorphae) in the Pilbara bioregion of Western Australia reveals a highly diverse biota. *Invertebrate Systematics,* **28**: 375–385.

Appendix 1. Specimen data for ten queried Mygalormorph specimens

REG. NO.	FIELD NO.	ORDER	INFRAORDER	GENUS	SPECIES (MOLECULAR ID)	SPECIES (MORPHOLOGICAL ID)	LOCALITY	COLLECTION METHOD	MALE	FEMALE	JUVENILE	HABITAT
T134418	M20140410WTF SRE03-01	Araneae	Mygalomorphae	*Aname*	*mellosa*	*mellosa*	17.2 km W. Tom Price	Dug from burrow		1		Open woodland
T134419	M20140411WTF SRE05-01	Araneae	Mygalomorphae	*Synothele*	`MYG309-DNA`	'MYG 127'	13.2 km WNW. Tom Price	Dug from burrow	1			Grassland
T134420	M20140411WTF SRE05-02	Araneae	Mygalomorphae	*Aname*	*mellosa*	*mellosa*	13.2 km WNW. Tom Price	Dug from burrow		1		Grassland
T134421	M20140411WTF SRE06-01	Araneae	Mygalomorphae	*Aname*	*mellosa*	*mellosa*	18.2 km WNW. Tom Price	Dug from burrow		1		Open grassland/ sedges/ herbs
T134422	M20140411WTF SRE07-01	Araneae			'Indet'	"By-catch"	15.4 km WNW. Tom Price	Dug from burrow			1	Open grassland/ sedges/ herbs
T134423	M20140412WTF SRE09-01	Araneae	Mygalomorphae	*Aname*	Sequencing QC failed	*mellosa*	13.1 km WNW. Tom Price	Dug from burrow		1		Open grassland
T134424	M20140412WTF SRE10-1	Araneae	Mygalomorphae	*Aname*	*mellosa*	*mellosa*	21.1 km WNW. Tom Price	Dug from burrow			1	Open grassland/ sedges/ herbs
T134425	M20140413WTF SRE08-01	Araneae	Mygalomorphae	*Synothele*	`MYG309-DNA`	'MYG 127'	20.1 km WNW. Tom Price	Dug from burrow			1	Under rocks
T134426	M20140413WTF SRE15-01	Araneae	Mygalomorphae	*Aname*	*mellosa*	*mellosa*	28.5 km WNW. Tom Price	Dug from burrow			1	Under rocks
T134427	M20140414WTF SRE16-01	Araneae	Mygalomorphae	*Aname*	*mellosa*	*mellosa*	21.3 km WNW. Tom Price	Dug from burrow			1	Under rocks

Appendix 2. WAM Short-Range Endemic Categories

	Taxonomic Certainty	Taxonomic Uncertainty
Distribution < 10 000km^2	**Confirmed SRE** • *A known distribution of < 10 000km².* • *The taxonomy is well known.* • *The group is well represented in collections and/ or via comprehensive sampling.*	**Potential SRE** • *Patchy sampling has resulted in incomplete knowledge of the geographic distribution of the group.* • *We have incomplete taxonomic knowledge.* • *The group is not well represented in collections.* • *This category is most applicable to situations where there are gaps in our knowledge of the taxon.* **Sub-categories for this SRE designation are outlined below**
Distribution > 10 000km^2	**Widespread (not an SRE)** • *A known distribution of > 10 000km².* • *The taxonomy is well known.* • *The group is well represented in collections and/ or via comprehensive sampling.*	

SRE SUB-CATEGORIES

If a taxon is determined to be a "Potential SRE", the following sub-categories will further elucidate this status.

A. <u>*Data Deficient:*</u>
- There is insufficient data available to determine SRE status.
- Factors that fall under this category include:
  - Lack of geographic information.
  - Lack of taxonomic information.
  - The group may be poorly represented in collections.
  - The individuals sampled (e.g. juveniles) may prevent identification to species level.

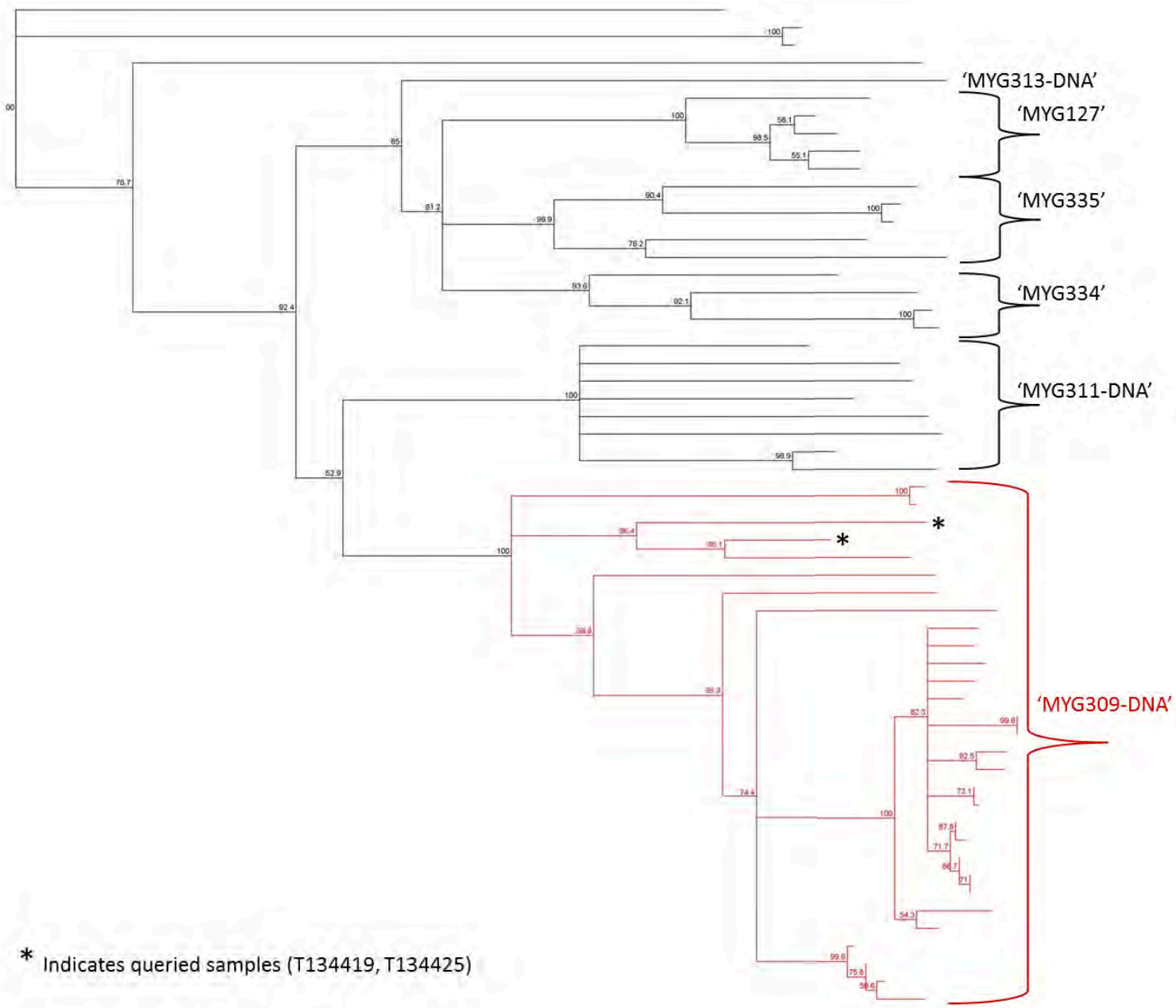
B. <u>*Habitat Indicators:*</u>
- It is becoming increasingly clear that habitat data can elucidate SRE status.
  - Below are some examples of habitats that are currently known to be associated with SRE taxa and vice versa.

C. <u>*Morphology Indicators:*</u>
- A suite of morphological characters are characteristic of SRE taxa.
- Below are some examples of morphological characters associated with SRE taxa and vice-versa.

D. <u>*Molecular Evidence:*</u>
- If molecular work has been done on this taxon (or a close relative), it may reveal patterns congruent or incongruent with SRE status.
- Below are some examples of phylogenetic patterns associated with SRE taxa and vice-versa.

E. <u>*Research & Expertise:*</u>
- Previous research and/ or WAM expertise elucidates taxon SRE status.
- This category takes into account the expert knowledge held within the WAM.

Appendix 3. Simple Neighbour-Joining (distance based) tree to be used *ONLY* for visualisation of genetic distance relationships (not a comprehensive analysis using appropriate molecular models and search algorithms).



Appendix 4. COI DNA sequence data for queried Mygalomorph specimens

>T134418
GACATTATATTTAATTTTAGGGGTATGGTCTGCTATGGTAGGGACGGCTATAAGAGTAATTATTCGAA
CAGAATTAGGTCAGGTAGGAAGATTTTTAGGAGATGATCATTTGTATAATGTTATTGTGACTGCTCAT
GCTTTAGTAATAATTTTTTTTTATAGTAATGCCTATTATAATTGGAGGGTTTGGGAATTGGTTAGTCCC
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>T134420
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>T134422
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TGATCCTGCGGGGGGAGGAGATCCTATTTTGTTTCAACATTTATTT

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24 May 2011

Re. Report on the molecular systematics of Nemesiidae from West Turner Syncline

Dear Dan,

Following is a summary of the results for the West Turner Mygalomorphae project. The specimen of Nemesiidae that you provided to us does not appear to belong to any species of Nemesiidae so far detected in Western Australia, based on the material available for comparison.

Thanks once again for collaborating on this project with Helix. We hope we can continue to provide you with useful information, and feel free to contact us if you have any questions or would like to discuss the results in detail.

Sincerely,

Dr. Terrie Finston
Helix Molecular Solutions

Introduction

The trapdoor spider fauna in WA is diverse, (Main, 1957; 1982), and many new species continue to be recovered (Schmidt, 2007). Morphological taxonomy can be difficult in this group of spiders especially where only one sex or adults have the diagnostic characters (Paquin & Hedin, 2004). Because morphological characters may not always capture true species diversity, DNA methodologies provide a rapid approach to this problem and are increasingly being employed. DNA sequencing allows a rapid assessment of genetic diversity and methods are readily transferred among taxa.

Objective

Twenty-five specimens of Nemesiidae from the Pilbara, most identified as belonging to the genus *Aname,* were sequenced for the mitochondrial gene cytochrome oxidase subunit I (COXI) to compare to the sequence from a single specimen of Nemesiidae collected from the West Turner Syncline region. The specimens were sequenced with the aim of determining whether the specimen collected at West Turner has been detected elsewhere in the Pilbara.

Executive summary

- Twenty-six specimens of trap door spiders from the Pilbara were sequenced for variation at the mitochondrial gene cytochrome oxidase subunit I (COXI).
- Twelve specimens failed to yield a DNA sequence.
- A phylogenetic analysis was conducted, which contained the 14 new specimens from the Pilbara analysed here, in addition to 31 specimens of Nemesiidae from previous studies throughout Western Australia.
- The specimen from West Turner was placed in a distinct lineage that contained no other specimens.
- The specimen from West Turner differed from the remaining specimens by between 14.3 and 21.6% sequence divergence.
- Owing to the high level of sequence divergence between the West Turner specimen and the specimens of Nemesiidae available for comparison, the West Turner specimen appears to be a distinct species.

Methods

Twenty-six new specimens of Mygalomorphae spiders in the family Nemesiidae (see Table 1; Jason, pers. comm.) were sequenced for variation at the COI gene using primers M200 (GGAGGATTTGGA AATTGATTAGTTCC) and M205 (ACTGTAAATATATGATGAGCTCA; Simon et al. 1994). The specimens were identified on the basis of morphology as belonging to five distinct taxonomic groups (*Aname* hooded, *Aname*, sp. Namuldi, *Aname* MGY125, *Teyl*? and Nemesiidae West Turner) (Table 1).

Sequences were edited using SEQUENCHER software (Gene Codes Corporation, Ann Arbor, MI, USA). Alignment was performed with CLUSTAL W (Thompson *et al*. 1994) using default parameters. To test that the amplified sequences were the target mtDNA, sequences were translated into proteins and checked for the presence of stop codons. Genetic distances between unique genetic sequences (haplotypes) were measured using uncorrected p-distances (total percentage of nucleotides different between sequences). To account for polymorphism within lineages, the net genetic diversity of Nei (1987) was calculated to give a 'corrected' distance between lineages.

MODELTEST software (Posada and Crandall, 1998) was used to determine the model of sequence evolution that best fitted the data. Bayesian analysis was used to construct the phylogenetic tree, incorporating General Time Reversible (GTR+I) model as identified in MODELTEST. The phylogeny, branch lengths and posterior probabilities were obtained by running two trees simultaneously, each running four simultaneous MCMC chains. The number of cycles needed was determined by the standard deviation of the split frequencies of the two trees. The analysis was paused after every 1 x 10^6 generations and when the standard deviation fell below 0.01, the analysis was stopped. A majority rule consensus tree was constructed after discarding the first 5000 ("burn-in") trees. The burn-in value was determined by plotting the posterior probabilities obtained after every generation and identifying the point at which the values reach stationarity (= the asymptote). Trees produced prior to stationarity were discarded.

Because a preliminary analysis indicated that the specimen from West Turner was substantially genetically divergent from the Pilbara specimens intended for comparison, thirty-one sequences of Nemesiidae from previous studies conducted at other Western Australia sites, were also included in the analysis (Helix, 2011). Two Araneomorphae spiders, *Octonoba varians* (Genbank accession #HQ441948) and *Tetragnatha* sp. (Genbank accession# HQ441947) were used as outgroups.

Results

A 288 to 423 base-pair (bp) fragment of COI was isolated from 14 of the 26 specimens (Appendix 1). The West Turner specimens had the shortest sequence at 288 bp. All five taxonomic groups were represented by at least one sequence (Table 1).

Phylogenetic analysis

The phylogenetic analysis, which included the 14 specimens analysed here in addition to 31 specimens from previous surveys in Western Australia (Helix, 2011), revealed the presence of 22 genetic lineages (Figure 1). The specimen of Nemesiidae from West Turner was placed in a distinct, well-supported lineage that contained no other specimens (lineage M; Figure 1).

Genetic variation between lineages

The 22 lineages differed from one another by between 14.3 and 25.6% net sequence divergence (Appendix 2). The lineage containing the West Turner specimen (lineage M) differed from the remaining lineages by between 16.0 and 20.6% net sequence divergence (Appendix 2). The specimen of Nemesiidae from West Turner differed from the remaining individuals by between 14.3 and 21.6% sequence divergence (Appendix 3). The West Turner specimen was most genetically similar to two specimens of Nemesiidae from Mt. Keith in lineage Q (Appendix 3).

Conclusions

COXI is widely considered to show suitable variation to distinguish species (Hebert et al., 2003a). In a comparison of COXI sequences for over 1200 pairs of chelicerates, Hebert et al (2003b) found a mean of 14.4% sequence divergence between distinct species. Over 97% of the comparisons showed that species pairs differed from one another by greater than 8% sequence divergence.

Using the Hebert findings of 8% as a 'genetic threshold', the observed level of sequence divergence between the West Turner specimen and the remaining specimens (14 – 22%) indicates that it is likely to be a distinct species. It is important to note that the West Turner specimen had the shortest sequence, which could impact the genetic distance estimates. However, the standard error around the distance values for the West Turner specimen was relatively low (approximately 2%), suggesting that the estimates still exceed the genetic threshold for species delineation.

The posterior probability value (which measures the reliability of the branching pattern) is below 0.50 for the branch containing the West Turner specimen. This indicates that more than 50% of the time, that specimen was placed somewhere else in the tree. Low posterior probability values mean that we can't make precise statements about the evolutionary relationship between the West Turner specimen and the remaining data set. However, the high level of sequence divergence between the West Turner specimen and the other specimens in the data set (≥14%) does tell us that it is not likely to be the same species as any other specimen. The inability to place the West Turner specimen phylogenetically may mean that we are lacking the relevant specimens for comparison.

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Table 1. Specimens of Nemesiidae used in the current study and the genetic lineage in which they were placed.

Specimen ID	Lab ID	Taxonomic ID	Lineage
88641	AF1	`Aname hooded`	S
88644	AF2	`Aname hooded`	S
88646	AF3	`Aname hooded`	S
88648	AF4	`Aname hooded`	No data
88650	AF5	`Aname hooded`	S
88676	AF6	Teyl?	T
88682	AF7	Teyl?	No data
88683	AF8	Teyl?	V
88684	AF9	Teyl?	No data
88685	AF10	Teyl?	No data
88689	AF11	Teyl?	T
98423	AF12	Aname MYG125	E
98424	AF13	Aname MYG125	No data
98425	AF14	Aname MYG125	No data
98426	AF15	Aname MYG125	No data
98427	AF16	Aname MYG125	No data
98428	AF17	Aname MYG125	No data
102729	AF18	Aname sp.	U
102730	AF19	Aname sp.	U
102731	AF20	Aname sp.	U
102732	AF21	Aname sp.	U
102733	AF22	Aname sp.	U
102734	AF23	Aname sp.	No data
102735	AF24	Aname sp.	No data
102911	AF25	Aname sp.	No data
98437	AF26	Nemesiidae W. Turner	M

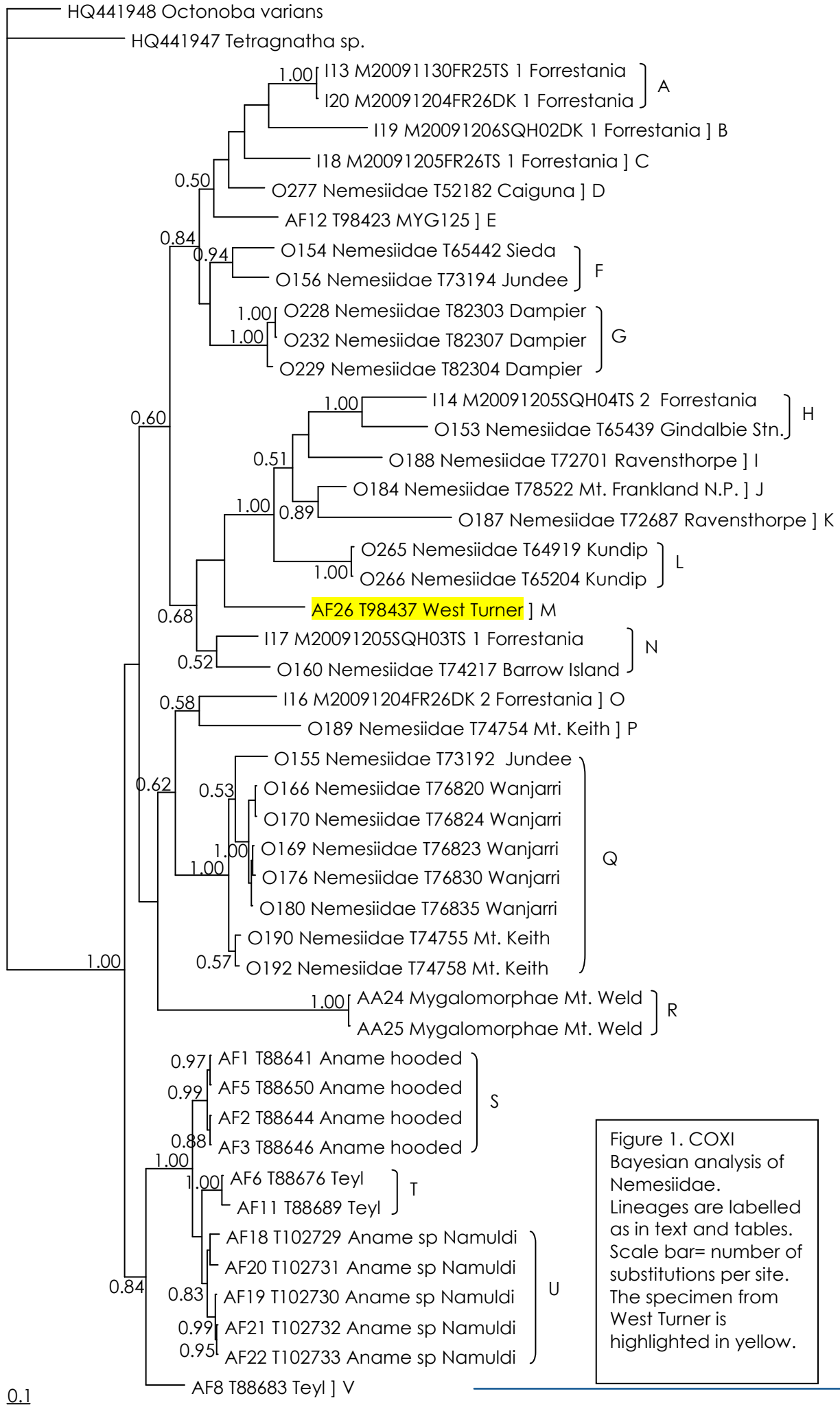


Figure 1. COXI Bayesian analysis of Nemesiidae. Lineages are labelled as in text and tables. Scale bar= number of substitutions per site. The specimen from West Turner is highlighted in yellow.

Appendix 1. COXI sequences for the specimens used in the present study.

#AF1_T88641_Aname_hooded
TCAAAATAAATGTTGAAACAAAATAGGATCCCCTCCCCCCGCAGGATCAAAAAAAGATGT
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TAATAATAGAATAGCAGTGATTAAAACTGACCATACAAACAAAGGAACACGTTCTATGGA
TATACCTGCTGAACGTATATTCACAATAGTAGAAATAAAATTAATTGCTCCCATAATAGA
GGATGCCCCAGCCAAATGCAACGAAAAAATAGCAAAATCTATCCCTCCCCCTCTATGCCC
CACCACTGAAGACAAAGGGGGATAAACCGTTCAACCTGCCCCCACTCCCACATCAGTCAA
TGACGATAAGACTAACAGAAACAACGAAGGAGGAAGTAACCAAAATCTCAAATTATTTAT
ACG

#AF2_T88644_Aname_hooded
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ATTAAAATTTCGATCAGTTAACAATATAGTAATCGCCCCCGCTAACACTGGTAAAGATAA
TAATAATAAAATAGCAGTAATTAAAACTGACCATACAAACAAAGGAACACGTTCTATGGA
TATTCCTGCTGAACGTATATTCACAATAGTAGAAATAAAATTAATTGCCCCCATAATAGA
GGATGCCCCAGCCAAATGCAACGAAAAAATAGCAAAATCTATCCCTCCCCCTCTATGCCC
CACCACTGAAGACAAAGGCGGATAAACAGTTCAACCTGCCCCCACTCCCACATCAGTCAA
TGACGATAAGACTAACAGAAACAACGAAGGAGGAAGTAACCAAAATCTCAAATTATTTAT
ACG

#AF3_T88646_Aname_hooded
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Appendix 2. Net sequence divergence (below diagonal) between lineages of Nemesiidae detected in the present study. Above diagonal= standard error.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
A		0.017	0.017	0.016	0.019	0.016	0.016	0.018	0.018	0.018	0.018	0.020	0.021	0.017	0.018	0.020	0.018	0.019	0.018	0.018	0.018	0.018
B	0.162		0.018	0.017	0.018	0.017	0.018	0.019	0.019	0.020	0.018	0.020	0.023	0.016	0.018	0.019	0.017	0.020	0.018	0.018	0.018	0.018
C	0.158	0.176		0.017	0.017	0.016	0.018	0.018	0.020	0.020	0.020	0.020	0.021	0.017	0.019	0.019	0.017	0.020	0.018	0.018	0.018	0.018
D	0.138	0.167	0.150		0.017	0.015	0.017	0.017	0.018	0.019	0.019	0.019	0.023	0.016	0.018	0.019	0.016	0.018	0.017	0.017	0.017	0.017
E	0.174	0.176	0.150	0.152		0.015	0.017	0.018	0.020	0.021	0.019	0.021	0.022	0.016	0.019	0.020	0.017	0.019	0.019	0.018	0.018	0.018
F	0.171	0.189	0.162	0.146	0.155		0.015	0.017	0.018	0.018	0.017	0.018	0.021	0.016	0.017	0.018	0.016	0.018	0.016	0.016	0.016	0.016
G	0.150	0.181	0.160	0.161	0.160	0.158		0.018	0.018	0.020	0.019	0.019	0.022	0.017	0.018	0.018	0.017	0.019	0.017	0.017	0.017	0.018
H	0.207	0.217	0.205	0.190	0.218	0.205	0.214		0.015	0.016	0.016	0.017	0.020	0.017	0.018	0.018	0.017	0.018	0.018	0.018	0.018	0.017
I	0.181	0.210	0.190	0.190	0.212	0.200	0.185	0.173		0.016	0.017	0.019	0.023	0.018	0.020	0.018	0.017	0.019	0.019	0.018	0.020	0.019
J	0.185	0.219	0.219	0.210	0.226	0.206	0.211	0.173	0.155		0.017	0.016	0.020	0.017	0.019	0.020	0.019	0.019	0.019	0.019	0.020	0.019
K	0.190	0.198	0.231	0.205	0.210	0.206	0.218	0.190	0.174	0.174		0.018	0.021	0.017	0.018	0.019	0.017	0.019	0.019	0.018	0.019	0.019
L	0.212	0.211	0.223	0.217	0.219	0.204	0.203	0.193	0.192	0.145	0.190		0.022	0.016	0.020	0.019	0.019	0.020	0.020	0.019	0.019	0.020
M	0.160	0.185	0.167	0.178	0.174	0.183	0.192	0.181	0.185	0.157	0.167	0.178		0.019	0.023	0.022	0.020	0.022	0.021	0.022	0.023	0.021
N	0.189	0.186	0.180	0.181	0.181	0.190	0.187	0.214	0.207	0.192	0.205	0.191	0.164		0.017	0.016	0.015	0.017	0.016	0.016	0.016	0.015
O	0.178	0.166	0.195	0.173	0.198	0.176	0.182	0.211	0.205	0.210	0.200	0.212	0.195	0.190		0.017	0.017	0.018	0.017	0.018	0.019	0.018
P	0.213	0.221	0.210	0.210	0.217	0.202	0.188	0.225	0.190	0.207	0.212	0.196	0.181	0.192	0.173		0.016	0.019	0.017	0.017	0.017	0.018
Q	0.193	0.185	0.170	0.156	0.183	0.174	0.185	0.192	0.182	0.207	0.191	0.193	0.159	0.181	0.177	0.181		0.018	0.016	0.016	0.016	0.015
R	0.211	0.229	0.221	0.198	0.203	0.211	0.219	0.233	0.213	0.230	0.215	0.256	0.192	0.211	0.193	0.202	0.220		0.019	0.018	0.018	0.019
S	0.205	0.175	0.193	0.164	0.199	0.191	0.177	0.226	0.210	0.221	0.203	0.236	0.181	0.169	0.168	0.167	0.174	0.205		0.013	0.012	0.016
T	0.200	0.192	0.195	0.168	0.187	0.187	0.178	0.218	0.220	0.217	0.202	0.229	0.192	0.178	0.175	0.175	0.172	0.194	0.102		0.012	0.016
U	0.211	0.178	0.186	0.168	0.176	0.183	0.169	0.222	0.222	0.239	0.213	0.223	0.206	0.180	0.190	0.181	0.175	0.207	0.087	0.091		0.016
V	0.180	0.162	0.183	0.152	0.170	0.164	0.178	0.207	0.207	0.202	0.198	0.206	0.167	0.164	0.166	0.176	0.159	0.206	0.130	0.150	0.143	

Biota Environmental Sciences

Western Turner Syncline Section 10 Below Water Table and Satellite Ore Bodies Subterranean Fauna Survey







Prepared for Rio Tinto

December 2014

Biota Environmental Sciences

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Western Turner Syncline Subterranean Fauna Survey

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Licence to Take Fauna for Scientific Purposes; Licence No. SF009675

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1.0 Introduction

1.1 Project Background

Hamersley Iron Pty Ltd (Hamersley Iron) owns and operates Western Turner Syncline (WTS) Section 10, an active iron ore mine approximately 20 km northwest of Tom Price in the Pilbara region of Western Australia (Figure 1.1). Hamersley Iron proposes to sustain mining at Section 10 by the commencement of dewatering in 2017 and subsequent below water table (BWT) mining in 2018-2020. A new satellite Marra Mamba ore body located to the north of Section 10 will also be mined from 2018, with dewatering at the Marra Mamba pit from 2019-2024. In addition, Hamersley Iron is also seeking approval for exploration of a potential Section 10 West pit, and other prospective mining areas between Section 10 and the WTS B1 deposit.

The proposed mining at Section 10, as well as associated waste dumps and stockpiles, the Marra Mamba pit, and other prospective mining areas between Section 10 and the B1 deposit require biological assessment and are hereafter referred to as the study area (Figure 1.2).

Biota Environmental Sciences (Biota) was commissioned by Rio Tinto to survey the subterranean fauna of the study area. Part of the study area has previously been covered by subterranean fauna surveys, which have been undertaken by Biota (Figure 1.1; Biota 2008, 2012). This report details the findings of the subterranean fauna survey of the study area, incorporating findings from previous surveys in the WTS locality.

1.2 Previous Studies at Western Turner Syncline

Biota has previously completed two phases of subterranean fauna sampling at WTS Section 10 (Figure 1.1), including one sampling phase for troglofauna (obligate cave fauna) and two phases for stygofauna (aquatic subterranean fauna) (Biota 2008, 2012c). The sampling at Section 10 included consideration of subterranean habitats (Biota 2008). Biota has also completed three phases of subterranean fauna sampling at WTS B1 and Section 17 deposits (Figure 1.1), including three sampling phases for troglofauna and two phases for stygofauna. The sampling at B1 and Section 17 included consideration of subterranean habitats (Biota 2012c).
This past sampling effort in the WTS locality comprises:

- 37 stygofauna sites over four phases (20 of which were at Section 10); and
- 72 troglofauna sites over four phases (11 of which were at Section 10).

Field surveys to date for stygofauna and troglofauna have recorded little to suggest that subterranean communities of conservation significance exist in the WTS locality. Habitat based assessments and genetic analysis of specimens have generally supported this view (Biota 2008, 2012c).

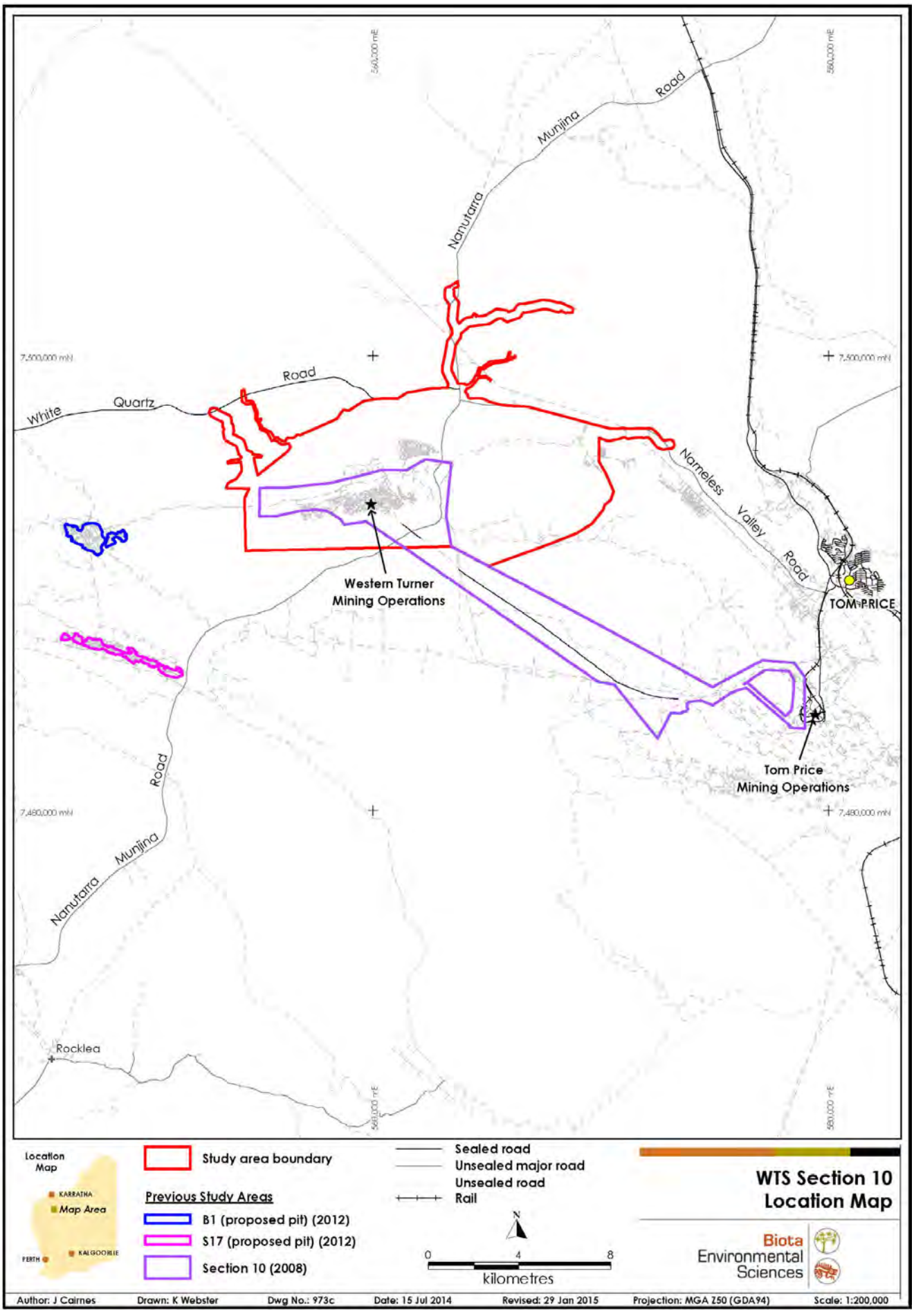


Figure 1.1: Locality map for the West Turner mining operations and .

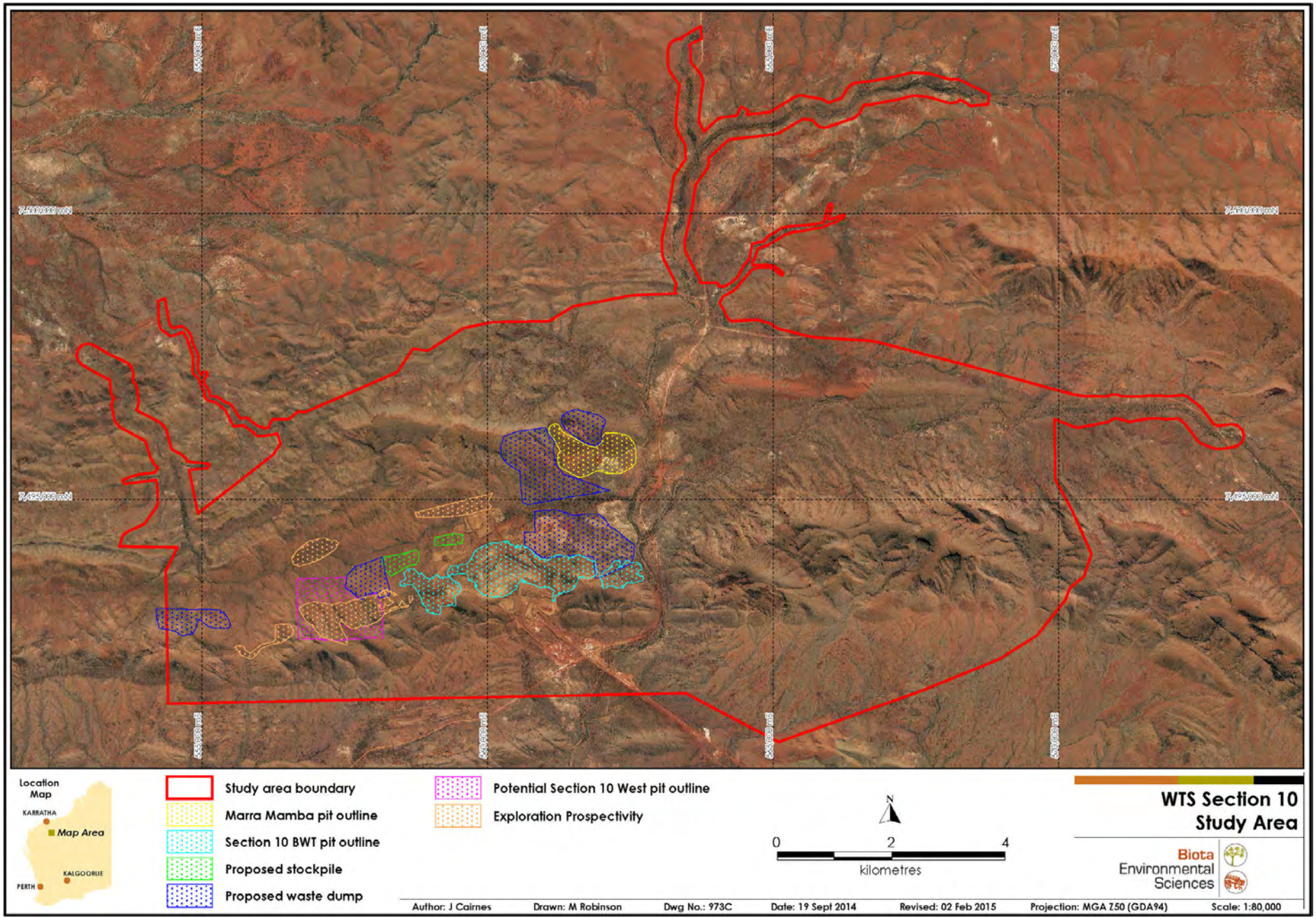


Figure 1.2: Current study area for West Turner Syncline and proposed development designations.

1.3 Scope and Objectives of this Study

The scope of the current study was to provide baseline data on the subterranean fauna within the study area, expand existing habitat-based assessments from previous WTS reporting to address the current study area, and develop an assessment of the potential for species restriction using multiple lines of evidence (consistent with Environmental Protection Authority (EPA) Environmental Assessment Guideline (EAG) No. 12 (EPA 2013)).

The specific objectives of the study were to:

- review available geological information and identify subterranean fauna habitats;
- complete a single phase of targeted subterranean fauna sampling (for both troglobitic fauna (troglofauna) and stygobitic fauna (stygofauna)) at available drillholes in the study area;
- morphologically identify collected troglofauna and stygofauna specimens to species level, where possible, and place them into a local and regional context;
- include the results of genetic analysis from previous WTS surveys and the wider Pilbara region, where appropriate, for context;
- assess the conservation status of the subterranean fauna present; and
- discuss potential impacts of the proposed below water table development at Section 10, with focus on the area of proposed drawdown.

This report primarily references EPA EAG No. 12 (EPA 2013), which is now the principal policy document setting out EPA expectations in regards to subterranean fauna assessments.

1.4 Subterranean Fauna Background

Australia was historically thought to lack habitat suitable for subterranean fauna. Studies in recent decades however, mostly with an emphasis on environmental impact assessment, have revealed Australia to be highly diverse in subterranean fauna with numerous areas of interest throughout the continent (Guzik et al. 2010). In Western Australia these zones of subterranean biodiversity can be found at Cape Range, Barrow Island, the Pilbara bioregion, the Yilgarn and the Nullarbor (Humphreys 2001a, Page et al. 2008, Guzik et al. 2010).

Subterranean fauna in northern Western Australia have been known for some time from karstic limestone systems on Cape Range and Barrow Island. Surveys in the Pilbara over the past decade or more have collected subterranean fauna from other geological units such as pisolitic iron formations, channel iron deposits, unconsolidated alluvium and sedimentary basalt (Marmonier et al. 1993, Biota 2004, 2006, 2010a, 2011a, 2013), indicating that the suitability of a formation as habitat for subterranean fauna is mostly a function of the availability of habitable space (Marmonier et al. 1993, Humphreys 1999, Biota 2006), rather than a specific geology unit.

Subterranean fauna habitats are characterised by shared physical parameters that include a lack of light, stable temperature, limited nutrient infiltration from surface environments and a constant humidity (Juberthie 2001, Romero 2009). These habitat characteristics have resulted in convergence in body morphology evolution amongst many subterranean fauna. Morphological characteristics common to most subterranean fauna include reduced or lack of pigmentation, reduced or lack of eyes, and elongate body morphology and appendages adapted for sensory movement (Culver and Pipan 2009, Romero 2009).

Subterranean fauna can be further categorised into two distinct ecological groups based on habitat, troglofauna and stygofauna. Troglofauna are a suite of fauna that survive only in air-filled cavities and interstices between the surface and the water table. Stygofauna occupy a similar niche, but comprise aquatic taxa and occur in groundwater aquifers and subterranean water bodies. Troglobites and stygobites are obligatory subterranean habitat dwellers, and while they may occur close to surface environments, are strongly adapted to subterranean environments.

This makes such fauna unable or highly unlikely to survive surface conditions. A range of similarly adapted fauna occur that opportunistically use subterranean habitats but are able to survive outside these stable environments. Studies from the Pilbara bioregion have demonstrated that these suites of fauna; troglophiles, trogloxenes and edaphobites, are not similarly restricted in range and therefore unlikely to be impacted by small scale developments (Biota and Helix 2011, Helix 2012).

Troglofauna in semi-arid Australia are thought to be relictual rainforest fauna. Fauna adapted to humid environments, which retreated underground to cave systems during the aridification of Australia (in the late Miocene; Humphreys 1993). This is inferred from affinities of the taxonomic groups represented amongst the troglofauna with other extant taxa in tropical climates. Some invertebrate groups with troglobitic representatives include the Arachnida (e.g. Schizomida, Pseudoscorpiones and Aranea), Chilopoda (e.g. Scolopendrida), Diplopoda (e.g. Polydesmida and Haplodesmida), and Insecta (e.g. Diplura, Thysanura, Coleoptera and Blattodea). A single troglobitic vertebrate species of blind snake (*Ramphotyphlops longissimus*) is known from Australia, collected from Barrow Island (Aplin 1998).

Due to their dependence on constant humidity, dispersal and distribution of troglobitic fauna species tends to remain limited to individual blocks of inter-connected habitat, leading to long periods of population isolation and speciation. As a result, troglobitic fauna are considered to be of conservation significance, given species often display extreme short-range endemism and species may therefore be affected by relatively small-scale developments such as mining and construction.

Stygal communities in Western Australia are predominantly Crustacean (e.g. Amphipoda, Isopoda, Decapoda, Syncarida, Ostracoda and Copepoda), however Annelida (e.g. Oligochaeta), Arachnida (e.g. Hydracarina) and Platyhelminthes are also commonly collected. Three species of stygal vertebrates have been recorded from Australia, from Barrow Island, Cape Range, and the Pilbara. This includes two species of blind gudgeon (*Milyeringa veritas,* and *M. justitia*) as well as a blind cave eel, *Ophisternon candidum* (Humphreys 2001b, DSEWPaC 2008, Foster and Humphreys 2011, Larson et al. 2013).

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2.0 Methodology

Subterranean fauna sampling was completed under "Licence to Take Fauna for Scientific Purposes" No. SF009675 issued to Dan Kamien (Appendix 1). Methodology and approach were consistent with those outlined in the EPA Guidance Statement No. 54 (EPA 2003), EPA Guidance Statement No. 54a (EPA 2007) and EPA EAG No. 12 (EPA 2013).

2.1 Survey Timing and Personnel

Mr Dan Kamien, Mr Chris Cole and Ms Sylvie Schmidt, all of Biota, completed the stygofauna sampling and troglofauna trap installation between the 7th and 15th of April, 2014. Chris Cole and Sylvie Schmidt completed the troglofauna trap retrieval between the 28th and 29th of May, 2014. The project was coordinated and managed by Mr Jason Alexander of Biota.

Preliminary identification of specimens to order level was completed by Mr Andrew Sheppard of Biota. Further Identifications of troglomorphic specimens was completed by Dr Mieke Strong (Pseudoscorpiones) and Mr Garth Humphreys (Cryptopidae), both of Biota. Pseudoscorpions and the Cryptopidae were lodged with the Western Australian Museum (WAM) with further identifications of the pseudoscorpions completed by Dr Kym Abrams.

Ms Kylie Webster and Ms Melissa Robinson of Biota prepared the maps for this report.

2.2 Troglobitic Fauna Sampling Methodology

Troglobitic fauna were primarily sampled by means of custom-built litter colonisation traps suspended within drillholes located within the study area. A series of colonisation traps were suspended at intervals, which allowed a greater coverage of the drillhole. Traps were constructed from 60 mm internal diameter PVC irrigation pipe cut to a length of 180 mm. Each trap had a series of 20 mm holes drilled into the side, and traps remained open at the upper end. Up to three traps were installed such that they were in contact with the interior of the sampled drillhole, facilitating fauna entry into the trap.

Leaf litter was gathered locally from the ground surface in the study area, particularly from the bases of *Acacia* shrubs. The collected litter was soaked in water and irradiated in a microwave oven for two minutes on maximum power setting. The microwave acted to kill any surface invertebrates present and assisted in the breaking down of organic matter. Wet litter was added to the traps, which were kept in sealed containers until immediately prior to insertion into the drillholes to avoid desiccation of leaf litter. After the installation of traps, the opening of each drillhole was sealed to maintain humidity and to avoid entry of surface fauna.

Traps were recovered from each drillhole after seven weeks and stored in labelled zip lock bags in order to maintain humidity and prevent desiccation of potential troglofauna specimens during transportation to Perth. Sampling for stygofauna (see Section 2.3) also included the use of haul net drags through potential troglofauna habitat, with any specimens dislodged preserved and identified during sorting.

Fauna specimens were recovered from the traps using specially designed Tullgren funnel units. Leaf litter from each trap was placed in a sieve under an aluminium lamp containing a 25-watt globe. This created a temperature of approximately 30°C at the surface of the leaf litter. A funnel situated below the leaf litter collected the fauna as they fell, directing them into an attached vial of 100% ethanol. Leaf litter was left in the Tullgren funnels for a period of 24 hours, or until dry, after which time the bulked invertebrate sample removed.

Fauna specimens collected via Tullgren funnels were identified to order level using dissecting microscopes (Olympus SZ40 and SZ61, magnification up to 40x). Fauna specimens were assigned a unique number based on drillhole name and tracked on customised data sheets. Specimens were preserved in 100% ethanol, which allows for both morphological and molecular analysis. Specimens that were lodged with the WAM for morphological analysis were identified using Leica dissecting microscopes (Abrams et al. 2014; Appendix 2).

2.3 Stygobitic Fauna Sampling Methodology

Stygobitic fauna sampling was undertaken using modified plankton haul nets. These sampling nets were constructed from 70 *µm* plankton mesh, with 80 mm apertures attached to a weighted catch jar. Stygofauna sampling nets were lowered to the bottom of the drillholes before being slowly hauled to the surface, including dislodging any troglofauna specimens on drillhole walls, where the contents of the catch jar were flushed into a uniquely labelled container. Each site was sampled in this way five times unless the water sample was very sedimented, in which case the site was only sampled two or three times. On the final haul the net was agitated gently, which acts to stir the benthos layer and mobilises any fauna present for more effective specimen collecting. Specimens were stored in a shaded esky in order to preserve the sample prior to sorting and identification. Following sampling of each drillhole, the nets were thoroughly rinsed with water, inspected and where possible, left to dry before using on another drillhole. This prevented cross-contamination of specimens between aquifers and sample sites.

2.4 Survey Design and Sampling Effort

A total of 24 sites were sampled for subterranean fauna at WTS in 2014. Fourteen of these 24 sites were trapped for troglofauna only, and 10 were sampled for both stygofauna and troglofauna (see Sections 2.4.1 and 2.4.3 respectively).

2.4.1 Troglofauna Trapping Effort

A total of 20 sites were successfully trapped for troglofauna at WTS in 2014 (Table 2.1, Figure 2.1). Nine of these sites are inside the Marra Mamba proposed pit outlines (Impact sites) and 11 are outside (Reference sites). Traps installed at site RC13S10M0056 were unable to be recovered (Table 2.1).

Table 2.1: Sampling location and effort of sites trapped for troglofauna at WTS in 2014.

Site Name	Impact / Reference Site	Easting (m E)	Northing (m N)	Traps Installed	Traps Retrieved	Trap Depths (m)	Notes
RC13S10M0010	Impact	562109	7496135	2	2	15, 35	
RC13S10M0043	Impact	562245	7495904	2	2	15, 30	
RC13S10M0046	Impact	562343	7496055	2	2	15, 30	
RC13S10M0056	Impact	561634	7495514	2	0	15, 30	Traps stuck
RC13S10M0058	Impact	561700	7495615	3	3	15, 30, 45	
RC13S10M0085	Impact	561996	7495851	2	2	15, 30	
RC13S10M0089	Impact	562064	7495735	3	2	15, 30	
RC13S10M0096	Impact	562274	7495618	3	3	15, 30, 45	
RC13S10M0099	Impact	562363	7495756	3	3	15, 30, 45	
RC13S10M0101	Impact	562429	7495856	2	2	20, 40	
RC13MTSA0003	Reference	569900	7495000	3	3	15, 30, 45	
RC13MTSA0005	Reference	569850	7495050	2	2	20, 40	
RC13MTSA0007	Reference	569900	7495100	2	2	20, 40	
RC13MTSA0019	Reference	569750	7495250	2	2	15, 30	
RC13MTSA0023	Reference	569550	7495150	2	2	15, 30	
RC13MTSA0028	Reference	569450	7495350	2	2	15, 30	
RC13MTSA0037	Reference	569250	7495250	2	2	15, 30	
RC13MTSA0056	Reference	569398	7495297	2	2	15, 30	
RC13S10M0068	Reference	561990	7496057	2	2	15, 30	
RC13S10M0108	Reference	562796	7495761	2	2	20, 40	
RC13S10M0111	Reference	562627	7495942	2	2	5, 20	
			Total Traps Retrieved		44		

2.4.2 Historical Troglofauna Sampling Effort in the Study Area

The proposed Section 10 pit mining has been sampled for troglofauna during previous survey work, with 11 of the 72 sites historically sampled for troglofauna in the wider WTS locality located in the current study area (Table 2.2, Figure 2.1). Ten of these are Impact sites and one is a Reference site.

Table 2.2: Sampling location and effort of historical sites sampled for troglofauna in the study area.

Site Name	Impact / Reference Site	Easting (m E)	Northing (m N)	Traps Installed	Traps Retrieved	Downhole Camera Utilised
RC07S10B003	Impact	558780	7493390	3	3	Yes
RC07S10B032	Impact	559020	7493550	3	3	Yes
RC07S10B095	Impact	559820	7493820	3	3	Yes
RC07S10B102	Impact	560330	7494120	3	3	Yes
RC07S10B112	Impact	560050	7493970	3	3	Yes
RC07S10B193	Impact	560110	7493380	3	3	No
RC07S10B202	Impact	560450	7493660	3	3	Yes
RC07S10B259	Impact	560690	7493620	3	3	Yes
RC07S10B264	Impact	560700	7494050	4	4	Yes
RC07S10B273	Impact	560820	7493760	3	3	Yes
RC07S10B079	Reference	559512	7493353	3	3	Yes
			Total Traps Retrieved		34	

In total, 92 sites have been sampled for troglofauna in the wider WTS locality, including 52 sites in proposed Impact areas (including Impact sites at the B1 and S17 deposits) and 40 sites in Reference areas (Figure 2.1, Figure 2.2).

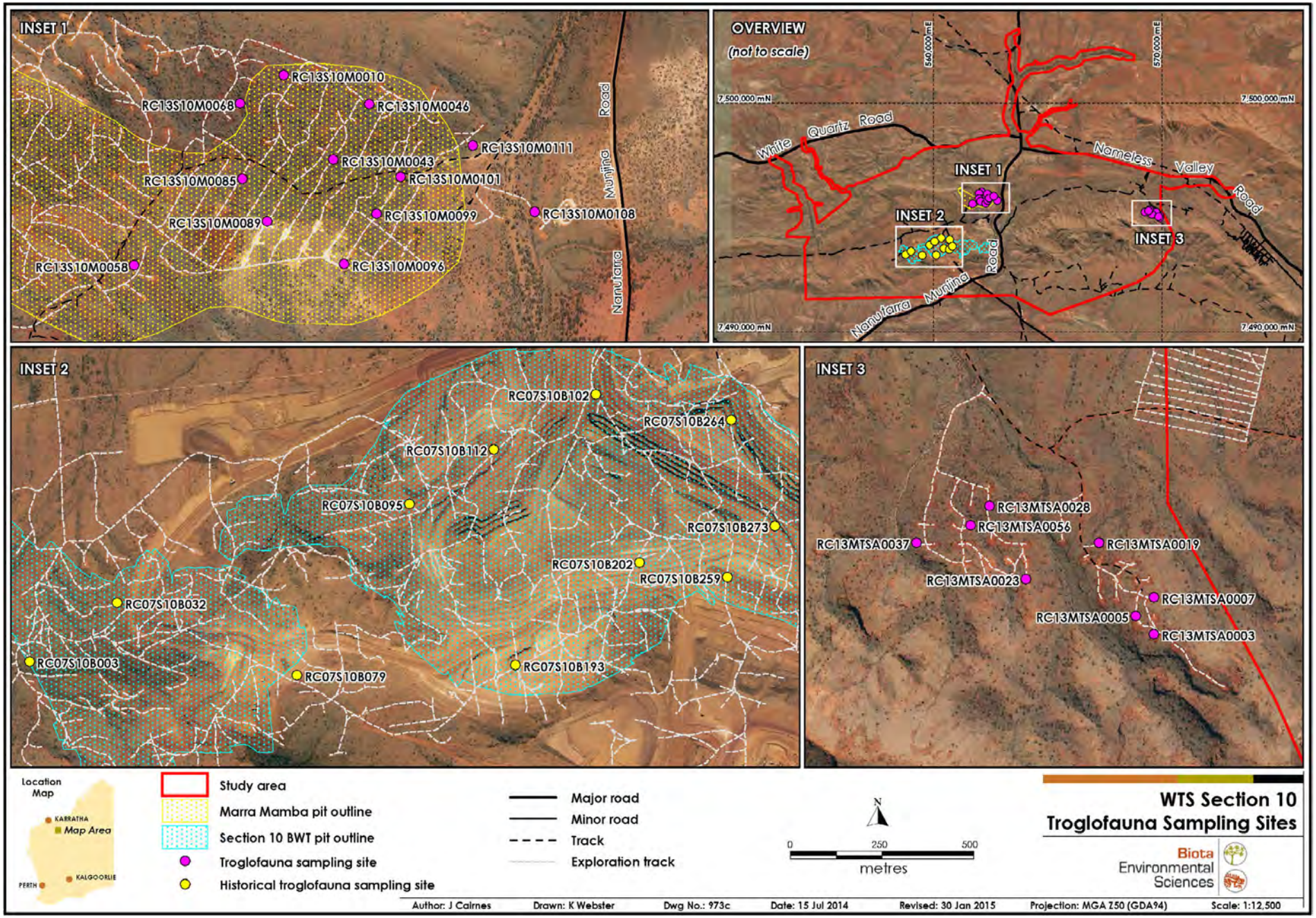


Figure 2.1: Troglofauna sampling sites at WTS Section 10.

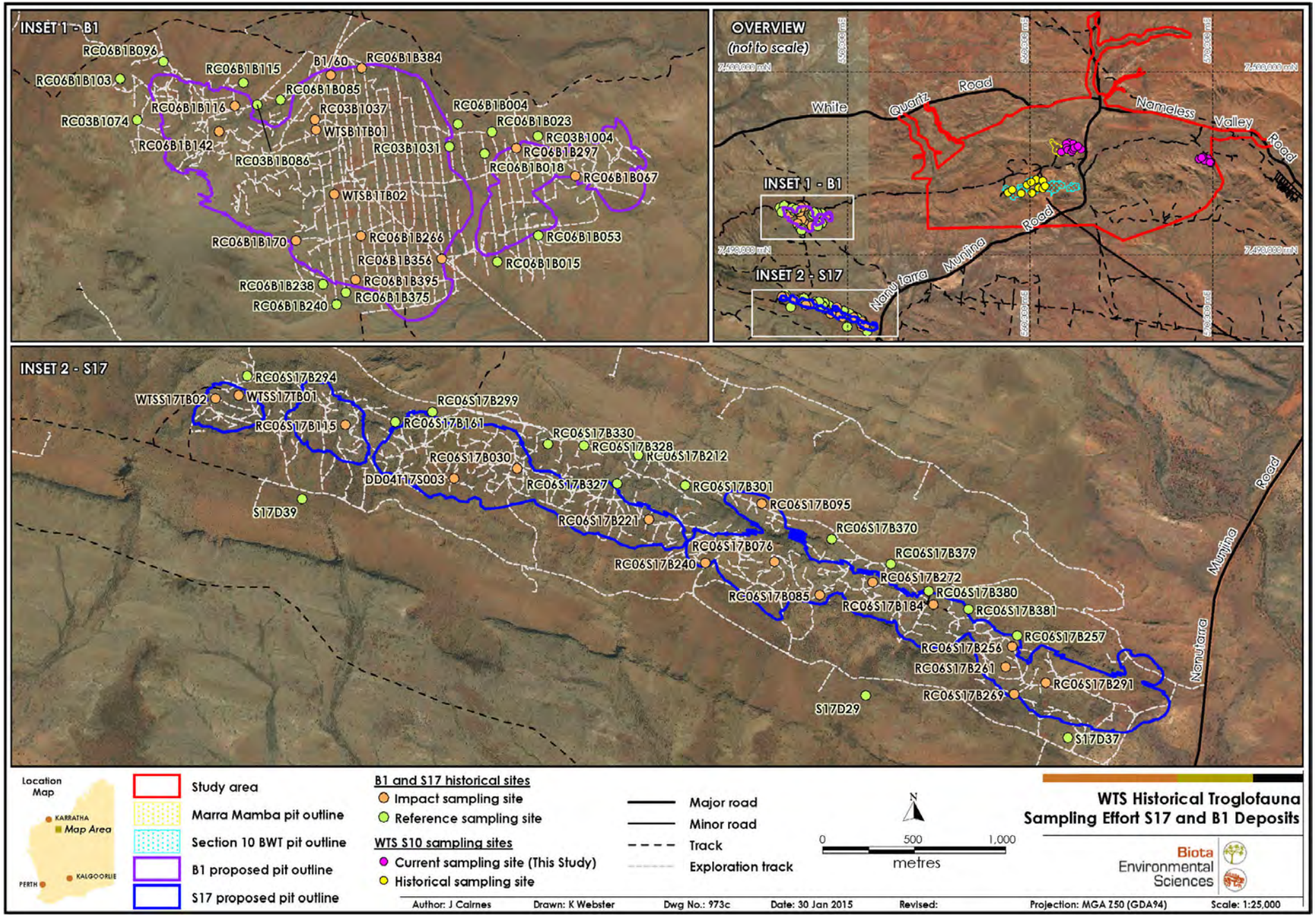


Figure 2.2: Historical sampling sites at S17 and B1 deposits.

2.4.3 Stygofauna Sampling Effort

A total of 10 sites were sampled with stygofauna haul nets at WTS in 2014 (Table 2.3, Figure 2.3). All of these sites are in Impact areas because they occur in predicted drawdown areas (Figure 2.3). Due to heavy sediment loads, seven of the sites sampled were only hauled three times instead of the suggested six times for haul net sampling (EPA 2007; Table 2.3).

Table 2.3: Sampling location and effort of sites sampled for stygofauna at WTS in 2014.

Site Name	Impact / Reference Site	Easting (m E)	Northing (m N)	Total Depth (m)	Depth to Water (m)	Number of Hauls	Comments
RC13S10M0039	Impact	562114	7495703	82	72	2	Very sedimented
RC13S10M0056	Impact	561634	7495514	82	71	3	Very sedimented
RC13S10M0058	Impact	561700	7495615	82	78	3	Very sedimented
RC13S10M0059	Impact	561732	7495665	94	78	3	Very sedimented
RC13S10M0089	Impact	562064	7495735	76	63	3	Very sedimented
RC13S10M0096	Impact	562274	7495618	88	71	3	Very sedimented
RC13S10M0099	Impact	562363	7495756	96	77	3	Very sedimented
RC13S10M0101	Impact	562429	7495856	58	56	5	
RC13S10M0108	Impact	562796	7495761	88	62	5	
RC14S10M0002	Impact	562406	7495606	76	62	5	

2.4.4 Historical Stygofauna Sampling Effort in the Study Area

The proposed Section 10 pit mining has been sampled for stygofauna during previous survey work, with sixteen of the 37 sites historically sampled for stygofauna in the wider WTS locality located in the current study area at Impact sites (Table 2.4, Figure 2.3).

Table 2.4: Sampling location of historical sites sampled for stygofauna in the study area.

Site Name	Impact / Reference Site	Easting (m E)	Northing (m N)
WTSRC07S10B101	Impact	560265	7494120
WTSML04	Impact	563309	7494760
WTSML05	Impact	562178	7494955
WTSML06	Impact	563697	7494999
WTSML08	Impact	563465	7495459
WTSRC07S10B109	Impact	560157	7494044
WTSRC07S10B114	Impact	559792	7494059
WTSRC07S10B119	Impact	560074	7493731
WTSRC07S10B121	Impact	560081	7493683
WTSRC07S10B125	Impact	560179	7493865
WTSRC07S10B142	Impact	560291	7493939
WTSRC07S10B169	Impact	559934	7493895
WTSRC07S10B171	Impact	559448	7493776
WTSRC07S10B199	Impact	560626	7494162
WTSRCO7S10B212	Impact	560506	7493664
WTSWB04S10-001	Impact	560670	7494778

In total, 47 sites have been sampled for stygofauna in the wider WTS locality, including 43 sites in proposed Impact areas (including Impact sites at the B1 and S17 deposits), and four sites in Reference areas (Figure 2.3, Figure 2.4).

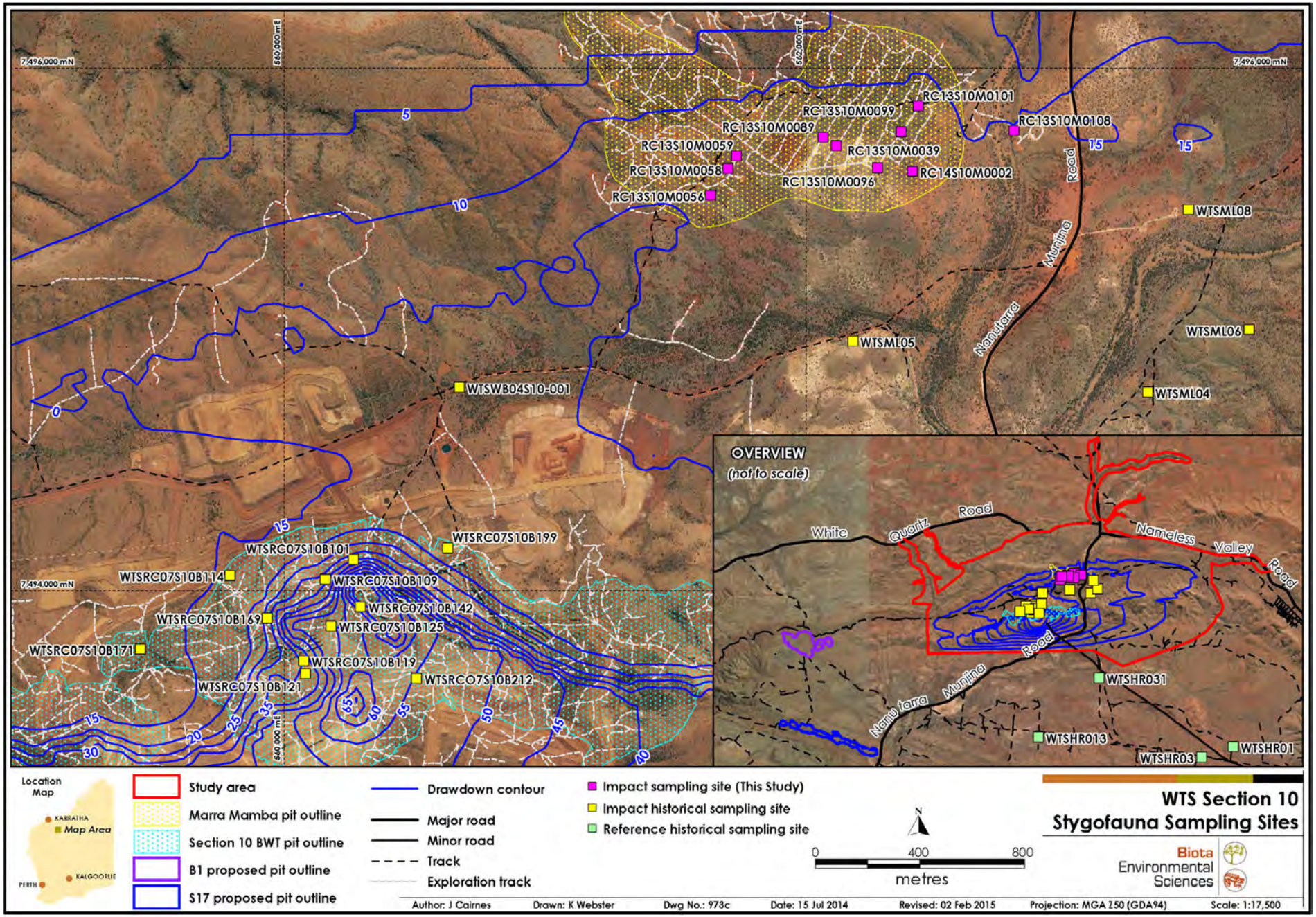


Figure 2.3: Stygofauna sampling sites at WTS Section 10.

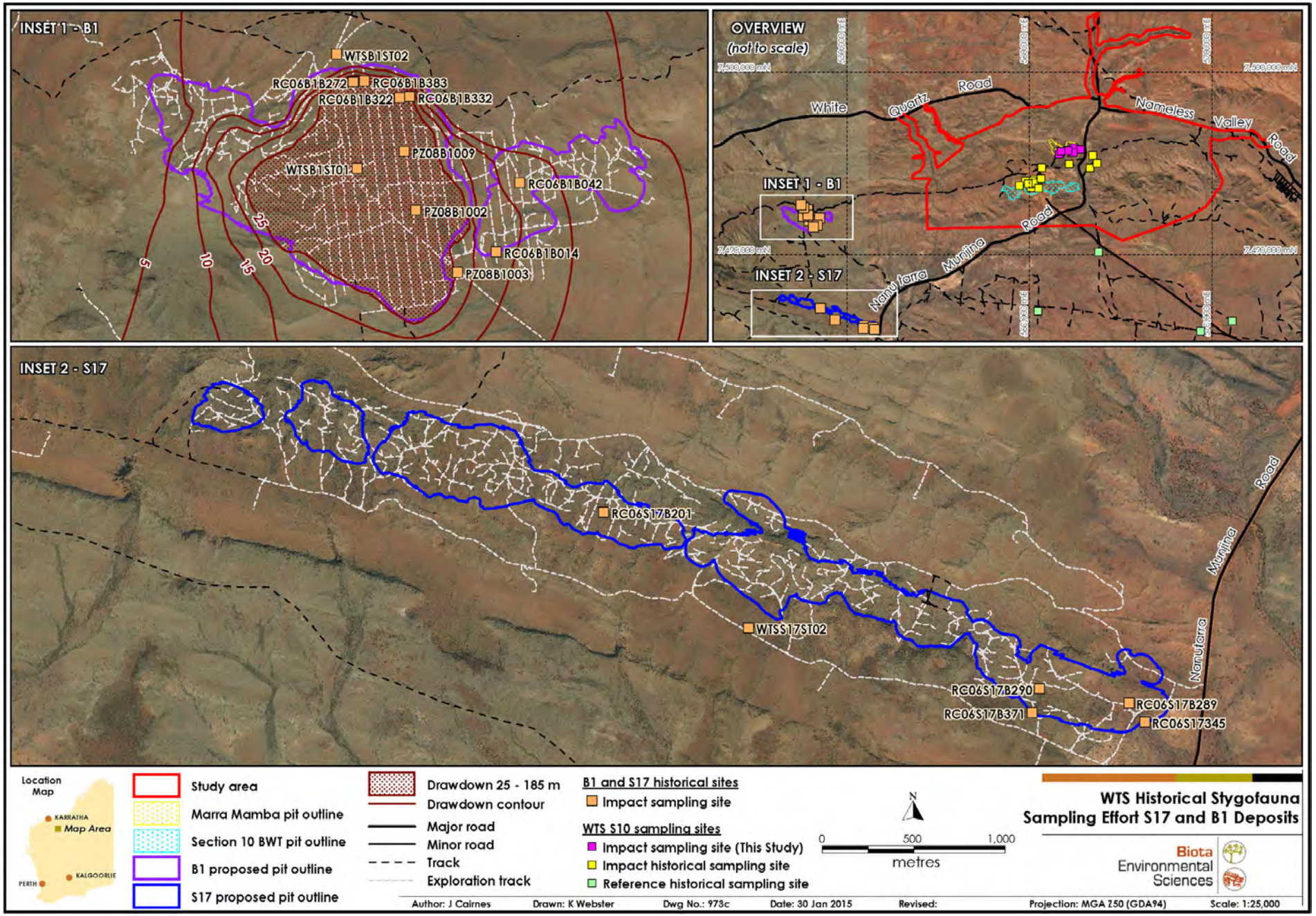


Figure 2.4: Historical stygofauna sampling sites from B1 and S17 deposits.

2.5 Study Limitations

I should be noted that several limitations apply to this study. During sampling, the number of hauls per stygofauna site was inconsistent overall due to heavy turbidity in the groundwater column. This may be due to the available drillholes lacking an above ground collar, which acts to keep loose substrate and detritus from the water column. High turbidity makes identification and sorting of stygal specimens difficult. Additionally, for some troglomorphic taxa, particularly the Chilopoda in the current study, there is a lack of adequate taxonomic framework within Australia. Without further specialist morphological analysis of this taxon, identification to species level is not currently possible. A further limitation to the work is that the sites sampled are clustered spatially and only cover a small section of the study area (Figure 2.1 and Figure 2.3). This is a function of the drillholes available during the field survey.

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3.0 Geology and Subterranean Fauna Habitat

3.1 Subterranean Fauna Habitat

For both stygofauna and troglofauna, the suitability of geological formations as habitat is primarily a function of available habitat space. Geological units that are currently recognised as core habitat for subterranean fauna include karstic limestone, calcrete, alluvium, gravels and pisolite (Marmonier et al. 1993, Humphreys 1999, Biota 2006). Characteristics in common amongst these formations include fractures, caverns, vugs, or interstices sufficient in size to physically accommodate stygobites or troglobites. More recent studies at Hope Downs 4 and Koodaideri have also found that units such as colluvium and banded ironstone formations, especially where hydrated zones occur or there is a lot of jointing or fracturing, are also suitable subterranean fauna habitat (Biota 2009a, 2014a).

3.2 Geology

The WTS region contains Archaean to Lower Proterozoic Fortescue and Hamersley group rocks, comprising the Jeerinah Formation, Bunjinah Formation, Marra Mamba Iron Formation, Mt McRae Shale and Mt Sylvia Formations, Robe Pisolite, Brockman Iron Formation, Weeli Wolli Formation, Woongarra Rhyolite and Boolgeeda Iron Formation (Seliani and Oliver 2003).

The study area, covering an area of approximately 10,074 ha, encompasses 14 major surface geology units, as outlined in Geological Survey of Western Australia (2002) (Table 3.1, Figure 3.1). The study area is mostly comprised of Czc "Colluvium" (almost 36% of the study area), and PLHb "Brockman Iron Formation: banded iron-formation, chert, and pelite" (almost 23% of the study area) (Table 3.1). The study area is typical of similar Banded Iron Formation (BIF) derived deposits that occur throughout the Pilbara.

Table 3.1: Geological units in the current WTS Section 10 study area.

Code	Description	Area (ha)	% of Study Area
Czc	Colluvium - partly consolidated quartz and rock fragments in silt and sand matrix; old valley-fill deposits, locally derived. G	3,583.0	35.6
PLHb	BROCKMAN IRON FORMATION: banded iron-formation, chert, and pelite	2,308.0	22.9
AHm	MARRA MAMBA IRON FORMATION: chert, banded iron-formation, and pelite	1,078.8	10.7
AFj	JEERINAH FORMATION: pelite, metasandstone, chert, metabasaltic pillow lava and breccia, and metamorphosed felsic volcanic rock	610.1	6.1
Qa	Alluvium - unconsolidated silt, sand, and gravel; in drainage channels and adjacent floodplains	578.8	5.7
AFd	Medium to coarse-grained metadolerite sills intruded into Fortescue Group	513.5	5.1
AHs	MOUNT McRAE SHALE and MOUNT SYLVIA FORMATION: pelite, chert, and banded iron formation	506.8	5.0
Qc	Colluvium - unconsolidated quartz and rock fragments in soil	314.8	3.1
Czk	Calcrete - sheet carbonate, found along major drainage lines	310.4	3.1
PLHj	WEELI WOLLI FORMATION: banded iron-formation (commonly jaspilitic), pelite, and numerous metadolerite sills	172.5	1.7
Czp	ROBE PISOLITE: pisolitic limonite deposits developed along river channels	47.4	0.5
AFu	BUNJINAH FORMATION: pillowed and massive metabasaltic flows, metabasaltic breccia, metamorphosed volcanic sandstone, and minor chert; amygda	45.5	0.5
PLHo	BOOLGEEDA IRON FORMATION: fine-grained, finely laminated iron-formation; pelite and chert	3.5	<0.0
PLHw	WOONGARRA RHYOLITE: metamorphosed rhyolite, rhyodacite, rhyolitic breccia, and banded iron-formation	1.2	<0.0
	Total	10,074.4	

Previous studies have shown that surface BIF geology has the potential to have above water table cavities and vugs, and may therefore provide suitable troglofauna habitat (Biota 2009b, 2009c, 2014a). Biota (2012c) showed that the locally occurring surface BIF is continuous throughout the WTS region. Therefore there is potential for subterranean fauna habitat to be continuous throughout the area, and any potential subterranean fauna occurring in the area are therefore less likely to have restricted distributions.

The sites that we sampled for subterranean fauna during this survey encompass five surface geological units including Czc "Colluvium", Czk "Calcrete", Qa "Alluvium", AHm "Marra Mamba Iron Formation" and AHs "Mt McRae Shale and Mt Sylvia Formation" (Figure 3.1). Troglobitic specimens have been collected in Czc and Czk at Hope Downs and Bungaroo (Biota 2010b, 2011b, 2014b). Troglobitic specimens have been collected in Qa "Alluvium" at Yandicoogina (Biota 2010a). Areas of BIF, especially where hydrated zones occur are a likely habitat for troglofauna (Biota 2012c). Therefore the BIF in the AHm and PLHb surface geologies at WTS are likely habitats to support troglofauna, however there is potential for troglofauna to occur in the surface colluvium and calcrete geologies also. These geologies account for 72.3% of surface geologies within the current study area.

3.3 Hydrology and Hydrogeology

The dominant surface hydrological feature in the WTS locality is a large, unnamed ephemeral tributary of the Hardey River. The tributary enters the Western Turner Syncline at a point approximately 2 km east of the mining operations area at Section 10 and flows south towards the Hardey River itself. Numerous ephemeral drainage lines feed the tributary and overland flow occurs off broad, shallow floodplain areas within the Western Turner Syncline. Surface flows along the along the Hardey River are intermittent, generally flowing only after significant rainfall events (Biota 2008).

The WTS study area is located in the Hardey River catchment and in the headwaters of the Hardey River catchment, immediately west of the Beasley River catchment divide. The underlying groundwater system in the study area can be described as a confined aquifer associated with the mineralised banded iron formation of the Brockman Iron Formation. The WTS Section 10 orebody aquifer is located in the Dales Gorge Member of the Brockman Iron Formation (Rio Tinto 2013). The aquifer is bounded by unmineralised BIF, low permeability Mount McRae Shale and Mount Sylvia Formation.

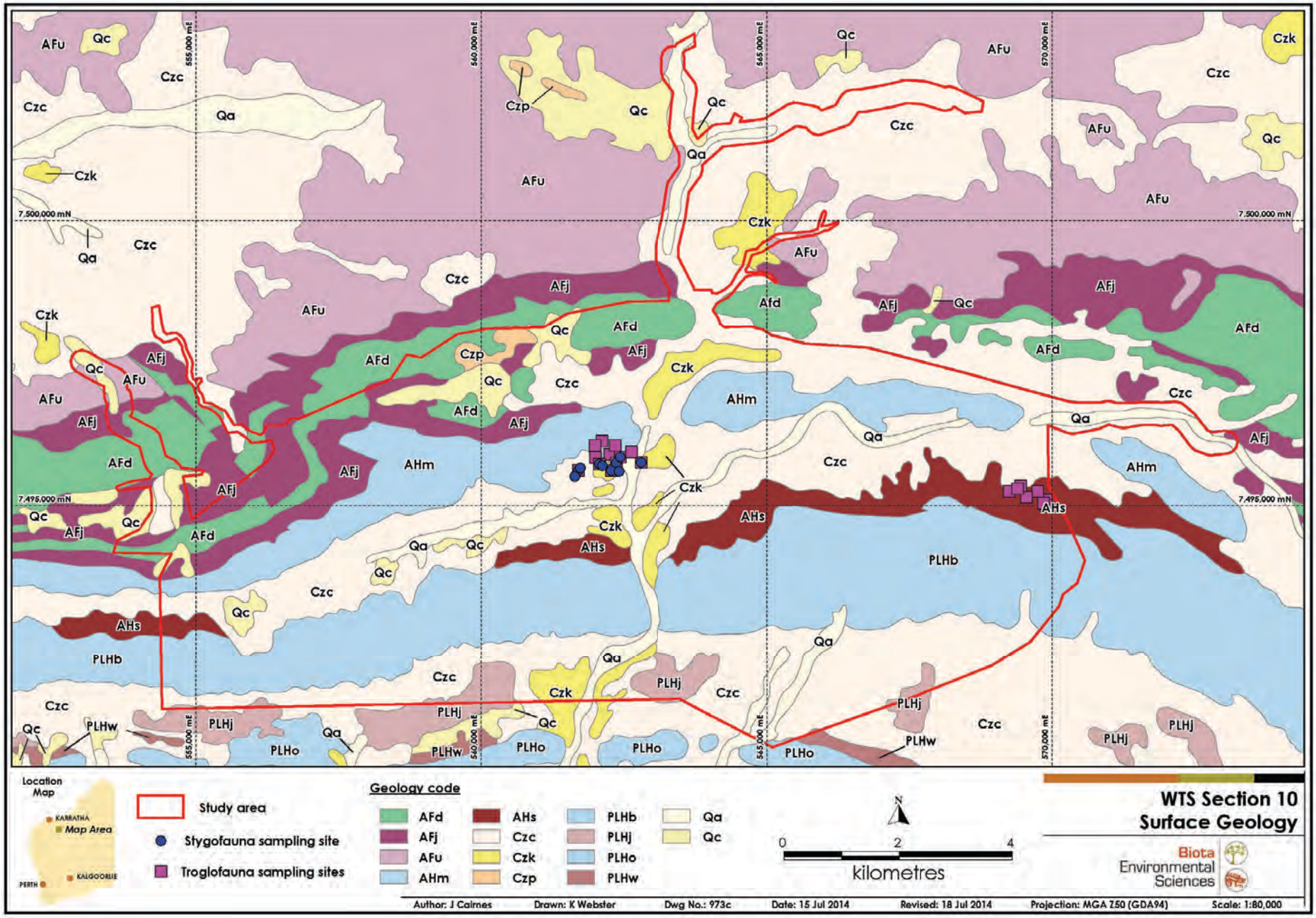


Figure 3.1: Geological units of the study area, showing subterranean fauna sites sampled (see Table 3.1 for unit codes and descriptions).

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4.0 Results

No stygofauna were recorded during the survey at WTS in 2014. Seven troglomorphic specimens were collected during troglofauna sampling at WTS in 2014 (see Section 4.1).

4.1 Troglobitic Fauna

4.1.1 Overview

A total of 499 invertebrate specimens were collected during troglofauna sampling at WTS in 2014, representing eight taxonomic orders. As is common with troglofauna sampling, the majority of specimens collected were not troglobitic but were surface animals or edaphobites, and are not likely to display short-range endemism (e.g. Acarina and Collembola (Biota 2006)). The edaphobites found during this survey are not discussed further in this report, as they are not relevant to the objectives of this study. A comprehensive list of all collected invertebrate fauna can be found in Appendix 3.

The remaining groups represented the troglobitic and troglophilic fauna, which comprised four orders, with a total of seven specimens collected (Table 4.1). These specimens were collected from five of the 20 drillholes sampled for troglofauna in 2014.

Specimens representing the orders Polyxenida and Blattodea are not considered troglobites, but are instead thought to be troglophiles (Biota 2012; Table 4.1). Troglophiles display troglomorphic characteristics and will also utilise subterranean habitats, but are not restricted to them (i.e. not obligate). As such troglophiles are less likely to display short-range endemism and therefore are at reduced risk of conservation impact by local scale developments.

Table 4.1: Summary of troglobitic and troglophilic taxa recorded at WTS Section 10 in 2014.

Taxonomy			Number Collected	Status
Phylum	Class	Order (Common Name)		
Arthropoda	Arachnida	Pseudoscorpiones (pseudoscorpions)	2	Troglobite
	Arachnida	Pseudoscorpiones (pseudoscorpions)	1	Troglophile
	Chilopoda	Scolopendrida (scolopendrid centipedes)	1	Troglobite
	Diplopoda	Polyxenida (pincushion millipedes)	1	Troglophile
	Insecta	Blattodea (cockroaches)	2	Troglophile
		Total	7	

4.1.2 Account of Troglobitic and Troglophilic Fauna

4.1.2.1 Pseudoscorpiones (Pseudoscorpions)

Three pseudoscorpions were collected from WTS in 2014 (Table 4.2, Figure 4.1). A female *Tyrannochthonius* (family Chthoniidae) was collected from an Impact drillhole at WTS (Plate 4.1, Plate 4.2), and a male *Tyrannochthonius* was collected from a Reference drillhole (Plate 4.3, Plate 4.4). These specimens are not represented in the collection of pseudoscorpions at the WAM and have been given the WAM species code *Tyrannochthonius* 'PSE088'. These specimens are troglobitic and are a confirmed SRE species (Abrams et al. 2014; Appendix 2).

Additionally, a juvenile from the family Atemnidae was collected from an Impact drillhole at WTS (Table 4.2, Figure 4.1). The genus of this specimen is currently undetermined however it has been given the WAM species code Atemnidae 'PSE087' as it is not represented in the collection of pseudoscorpions at the WAM (Abrams et al. 2014; Appendix 2). This specimen lacks pigment (possibly accounted for by it being a juvenile), but has eyespots and is therefore not regarded as troglobitic, but instead troglophilic (Mieke Burger, pers. comm. 2014) (Plate 4.5, Plate 4.6). This specimen is a potential SRE.

Table 4.2: Summary of Pseudoscorpiones records from WTS sampling in 2014.

Family	Species	Drillhole Collected (Impact / Reference)	WAM Number	Number Collected	Comments
Chthoniidae	*Tyrannochthonius* 'PSE088'	RC13S10M0043 (Imp.)	T133345	1	Female
Chthoniidae	*Tyrannochthonius* 'PSE088'	RC13S10M0068 (Ref.)	T133346	1	Male
Atemnidae	Atemnidae 'PSE087'	RC13S10M0101 (Imp.)	T133347	1	Juvenile



Plate 4.1: Dorsal view of female *Tyrannochthonius* 'PSE088'.



Plate 4.2: Ventral view of female *Tyrannochthonius* 'PSE088'.



Plate 4.3: Dorsal view of male *Tyrannochthonius* 'PSE088'.



Plate 4.4: Ventral view of male *Tyrannochthonius* 'PSE088'.



Plate 4.5: Dorsal view of juvenile Atemnidae 'PSE087'.



Plate 4.6: Ventral view of juvenile Atemnidae 'PSE087'.

4.1.2.2 Scolopendrida (Scolopendrid Centipedes)

One troglobitic scolopendrid was collected from Impact drillhole RC13S10M0043 (Plate 4.7, Plate 4.8, Figure 4.1). This scolopendrid belongs to the genus *Cryptops* (family Cryptopidae; WAM number T133344), which have been previously recorded as troglobitic (Biota 2006). Due to a lack of taxonomic resolution for this group within Australia, this specimen could not be identified to species level. This specimen is a potential SRE (Abrams et al. 2014; Appendix 2).

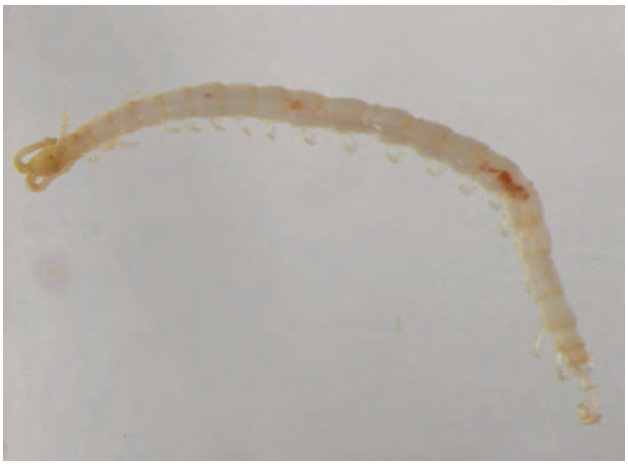


Plate 4.7: Dorsal view of *Cryptops* sp. collected from RC13S10M0043.

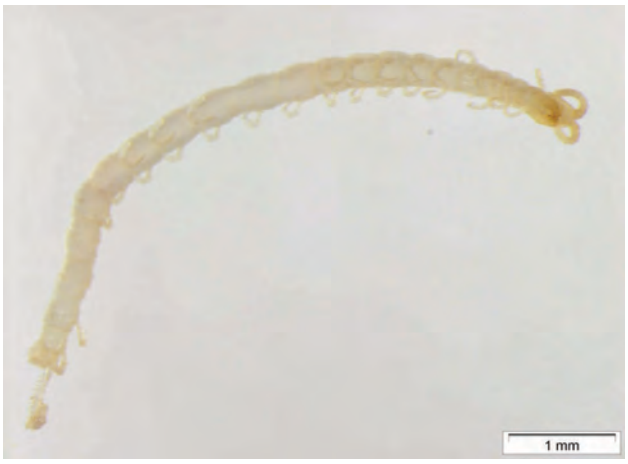


Plate 4.8: Ventral view of *Cryptops* sp. collected from RC13S10M0043.

4.1.2.3 Polyxenida (Pincushion Millipedes)

A single troglophilic polyxenid was collected from Reference drillhole RC13MTSA0019 at WTS in 2014 (Figure 4.1). Sequencing from previous studies at WTS (Biota 2012c) and in the wider Pilbara region (Biota and Helix 2011) have shown that many polyxenids have large distributions and similar dispersal capabilities. Therefore this order is not considered a SRE taxon.

4.1.2.4 Blattodea (Cockroaches)

Two troglophilic cockroaches were collected from Impact drillhole RC13S10M0010 at WTS in 2014 (Figure 4.1). Given the results of historical sequencing of Blattodea at WTS (Biota 2012c), and in the wider Pilbara region (Helix 2010, 2011) that have shown that short-range endemism is not prevalent within the Blattodea, these specimens are unlikely to represent SRE species.

4.2 Historical Subfauna Results from the Study Area

4.2.1 Stygobitic Fauna

There was very little evidence of a stygal community recorded during either of the first two phases of stygofauna sampling at WTS Section 10. A single individual, from the phylum Rotifera, was collected from Impact production bore WTSML06 (Figure 4.2; Biota 2008).

4.2.2 Troglobitic Fauna

A total of 115 troglophilic polyxenids were the only troglomorphic specimens collected during the first phase of troglofauna sampling at WTS Section 10 (Figure 4.2; Biota 2008). As discussed in Section 4.1.2.3, historical genetic analysis indicates that these specimens do not represent SRE taxa (Biota and Helix 2011).

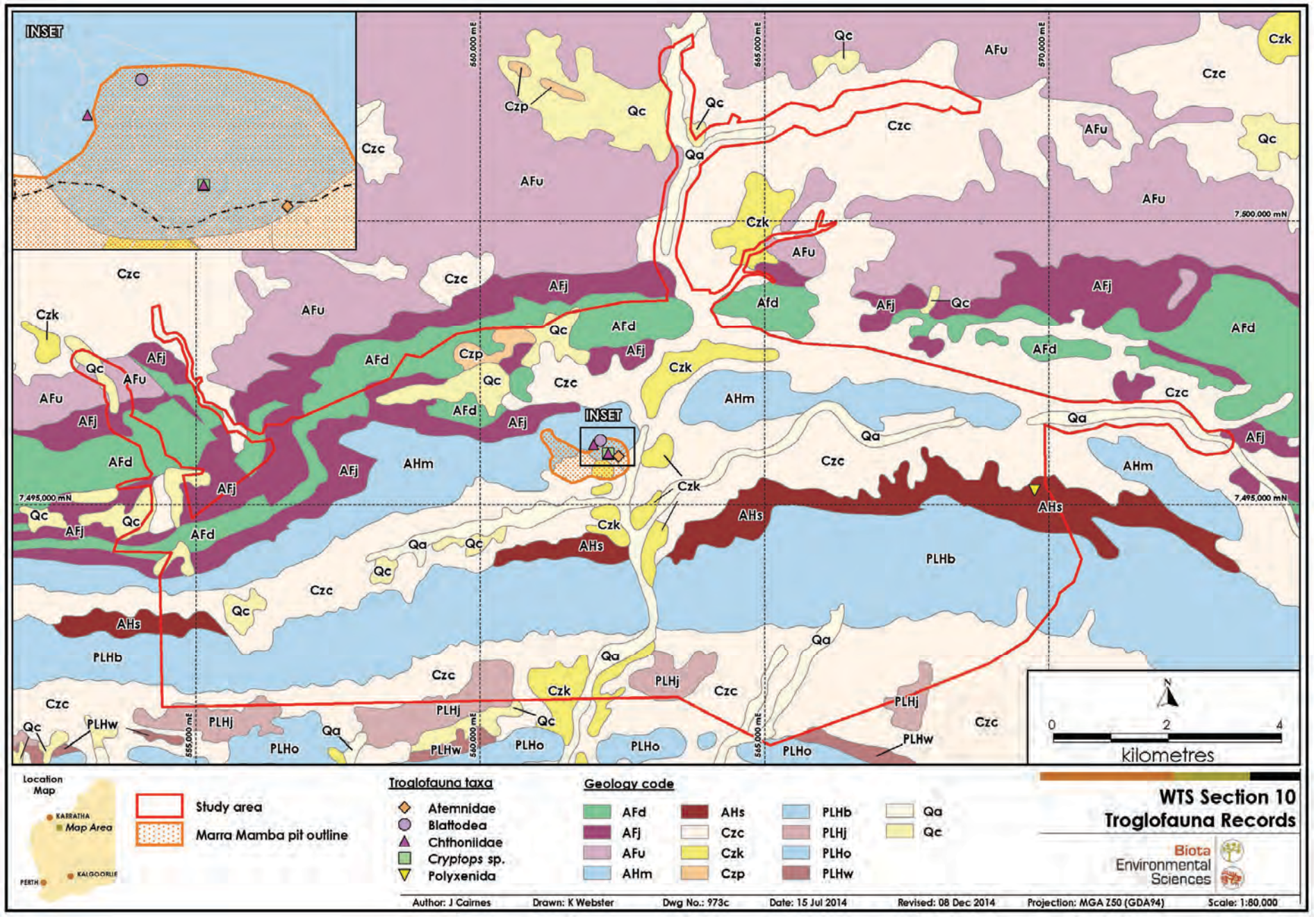


Figure 4.1: Distribution of troglobitic and troglophilic taxa recorded at WTS Section 10 in 2014, showing geology units.

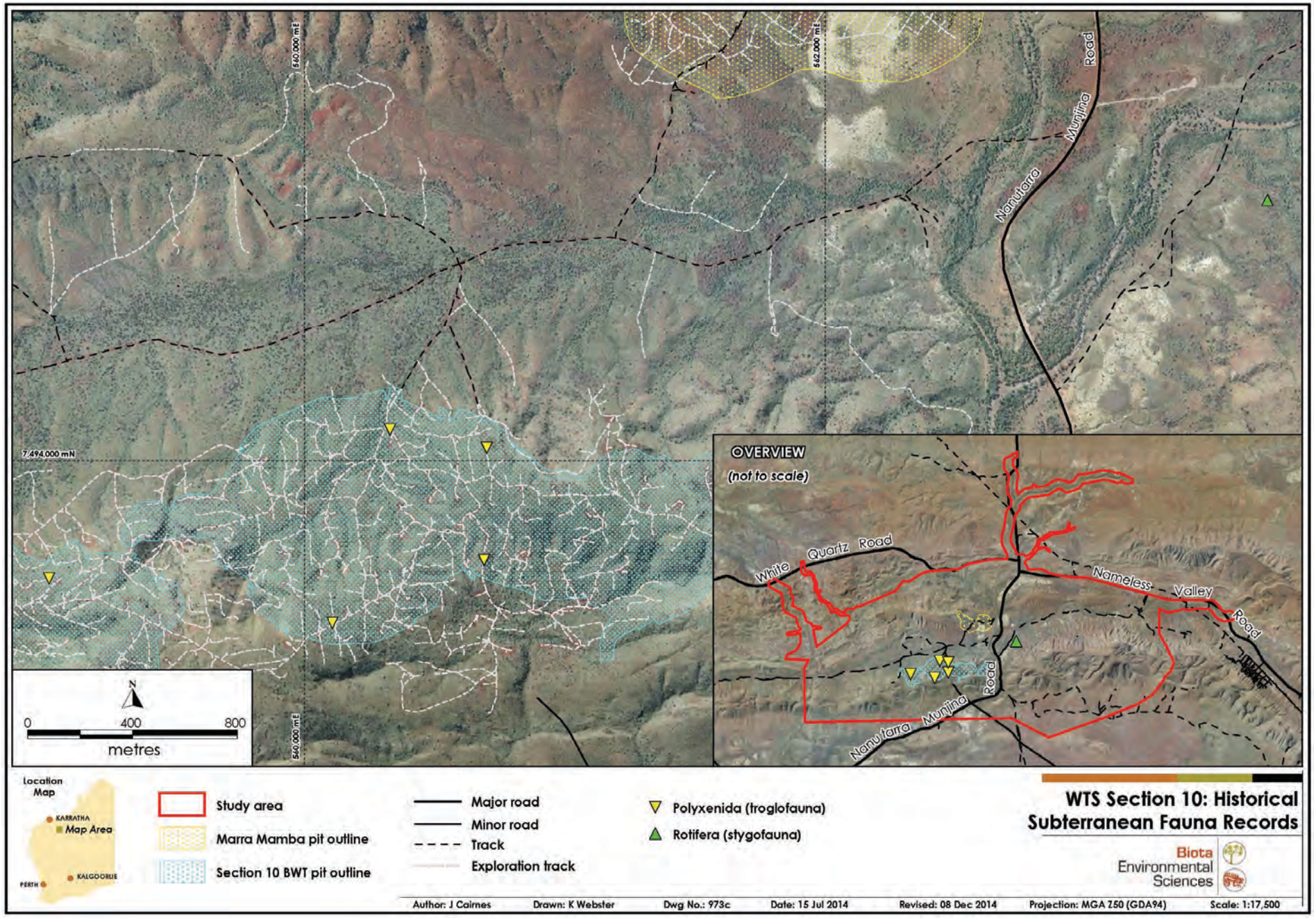


Figure 4.2: Distribution of historical stygofauna and troglofauna recorded at WTS Section 10.

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5.0 Discussion

To date, and including the 2014 survey, subterranean fauna sampling effort in the WTS locality comprises:

- 47 stygofauna sites over five phases (26 of which are in the current study area); and
- 92 troglofauna sites over five phases (31 of which are in the current study area).

Considering the sampling effort completed to date in the WTS locality, our results suggest that subterranean fauna populations occur here in low densities and limited diversity. Similar sampling effort at other sites known to support subterranean communities typically yields greater numbers and diversity of both troglobitic and stygobitic animals (Biota 2002, 2006).

Troglobitic fauna collected to date in the WTS locality were recorded only during this current phase of sampling. Two troglobitic pseudoscorpions belonging to the genus *Tyrannochthonius* (family Chthoniidae) were recorded from an Impact and a Reference drillhole, and one scolopendrid centipede belonging to the genus *Cryptops* (family Cryptopidae) was recorded from an Impact drillhole (Figure 4.1). The two *Tyrannochthonius* 'PSE088' specimens collected during the current survey are of conservation significance as they are a confirmed SRE species. *Cryptops* sp. is a potential SRE species.

The two *Tyrannochthonius* specimens and the *Cryptops* sp. were collected from geology unit AHm "Marra Mamba Iron Formation: banded iron-formation" (Figure 4.1). Figure 5.1 shows that the AHm geological unit is continuous throughout the Western Turner Syncline, and is also continuous in areas surrounding the WTS locality. Multiple studies have now demonstrated that troglobitic species' distributions are often related to the geological history and the nature of the contemporary landform in which they occur (e.g. Biota 2006, 2010c, 2014a). The AHm geological unit is continuous and extends in a band beyond of the edge of the current study area. As such we can infer that the *Tyrannochthonius* 'PSE088' and *Cryptops* sp. collected during this survey are at reduced risk of restriction by habitat isolation and would be likely to occur locally over the geological unit. However further sampling for troglofauna in the AHm geology unit in the WTS locality and molecular comparisons of specimens would be required to confirm.

A number of troglophilic taxa have been collected in the WTS locality including Polyxenida, Blattodea, Hemiptera, Pauropoda and Symphyla (Biota 2008, 2012c). Molecular analysis of Polyxenida and Blattodea taxa collected during previous studies in the WTS locality showed that these species have been recorded from multiple sites outside of the WTS area and are not of conservation significance (Biota and Helix 2011, Biota 2012c). Hemiptera, Pauropoda and Symphyla cannot be confirmed due to identification limitations on material and reference data available. There are currently no data indicating high risk of short-range restrictions in these groups and work that has been done to date suggests they may be a component of the soil fauna and less prone to short range endemism (Biota 2005, Scheller 2013).

Only four of the 47 sites sampled for stygofauna were reference sites, with 43 sites located in the pit deposit or in close proximity outline or within rexpected drawdown from dewatering. Given the lack of density of stygofauna from the Western Turner wider area, and that no fauna were recorded from current sampling, further survey effort in surrounding reference areas is not required.

The stygofauna results to date in the WTS locality indicate a low density stygal community with only 17 specimens of stygofauna recorded over five phases of sampling. Sixteen of these specimens were recorded at the B1 and S17 deposits and belong to two taxa including Paramelitidae B22 (order Amphipoda) and *Diacyclops* sp. (order Cyclopoida) (Biota 2012c). One specimen belonging to the phylum Rotifera was collected from Section 10 (Biota 2008). Paramelitidae B22 is widespread throughout the Pilbara and the *Diacyclops* sp. is likely to be widespread (Biota 2008, 2012c). The distribution of taxa from the phylum Rotifera in the Pilbara is poorly known, however Rotifers can occur in high densities in inland Australian waters and globally (Segers 2008). Sampling and records from the study area suggest that the phyla Rotifera do not are not a significant groundwater fauna in the locality, and do not occur in abundance. There is minimal risk of he development impacting significantly on the wider rotifer population.

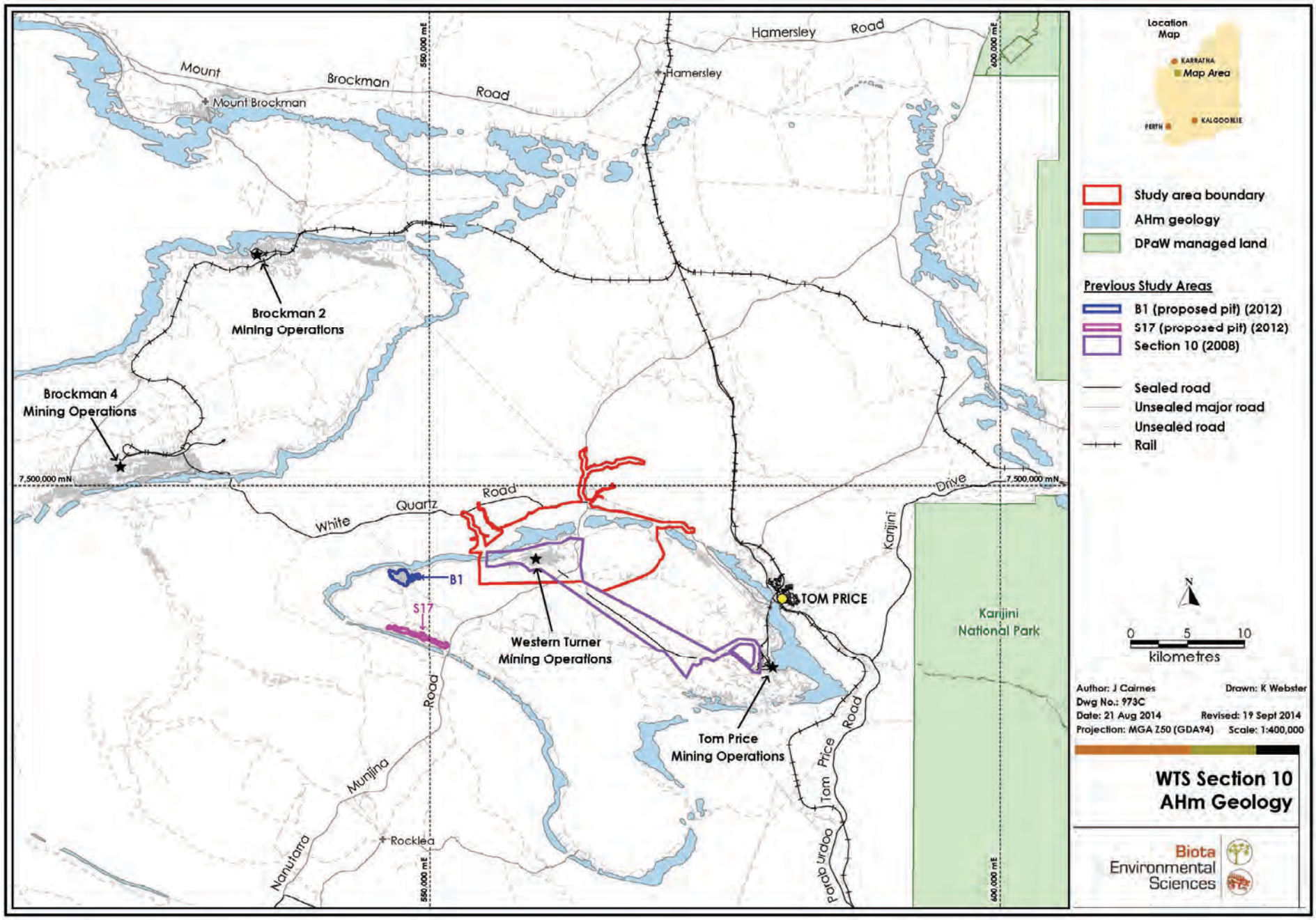


Figure 5.1: AHm BIF geology unit distribution in the WTS locality and wider area.

5.1 Potential Impacts to Subterranean Fauna

The predicted impacts of dewatering and BWT mining at Section 10, and mining a new satellite pit and dewatering at Marra Mamba on subterranean fauna can be divided into two categories: direct and indirect (EPA 2013). Direct impacts include aspects of the proposal that may lead to the direct removal of usable habitat, such as mining and dewatering, which results in a reduction of available habitat. Indirect impacts include threatening processes that are more likely to lead to reduction in population sizes and secondary impacts to subterranean fauna habitat (EPA 2013). Examples of indirect impacts include the alteration to groundwater flow, increased sedimentation and potential pollution of the subterranean environment.

5.1.1 Troglofauna Impacts

Habitat removal through the construction of new satellite pits at Marra Mamba is the principal direct potential impact on the troglofauna for the project. The surface geology AHm BIF, likely provides the most habitable voids suitable for troglofauna, and yielded troglobites during this survey (Figure 4.1 and Figure 5.1), would effectively be removed during mining.

Habitat removal may impact the troglobitic pseudoscorpion *Tyrannochthonius* 'PSE088', and *Cryptops* sp. recorded from the study area, however as discussed in Section 5.0, it is likely that these taxa occur over at least the locality scale. Therefore habitat removal is unlikely to result in the loss of these species.

Other aspects of the project that could indirectly affect troglobitic fauna include:

- vibrations from heavy equipment and blasting during construction and operations;
- reduction in organic inputs: removal of vegetation and stockpiling of topsoil, as well as waste dump areas, may reduce organic material input to subterranean systems;
- changes to the local surface hydrology, which may alter local recharge/discharge areas; and
- changes to subterranean microclimate: reduction in the key microclimate parameters, particularly humidity levels.

The direct removal of troglofauna habitat from the Marra Mamba deposit is likely to have significantly greater localised impact to communities than indirect impacts, which will be localised around the shell of the deposit. Ongoing monitoring in the Pilbara has demonstrated that troglofauna are able to persist with indirect impacts in close proximity to mining operations (Biota 2007, 2012a, 2012b).

5.1.2 Stygofauna Impacts

Groundwater drawdown and changes in groundwater chemistry associated with dewatering and BWT mining at Section 10 are considered to be the principal potential impacts on stygofauna for the project.

The current data suggest that no significant stygofauna populations occur in the locality, and there is minimal risk of any short-range spatial restrictions in the stygofauna of WTS. The only stygofauna specimen known from the study area was recorded in an area where 10 m of groundwater drawdown is predicted to occur (Figure 5.2). However, the specimen recorded is not of conservation significance.

Other aspects of the project that could indirectly affect stygofauna include:

- groundwater contamination: hydrocarbon spills/leaks and wastewater;
- reduction in organic inputs: removal of vegetation and stockpiling of topsoil, as well as waste dump areas, may reduce organic material input to subterranean systems; and
- changes to the local surface hydrology, which may alter local recharge/discharge areas.

As no significant stygofauna have been found in the WTS locality, it is unlikely that these indirect impacts will have any affect on potential stygofauna populations in the study area.

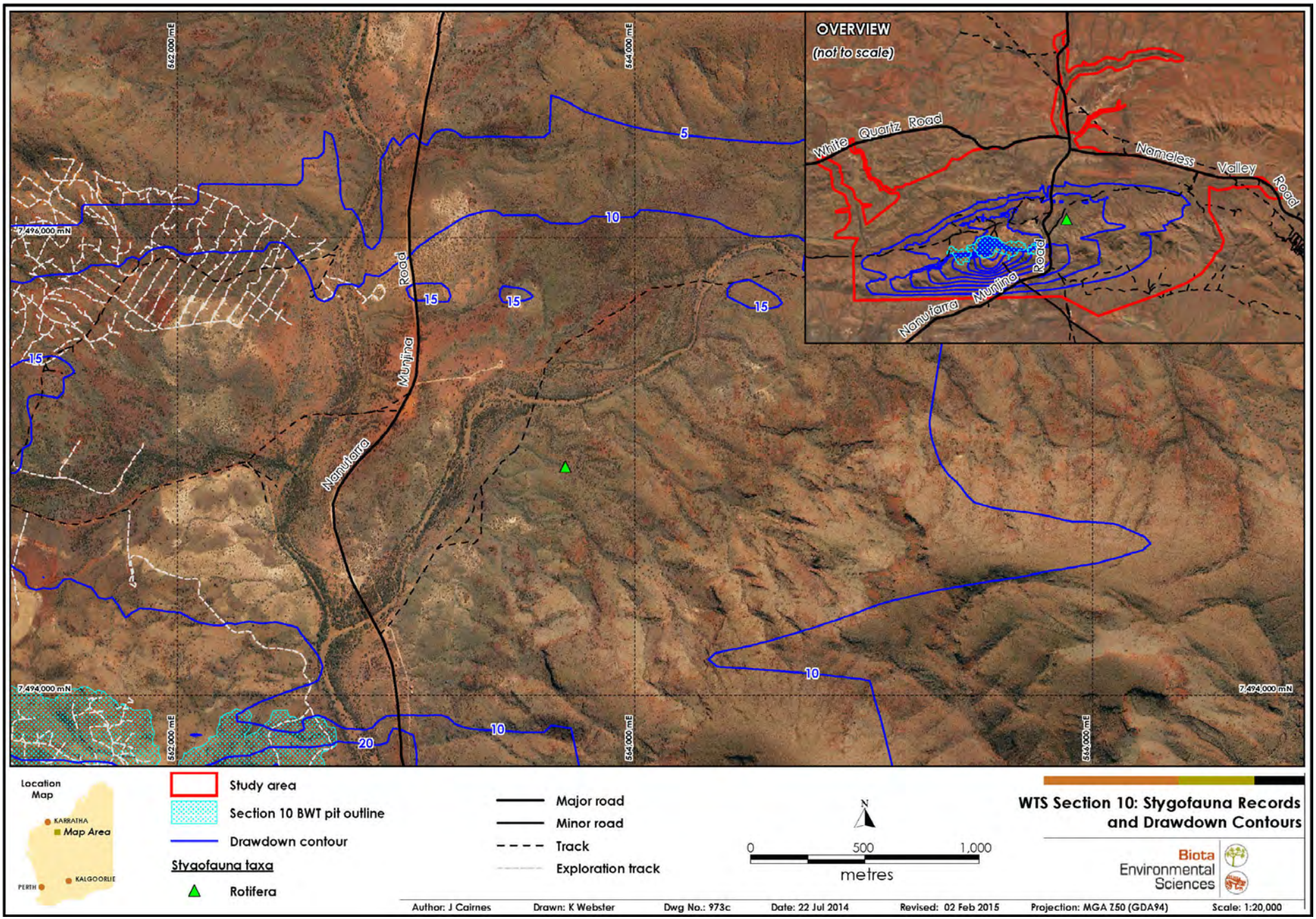


Figure 5.2: Stygofauna records and drawdown contours in the study area.

6.0 Glossary

Edaphobitic / Edaphobite	Soil dwelling fauna that can often display troglomorphic characteristics. Edaphobites are unlikely to have limited distributions and therefore unlikely to be classified as short-range endemics.
Interstices	An opening or space, especially a small or narrow one between mineral grains in a rock or within sediments or soil.
Karst	Soluble-rock landscape; terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well-developed secondary porosity (Goodall et al. 2000).
Mesa	Broad, flat-topped tableland with one or more steep edges.
Short-Range Endemic (SRE)	A species that has a naturally small distribution and is often characterised by having poor dispersal capabilities, confinement to disjunct habitats and low fecundity.
Taxonomy	Theory and practice of biological classification.
Troglomorphic	Pertaining to morphological, behavioural and physiological characters that are convergent in subterranean populations (Christiansen 1962).
Troglophilic / Troglophile	Species able to live and reproduce underground as well as in the epigean environment (Goodall et al. 2000).
Troglobite / Troglofauna	Species living obligatory in caves; also blind, depigmented and often having an elongate body morphology.
Trogloxene	Organisms that can come and go from a cave environment but use it during certain periods of their life cycles, such as nesting and hibernation.
Stygobite / Stygofauna	Obligate groundwater fauna.
Vug	A small cavity in a rock or vein, often with a mineral lining of different composition from that of the surrounding rock.

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Appendix 1

Licence to Take Fauna for Scientific Purposes; Licence No. SF009675

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Facsimile: 08 9334 0242

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STEWART FORD

DATE OF ISSUE 29/01/2014
VALID FROM 01/03/2014
DATE OF EXPIRY 31/05/2014

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LICENSEE: MR D KAMIEN (DANIEL)
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PAGE NO. 1
SF009675
PERSON NO. 70754

RECEIPT NO. **AMOUNT**
$0.00

WILDLIFE CONSERVATION ACT 1950
REGULATION 17
LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

DIRECTOR GENERAL

CONDITIONS

1 THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.

2 UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE DIRECTOR GENERAL, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.

3 NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE DIRECTOR GENERAL. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.

4 NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.

5 NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR BE HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE DIRECTOR GENERAL, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.

6 THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.

7 **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE DEPT OF SUSTAINABILITY, ENVIRONMENT, WATER, POPULATION & COMMUNITIES PH 02 6274 1111. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS DPaW'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********

8 NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE DIRECTOR GENERAL OF DPaW.

9 FURTHER CONDITIONS (NUMBERED 1 TO 9) ARE ATTACHED.

PURPOSE FAUNA SURVEYS: TARGETED VERTEBRATE (NORTHERN QUOLL (TAKE EAR TISSUE SAMPLES), ORANGE LEAF-NOSED BAT, GHOST BAT, PILBARA OLIVE PYTHON, USING ELLIOTT AND CAGE TRAPS, MOTION SENSITIVE CAMERAS, ECHOLOCATOR RECORDERS); SHORT RANGE ENDEMIC (SRE) INVERTEBRATE (ACTIVE SEARCHES / FORAGING, AND UP TO 3 INDIVIDUALS OF EACH PERCEIVED NOMINAL TAXA RETAINED FOR SPECIMENS); AND SUBTERRANEAN (STYGOFAUNA PLANKTON HAUL NETS AND TROGLOFAUNA HABITAT TRAPS) AT THE WEST TURNER SYNCLINE SECTION 10 EXPANSION PROJECT AREA, 40KM WEST OF TOM PRICE TOWN, FOR RIO TINTO.

WILDLIFE CONSERVATION REGULATIONS 1970

Regulation 17:- Licence to Take Fauna for Scientific Purposes

FURTHER CONDITIONS (OF LICENCE NUMBER SF 009675)

1. The licensee shall take fauna only in the manner stated on the endorsed Regulation 17 licence application form and endorsed related correspondence.

2. Except in the case of approved lethal traps, the licensee shall ensure that measures are taken in the capture and handling of fauna to prevent injury or mortality resulting from that capture or handling. Where traps or other mechanical means or devices are used to capture fauna these shall be deployed so as to prevent exposure of trapped animals to ants and debilitating weather conditions and inspected at regular intervals throughout each day of their use. At the conclusion of research all markers etc and signs erected by the licensee and all traps shall be removed, all pitfalls shall be refilled or capped and the study area returned to the condition it was in prior to the research/capture program. During any break in research, cage traps should be removed and pitfalls either removed, capped or filled with sand.

3. No collecting is to be undertaken in areas where it would impinge on pre-existing scientific research programs.

4. Any form of colour marking of birds or bats shall only be undertaken in accordance with the requirements of the Australian Bird and Bat Banding Scheme.

5. Any inadvertently captured specimen of fauna which is declared as likely to become extinct, rare or otherwise in need of special protection is to be released immediately at the point of capture. Where such a specimen is injured or deceased, the licensee shall contact Department of Parks and Wildlife licensing staff at Kensington (08 9219 9831) for advice on disposal. Records are to be kept of any fauna so captured and details included in the report required under further condition 6 below.

6. Within one month of the expiration of this licence, the holder shall submit an electronic return detailing the locality, site, geocode, date and number of each species captured, sighted or vouchered during the currency of the licence, into the Department of Parks and Wildlife Fauna Survey Database (FSD). A copy of any paper, report or thesis resulting from the research shall on completion be lodged with the Director General. If a renewal of this licence is required, the licensee shall submit a written progress report for activities undertaken during this licence period prior to the expiry of this licence.

7. Not more than ten specimens of any one protected species shall be taken and removed from any location less than 20km apart. Where exceptional circumstances make it necessary to take large series in order to obtain adequate statistical data the collector will proceed with circumspection and justify their actions to the Director General in advance.

8. All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this licence shall be donated to the Western Australian Museum. Duplicates (one pair in each case) of any species collected which represents a significant extension of geographic range shall be donated on request to the Western Australian Museum.

9. To prevent any unnecessary collecting in this State, all specimens and material collected under the authority of this license shall, on request, be loaned to the Western Australian Museum. Also, the unused portion or portions of any specimen collected under the authority of this license shall be offered for donation to the Western Australian Museum or made available to other scientific workers if so required.

Appendix 2

Western Australian Museum Arachnida and Myriapoda Morphology Report

WAMTS321: Arachnida/Myriapoda

Arachnids and myriapods from West Turner, Western Australia

(Biota Project *973C West Turner*)

Report to Biota

01 September 2014

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Although identifications in this report were consistent with the best available information and current scientific thinking at the time of identification the use of this report is at the risk of the user. Any liability to users of this report for loss of any kind arising out of the use of this report or the information and identifications it contains is expressly disclaimed.

SUMMARY

WAMTS321 specimens were submitted to the Western Australian Museum on the 7 July 2014. The project contained: a centipede from the family Cryptopidae (n=1); and pseudoscorpions from the families Chthoniidae (n=2) and Atemnidae (n=1). A summary of specimen identifications together with their SRE status may be found in Table 1. A full explanation of the SRE categories used by the Western Australian Museum may be found in Appendix 1.

Table 1. Summary of WAMTS321 specimen identifications and SRE status.

ORDER	FAMILY	GENUS	SPECIES	# OF SPECIMENS	SRE STATUS	SRE SUB-CATEGORY
	[Family]	[Genus]	[species]	[# of specimens]	SRE Status	SRE Sub-Category
Pseudoscorpiones	Atemnidae	*`genus indet.`*	`sp. PSE087`	1	Potential	(A) Juvenile (B) Habitat (subterranean) (C) Morphology indicators (troglobitic) (E) Research & expertise
Pseudoscorpiones	Chthoniidae	*Tyrannochthonius*	`sp. PSE088`	2	Confirmed	(B) Habitat (subterranean) (C) Morphology indicators (troglobitic) (E) Research & expertise
Scolopendromorpha	Cryptopidae	*Cryptops*	`sp indet.`	1	Potential	(A) Lack of taxonomic resolution

SHORT-RANGE ENDEMISM

The terrestrial invertebrate fauna of inland Australia contains a plethora of species, and just the arthropods were recently estimated to consist of more than 250,000 species (Yeates, Harvey et al. 2004; Chapman 2009). The vast majority of these are found within the Insecta and Arachnida, although significant numbers of millipedes are to be expected. For many years, the prospect of including invertebrates in assessments of biological systems subject to modification proved daunting because of the large numbers of unknown species. These animals were largely ignored, as they were too diverse and their taxonomy too little known for them to be considered in environmental surveys that require a rapid turn-around time.

In a recent publication, the issue of Short-Range Endemism in the Australian invertebrate fauna was examined (Harvey 2002),. Species that could be defined as Short-Range Endemics (SRE) were those that had a naturally small range of less than 10,000 km^2. Harvey (2002) found that those species possessed a series of distinct ecological and life-history traits that contributed to their limited distributions, including:

- poor powers of dispersal;
- confinement to discontinuous habitats;
- usually highly seasonal, only active during cooler, wetter periods; and
- low levels of fecundity.

A number of major invertebrate groups have a high proportion of individual species that show these traits and can be considered SRE's. The Western Australian fauna contains a number of SRE taxa, including millipedes, land snails, trap-door spiders, some pseudoscorpions, slaters, and onychophorans and these represent focal groups in Environmental Impact Assessment studies in the state (EPA 2009). The south coast region is relatively well known compared with other regions of the state (Framenau, Moir et al. 2008), but there are many poorly known species and gaps in our understanding of the distributions of many species.

METHODS

Specimens collected by *Biota* were submitted to the Western Australian Museum on the 10 July 2014. The specimens were examined at the WA museum using Leica dissecting microscopes (MZ6, MZ16). The SRE status of each taxonomic group was given using the SRE categorisation system developed and implemented by the Western Australian Museum. A full explanation of the WAM SRE categories is available in Appendix 1.

SIGNIFICANT OUTCOMES

The significant findings of WAMTS321 are summarised below.

ARACHNIDA

ORDER Pseudoscorpiones

Family Atemnidae

1. *PSE087*:
    - **SRE Category: potential SRE.**
    - This study identified a previously unknown species of Atemnidae which has been given the species code `PSE087`. This specimen (T133347) is the only known example of this species at present. Furthermore, ` PSE087` is the only blind atemnid known from West Turner Syncline. However, due to a lack of adult specimens it is not possible to determine whether this specimen is conspecific with another blind atemnid species from a site 60km away, which is a confirmed SRE.

      ` PSE087` has been categorized as a potential SRE due to the restricted geographic distribution of the taxon to the West Turner region. In addition, the fact that this specimen lacks eyes (i.e. is troglobitic) supports the classification of ` PSE087` as a potential SRE.

Family Chthoniidae

2. *PSE088:*
    - **SRE Category: confirmed SRE.**
    - This study identified a previously unknown species of *Tyrannochthonius* which has been given the species code `PSE088`. These specimens (T133345 and T133346) are the only known examples of this species at present. Furthermore, `PSE088` is the only blind *Tyrannochthonius* species known from West Turner Syncline.

      ` PSE088` has been categorized as a SRE due to the restricted geographic distribution of the taxon to the West Turner Syncline region and based on prior research that has shown other blind *Tyrannochthonius* species to be SREs. In addition, the fact that this specimen lacks eyes (i.e. is troglobitic) supports the classification of ` PSE088` as a SRE.

APPENDIX 1. WAM SHORT-RANGE ENDEMIC CATEGORIES

	Taxonomic Certainty	Taxonomic Uncertainty
Distribution < 10 000km^2	**Confirmed SRE** • *A known distribution of < 10 000km².* • *The taxonomy is well known.* • *The group is well represented in collections and/ or via comprehensive sampling.*	**Potential SRE** • *Patchy sampling has resulted in incomplete knowledge of the geographic distribution of the group.* • *We have incomplete taxonomic knowledge.* • *The group is not well represented in collections.* • *This category is most applicable to situations where there are gaps in our knowledge of the taxon.* **Sub-categories for this SRE designation are outlined below**
Distribution > 10 000km^2	**Widespread (not an SRE)** • *A known distribution of > 10 000km².* • *The taxonomy is well known.* • *The group is well represented in collections and/ or via comprehensive sampling.*	

SRE SUB-CATEGORIES

If a taxon is determined to be a "Potential SRE", the following sub-categories will further elucidate this status.

A. *Data Deficient:*
- There is insufficient data available to determine SRE status.
- Factors that fall under this category include:
  - New species.
  - Lack of geographic information.
  - Lack of taxonomic information.
  - The group may be poorly represented in collections.
  - The individuals sampled (e.g. juveniles) may prevent identification to species level.

B. *Habitat Indicators:*
- It is becoming increasingly clear that habitat data can elucidate SRE status.
- Where habitat is known to be associated with SRE taxa and vice versa, it will be noted here.

C. *Morphology Indicators:*
- A suite of morphological characters are characteristic of SRE taxa.
- Where morphological characters are known to be associated with SRE taxa and vice-versa, it will be noted here.

D. *Molecular Evidence:*
- If molecular work has been done on this taxon (or a close relative), it may reveal patterns congruent or incongruent with SRE status.

E. *Research & Expertise:*
- Previous research and/ or WAM expertise elucidates taxon SRE status.
- This category takes into account the expert knowledge held within the WAM.

APPENDIX 2. SPECIMEN DATA FOR WAMTS321 COLLECTED FROM WEST TURNER SYNCLINE

REGNO	FLDNO	ORDER	FAMILY	GENUS	SPECIES	STATE	SITE	LATITUDE	LONGITUDE	M	F	JUV	TOT
133344	RC13S10M004320140529T1-01	Scolopendromorpha	Cryptopidae	`genus indet.`	`sp. indet.`	W.A.	West Turner Syncline, 20.3 km WNW. Tom Price	22°38`33.72"S	117°36`20.91"E				1
133345	RC13S10M004320140529T2-02	Pseudoscorpiones	Chthoniidae	Tyrannochthonius	`PSE088`	W.A.	West Turner Syncline, 20.3 km WNW. Tom Price	22°38`33.72"S	117°36`20.91"E		1		1
133346	RC13S10M006820140529T2-04	Pseudoscorpiones	Chthoniidae	Tyrannochthonius	`PSE088`	W.A.	West Turner Syncline, 20.6 km NW. Tom Price	22°38`29.08"S	117°36`11.85"E	1			1
133347	RC13S10M010120140529T1-01	Pseudoscorpiones	Atemnidae	`genus indet.`	`PSE087`	W.A.	West Turner Syncline, 8.7 km NW. Tom Price	22°38`35.31"S	117°36`27.40"E			1	1

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Appendix 3

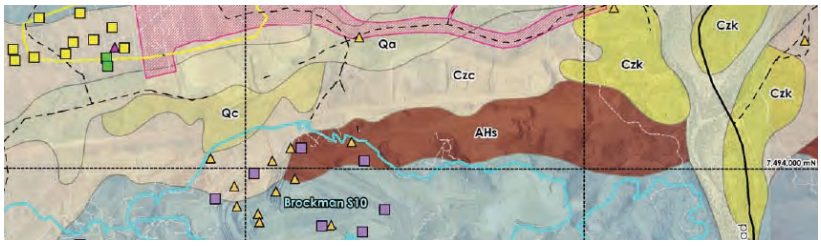
Raw Collection Data 2014

Date	Drillhole	Specimen ID	Taxon	# Specimens	Identifier	Notes
28/05/14	RC13MTSA0003	RC13MTSA000320140528T1-01	Acarina	9	Andrew Sheppard	
28/05/14	RC13MTSA0003	RC13MTSA000320140528T2-01	Acarina	12	Andrew Sheppard	
28/05/14	RC13MTSA0003	RC13MTSA000320140528T3-01	Acarina	20	Andrew Sheppard	
28/05/14	RC13MTSA0005	RC13MTSA000520140528T1-01	Acarina	1	Andrew Sheppard	
28/05/14	RC13MTSA0007	RC13MTSA000720140528T2-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13MTSA0007	RC13MTSA000720140529T1-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0019	RC13MTSA001920140529T1-02	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0019	RC13MTSA001920140529T2-02	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0023	RC13MTSA002320140529T1-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0023	RC13MTSA002320140529T2-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0028	RC13MTSA002820140529T1-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0028	RC13MTSA002820140529T2-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0037	RC13MTSA003720140528T1-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0037	RC13MTSA003720140528T2-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0056	RC13MTSA005620140529T1-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13MTSA0056	RC13MTSA005620140529T2-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0010	RC13S10M001020140529T1-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0010	RC13S10M001020140529T2-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0043	RC13S10M004320140529T1-02	Acarina	5	Andrew Sheppard	
29/05/14	RC13S10M0043	RC13S10M004320140529T2-03	Acarina	20	Andrew Sheppard	
29/05/14	RC13S10M0046	RC13S10M004620140529T2-02	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0058	RC13S10M005820140529T1-01	Acarina	15	Andrew Sheppard	
29/05/14	RC13S10M0058	RC13S10M005820140529T2-01	Acarina	16	Andrew Sheppard	
29/05/14	RC13S10M0058	RC13S10M005820140529T3-01	Acarina	16	Andrew Sheppard	
29/05/14	RC13S10M0068	RC13S10M006820140529T1-02	Acarina	6	Andrew Sheppard	
29/05/14	RC13S10M0068	RC13S10M006820140529T2-03	Acarina	5	Andrew Sheppard	
29/05/14	RC13S10M0096	RC13S10M009620140529T1-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0096	RC13S10M009620140529T2-01	Acarina	3	Andrew Sheppard	
29/05/14	RC13S10M0096	RC13S10M009620140529T3-02	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0099	RC13S10M009920140529T1-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0099	RC13S10M009920140529T2-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0099	RC13S10M009920140529T3-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0101	RC13S10M010120140529T1-02	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0101	RC13S10M010120140529T2-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0108	RC13S10M010820140529T1-01	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0111	RC13S10M011120140529T1-01	Acarina	10	Andrew Sheppard	
28/05/14	RC13S10M0111	RC13S10M011120140529T2-02	Acarina	10	Andrew Sheppard	
29/05/14	RC13S10M0089	RC13S10M008920140529T1-02	Acarina	16	Jess Cairnes	
29/05/14	RC13S10M0010	RC13S10M001020140529T1-02	Blattodea	2	Andrew Sheppard	Troglophile
29/05/14	RC13S10M0089	RC13S10M008920140529T1-01	Coleoptera	2	Jess Cairnes	
28/05/14	RC13MTSA0019	RC13MTSA001920140529T2-03	Collembola	2	Andrew Sheppard	
29/05/14	RC13S10M0010	RC13S10M001020140529T2-02	Collembola	5	Andrew Sheppard	
29/05/14	RC13S10M0043	RC13S10M004320140529T2-01	Collembola	10	Andrew Sheppard	
29/05/14	RC13S10M0046	RC13S10M004620140529T1-01	Collembola	20	Andrew Sheppard	
29/05/14	RC13S10M0046	RC13S10M004620140529T2-01	Collembola	20	Andrew Sheppard	
29/05/14	RC13S10M0068	RC13S10M006820140529T1-01	Collembola	12	Andrew Sheppard	
29/05/14	RC13S10M0068	RC13S10M006820140529T2-02	Collembola	20	Andrew Sheppard	
29/05/14	RC13S10M0096	RC13S10M009620140529T3-01	Collembola	1	Andrew Sheppard	
29/05/14	RC13S10M0108	RC13S10M010820140529T2-01	Collembola	1	Andrew Sheppard	
29/05/14	RC13S10M0111	RC13S10M011120140529T2-01	Collembola	4	Andrew Sheppard	
29/05/14	RC13S10M0043	RC13S10M004320140529T1-01	*Cryptops* sp.	1	Andrew Sheppard	Troglobite
29/05/14	RC13S10M0068	RC13S10M006820140529T2-01	Isopoda	1	Andrew Sheppard	
28/05/14	RC13MTSA0019	RC13MTSA001920140529T2-01	Polyxenida	1	Andrew Sheppard	Troglophile
29/05/14	RC13S10M0043	RC13S10M004320140529T2-02	Chthoniidae	1	Mieke Strong	Troglobite
29/05/14	RC13S10M0068	RC13S10M006820140529T2-04	Chthoniidae	1	Mieke Strong	Troglobite
29/05/14	RC13S10M0101	RC13S10M010120140529T1-01	Atemnidae	1	Mieke Strong	Troglophile

Biota Environmental Sciences

Western Turner Syncline Section 10 Hub Subterranean Fauna Assessment







Prepared for Rio Tinto

October 2015

Biota Environmental Sciences

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Licence To Take Fauna

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1.0 Summary

1.1 Introduction

Rio Tinto plans to expand the currently operational Western Turner Syncline (WTS) Section 10 mine. The proposed expansions include the commencement of dewatering operations in 2017, and subsequent below water table (BWT) mining in 2018.

In 2014, as part of Environmental Impact Assessment (EIA) requirements, Biota Environmental Sciences (Biota) completed a survey investigating the occurrence of subterranean fauna and assessing habitat suitability for both stygobitic fauna (stygofauna) and troglobitic fauna (troglofauna). This initial survey focussed on the proposed Section 10 expansion and satellite Marra Mamba ore bodies.

Subsequent to that 2014 survey, Rio Tinto amended the proposed expansion plans, which now comprise four pit expansion areas. This Section 10 "hub" (hereafter 'the study area') includes the Section 10 Brockman pit, the Section 10 Brockman West Extension, the Section 10 Marra Mamba East Pit and the Section 10 Marra Mamba West pit (Figure 2.2). The Office of the Environmental Protection Authority (OEPA) advised that further work was needed on subterranean fauna to support the assessment of the proposal.

1.2 Methodology

The 2015 field survey comprised two sampling phases (Table 1.1). The Phase 2 troglofauna samples are to be recovered at the end of August and will be reported on in a separate addendum to this report.

Table 1.1: Subterranean fauna sampling phases.

Survey Phase	Date	Purpose
Phase 1	15 -19 May, 2015	• Troglofauna trap installation; and • Stygofauna sampling.
Phase 2a	8 -13 July, 2015	• Troglofauna trap recovery and reinstallation; and • Stygofauna sampling.
Phase 2b	August 2015	• Troglofauna trap recovery.

Survey effort was targeted to areas that had not been previously surveyed to a Level 2 standard. Troglofauna was sampled by means of litter colonisation traps, while stygofauna sampling was undertaken using modified plankton haul nets. Table 2.1 outlines the sampling effort.

Table 1.2: Sampling effort.

Locality	Troglofauna		Stygofauna	
	Phase 1	Phase 2	Phase 1	Phase 2
Marra Mamba East	12	12	8	9
Marra Mamba West	10	11	–	1
Section 10 Brockman Extension	10	9	–	–

During the two sampling phases a total of 34 drill holes were sampled for troglofauna and 11 sites were sampled for stygofauna.

The extent of the sampling was limited by the availability of viable drill holes and the nature of the proposed development. Only the Marra Mamba pits were assessed for stygofauna, as the proposed development of the Brockman West Extension pit will not reach the water table. Additionally, stygofauna sampling at Marra Mamba East and Marra Mamba West was limited by depth to water table, with the groundwater not reached by many of the drill holes. Sampling design was further limited by the exclusion of a portion of the study area due to the presence of asbestos fibres.

1.3 Results

No stygobitic fauna specimens were recorded from the Marra Mamba pit outlines sampled within the study area. A total of 5,414 invertebrate specimens were recorded during the Phase 1 troglofauna sampling, three of which were identified as being either troglophilic or troglobitic.

Two of these specimens belonged to the order Blattodea (cockroaches) and were recorded from Marra Mamba West. The specimens were assessed as being troglophilic, rather than troglobitic. Troglophiles are generally less likely to display short-range endemism and such taxa are therefore considered to be at reduced risk of changes to their conservation status due to impacts at local scales.

A troglobitic centipede belong to the family Cryptopidae was also recorded from Marra Mamba West. It is considered likely to represent the same potential SRE taxon, *Crytops* sp., recorded from the same drill hole in 2014 (Biota 2014d).

1.4 Conclusions

With the completion of the additional 2015 survey, the overall subterranean fauna sampling effort reported by Biota (2014d) for the wider WTS locality can be updated to now comprise:

- 58 stygofauna sites over five phases (37 of which fall within the current study area); and
- 126 troglofauna sites over five phases (65 of which fall within the current study area).

The results from the 2015 survey were again consistent with previous sampling in the WTS locality, with very few subterranean fauna recorded relative to the number of sites sampled. Considering the sampling effort completed to date in the WTS locality, the data suggest that subterranean fauna populations occur here in low densities and limited diversity. Similar sampling effort at other sites known to support subterranean communities typically yields greater numbers and diversity of both troglobitic and stygobitic animals (Biota 2002, 2006).

Stygofauna sampling during the 2015 survey focused on the Marra Mamba pits and the data obtained again indicate it is unlikely that a stygal community of any significance is present. No stygofauna were recorded and this is probably a function of the aquifer habitats in the Marra Mamba pit areas. The overall body of data from the Pilbara shows that once depth from surface to water table exceeds approximately 40 m, there are generally few if any stygofauna present (Biota 2003, 2005a, 2010d, unpublished data). The groundwater at Marra Mamba West in particular was at considerable depth, with more than 20 sites unable to be sampled as drillholes exceeding 50 m in depth still did not reach the water table. The nature of the groundwater habitats therefore suggests a low risk that a significant stygal community is present.

Troglobitic fauna have only been collected from three of the 65 drillholes collectively sampled in the study area. All of these records have come from the AHm "Marra Mamba Iron Formation: banded iron-formation" geological unit and it appears likely that this represents potential troglofauna habitat in the locality. Geological mapping shows that the AHm geological unit is continuous throughout the Western Turner Syncline, and is also continuous in areas surrounding the WTS locality. Multiple studies have now demonstrated that troglobitic species' distributions are often related to the geological history and the nature of the contemporary landform in which they occur (e.g. Biota 2006, 2010c, 2014a). The AHm geological unit is continuous and extends in a band beyond the proposed pit boundaries and further afield beyond the edge of the current study area. As this represent confirmed troglofauna habitat for both *Tyrannochthonius* 'PSE088' and *Cryptops* sp. the distribution of the AHM unit suggests reduced risk of restriction by habitat isolation and that these taxa may occur locally over the geological unit.

2.0 Introduction

2.1 Project Background

Rio Tinto plans to expand the currently operational Western Turner Syncline (WTS) Section 10 mine, located approximately 17 km west of Tom Price, in the Pilbara Region of Western Australia (Figure 2.1). The Section 10 deposit will supply ore for processing in the existing Mount Tom Price plant, with the aim of further extending the life of the Mount Tom Price mine. The proposed expansions include the commencement of dewatering operations in 2017, and subsequent below water table (BWT) mining in 2018.

In 2014, as part of Environmental Impact Assessment (EIA) requirements, Biota Environmental Sciences (Biota) completed a survey investigating the occurrence of subterranean fauna and assessing habitat suitability for both stygobitic fauna (stygofauna) and troglobitic fauna (troglofauna). This initial survey focussed on the proposed Section 10 expansion and satellite Marra Mamba ore bodies.

Subsequent to that 2014 survey, Rio Tinto amended the proposed expansion plans, which now comprise four pit expansion areas. This Section 10 "hub" (hereafter 'the study area') includes the Section 10 Brockman pit, the Section 10 Brockman West Extension, the Section 10 Marra Mamba East Pit and the Section 10 Marra Mamba West pit (Figure 2.2). The Office of the Environmental Protection Authority (OEPA) advised that further work was needed on subterranean fauna to support the assessment of the proposal.

2.2 Objectives of this Study

The objective of this study was to carry out further subterranean fauna sampling work within the WTS Section 10 Hub to supplement the existing data and bring the WTS subterranean fauna assessment up to a full Level 2 standard as defined by EPA (2013). The specific tasks required to meet this objective are as follows:

- Review previous troglofauna and stygofauna sampling locations in the study area vicinity and determine the most appropriate sampling locations to bring the assessment of the entirety of the proposed hub up to Level 2 standard;
- Conduct two phases of targeted subterranean fauna sampling for both stygofauna and troglofauna at available drill holes in the study area;
- Morphologically identify collected troglofauna and stygofauna specimens to species level, where possible, and place them into a local and regional context; and
- Assess the conservation status of the subterranean fauna present.

2.3 Subterranean Fauna Background

Subterranean fauna can be categorised into two distinct ecological groups based on habitat, troglobitic fauna (troglofauna) and stygobitic fauna (stygofauna). Troglofauna are a suite of fauna that survive only in air-filled cavities and interstices between the surface and the water table. Troglobites are obligatory subterranean habitat dwellers, and while they may occur close to surface environments, are strongly adapted to subterranean environments. This makes such fauna unable or highly unlikely to survive surface conditions. A range of similarly adapted fauna occur that opportunistically use subterranean habitats but are able to survive outside these stable environments. Studies from the Pilbara bioregion have demonstrated that these latter suites of fauna; troglophiles, trogloxenes and edaphobites, are not similarly restricted in range and therefore unlikely to be impacted at taxon level by small scale developments (Biota and Helix 2011, Helix 2012).

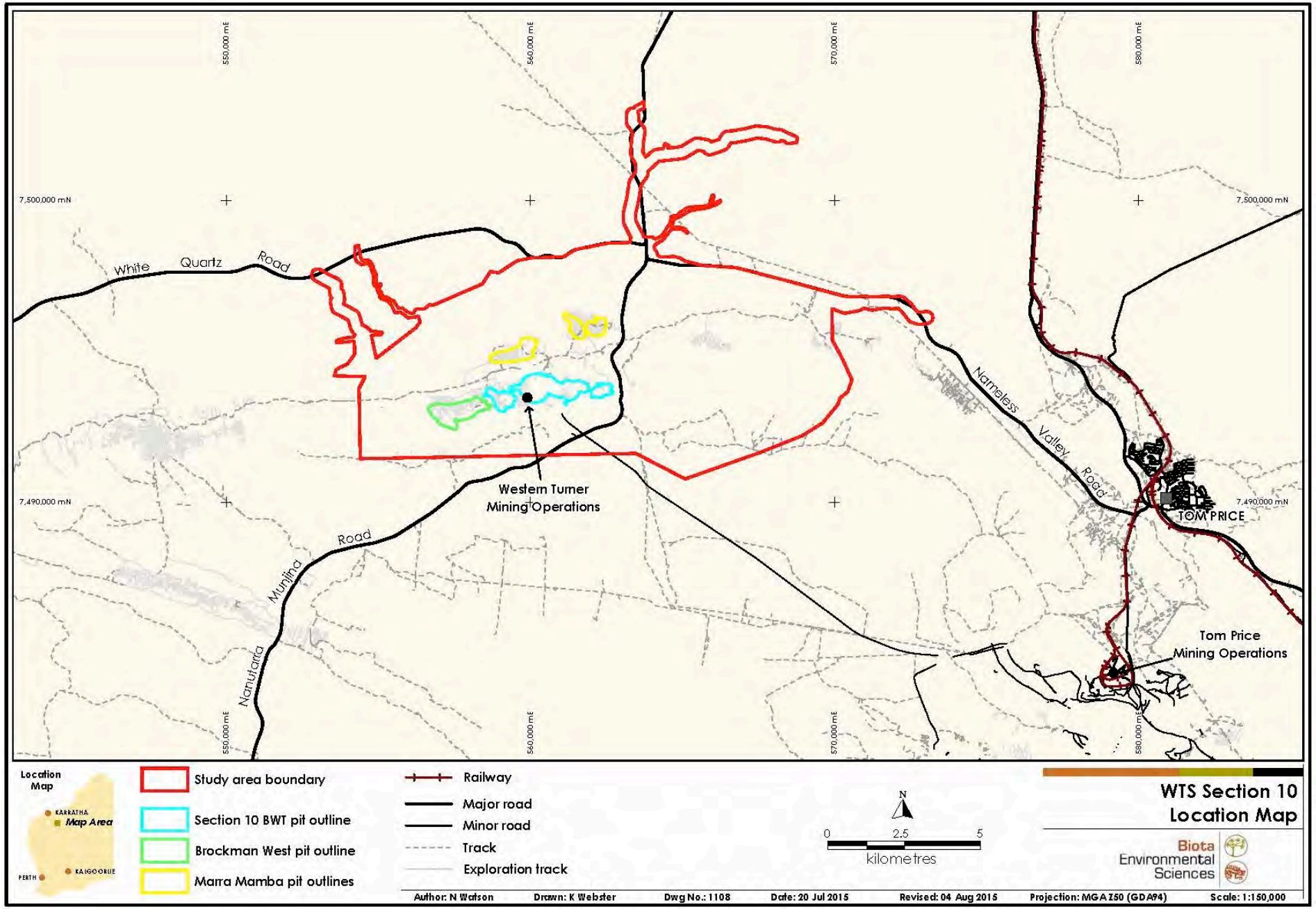


Figure 2.1: Location of WTS Section 10 mining operations.

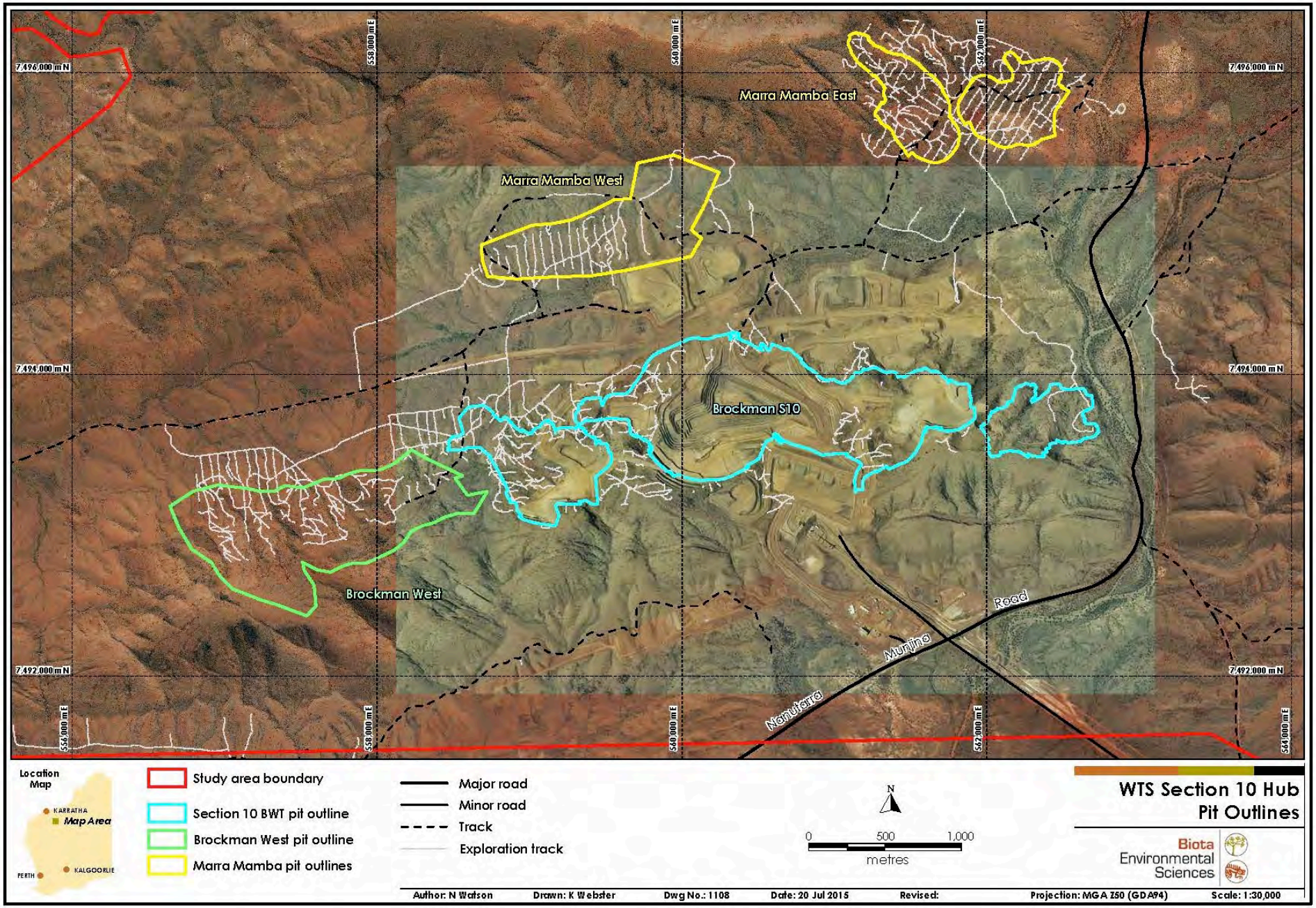


Figure 2.2: WTS Section 10 study area pit outlines.

Troglofauna in northern Western Australia have been known for some time from karstic limestone systems on Cape Range and Barrow Island. Surveys in the Pilbara over the past decade or more have collected subterranean fauna from other geological units such as banded iron formations, channel iron deposits, unconsolidated alluvium and sedimentary basalt (Marmonier et al. 1993, Biota 2004, 2006, 2010b, 2011a, 2013), indicating that the suitability of a formation as habitat for troglobitic fauna is mostly a function of the availability of habitable space (Marmonier et al. 1993, Humphreys 1999, Biota 2006), rather than a specific rock type.

Subterranean habitats are characterised by shared physical parameters that include a lack of light, stable temperature, limited nutrient infiltration from surface environments and a constant humidity (Juberthie 2001, Romero 2009). These habitat characteristics have resulted in convergence in body morphology evolution amongst many subterranean fauna. These adaptations consist of reduced or no eyes, loss of pigment and elongate appendages (Coineau 2001). A suite of superficial soil fauna, known as edaphobitic fauna, can display similar troglomorphic traits but generally do not have limited distributions (Berry 2005, Biota 2006, 2011b, Biota and Helix 2011).

2.4 Previous Sampling at Western Turner Syncline

A substantial amount of previous subterranean fauna sampling has been conducted at WTS Section 10 and at other locations in the WTS locality (see Sections 2.4.1 and 2.4.2). An overview is provided here to set context for the current survey.

2.4.1 WTS Section 10

Sampling for subterranean fauna was first commenced at WTS Section 10 in 2007 as outlined in Table 2.1. That survey included two troglofauna sampling phases and three stygofauna sampling phases (Biota 2008, 2014a).

Table 2.1: Subterranean survey effort at WTS Section 10.

Survey	Survey Dates	Survey type	Stygofauna sites	Troglofauna sites
WTS Section 10 Subterranean Fauna Assessment (Biota 2008)	26th November – 3rd December 2007	• Stygofauna Phase 1; and • Troglofauna Phase 1	8	11
	23rd January 2008	• Phase 1 troglofauna trap retrieval.		
	15th-17th March 2008	• Stygofauna Phase 2	15	
WTS Section 10 Subterranean Fauna survey (Biota 2014a)	7th -15th April 2014	• Stygofauna Phase 3; and Troglofauna Phase 2	10	20
	28th – 29th May 2014	• Phase 2 troglofauna trap retrieval.		
		Total sites sampled:	33	31

Overall, the sampling effort in at WTS Section 10 comprised:

- 33 stygofauna drill holes over three sampling phases; and
- 31 troglofauna drill holes over two sampling phases.

Only a single stygal rotifer was recorded from three sampling phases (Table 2.2). Similarly, a total of just three troglobitic specimens representing two taxa have been recorded during the two previous sampling phases (Table 2.2).

Table 2.2: Stygobitic and troglobitic fauna recorded from WTS Section 10.

Survey	Stygofauna	Sites (number of specimens)	Troglofauna	Sites (number of specimens)
WTS Section 10 Subterranean Fauna Assessment (Biota 2008)	Rotifera	WTSML06 (1)	Nil	NA
WTS Section 10 Subterranean Fauna survey (Biota 2014a)	Nil	NA	*Tyrannochthonius* 'PSE088'	RC13S10M0043 (1), RC13S10M0068 (1)
			Cryptops sp.	RC13S10M0043 (1)

Potential impacts on troglofauna arising from Section 10 were previously assessed by the EPA (EPA 2009) and the current hub proposal only addresses the extension of the pit below water table and its impacts on stygofauna.

As the three previous phases of stygofauna sampling effort met the requirements of EPA (2007, 2013), and the findings of the surveys suggest low stygal diversity and abundance, no further sampling was conducted at Section 10 during the current 2015 survey (see Section 3.2).

2.4.2 WTS Stage 2 B1 and Section 17

While not directly relevant to the current hub proposal, previous work at nearby B1 and Section 17 are relevant for context to the current study.

Five phases of subterranean fauna sampling (three troglofauna phases and two stygofauna phases) were conducted to the west of the current study area, at the WTS Section 10 Stage 2 B1 and Section 17 deposits (Table 2.3) (Biota 2012).

Table 2.3: Subterranean survey effort in the WTS B1 and S17 study areas.

Survey	Survey Dates	Survey type	Stygofauna sites	Troglofauna sites
WTS Stage 2 B1 and Section 17 Deposits Subterranean Fauna Survey (Biota 2012)	3rd – 10th June 2009	• Stygofauna Phase 1; and • Troglofauna Phase 1	17	34
	21st – 23rd July 2009	• Phase 1 troglofauna trap retrieval.		
	1st – 5th August 2011	• Stygofauna Phase 2; and • Troglofauna Phase 2	15	34
	4th – 6th October 2011	• Phase 2 troglofauna trap retrieval; and • Troglofauna Phase 3		26
	13th – 14th December 2011	• Phase 3 troglofauna trap retrieval.		
		Total number of sites	32	94

Few subterranean fauna records were again obtained at the WTS Stage 2 B1 and Section 17 deposits relative to survey effort. Sixteen stygofauna specimens representing two regionally common taxa were recorded, with no troglobitic fauna specimens recorded (Table 2.4).

Table 2.4: Recorded stygobitic and troglobitic fauna from WTS B1 and S17 study areas.

Survey	Stygofauna	Sites (number of specimens)	Troglofauna	Sites (number of specimens)
WTS Stage 2 B1 and Section 17 Deposits Subterranean Fauna Survey (Biota 2012)	Paramelitidae sp. B22	PZ08B1003 (1), RC06B1B014 (11), RC06B1B332 (3)	Only troglomorphs recorded.	NA
	Diacyclops sp.	RC06S17345 (1)		

3.0 Methodology

3.1 Survey Timing and Personnel

The 2015 subterranean fauna sampling was completed under "Licence to Take Fauna for Scientific Purposes" No. SF010293 issued to Mr Dan Kamien (Appendix 1). Methodology and approach were consistent with those outlined in the EPA Guidance Statement No. 54 (EPA 2003), EPA Guidance Statement No. 54a (EPA 2007) and EPA Environmental Assessment Guideline No. 12 (EPA 2013).

Table 3.1: Survey timing and personnel.

Survey phase	Survey components	Dates	Personnel
Phase 1	Troglofauna trap installation and stygofauna sampling	15th-19th of May 2015	Ms Penny Brooshooft and Ms Prue Anderson
Phase 2	Troglofauna trap recovery, reinstallation and stygofauna sampling	8th-13th July 2015	Dr Nicola Watson and Mr Michael Delaney
Phase 3*	Troglofauna trap recovery	Planned for 17th-19th August 2015	Mr Michael Delaney and Ms Penny Brooshooft

*Results from Phase 3 will be presented as an addendum to the current report.

Preliminary identification of specimens to the order level was completed by Mr Andrew Sheppard, Mr David Keirle and Mr Chris Cole of Biota.

Ms Kylie Webster and Ms Melissa Robinson of Biota prepared the maps for this report.

3.2 Sampling Effort

Survey effort was targeted at pit outlines within the study area that had historically not been surveyed to a Level 2 standard. Sample sites were located across the following pit areas:

- Marra Mamba East (new pit with dewatering required - stygofauna and troglofauna);
- Marra Mamba West (new pit with dewatering required - stygofauna and troglofauna); and
- Section 10 Brockman Extension (new above water table only pit - troglofauna).

3.2.1 Stygofauna

Stygofauna sampling was completed at both Marra Mamba pits as dewatering will be required to access the ore at both pits. The number of drill holes suitable for stygofauna sampling was, however, limited, particularly in the Marra Mamba West pit. Attempts were made to sample 20 drillholes in the latter pit area but all were unsuccessful as the drillholes did not reach the water table (in excess of 50 m below ground level). A substantial proportion of the same pit was also unsafe to sample due to the presence of fibrous (asbestiform) material (Figure 3.1).). Only a single drill hole reached the groundwater and was able to be sampled at Marra Mamba West (Table 3.2).

A total of 11 drill holes were sampled successfully for stygofauna across the two phases, with eight drill holes sampled during Phase 1 and 10 drill holes sampled during Phase 2 (Table 3.2 and Figure 3.1).

Table 3.2: Stygofauna sampling sites within the Marra Mamba East and West pits.

Site	Easting (mE)	Northing (mN)	Location	Phase	
RC12S10M003	562864	7495741	Marra Mamba East	1	2
RC13S10M0039	562117	7495703	Marra Mamba East	1	2
RC13S10M0052	562481	7495827	Marra Mamba East	1	2
RC13S10M0059	561731	7495667	Marra Mamba East	1	2
RC13S10M0089	562064	7495739	Marra Mamba East	1	2
RC13S10M0101	562432	7495856	Marra Mamba East	1	2
RC13S10M0164	562002	7495647	Marra Mamba East	1	2
RC14S10M0003	562205	7495524	Marra Mamba East	1	–
RC13S10M0048	562351	7495624	Marra Mamba East	–	2
RC12S10M012	562329	7495800	Marra Mamba East	–	2
RC15S10M0024	559225	7494717	Marra Mamba West	–	2

3.2.2 Troglofauna

Troglofauna sampling was conducted in all three pits areas that had not been previously surveyed: Marra Mamba East (12 drill holes), Marra Mamba West (11 drill holes), and the Section 10 Brockman Extension area (11 drill holes), for a total of 34 sampling sites over two phases (see Table 3.3 and Figure 3.1). An overall total of 194 troglofauna traps was deployed in the study area over the two phases of sampling (Table 3.3).

3.3 Sampling Methodology

3.3.1 Stygofauna

Stygofauna sampling was undertaken using modified plankton haul nets. These sampling nets were constructed from 70 *µm* plankton mesh, with 80 mm apertures attached to a weighted catch jar. Stygofauna sampling nets were lowered to the bottom of the drill holes before being slowly hauled to the surface, where the contents of the catch jar were flushed into a uniquely labelled container. Stygofauna sampling also potentially dislodged any troglofauna specimens occurring on drill hole walls (Section 3.3.2).

Each drill hole was subjected to five hauls unless the water sample was very turbid, in which case the site was only sampled two or three times. On the final haul the net was agitated gently, acting to stir the benthos layer and mobilises any fauna present for more effective specimen collecting. Specimens were stored in a shaded esky in order to preserve the sample prior to sorting and identification. Following each haul, the nets were thoroughly rinsed with water and inspected. Where possible, nets were left to dry before using on another drill hole, thus preventing cross-contamination of specimens between aquifers and sample sites.

3.3.2 Troglofauna

Troglofauna were primarily sampled by means of custom-built litter colonisation traps suspended within drill holes. A series of colonisation traps were suspended at intervals, which allowed a greater coverage of each drill hole. Traps were constructed from 60 mm internal diameter PVC irrigation pipe cut to a length of 180 mm. Each trap had a series of 20 mm holes drilled into the side, and traps remained open at the upper end. Up to three traps were installed such that they were in contact with the interior of the sampled drill hole, facilitating fauna entry into the trap.

Leaf litter was gathered locally from the ground surface in the study area, particularly from the bases of *Acacia* shrubs. The collected litter was soaked in water and irradiated in a microwave oven for two minutes on maximum power setting. The microwave acted to kill any surface invertebrates present and assisted in the breaking down of organic matter. Wet litter was added to the traps, which were kept in sealed containers until immediately prior to insertion into the drill holes to avoid desiccation of leaf litter. After the installation of traps, the opening of each drill hole was sealed to maintain humidity and to avoid entry of surface fauna.

Traps were recovered from each drill hole after approximately eight weeks and stored in labelled zip lock bags in order to maintain humidity and prevent desiccation of potential troglofauna specimens during transportation to Perth. Sampling for stygofauna (see Section 3.3.1) also included the use of haul net drags through potential troglofauna habitat, where any dislodged specimens were preserved and identified during sorting.

Fauna specimens were recovered from the traps using specially designed Tullgren funnel units. Leaf litter from each trap was placed in a sieve under an aluminium lamp containing a 25-watt globe. This created a temperature of approximately 30°C at the surface of the leaf litter. A funnel situated below the leaf litter collected the fauna as they fell, directing them into an attached vial of 100% ethanol. Leaf litter was left in the Tullgren funnels for a period of 24 hours, or until dry, after which time the bulked invertebrate sample removed.

Fauna specimens collected via Tullgren funnels were identified to order level using dissecting microscopes (Olympus SZ40 and SZ61, magnification up to 40x). Fauna specimens were assigned a unique number based on drill hole name and tracked on customised data sheets. Specimens were preserved in 100% ethanol, which allows for both morphological and molecular analysis.

3.4 Limitations

The following limitations should be recognised when considering the findings from this study:

- The extent of the sampling was limited by the availability of viable drill holes, which may have resulted in sampling bias in respect to habitat and geology;
- The number of drill holes suitable for stygofauna sampling at Marra Mamba East and Marra Mamba West was limited as the water table was not reached by the majority of available drill holes;
- Access at Marra Mamba West was limited due to exclusion from a portion of the study area due to the presence of asbestos fibres; and
- For some subterranean fauna groups, the current lack of taxonomic framework and sufficient taxonomic expertise limits definitively assignment of specimens to taxa and thereby a species-level analysis of results.

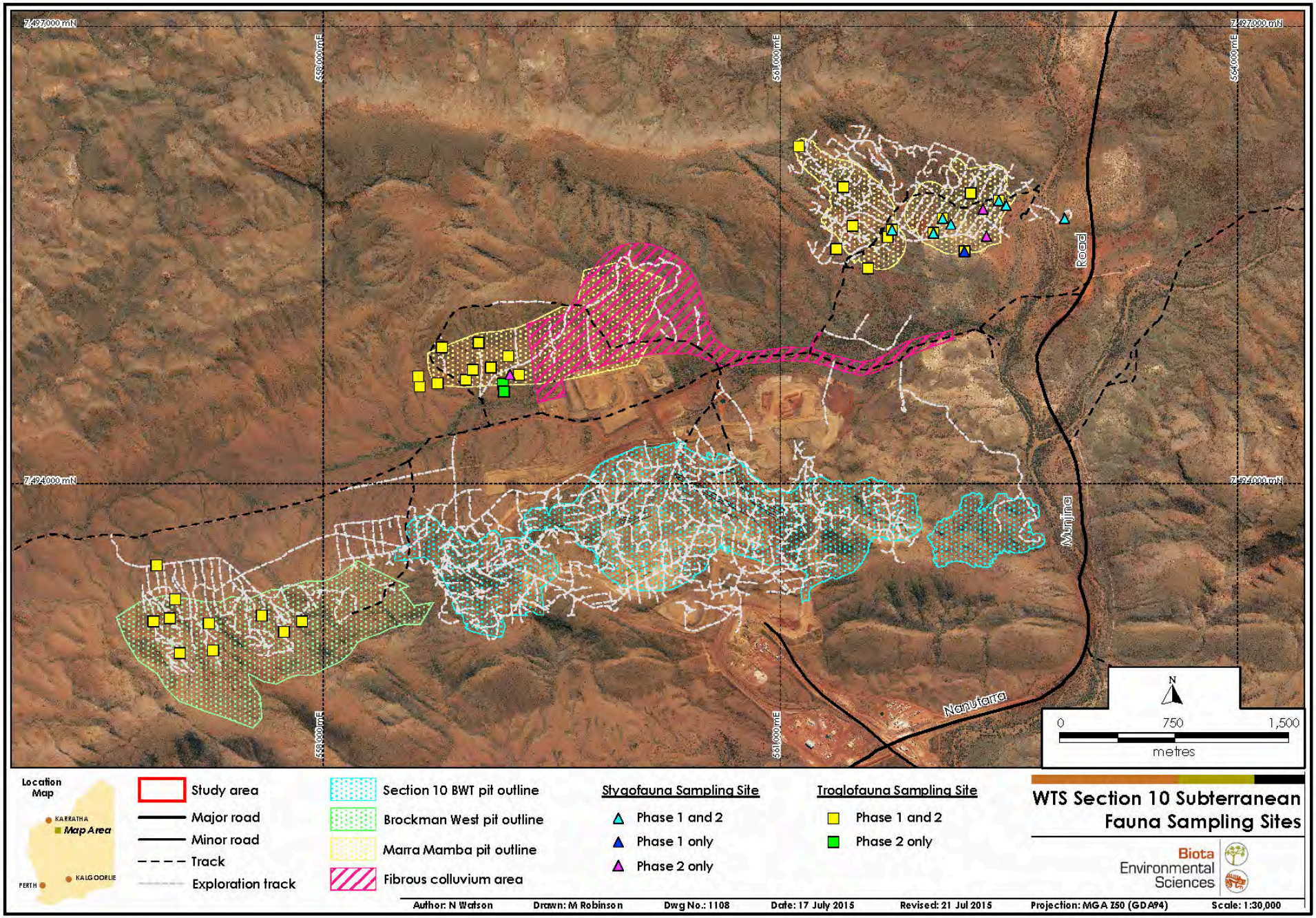


Figure 3.1: Stygofauna and troglofauna survey effort during 2015 at WTS Section10.

Table 3.3: Troglofauna sampling sites within the study area.

Drill Hole	Easting (mE)	Northing (mN)	Location	Trap Depths (m)	Phase 1			Phase 2		
					No. Traps Installed	Borehole Scraping	Comments	No. Traps Retrieved	No. Traps installed	Comments
RC13S10W0006	557059	7492891	Brockman West	20, 40, 60	3	Yes		3	3	Retrieved and installed
RC13S10W0014	557028	7493243	Brockman West	15, 30, 45	3	Yes		3	3	Retrieved and installed
RC13S10W0018	557277	7492908	Brockman West	10, 20, 30	3			3	3	Retrieved and installed
RC14S10W0009	556886	7493099	Brockman West	7, 22, 37	3	Yes		3	3	Retrieved and installed
RC14S10W0032	556993	7493119	Brockman West	10, 20, 30	3			3	3	Retrieved and installed
RC14S10W0055	557248	7493087	Brockman West	5, 12, 17	3	Yes	Blocked at 20m	3	3	Retrieved and installed
RC14S10W0080	557598	7493137	Brockman West	15, 30, 45	3			3	3	Retrieved and installed
RC14S10W0089	557741	7493030	Brockman West	15, 30, 45	3			3	3	Retrieved and installed
RC14S10W0103	557860	7493100	Brockman West	5, 10, 15	3			3	3	Retrieved and installed
RC14S10W0111	556905	7493467	Brockman West	10, 10, 10	3	Yes		0	3	Blocked - could not retrieve
GR14S10M0007	561702	7495617	Marra Mamba East	5, 20, 35	3	Yes	Blocked at 45m	3	3	Retrieved and installed
RC13S10M0025	561412	7495945	Marra Mamba East	15, 30, 35	3	Yes		3	3	Retrieved and installed
RC13S10M0043	562247	7495905	Marra Mamba East	3, 8, 13, 18	4			4	4	Retrieved and installed
RC13S10M0059	561731	7495667	Marra Mamba East	10, 20, 30	3			3	3	Retrieved and installed
RC13S10M0072	561471	7495692	Marra Mamba East	5, 10, 15	3	Yes		3	3	Retrieved and installed
RC13S10M0089	562064	7495739	Marra Mamba East	5, 10, 15, 20	4			4	4	Retrieved and installed
RC13S10M0101	562432	7495856	Marra Mamba East	5, 10, 15, 20	4			4	4	Retrieved and installed
RC13S10M0135	561365	7495540	Marra Mamba East	7, 22, 29	3	Yes		3	3	Retrieved and installed
RC13S10M0157	561120	7496213	Marra Mamba East	5, 15, 25	3	Yes		3	3	Retrieved and installed
RC13S10M0164	562002	7495647	Marra Mamba East	5, 12, 24	3			3	3	Retrieved and installed
RC14S10M0003	562205	7495524	Marra Mamba East	5, 10, 15, 20	4			4	4	Retrieved and installed
RC14S10M0019	561573	7495412	Marra Mamba East	5, 10, 15	3		Blocked at 35m	3	3	Retrieved and installed
GR15S10M004	559176	7494655	Marra Mamba West	15, 15, 15	–			–	3	Installed
GR15S10M005	559183	7494605	Marra Mamba West	15, 15, 15	–			–	3	Installed
RC13S10M0209	558778	7494895	Marra Mamba West	5, 10, 15	3			3	3	Retrieved and installed

Drill Hole	Easting (mE)	Northing (mN)	Location	Trap Depths (m)	Phase 1			Phase 2		
					No. Traps Installed	Borehole Scraping	Comments	No. Traps Retrieved	No. Traps installed	Comments
RC13S10M0212	559019	7494924	Marra Mamba West	7, 14, 21	3	Yes		3	3	Retrieved and installed
RC14S10M0028	558935	7494680	Marra Mamba West	15, 30, 45	3	Yes		0	0	Area ripped – drill hole destroyed
RC14S10M0038	559283	7494713	Marra Mamba West	20, 40, 60	3			3	3	Retrieved and installed
RC15S10M0001	558634	7494639	Marra Mamba West	10, 20, 30	3			3	3	Retrieved and installed
RC15S10M0002	558623	7494704	Marra Mamba West	15, 30, 45	3	Yes		3	3	Retrieved and installed
RC15S10M0003	558749	7494659	Marra Mamba West	10, 20, 30	3	Yes		3	3	Retrieved and installed
RC15S10M0011	558980	7494748	Marra Mamba West	15, 30, 38	3	Yes		3	3	Retrieved and installed
RC15S10M0018	559099	7494762	Marra Mamba West	15, 30, 45	3			3	3	Retrieved and installed
RC15S10M0022	559211	7494836	Marra Mamba West	10, 20, 30	3			3	3	Retrieved and installed
				Total traps	100			94	100	

4.0 Subterranean Habitats

4.1 Geology

The WTS locality contains Archaean to Lower Proterozoic Fortescue and Hamersley group rocks, comprising the Jeerinah Formation, Bunjinah Formation, Marra Mamba Iron Formation, Mt McRae Shale and Mt Sylvia Formations, Robe Pisolite, Brockman Iron Formation, Weeli Wolli Formation, Woongarra Rhyolite and Boolgeeda Iron Formation (Seliani and Oliver 2003).

The 10,074 ha study area encompasses 14 major surface geology units, as outlined in Geological Survey of Western Australia (2002) (Table 4.1, Figure 4.1). The study area is mostly comprised of Czc "Colluvium" (almost 36% of the study area), and PLHb "Brockman Iron Formation: banded iron-formation, chert, and pelite" (almost 23% of the study area) (Table 4.1). The study area is typical of similar Banded Iron Formation (BIF) derived deposits that occur throughout the Pilbara (Seliani and Oliver 2003).

Table 4.1: Surface geology units of the study area.

Code	Description	Area (ha)	% of Study Area
Czc	Colluvium - partly consolidated quartz and rock fragments in silt and sand matrix; old valley-fill deposits, locally derived.	3, 583.0	35.6
PLHb	BROCKMAN IRON FORMATION: banded iron-formation, chert, and pelite.	2, 308.0	22.9
AHm	MARRA MAMBA IRON FORMATION: chert, banded iron-formation, and pelite.	1, 078.8	10.7
AFj	JEERINAH FORMATION: pelite, metasandstone, chert, metabasaltic pillow lava and breccia, and metamorphosed felsic volcanic rock.	610.1	6.1
Qa	Alluvium - unconsolidated silt, sand, and gravel; in drainage channels and adjacent floodplains.	578.8	5.7
AFd	Medium to coarse-grained metadolerite sills intruded into Fortescue Group.	513.5	5.1
AHs	MOUNT McRAE SHALE and MOUNT SYLVIA FORMATION: pelite, chert, and banded iron formation.	506.8	5.0
Qc	Colluvium - unconsolidated quartz and rock fragments in soil.	314.8	3.1
Czk	Calcrete - sheet carbonate, found along major drainage lines.	310.4	3.1
PLHj	WEELI WOLLI FORMATION: banded iron-formation (commonly jaspilitic), pelite, and numerous metadolerite sills.	172.5	1.7
Czp	ROBE PISOLITE: pisolitic limonite deposits developed along river channels.	47.4	0.5
AFu	BUNJINAH FORMATION: pillowed and massive metabasaltic flows, metabasaltic breccia, metamorphosed volcanic sandstone, and minor chert; amygda.	45.5	0.5
PLHo	BOOLGEEDA IRON FORMATION: fine-grained, finely laminated iron-formation; pelite and chert.	3.5	<0.0
PLHw	WOONGARRA RHYOLITE: metamorphosed rhyolite, rhyodacite, rhyolitic breccia, and banded iron-formation.	1.2	<0.0
	Total	10,074.4	

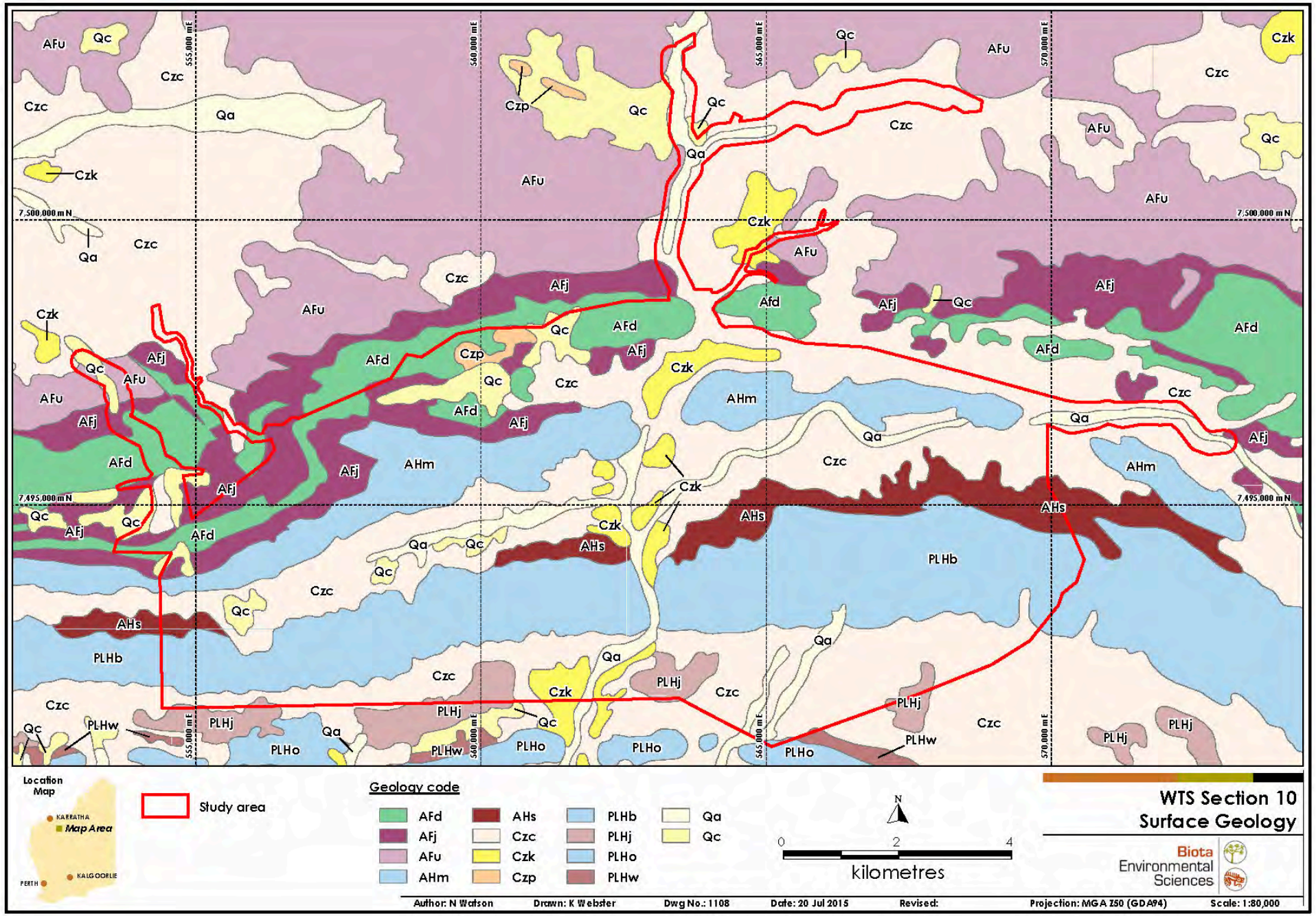


Figure 4.1: Surface geology of WTS study area.

4.2 Hydrology and Hydrogeology

The dominant surface hydrological feature in the WTS locality is a large, unnamed ephemeral tributary of the Hardey River. The tributary enters WTS at a point approximately 2 km east of the mining operations area at Section 10 and flows south towards the Hardey River itself. Numerous ephemeral drainage lines feed the tributary and overland flow occurs off broad, shallow floodplain areas within WTS. Surface flows along the along the Hardey River are intermittent, generally flowing only after significant rainfall events (Biota 2008).

The WTS study area is located in the Hardey River catchment and in the headwaters of the Hardey River catchment, immediately west of the Beasley River catchment divide. The underlying groundwater system in the study area can be described as a confined aquifer associated with the mineralised banded iron formation of the Brockman Iron Formation. The WTS Section 10 orebody aquifer is located in the Dales Gorge Member of the Brockman Iron Formation (Rio Tinto 2013). The aquifer is bounded by unmineralised BIF, low permeability Mount McRae Shale and Mount Sylvia Formation.

4.3 Subterranean Fauna Habitat

The suitability of geological formations as habitat for subterranean fauna is primarily a function of available habitat space. Geological units that are currently recognised as core habitat for subterranean fauna include karstic limestone, calcrete, alluvium, gravels and pisolite (Marmonier et al. 1993, Humphreys 1999, Biota 2006). These formations are characterised partly by the presence of fractures, caverns, vugs, or interstices sufficient in size to physically accommodate stygobites or troglobites. Previous studies have shown that surface BIF geology has the potential to have above water table cavities and vugs, and may therefore provide suitable troglofauna habitat (Biota 2009a, 2009b, 2014b).

Troglobitic specimens have been historically recorded from in Czc and Czk geologies at Hope Downs and Bungaroo (Biota 2010a, 2011, 2014c) and in Qa "Alluvium" at Yandicoogina (Biota 2010b). More recent studies at Hope Downs 4 and Koodaideri have also found that units such as colluvium and banded ironstone formations, especially where hydrated zones occur or there is a lot of jointing or fracturing, are also suitable subterranean fauna habitat (Biota 2009c, 2014b).

Therefore the banded iron formations in the AHm and PLHb geologies at WTS are likely habitats to support troglofauna, and there is also potential for troglofauna to occur in the surface colluvium and calcrete geologies. These geologies account for 72.3% of surface geologies within the study area.

The three pit areas of the WTS Section10 study area targeted in the current survey were represented by six geological units: Czc "Colluvium", Czk "Calcrete", Qa "Alluvium", AHm "Marra Mamba Iron Formation", and PLHb "Brockman Iron Formation" (Table 4.2; Figure 4.2). Previous survey effort focussed on Brockman Section 10 and the eastern portion of Marra Mamba East (Biota 2008, 2014a) (Table 4.2; Figure 4.2).

Table 4.2: Surface geology units of the WTS Section10 Mining Hub proposal pit areas.

Unit	Marra Mamba East (ha)	Marra Mamba West (ha)	Brockman West Extension (ha)	Brockman Section10 (ha)
Qa	1.2	–	–	–
Qc	–	–	–	1.2
AHm	27.4	8.3	–	–
AHs	–	–	–	10.9
Czc	22.7	58.9	19.9	28.0
Czk	8.6	–	–	–
PLHb	–	–	89.4	175.5
Total	59.9	67.2	109.3	215.6

A review of the 2015 sampling effort in combination with that of previous surveys within the study area (Biota 2008, 2014a), demonstrates that the most prospective subterranean habitats have been targeted by the sampling. The majority of the troglofauna sampling has been conducted within Czc "Colluvium" and PLHb "Brockman Iron Formation" and AHm "Marra Mamba Iron Formation" (Table 4.3; Figure 4.2). For stygofauna, the majority of sampling occurred within Czc "Colluvium", followed by Czk "Calcrete" and by PLHb "Brockman Iron Formation" (Table 4.3; Figure 4.2).

Table 4.3: Number of drill holes sampled within the geological units of the study area.

	Previous surveys (Biota 2008, 2014a)		Current survey		Combined survey effort	
Geological unit	Troglofauna Samples	Stygofauna Samples	Troglofauna Samples	Stygofauna Samples	Troglofauna Samples	Stygofauna Samples
Czc (Colluvium)	6	12	21	4	27	16
PLHb (BIF)	10	5	5		15	5
AHm (Marra Mamba)	6	1	5	1	11	2
AHs (Shales)	8	2	0	0	8	2
Czk (Calcrete)	4	2	3	5	7	7
Qa (Alluvium)	2	2	0	1	2	3
Total	36	24	34	11	70	35

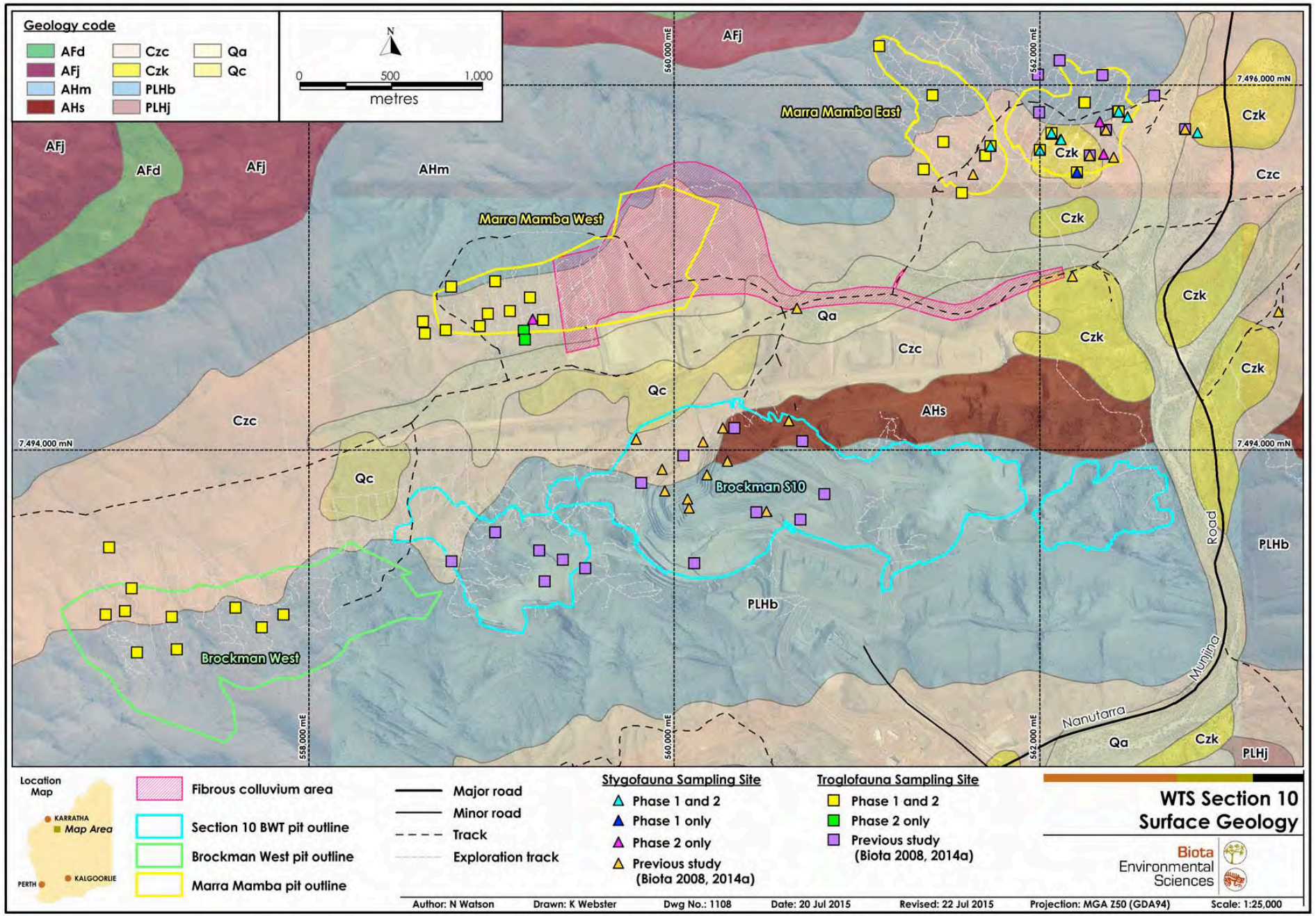


Figure 4.2: Historical and current survey effort and geology in the study area.

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5.0 Results

5.1 Stygobitic Fauna

No stygobitic fauna specimens were recorded during the 2015 survey from any of the sites sampled at Marra Mamba East and Marra Mamba West.

5.2 Troglobitic Fauna

A total of 5,414 invertebrate specimens were collected during the 2015 troglofauna sampling completed in the study area. An account of the recorded fauna is provided in Table 5.1.

Table 5.1: Specimens collected during the 2015 troglofauna sampling in the study area.

Phylum	Class	Order (Common name)	No. of specimens	No. of Drill Holes	Troglobitic
Uniramia	Insecta	Blattodea (Cockroaches)	21	5	Troglophilic (2 specimens)
		Coleoptera (Beetles)	5	1	No
		Dermaptera	1	1	No
		Diptera (Flies)	4	2	No
		Isoptera (Termites)	17	4	No
		Phthiraptera (Lice)	1	1	No
	Collembola	Collembola (Springtails)	3,071	29	No
	Chilopoda	Scolopendrida (Scolopendrid centipede)	1	1	Yes
	Diplopoda	Polyxenida (Pincushion millipedes)	1	1	No
Chelicerata	Arachnida	Acarina (Mites)	2,275	27	No
		Araneae (Spiders)	2	2	No
Crustacea	Malacostraca	Isopoda (Slaters)	15	6	No
		Total	5,414	80	

As is commonly the case with troglofauna sampling, the majority of specimens collected during the recent survey were not troglobitic but were surface animals or soil taxa that are not likely to display short-range endemism. Only three specimens were identified as being troglobitic or troglophilic: one scolopendrid centipede (Section 5.2.1) and two Blattodea (cockroaches) specimens (Section 5.2.2).

5.2.1 Scolopendrida

One troglobitic centipede specimen belonging to the order Scolopendrida was recorded from drill hole RC13S10M0043 in Marra Mamba East (Plate 5.1 and Plate 5.2). A specimen of this order was also recorded from the same drill hole during the previous survey (Biota 2014a), and was identified as *Cryptops* sp. The *Cryptops* sp. specimen recorded in 2014 was unable to be identified further due to a lack of taxonomic resolution available for the group, however it was determined to be a potential SRE based on available knowledge (Abrams et al. 2014, Biota 2014a). It is likely that the Scolopendrid specimen recorded from the recent survey belongs to the same taxon, however specialist identification would be required to confirm this. This specimen represents a potential SRE taxon.



Plate 5.1: *Cryptops* sp. centipede from RC13S10M0043 (dorsal view).

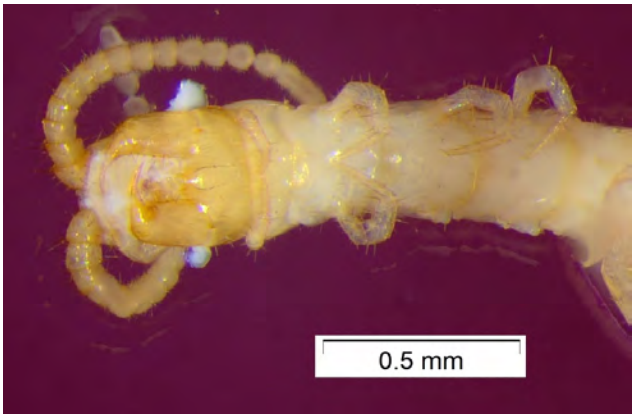


Plate 5.2: *Cryptops* sp centipede from RC13S10M0043 (ventral view).

5.2.2 Blattodea

Two troglophilic Blattodea specimens were recorded from a single site at Marra Mamba West (RC13S10M0209). Specimens from the order Blattodea are not considered troglobitic, but are instead thought to be troglophiles (Biota 2008, 2010a, 2011b). Troglophiles display troglomorphic characteristics and will also utilise the same subterranean habitats as troglobites, but are not confined to them. As such troglophiles are less likely to display short-range endemism and are therefore at a reduced risk of impact by local scale developments (Biota 2008, 2010a, 2011b).

6.0 Conclusions

With the completion of the additional 2015 survey, the overall subterranean fauna sampling effort reported by Biota (2014d) for the wider WTS locality can be updated to now comprise:

- 58 stygofauna sites over five phases (37 of which fall within the current study area); and
- 126 troglofauna sites over five phases (65 of which fall within the current study area).

The results from the 2015 survey were again consistent with previous sampling in the WTS locality, with very few subterranean fauna recorded relative to the number of sites sampled. Considering the sampling effort completed to date in the WTS locality, the data suggest that subterranean fauna populations occur here in low densities and limited diversity. Similar sampling effort at other sites known to support subterranean communities typically yields greater numbers and diversity of both troglobitic and stygobitic animals (Biota 2002, 2006).

Stygofauna sampling during the 2015 survey focused on the Marra Mamba East and West pits and the somewhat limited sampling data obtained again indicate it is unlikely that a stygal community of any significance is present. No stygofauna were recorded and this is probably a function of the aquifer habitats in the Marra Mamba pit areas. The overall body of data from the Pilbara shows that once depth from surface to water table exceeds approximately 40 m, there are generally few if any stygofauna present (Biota 2003, 2005a, 2010d, unpublished data). The groundwater at Marra Mamba West in particular was at considerable depth, with more than 20 sites unable to be sampled as drillholes exceeding 50 m in depth still did not reach the water table (Section 3.2.1). Therefore, while Marra Mamba West could not be adequately sampled for stygofauna, the nature of the groundwater habitats suggest a low risk that a significant stygal community is present. This is supported by both the results from the nearby, and geologically very similar, Marra Mamba East pit, where no fauna were recorded from the 11 holes sampled, and the lack of stygofauna from the wider WTS locality (Biota 2014d).

Troglobitic fauna have only been collected from three of the 65 drillholes collectively sampled in the study area. Two troglobitic pseudoscorpions belonging to the genus *Tyrannochthonius* and a scolopendrid centipede belonging to the genus *Cryptops* (family Cryptopidae) were recorded in 2014 (Biota 2014d). An additional *Cryptops* sp. was recorded during the 2015 survey from the same site as the earlier record (Section 5.2.1).

All of the troglofauna records from the study area have come from the AHm "Marra Mamba Iron Formation: banded iron-formation" geological unit (Figure 6.1) and it appears likely that this represents potential troglofauna habitat in the locality. Figure 6.1 shows that the AHm geological unit is continuous throughout the Western Turner Syncline, and is also continuous in areas surrounding the WTS locality. Multiple studies have now demonstrated that troglobitic species' distributions are often related to the geological history and the nature of the contemporary landform in which they occur (e.g. Biota 2006, 2010c, 2014a). The AHm geological unit is continuous and extends in a band beyond the proposed pit boundaries and further afield beyond the edge of the current study area. As this represents confirmed habitat for both *Tyrannochthonius* 'PSE088' and *Cryptops* sp., the distribution of the AHm unit suggests reduced risk of restriction by habitat isolation and that these taxa may occur locally over the geological unit. However further sampling for troglofauna in the AHm geology unit in the wider WTS locality and molecular comparisons of specimens would be required to confirm any predictions of the species having wider distributions.

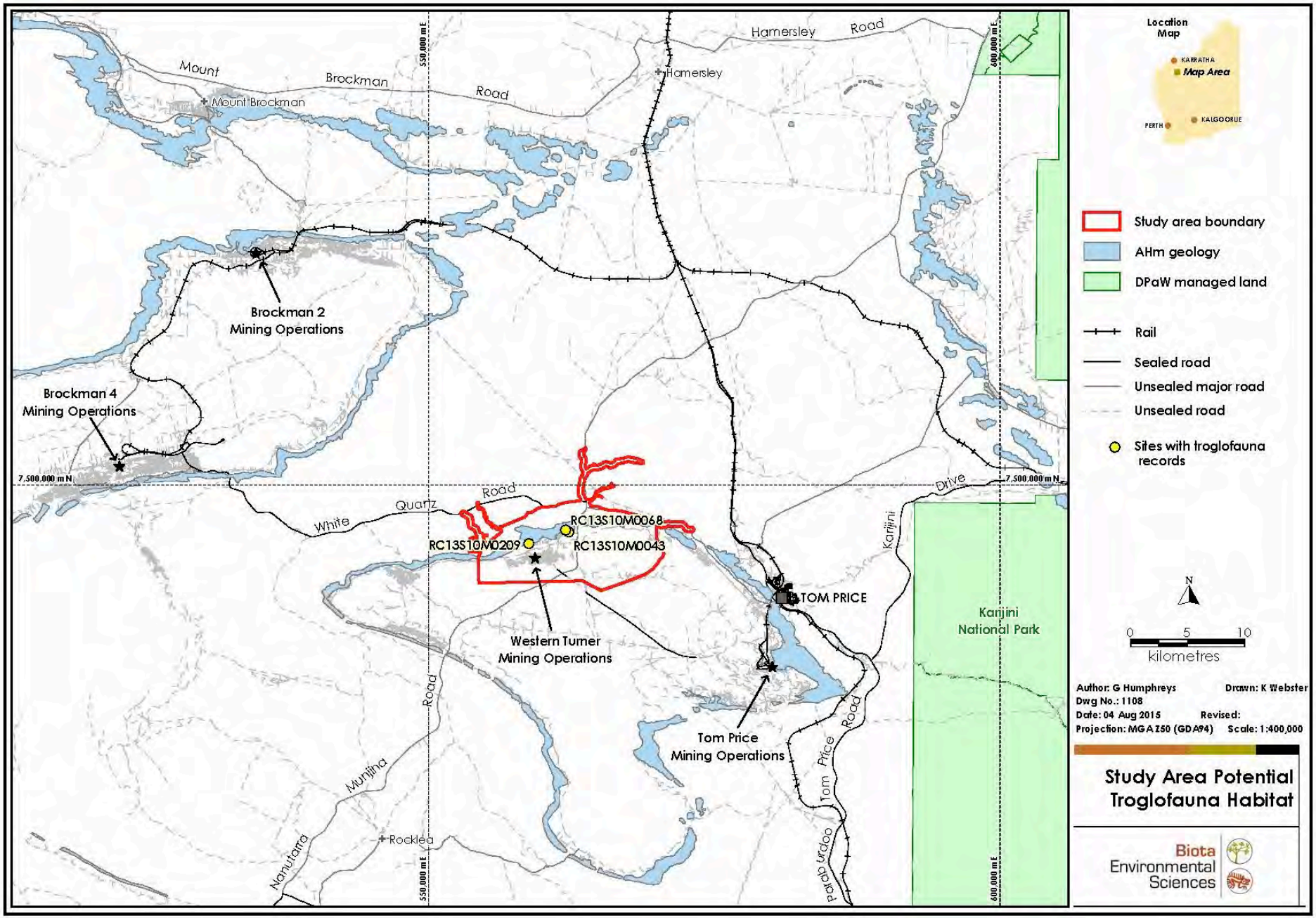


Figure 6.1: Potential troglobitic fauna habitat in the WTS locality in relation to sites that have yielded troglofauna.

7.0 Glossary

BIF	Banded Iron Formation.
Edaphobitic / Edaphobite	Soil dwelling fauna that can often display troglomorphic characteristics. Edaphobites are unlikely to have limited distributions and therefore unlikely to be classified as short-range endemics.
EPA	Environmental Protection Authority of Western Australia.
Interstices	An opening or space, especially a small or narrow one between mineral grains in a rock or within sediments or soil.
Karst	Soluble-rock landscape; terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well-developed secondary porosity (Goodall et al. 2000).
Short-Range Endemic (SRE)	A species that has a naturally small distribution and is often characterised by having poor dispersal capabilities, confinement to disjunct habitats and low fecundity.
Taxonomy	Theory and practice of biological classification.
Troglomorphic	Pertaining to morphological, behavioural and physiological characters that are convergent in subterranean populations (Christiansen 1962).
Troglophilic / Troglophile	Species able to live and reproduce underground as well as in the epigean environment (Goodall et al. 2000).
Troglobite / Troglofauna	Species living obligatory in caves; also blind, depigmented and often having an elongate body morphology.
Stygobite / Stygofauna	Obligate groundwater fauna.
Vug	A small cavity in a rock or vein, often with a mineral lining of different composition from that of the surrounding rock.

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Appendix 1

Licence To Take Fauna

DEPARTMENT OF PARKS AND WILDLIFE

Department of
Parks and Wildlife

Enquiries: 17 DICK PERRY AVE, KENSINGTON, WESTERN AUSTRALIA
Telephone: 08 9334 0333
Facsimile: 08 9334 0242

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Bentley Delivery Centre WA 6983

PERSON NO. SF010293
70754

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DAVID KEIRLE
CHRIS COLE
NICOLA WATSON
SYLVIE SCHMIDT
STEWART FORD
JACINTA KING
MICHAEL DELANEY
ANDREW SHEPPARD
SCOTT WERNER

DATE OF ISSUE 10/04/2015
VALID FROM 28/04/2015
DATE OF EXPIRY 31/12/2015

LICENSING OFFICER

RESIDENTIAL ADDRESS:
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LICENSEE: MR D KAMIEN (DANIEL)
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PO BOX 155
LEEDERVILLE WA 6903

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DEPARTMENT OF PARKS AND WILDLIFE

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PAGE NO. 1
SF010293
PERSON NO. 70754

RECEIPT NO. **AMOUNT** $0.00

WILDLIFE CONSERVATION ACT 1950
REGULATION 17
LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

DIRECTOR GENERAL

CONDITIONS

1 THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.

2 UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE DIRECTOR GENERAL, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.

3 NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE DIRECTOR GENERAL. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.

4 NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.

5 NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR BE HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE DIRECTOR GENERAL, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.

6 THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.

7 **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE DEPT OF SUSTAINABILITY, ENVIRONMENT, WATER, POPULATION & COMMUNITIES PH 02 6274 1111. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS DPaW'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********

8 NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE DIRECTOR GENERAL OF DPaW.

9 FURTHER CONDITIONS (NUMBERED (TO 9) ARE ATTACHED.

PURPOSE SUBTERRANEAN FAUNA SURVEY SAMPLING OF TROGLOFAUNA WILL BE VIA CUSTOM-BUILT LEAF-LITTER COLONISATION TRAPS AND STYGOFAUNA HAUL NETS WITHIN DRILL HOLES IN ACCORDANCE WITH EPA GUIDANCE STATEMENT 54A, FOR ENVIRONMENTAL IMPACT ASSESSMENT AT WEST TURNER SYNCLINE SECTION 10 SATELLITE ORE BODIES 40KM WEST OF TOM PRICE

WILDLIFE CONSERVATION REGULATIONS 1970

Regulation 17:- Licence to Take Fauna for Scientific Purposes

FURTHER CONDITIONS (OF LICENCE NUMBER SF010293)

1. The licensee shall take fauna only in the manner stated on the endorsed Regulation 17 licence application form and endorsed related correspondence.

2. Except in the case of approved lethal traps, the licensee shall ensure that measures are taken in the capture and handling of fauna to prevent injury or mortality resulting from that capture or handling. Where traps or other mechanical means or devices are used to capture fauna these shall be deployed so as to prevent exposure of trapped animals to ants and debilitating weather conditions and inspected at regular intervals throughout each day of their use. At the conclusion of research all markers etc and signs erected by the licensee and all traps shall be removed, all pitfalls shall be refilled or capped and the study area returned to the condition it was in prior to the research/capture program. During any break in research, cage traps should be removed and pitfalls either removed, capped or filled with sand.

3. No collecting is to be undertaken in areas where it would impinge on pre-existing scientific research programs.

4. Any form of colour marking of birds or bats shall only be undertaken in accordance with the requirements of the Australian Bird and Bat Banding Scheme.

5. Any inadvertently captured specimen of fauna which is declared as likely to become extinct, rare or otherwise in need of special protection is to be released immediately at the point of capture. Where such a specimen is injured or deceased, the licensee shall contact Department of Parks and Wildlife licensing staff at Kensington (08 9219 9831) for advice on disposal. Records are to be kept of any fauna so captured and details included in the report required under further condition 6 below.

6. Within one month of the expiration of this licence, the holder shall submit an electronic return detailing the locality, site, geocode, date and number of each species captured, sighted or vouchered during the currency of the licence, into the Department of Parks and Wildlife Fauna Survey Database (FSD). A copy of any paper, report or thesis resulting from the research shall on completion be lodged with the Director General. If a renewal of this licence is required, the licensee shall submit a written progress report for activities undertaken during this licence period prior to the expiry of this licence.

7. Not more than ten specimens of any one protected species shall be taken and removed from any location less than 20km apart. Where exceptional circumstances make it necessary to take large series in order to obtain adequate statistical data the collector will proceed with circumspection and justify their actions to the Director General in advance.

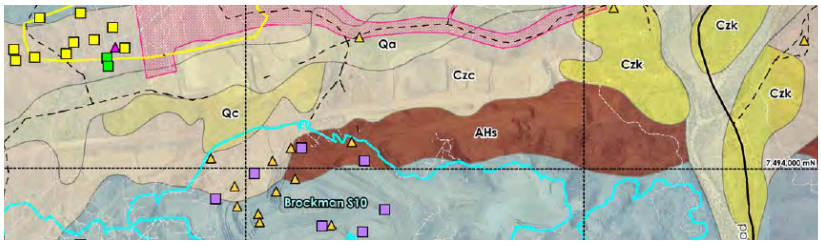
8. All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this licence shall be donated to the Western Australian Museum. Duplicates (one pair in each case) of any species collected which represents a significant extension of geographic range shall be donated on request to the Western Australian Museum.

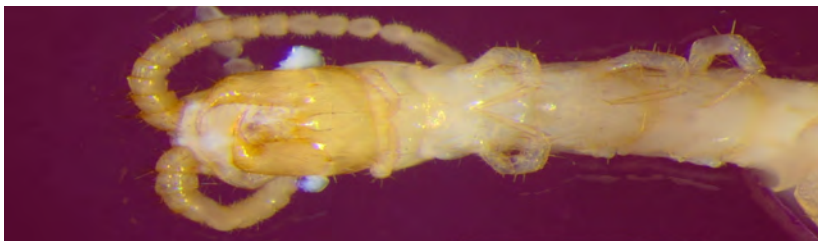
9. To prevent any unnecessary collecting in this State, all specimens and material collected under the authority of this license shall, on request, be loaned to the Western Australian Museum. Also, the unused portion or portions of any specimen collected under the authority of this license shall be offered for donation to the Western Australian Museum or made available to other scientific workers if so required.

Biota Environmental Sciences

Western Turner Syncline S10 Hub Subterranean Fauna Assessment Addendum Report







Prepared for Rio Tinto

DRAFT October 2015

Biota Environmental Sciences

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WTS S10 Subterranean Fauna Addendum

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1.0 Summary

Rio Tinto plans to sustain the currently operational Western Turner Syncline (WTS) Section 10 mine. The proposed works include the commencement of dewatering operations in 2017, and subsequent below water table (BWT) mining in 2018.

In 2014, as part of Environmental Impact Assessment (EIA) requirements, Biota Environmental Sciences (Biota) completed a survey investigating the occurrence of subterranean fauna and assessing habitat suitability for both stygobitic fauna (stygofauna) and troglobitic fauna (troglofauna). This initial survey focussed on the proposed Section 10 works and satellite Marra Mamba ore bodies.

Subsequently Rio Tinto has amended the proposed plans, which now comprise four pit areas. This Section 10 "hub" (hereafter referred to as 'the study area') includes the Section 10 Brockman pit, the Section 10 Brockman West Extension, the Section 10 Marra Mamba East Pit and the Section 10 Marra Mamba West pit. The Office of the Environmental Protection Authority (OEPA) advised that further work on subterranean fauna was needed to support the assessment of the proposal.

In response to this, a subterranean fauna sampling program was undertaken in 2015, with field sampling comprising two phases of stygofauna and troglofauna sampling. The sampling at WTS was undertaken in three field surveys in mid-May (Phase 1), early July (Phase 2a) and mid-August (Phase 2b). The findings from Phase 1 and Phase 2a were reported in Biota (2015). The findings from Phase 2b are presented here.

Troglofauna were sampled by means of leaf litter colonisation traps suspended in drillholes. During Phase 2b, all of the traps installed at 32 drillholes in Phase 2a were successfully retrieved.

A total of 256 specimens from 13 taxonomic groups were recorded from 31 of the 32 drillholes sampled in Phase 2b of the survey, bringing the total for the 2015 sampling programme to 5,670 specimens. No specimens collected during the Phase 2b survey were troglobitic (obligate troglofauna), however 13 specimens were recognised as being troglophilic: three blattodea, one pauropoda and nine isopoda.

The fact that no troglobitic fauna were recorded during Phase 2b is consistent with the very low numbers of such fauna recorded during previous sampling in the study area and locality. A total of four troglobitic specimens have been recorded from the study area to date: two pseudoscorpions belonging to the genus *Tyrannochthonius* and two scolopendrid centipedes belonging to the genus *Cryptops* (Biota 2014, 2015).

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2.0 Introduction

2.1 Project Background

Rio Tinto plans to sustain the currently operational WTS Section 10 mine, located approximately 17 km west of Tom Price, in the Pilbara region of Western Australia (Figure 2.1). The Section 10 deposit will supply ore for processing in the existing Mount Tom Price plant. The proposed works include the commencement of dewatering operations in 2017, and subsequent BWT mining in 2018.

In 2014, as part of EIA requirements, Biota completed a survey investigating the occurrence of subterranean fauna and assessing habitat suitability for both stygobitic fauna (stygofauna) and troglobitic fauna (troglofauna). This initial survey focussed on the proposed Section 10 works and satellite Marra Mamba ore bodies (see Biota 2014).

Subsequent to that 2014 survey, Rio Tinto amended the proposed plans, which now comprise four pit areas. This Section 10 "hub" (hereafter 'the study area') includes the Section 10 Brockman pit, the Section 10 Brockman West Extension, the Section 10 Marra Mamba East Pit and the Section 10 Marra Mamba West pit (Figure 2.1). The OEPA advised that further work was needed on subterranean fauna to support the assessment of the proposal.

2.2 Objectives of the 2015 Study

The objective of the subterranean fauna sampling work within the WTS Section 10 Hub in 2015 was to supplement the existing data and bring the WTS subterranean fauna assessment up to a full Level 2 standard as defined by EPA (2013). The specific tasks required to meet this objective were as follows:

- review previous troglofauna and stygofauna sampling locations in the vicinity of the study area and determine the most appropriate sampling locations to bring the assessment of the entirety of the proposed hub up to Level 2 standard;
- conduct two phases of targeted subterranean fauna sampling for both stygofauna and troglofauna at available drillholes in the study area;
- morphologically identify collected troglofauna and stygofauna specimens to species level, where possible, and place them into a local and regional context; and
- assess the conservation status of the subterranean fauna present.

2.3 Purpose of this Report

This report is not intended as a standalone document but acts as an addendum to the existing Biota (2015) report, which reported on the first phase of troglofauna sampling and two phases of stygofauna sampling at the WTS S10 hub.

This report presents the findings of the final phase of troglofauna sampling, which was completed after the proposal submission deadline.

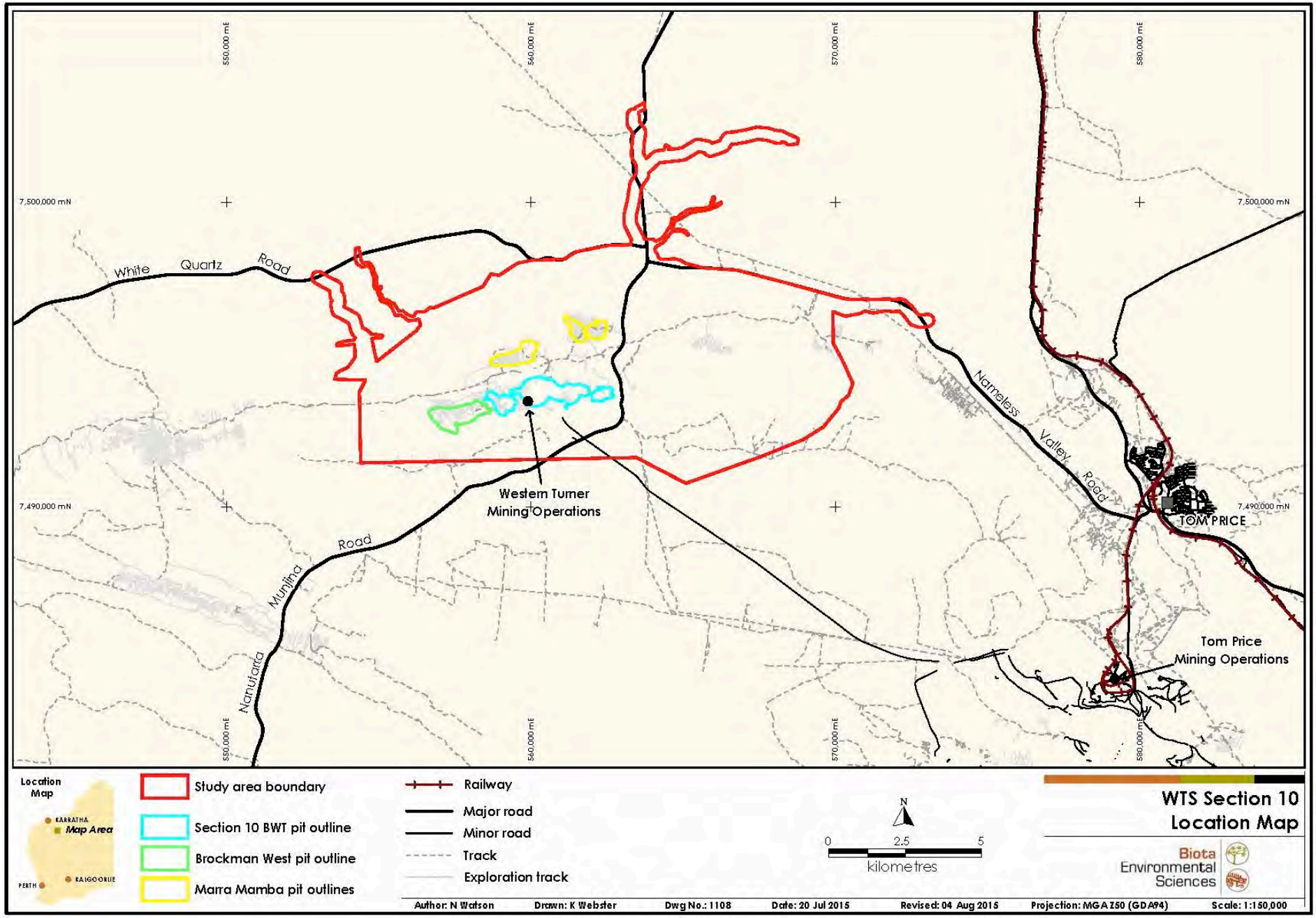


Figure 2.1: Location of the WTS S10 Hub.

2.4 Subterranean Fauna Background

Subterranean fauna can be categorised into two distinct ecological groups, troglobitic fauna (troglofauna) and stygobitic fauna (stygofauna). Troglofauna comprise fauna that survive only in air-filled cavities and interstices between the surface and the water table. Troglobites are obligatory subterranean habitat dwellers, and while they may occur close to surface environments, they are strongly adapted to subterranean environments. This makes such fauna unable or highly unlikely to survive surface conditions. A range of similarly adapted fauna occurs that can opportunistically use subterranean habitats but are able to survive outside these stable environments. Studies from the Pilbara bioregion have demonstrated that these latter suites of fauna (troglophiles, trogloxenes and edaphobites) are not similarly restricted in range and are therefore unlikely to be impacted at taxon level by small scale developments (Biota and Helix 2011, Helix 2012).

2.5 Subterranean Fauna Habitat

The suitability of geological formations as habitat for subterranean fauna is primarily a function of available habitat space. Detailed discussion of subterranean fauna habitat in relation to the WTS S10 hub is presented in the report supported by this addendum (Biota 2015), as well as in previous studies for the locality (Biota 2008, 2012, 2014).

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3.0 Methodology

3.1 Survey Timing and Personnel

The 2015 subterranean fauna sampling was completed under "Licence to Take Fauna for Scientific Purposes" No. SF010293 issued to Mr Dan Kamien (Appendix 1). The methodology and approach were consistent with those outlined in EPA Guidance Statement No. 54 (EPA 2003), EPA Guidance Statement No. 54a (EPA 2007) and EPA Environmental Assessment Guideline No. 12 (EPA 2013).

The 2015 sampling was undertaken over three field survey phases (see Table 3.1). Further detail regarding the methodology utilised for Phase 2b is provided below; for detail on the methodology employed for Phases 1 and 2a, see Biota (2015).

Table 3.1: Survey timing and personnel.

Survey Phase	Survey Components	Dates	Personnel
Phase 1	Troglofauna trap installation and stygofauna sampling	15th – 19th of May 2015	Ms Penny Brooshooft and Ms Prue Anderson
Phase 2a	Troglofauna trap recovery, trap reinstallation and stygofauna sampling	8th –13th July 2015	Dr Nicola Watson and Mr Michael Delaney
Phase 2b	Troglofauna trap recovery	19th –20th August 2015	Mr Michael Delaney and Ms Penny Brooshooft

Preliminary identification of specimens to the order level was completed by Mr Tim Sachse, Mr Chris Cole, Ms Jessica Cairnes and Ms Jenna Wyatt, all of Biota.

Ms Kylie Webster and Mrs Melissa Robinson of Biota prepared the maps for this report.

3.2 Sampling Effort

Sites were sampled in three pit areas: Marra Mamba East (12 drillholes), Marra Mamba West (11 drillholes), and the Section 10 Brockman Extension area (9 drillholes) (Figure 3.1). All troglofauna traps installed in the 32 drillholes during Phase 2a were retrieved successfully during Phase 2b (see Table 3.2). Sampling effort for all phases of troglofauna sampling is presented in Table 3.2.

3.3 Troglofauna Trap Retrieval

Traps were recovered from each drillhole six weeks after installation. Each trap was stored in a labelled zip lock bag in order to maintain humidity and prevent desiccation of potential troglofauna specimens during transportation to Perth.

Fauna specimens were recovered from the traps using specially designed Tullgren funnel units. Leaf litter from each trap was placed in a sieve under an aluminium lamp containing a 25-watt globe. This created a temperature of approximately 30 °C at the surface of the leaf litter. A funnel situated below the leaf litter collected the fauna as they fell, directing them into an attached vial of 100% ethanol. Leaf litter was left in the Tullgren funnels for a period of 24 hours, or until dry, after which time the bulked invertebrate sample removed.

Fauna specimens collected via Tullgren funnels were identified to the lowest taxonomic group possible (usually to order level) using dissecting microscopes (Olympus SZ40 and SZ61, magnification up to 40x). Fauna specimens were assigned a unique number based on drillhole name and tracked on customised data sheets. Specimens were preserved in 100% ethanol, which allows for both morphological and molecular analysis.

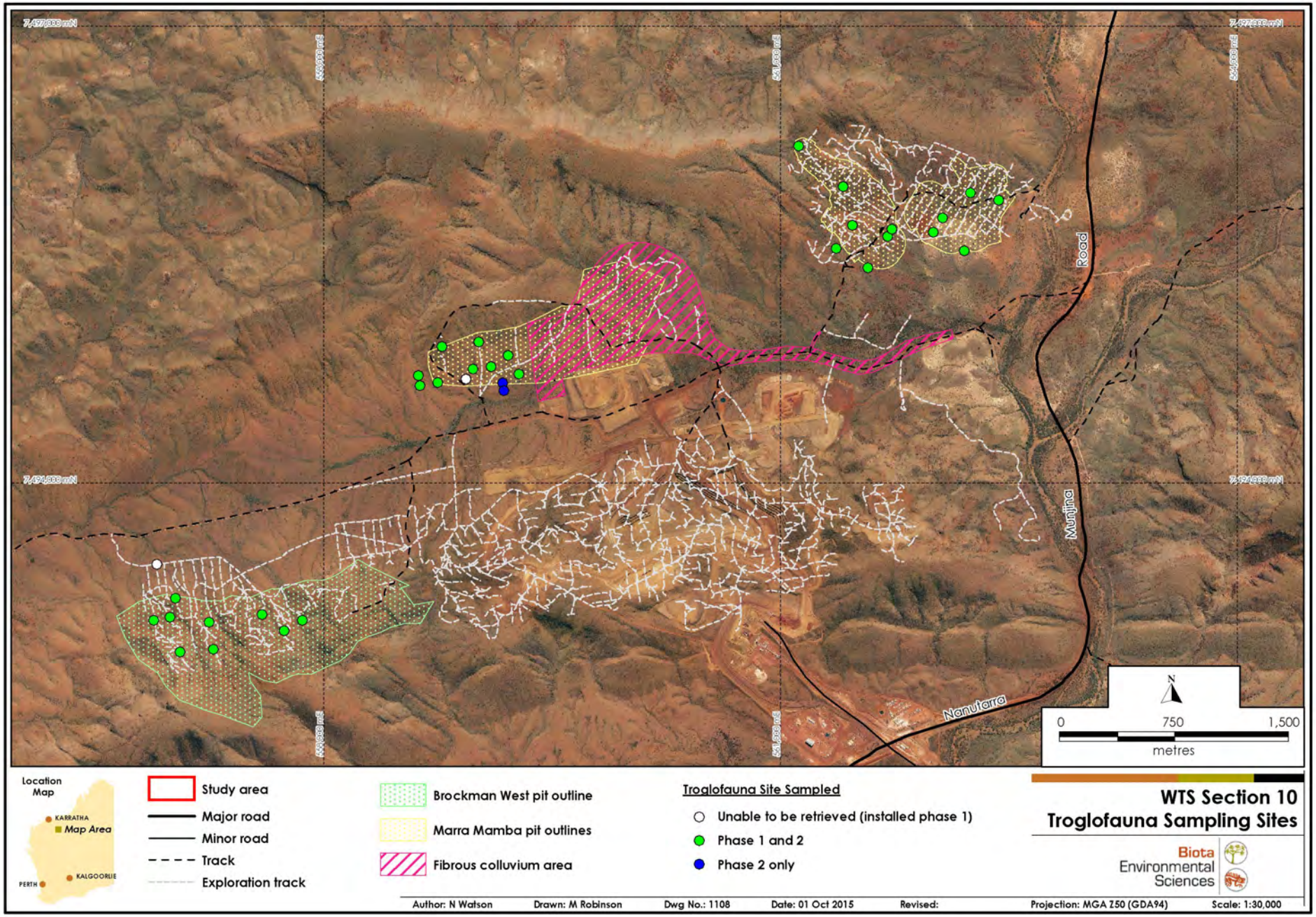


Figure 3.1: Troglofauna sampling sites at WTS S10 in 2015.

Table 3.2: Total troglofauna sampling effort at WTS S10 in 2015.

Drillhole	Easting (mE)	Northing (mN)	Location	Trap Depths (m)	Phase 1			Phase 2a			Phase 2b
					No. Traps Installed	Borehole Scraping	Comments	No. Traps Retrieved	No. Traps installed	Comments	No. Traps Retrieved
RC13S10W0006	557059	7492891	Brockman West	20, 40, 60	3	Yes		3	3	Retrieved and installed	3
RC13S10W0014	557028	7493243	Brockman West	15, 30, 45	3	Yes		3	3	Retrieved and installed	3
RC13S10W0018	557277	7492908	Brockman West	10, 20, 30	3			3	3	Retrieved and installed	3
RC14S10W0009	556886	7493099	Brockman West	7, 22, 37	3	Yes		3	3	Retrieved and installed	3
RC14S10W0032	556993	7493119	Brockman West	10, 20, 30	3			3	3	Retrieved and installed	3
RC14S10W0055	557248	7493087	Brockman West	5, 12, 17	3	Yes	Blocked at 20 m	3	3	Retrieved and installed	3
RC14S10W0080	557598	7493137	Brockman West	15, 30, 45	3			3	3	Retrieved and installed	3
RC14S10W0089	557741	7493030	Brockman West	15, 30, 45	3			3	3	Retrieved and installed	3
RC14S10W0103	557860	7493100	Brockman West	5, 10, 15	3			3	3	Retrieved and installed	3
RC14S10W0111	556905	7493467	Brockman West	10, 10, 10	3	Yes		0	0	Blocked – could not retrieve	0
GR14S10M0007	561702	7495617	Marra Mamba East	5, 20, 35	3	Yes	Blocked at 45 m	3	3	Retrieved and installed	3
RC13S10M0025	561412	7495945	Marra Mamba East	15, 30, 35	3	Yes		3	3	Retrieved and installed	3
RC13S10M0043	562247	7495905	Marra Mamba East	3, 8, 13, 18	4			4	4	Retrieved and installed	4
RC13S10M0059	561731	7495667	Marra Mamba East	10, 20, 30	3			3	3	Retrieved and installed	3
RC13S10M0072	561471	7495692	Marra Mamba East	5, 10, 15	3	Yes		3	3	Retrieved and installed	3
RC13S10M0089	562064	7495739	Marra Mamba East	5, 10, 15, 20	4			4	4	Retrieved and installed	4
RC13S10M0101	562432	7495856	Marra Mamba East	5, 10, 15, 20	4			4	4	Retrieved and installed	4
RC13S10M0135	561365	7495540	Marra Mamba East	7, 22, 29	3	Yes		3	3	Retrieved and installed	3
RC13S10M0157	561120	7496213	Marra Mamba East	5, 15, 25	3	Yes		3	3	Retrieved and installed	3
RC13S10M0164	562002	7495647	Marra Mamba East	5, 12, 24	3			3	3	Retrieved and installed	3
RC14S10M0003	562205	7495524	Marra Mamba East	5, 10, 15, 20	4			4	4	Retrieved and installed	4
RC14S10M0019	561573	7495412	Marra Mamba East	5, 10, 15	3		Blocked at 35 m	3	3	Retrieved and installed	3
GR15S10M004	559176	7494655	Marra Mamba West	15, 15, 15	–			–	3	Installed	3
GR15S10M005	559183	7494605	Marra Mamba West	15, 15, 15	–			–	3	Installed	3
RC13S10M0209	558778	7494895	Marra Mamba West	5, 10, 15	3			3	3	Retrieved and installed	3
RC13S10M0212	559019	7494924	Marra Mamba West	7, 14, 21	3	Yes		3	3	Retrieved and installed	3
RC14S10M0028	558935	7494680	Marra Mamba West	15, 30, 45	3	Yes		0	0	Area ripped – drillhole destroyed	–
RC14S10M0038	559283	7494713	Marra Mamba West	20, 40, 60	3			3	3	Retrieved and installed	3
RC15S10M0001	558634	7494639	Marra Mamba West	10, 20, 30	3			3	3	Retrieved and installed	3
RC15S10M0002	558623	7494704	Marra Mamba West	15, 30, 45	3	Yes		3	3	Retrieved and installed	3
RC15S10M0003	558749	7494659	Marra Mamba West	10, 20, 30	3	Yes		3	3	Retrieved and installed	3
RC15S10M0011	558980	7494748	Marra Mamba West	15, 30, 38	3	Yes		3	3	Retrieved and installed	3
RC15S10M0018	559099	7494762	Marra Mamba West	15, 30, 45	3			3	3	Retrieved and installed	3
RC15S10M0022	559211	7494836	Marra Mamba West	10, 20, 30	3			3	3	Retrieved and installed	3
			Total traps		100			94	100		100

3.4 Limitations

The following limitations should be recognised when considering the findings from this study:

- The extent of the sampling was limited by the availability of viable drillholes, which may have resulted in sampling bias with respect to habitat and geology.
- Access at Marra Mamba West was limited due to the exclusion of a portion of the study area because of the presence of asbestos fibres.
- For some subterranean fauna groups, the current lack of taxonomic framework and sufficient taxonomic expertise limits definitive assignment of specimens to taxa and consequently also a species-level analysis of results.

4.0 Results

4.1 Troglofauna Recorded

A total of 256 specimens were recorded from Phase 2b of the survey, bringing the total for the 2015 sampling program to 5,670 specimens. Identified specimens belong to 13 taxonomic groups (Table 4.1).

As is commonly the case with troglofauna sampling, the majority of specimens collected during Phase 2b were surface animals or soil taxa that are not likely to display short-range endemism.

Of the 256 specimens recorded, 13 were identified as being troglophilic: three cockroaches (Section 4.1.1), one pauropod (Section 4.1.2) and nine isopods (Section 4.1.3). No specimens were identified as true troglobites.

Table 4.1: Specimens collected during Phase 2b of the 2015 troglofauna sampling program at WTS S10.

Phylum	Class	Order (Common Name)	Number	No. of Drillholes	Troglobitic Status
Chelicerata	Arachnida	Acarina (Mites)	86	30	No
		Araneae (Spiders)	11	6	No
Uniramia	Insecta	Blattodea (Cockroaches)	3	3	Troglophilic
		Coleoptera (Beetles)	25	12	No
		Diptera (Flies)	23	13	No
		Isoptera (Termites)	1	1	No
		Psocoptera (Book lice)	2	2	No
		Hemiptera (Bugs)	5	5	No
		Hymenoptera (Ants, wasps, bees)	8	5	No
	Collembola	Collembola (Springtails)	71	27	No
Pauropoda	-	- (Pauropods)	1	1	Troglophilic
Crustacea	Malacostraca	Isopoda (Slaters)	17	9	Troglophilic
Nematoda	-	- (Round worms)	3	2	No
		Total	256	31	

4.1.1 Blattodea (Cockroaches)

Three troglophilic Blattodea specimens were recorded from two drillholes; one specimen from drillhole RC13S10M0025 at Marra Mamba East and two specimens from drillhole RC13S10M0209 at Marra Mamba West. Troglophilic Blattodea were recorded from the same drillhole (RC13S10M0209) at Marra Mamba West during Phase 1 (Biota 2015).

Specimens from the order Blattodea are not regarded as troglobitic, but are instead thought to be troglophiles (Biota 2008, 2010, 2011). Troglophiles display troglomorphic characteristics and will utilise the same subterranean habitats as troglobites, but differ from troglobites in that they are not confined to troglobitic habitats for their entire life cycle.

4.1.2 Pauropoda

One pauropod specimen was recorded from a drillhole at Marra Mamba East (RC13S10M0135). A single pauropod has been recorded previously from the WTS locality at Section 17 (Biota 2012). Whilst it is possible that there may be pauropod species that exhibit short-range endemism (Harvey 2002), many pauropods are widely distributed, which may suggest that short-range endemism is not prevalent in this group. It remains unknown whether pauropods may include short-range endemic species.

4.1.3 Isopoda

A total of nine isopod specimens were recorded from three drillholes within the study area:

- five specimens from Marra Mamba West (RC13S10M0209); and
- four specimens from two sites at Marra Mamba East: RC13S10M0157 (n=3) and RC13S10M0043 (n=1).

These specimens were identified as troglophilic rather than troglobitic; although the recorded specimens lacked pigmentation, they had eyes.

5.0 Conclusions

A total of 13 troglophilic specimens were recorded from the final phase of the 2015 troglofauna sampling program at WTS S10; no troglobites were recorded. These findings are consistent with previous sampling in the study area as well as in the locality, which suggests that subterranean fauna populations occur here in low densities and with limited diversity (Biota 2008, 2012, 2015).

A total of four troglobitic specimens have been recorded from the WTS S10 study area to date; two pseudoscorpions belonging to the genus *Tyrannochthonius* and two scolopendrid centipedes belonging to the genus *Cryptops* (Biota 2014, 2015). For further discussion of the subterranean fauna recorded in the WTS S10 locality, refer to Biota (2015).

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6.0 Glossary

Edaphobite / Edaphobitic	Soil dwelling fauna that can often display troglomorphic characteristics. Edaphobites are unlikely to have limited distributions and are therefore unlikely to be classified as short-range endemics.
EPA	Environmental Protection Authority of Western Australia.
Interstice	An opening or space, especially a small or narrow one between mineral grains in a rock or within sediments or soil.
Short-Range Endemic (SRE)	A species that has a naturally small distribution and is often characterised by having poor dispersal capabilities, confinement to disjunct habitats and low fecundity.
Stygobite / Stygofauna	Obligate groundwater fauna.
Troglobite / Troglofauna	Species living obligatorily in caves; typically blind, depigmented and often having an elongate body morphology.
Troglomorphic	Pertaining to morphological, behavioural and physiological characters that are convergent in subterranean populations (Christiansen 1962).
Troglophile / Troglophilic	Species able to live and reproduce underground as well as in the epigean environment (Goodall et al. 2000).

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Appendix 1

Licence To Take Fauna

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WILDLIFE CONSERVATION ACT 1950
REGULATION 17
LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

DIRECTOR GENERAL

CONDITIONS

1 THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.

2 UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE DIRECTOR GENERAL, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.

3 NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE DIRECTOR GENERAL. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.

4 NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.

5 NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR BE HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE DIRECTOR GENERAL, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.

6 THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.

7 **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE DEPT OF SUSTAINABILITY, ENVIRONMENT, WATER, POPULATION & COMMUNITIES PH 02 6274 1111. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS DPaW'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********

8 NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE DIRECTOR GENERAL OF DPaW.

9 FURTHER CONDITIONS (NUMBERED (TO 9) ARE ATTACHED.

PURPOSE SUBTERRANEAN FAUNA SURVEY SAMPLING OF TROGLOFAUNA WILL BE VIA CUSTOM-BUILT LEAF-LITTER COLONISATION TRAPS AND STYGOFAUNA HAUL NETS WITHIN DRILL HOLES IN ACCORDANCE WITH EPA GUIDANCE STATEMENT 54A, FOR ENVIRONMENTAL IMPACT ASSESSMENT AT WEST TURNER SYNCLINE SECTION 10 SATELLITE ORE BODIES 40KM WEST OF TOM PRICE

WILDLIFE CONSERVATION REGULATIONS 1970

Regulation 17:- Licence to Take Fauna for Scientific Purposes

FURTHER CONDITIONS (OF LICENCE NUMBER SF010293)

1. The licensee shall take fauna only in the manner stated on the endorsed Regulation 17 licence application form and endorsed related correspondence.

2. Except in the case of approved lethal traps, the licensee shall ensure that measures are taken in the capture and handling of fauna to prevent injury or mortality resulting from that capture or handling. Where traps or other mechanical means or devices are used to capture fauna these shall be deployed so as to prevent exposure of trapped animals to ants and debilitating weather conditions and inspected at regular intervals throughout each day of their use. At the conclusion of research all markers etc and signs erected by the licensee and all traps shall be removed, all pitfalls shall be refilled or capped and the study area returned to the condition it was in prior to the research/capture program. During any break in research, cage traps should be removed and pitfalls either removed, capped or filled with sand.

3. No collecting is to be undertaken in areas where it would impinge on pre-existing scientific research programs.

4. Any form of colour marking of birds or bats shall only be undertaken in accordance with the requirements of the Australian Bird and Bat Banding Scheme.

5. Any inadvertently captured specimen of fauna which is declared as likely to become extinct, rare or otherwise in need of special protection is to be released immediately at the point of capture. Where such a specimen is injured or deceased, the licensee shall contact Department of Parks and Wildlife licensing staff at Kensington (08 9219 9831) for advice on disposal. Records are to be kept of any fauna so captured and details included in the report required under further condition 6 below.

6. Within one month of the expiration of this licence, the holder shall submit an electronic return detailing the locality, site, geocode, date and number of each species captured, sighted or vouchered during the currency of the licence, into the Department of Parks and Wildlife Fauna Survey Database (FSD). A copy of any paper, report or thesis resulting from the research shall on completion be lodged with the Director General. If a renewal of this licence is required, the licensee shall submit a written progress report for activities undertaken during this licence period prior to the expiry of this licence.

7. Not more than ten specimens of any one protected species shall be taken and removed from any location less than 20km apart. Where exceptional circumstances make it necessary to take large series in order to obtain adequate statistical data the collector will proceed with circumspection and justify their actions to the Director General in advance.

8. All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this licence shall be donated to the Western Australian Museum. Duplicates (one pair in each case) of any species collected which represents a significant extension of geographic range shall be donated on request to the Western Australian Museum.

9. To prevent any unnecessary collecting in this State, all specimens and material collected under the authority of this license shall, on request, be loaned to the Western Australian Museum. Also, the unused portion or portions of any specimen collected under the authority of this license shall be offered for donation to the Western Australian Museum or made available to other scientific workers if so required.

Iron Ore
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Internal memo

From	Cecilia Lazo-Skold
Department	WRE
To	Kirsty Beckett, Bill Jaen, Shreya Shah, Tammy Souster, Nigel Forsyth
CC	Ros Green, Neal Geddes, Mark Pearcey, Keith Brown
Reference	WTS S10 geochemical pit lake model
Date	03 Jul 2015
Number of pages	6 + appendices

Western Turner Syncline (WTS) S10 Pit Lake Model

A geochemical model has been developed to predict the chemical composition of the WTS S10 pit lake over time. The model calculates the evolution of the pit lake water quality in time as a result of chemical interactions between the groundwater, wall rock runoff, rain, and successive pit lake compositions. In addition to considering mixing of all inputs, the model also accounts for chemical reactions resulting from continuous dilution and evaporation processes affecting the pit lake in time.

1. Conceptual Model and Modelling Assumptions

Physical properties of the WTS S10 pit and climatic factors will determine the limnological behaviour of the pit lake that will form in this void. The limnological behaviour of the pit lake will in turn determine whether the lake will stratify and this was initially assessed to determine if the lake can be modelled as completely mixed system. Because a comprehensive limnological assessment of the WTS S10 pit lake is outside the scope of this modelling effort, simple calculations to determine if the pit lake will stratify were conducted in order to develop a conceptual model for the WTS S10 pit lake. A common technique used to determine if lakes will mix or stratify is the relative depth factor defined by:

$$D_r = \frac{50 \times Z_m \times \sqrt{\pi}}{\sqrt{A}}$$

Where:

D_r = Relative depth (in %)
Z_m = Maximum lake depth
A = Lake area

Generally, if the relative depth is greater than 20%, the lake will be permanently stratified (Castendyk et al, 2009). As can be seen Table 1 the D_r of the WTS S10 pit lake indicates that the lake will tend to behave as a completely mixed system. Thus, the conceptual model for the WTS S10 pit lake calls for a system where solid, aqueous and gas inputs

(i.e., source terms) fully mix before leaving the system as outputs. Because the system is not only fully mixed but also open to the atmosphere, gas phases enter and leave the system at all times according to the laws of thermodynamics.

Table 1 - Relative Depth of the WTS S10 Pit Lake

Depth (Z_m)	Area (A)		Relative depth (D_r)
m	km^2	m^2	(%)
50	0.28	276,624	8.4

2. Western Turner Syncline S10 Pit Lake Model Structure

The model structure the WTS S10 pit lake is essentially comprised of a water balance for the pit and a geochemical mixing model of all source terms.

2.1 Western Turner Syncline S10 Water Balance

The water balance for the WTS S10 pit was developed using the existing GoldSim model developed for the WTS B1 pit (Tetratech, 2103), with revisions to: 1) climate inputs and 2) parameters specific to the WTS S10 void including void surface area and volume and groundwater inflow. The WTS S10 water balance is a mass balance of all water inputs and outputs expected to occur at closure, and can be expressed as:

$$\Delta_{\text{pit lake volume}} = \text{precip} + \text{pit run-off} + gw_{\text{inflow}} - \text{evap} - gw_{\text{outflow}}$$

Specific parameters used in the different model components are discussed in Section 3.

2.2 Western Turner Syncline S10 Geochemical Pit Lake Model

The geochemical equilibrium modelling of the WTS S10 pit lake was conducted using PhreeqC version 2.18 (Parkhurst and Appelo, 1999) and the Minteq.v4 database.

The pit lake geochemical model was developed as a stepwise mixing of all inputs to the pit lake at proportions dictated by the water balance progression and the ultimate pit shell (UPS) geology above the pit lake. Inputs to the model included groundwater, runoff, and direct precipitation. System outputs consist of evaporation only as it is considered that the lake will never overflow. Source terms used to represent input chemistries included groundwater chemistry and laboratory leach tests from rock types predicted to be exposed on the ultimate pit shell (UPS) with no upscaling factor applied. Gas phase inputs and outputs including O2 and CO2 are allowed in and out of the system as governed by the thermodynamics of an open system located at sea level (i.e., fO2 = 1e-21, fCO2 = 0.03). No sorption processes were included in the model in order to be conservative and simulate the worst case scenario.

3. Model Components

3.1 Groundwater Inflow and Quality

Groundwater recovery in the WTS S10 pit for a no-backfill scenario was simulated using MODFLOW. Groundwater inputs to the Goldsim model were included as net inflows by pit level, which were estimated from the MODFLOW model outputs (i.e., inflows minus outflows) and by converting the time-dependent data into pit level dependent data using the MODFLOW predicted water levels for bore PZ08S10015. Figure 1 shows the time stage plot of the pit lake as would be observed in bore PZ08S10015. The pit lake is anticipated to form relatively rapidly though a steady state conditions may only be

reached after 100 years, likely at around 530 mRL. The maximum depth of the pit lake at this level is estimated to be 50 m.

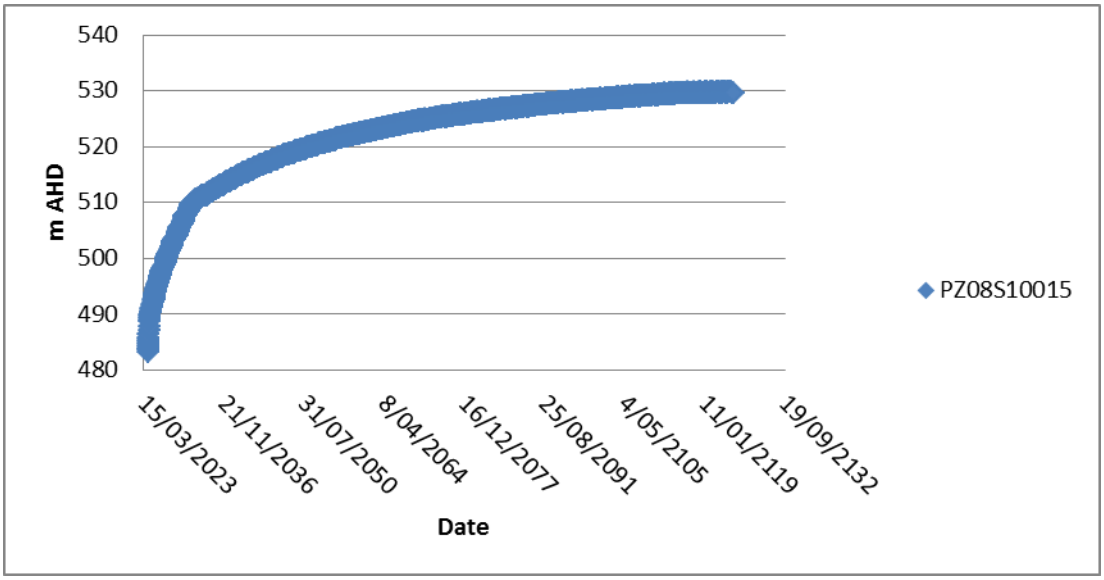


Figure 1 - Modelled groundwater recovery at WTS S10 pit void

The quality of groundwater flowing into the WTS S10 pit lake was assumed to be equal to median concentrations found in bores MLP3, WB08S10003, WB08S10004, and WB08S10005 and was not assumed to degrade as it approaches the pit walls (i.e., blasted rock behind pit walls were not reactive). As can be seen in Table A Appendix 1, groundwater in these bores is circumneutral with important concentrations of alkalinity, sulfate and chloride. Metals and trace elements are low with only boron and nitrate exceeding ANZECC guidelines for aquatic ecosystems.

3.2 Precipitation and Evaporation

Revisions to the WTS B1 water balance were necessary to incorporate actual Tom Price weather data, which are summarised in Table 2. In the existing Goldsim model, rainfall was represented stochastically by applying a Weibull distribution to the Tom Price weather data over the period of record. Since the number of rainy days per month was recorded at Tom Price, the likelihood of a rainy day was calculated. If a rainy day occurred, the precipitation depth typical for a day within that month was assigned.

Table 2 – Tom Price Weather Data Summary

	Average daily rain	Maximum daily rain	Probability rain	Average rain days	Average monthly rain	Evaporation
January	1.46	71.4	0.37	11	94.6	424
February	2.46	76.8	0.41	12	91.2	321
March	1.68	136.4	0.33	10	73.5	319
April	0.72	37	0.19	6	27	264
May	0.15	15.4	0.09	3	10.4	190
June	0.47	48.4	0.09	3	22.5	170
July	0.47	71.2	0.10	3	16.2	177
August	0.13	35.4	0.04	1	4.9	190
September	0.07	10.8	0.04	1	3.0	274
October	0.20	34.2	0.08	2	7.2	371
November	0.29	29.2	0.14	4	14.8	409
December	0.88	52.7	0.22	7	47.8	460

Evaporation in the hydrologic budget was included by applying a pan evaporation coefficient of 0.65 to the Tom Price evaporation data shown in Table 2. Stage evaporation output from the water balance, which depends on the pit lake surface area was then translated into moles of water to be removed in the geochemical model in order to reflect evaporative processes. After year 8, median evaporation rates stabilises to median values of 1800 m3/day, which translate into 0.03 moles per litre of water for the pit lake.

Rain quality in the model was assumed to be equal to the Pilbara rain composition provided by Drogramaci et al, 2012

3.3 Run-off

The Goldsim model was instructed to generate run-off for the WTS S10 pit based on input values shown in Table 3.

Table 3 – Run off model inputs

Input	Value	Source
Up catchment area	0.246 km2	Murray, E., e-mail communication, 2015
Run off coefficient	0.35	Murray, E., e-mail communication, 2015
WTS S10 pit catchment	1.451 km2	Murray, E., e-mail communication, 2015
WTS S10 pit wall run off	0.9	Murray, E., e-mail communication, 2015

Runoff chemistry was estimated by the volume of rainwater that would come into contact with each lithology exposed on the pit wall above the pit lake level at a given time step. Rock wall areas for each lithology were estimated using VULCAN modelling and the geology of the UPS.

As can be seen on Figure 2, the WTS S10 UPS is predominantly composed of Dales Gorge (DG), Footwall (FWZ), Whaleback Shale (WS) and oxidised McRae Shale (MCS) rock types. Lesser amounts of the Joffre (JOF), Detritals (DET) and Mount Sylvia (MTS) are also found on the UPS. Upon contact with rain, these lithologies will affect the composition of the pit wall run-off that enters the pit lake, as readily soluble components get released and salts accumulating on the wall get flushed.

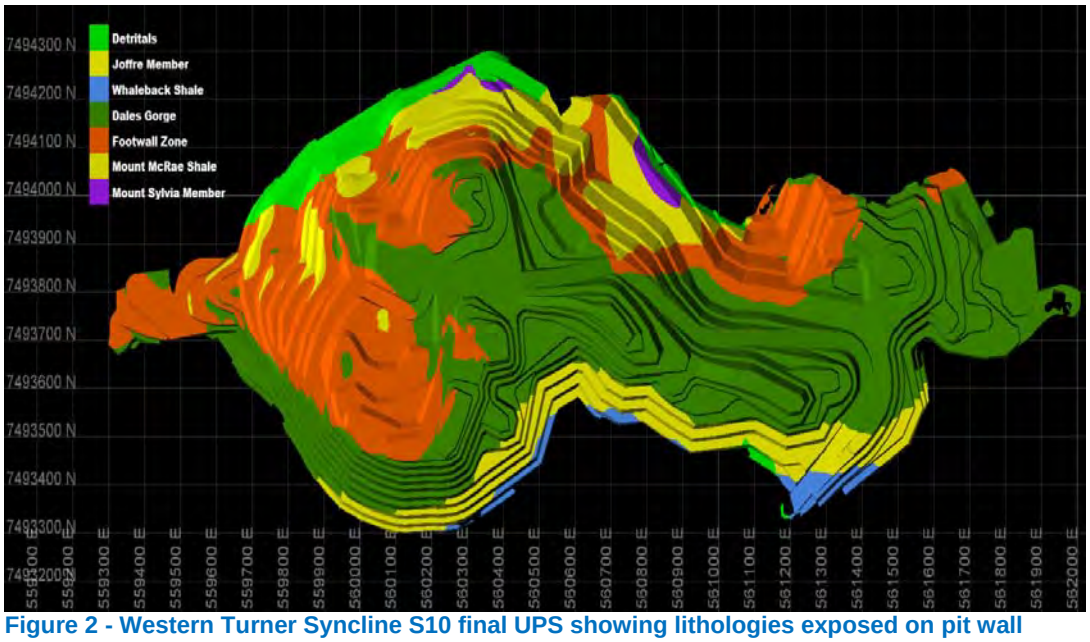


Figure 2 - Western Turner Syncline S10 final UPS showing lithologies exposed on pit wall

Source terms for run off are presented in Table B Appendix 1 and consist of static leach test median values for all lithologies exposed on the WTS S10 UPS. Leach tests for WS were also used to represent both the oxidised MCS and MTS lithologies due to their similarities.

4. Model Results and Discussion

4.1 Water Balance Results

The results from the water balance used in the geochemical model are presented in Table C Appendix 2 and confirm that an incipient lake will form in less than a year and will rapidly become the main component of the future WTS S10 pit lake in time, as groundwater, rain and runoff remain fairly steady over the years. Thus, the quality of the incipient lake appears to impart the main characteristics of the evolving WTS S10 pit lake. It is important to note that in the model this incipient lake is very much dependent on the relative contributions of all inputs at time zero. Because the yearly resolution of MODFLOW groundwater inflows may be too large to capture key changes occurring in the incipient lake, the water balance has been run using a lower and upper limit for the relative contributions of groundwater in attempt to constrain the chemistry of the incipient lake.

4.1 Geochemical Pit Lake Model Results

The results of the geochemical pit lake model are presented in Appendix 2 and in graphic form in Appendix 3. The results indicate that **the WTS S10 pit lake will be fresh and neutral to moderately alkaline with pH values around 8 and total dissolved solids (TDS) ranging from 146 mg/L to 690 mg/L** depending on the timing (i.e., season) and relative contribution of groundwater inflows during year zero when the incipient lake forms. Consistent with the overall pH range expected for the lake, most metals and trace elements will be low with only **boron and copper** barely approaching or slightly exceeding ANZECC guidelines for aquatic ecosystems. As can be seen on Figures 3 through 11, most parameters display **increasing trends** in time due primarily to evapoconcentration effects. Parameters such as barium, calcium and others display decreasing concentrations as geochemical controls known to exist for them were imposed in the model.

Applying the concepts of geo-environmental models (Plumlee et al, 1995) and to put current model results in perspective, a comparison between the predicted WTS S10 water quality and the current NTD pit lake water quality has been conducted and is shown in Table D. Though the NTD pit lake has undergone significant disturbances since it first developed in 2011, this pit lake is still considered a good analogue for the WTS S10 pit lake as it is located in the vicinity of this void, and it not only shares similar climatic conditions but also similar geology. As can be seen in Table D, very good agreement exist between the WTS S10 predicted values and the existing NTD pit lake for most water quality parameters except sulfate, calcium, chloride, iron, and manganese. Potential reasons for these discrepancies, which in some cases can be substantive may include 1) differences in groundwater quality, particularly for chloride, 2) differences on wall exposures (i.e., NTD is known to have alunitic material exposed on walls, 3) appropriateness of the geochemical database and controls imposed in the model, which do not seem to be applying in real world.

5. Summary and Recommendations

The WTS S10 Pit Lake was modelled as a completely mixed system open to the atmosphere by incorporating the hydrology, hydrogeology and geochemistry of this mine void. The groundwater model indicates that a lake will develop in the WTS S10 void following the cessation of dewatering. The lake may reach steady state after at least 100

years if no backfill is placed in the void, with an estimated maximum depth of 50 metres. The geochemical model predicts that the WTS S10 pit lake will be fresh and moderately alkaline, while suggesting that the main driver for this outcome is the rate of groundwater inflows to the incipient lake that forms at the cessation of dewatering. The model also suggests that evaporation imparts an overall increasing trend in concentrations in the long term; however, it does not appear to significantly change the main character of the lake (i.e. rate of increases in time is quite low).

The existing NTD pit lake was considered to be a good analogue for comparison with the predicted WTS S10 pit lake water quality. Though there is a very good agreement between the predicted WTS S10 pit lake water quality and the existing NTD pit lake water quality, further refinements to the model may be necessary in order to reduce significant discrepancies for some parameters and the effects of evaporation in time (i.e., concentration increase rates). Based on all this, the following may help address some of the uncertainty associated with the results:

- Re-run the MODFLOW model using monthly steps for year 0 and incorporate those values into the water balance model to reduce uncertainty in year 0 inputs.
- Run a sensitivity analysis with respect to evaporation rates while attempting to simulate concentration increase rates observed in the NTD pit lake
- Refine comparison with NTD data after ruling out external factors such as original groundwater quality and the UPS geology

6. References

- Castendyk D.and Eary, E., 2009 Mine Pit Lakes Characteristics, Predictive Modeling and Sustainability. Volume 3
- Tetra Tech Inc. Western Turner Syncline Stage 3 Predictive Water Quality Assessment Draft-Report. June, 2013
- Parhurst, D.L., and Appelo, C.A.J., 1999. User's Guide to PHREEQC (Version 2) A Computer Program for Speciation, Batch-Reaction, One Dimensional Transport, and Inverse Geochemical Calculations, USGS WRIR 99-4259
- Drogramaci S., Skrzypek, G., Dodson, W., Grierson, P., 2012 Stable isotope and hydrochemical evolution of groundwater in the semi-arid Hamersley Basin of subtropical northwest Australia.
- Plumlee, G.S., and Nash, J.T., 1995, Geoenvironmental models of mineral deposits – fundamentals and applications: U.S. Geological Survey Open-File Report 95-831, p. 1-9.

7. Acknowledgements

The development of the S10 geochemical pit lake model was a multidisciplinary approach possible only with the following contributions:

- Ellen Murray and Mark Pearcey provided necessary inputs to the water balance run off and climate data and review of the water balance climate component
- Kate Bailue and Keith Brown provided groundwater inflow and outflow data
- Eddy Lim provided input for MODFLOW data transformation and interpretation
- Steven Lee conducted VULCAN modelling to provide the final S10 UPS geology, pit surface area and volume stage curves as well as run-off chemical compositions based on geology

Yours faithfully
Cecilia Lazo Skold
Specialist Geochemist

Appendix 1

Table A - Groundwater Chemistry Source Terms

Parameter	Min	Max	Median	Sample Count
pH	6.28	8.1	**6.84**	67
Alkalinity as $CaCO_3$	245	360	**283**	6
Al	0.01	0.2	**0.01**	25
Sb	0.001	0.001	**0.0005**	3
As	0.001	0.05	**0.0023**	23
Ba	0.006	0.2	**0.024**	23
B	0.2	0.7	**0.385**	24
Cd	0.0001	0.01	**0.00005**	25
Ca	63	110	**92.5**	24
Cl	180	278	**200**	23
Cr	0.001	0.05	**0.0005**	24
Co	0.001	0.001	**0.00075**	3
Cu	0.001	0.057	**0.0025**	25
F	0.4	0.8	**0.5**	21
Fe	0.02	1.8	**0.264**	25
Pb	0.001	0.05	**0.0025**	25
Mg	57	110	**97.5**	24
Mn	0.005	0.93	**0.45**	25
Hg	0.0001	0.0001	**0.00005**	3
Mo	0.001	0.02	**0.0005**	21
Ni	0.001	0.002	**0.001**	3
K	9.3	16	**11**	24
Se	0.01	0.01	**0.005**	3
Si	9	9	**9**	1
Ag	0.001	0.01	**0.0005**	3
Na	116	164	**130**	24
NO3	0.001	3.2	**1.27**	
SO_4	143	392	**350**	23
U	0.001	0.001	**0.0005**	3
Zn	0.005	0.23	**0.038**	25

Notes:
All values are in mg/L except pH
Where data reported as the Method Detection Limit, half of the detection limit was used for calculations
Values in bold represent source terms used in the geochemical model

Table B - Median Leachate Chemistry Source Terms

Parameter	Whaleback (n=16)	Footwall (n=12)	Dales Gorge (n=11)	Joffre (n=8)
pH	7.4	7.3	7.6	7.4
Al	0.07	0.068	0.100	0.08
Ca	7	1.0	1.0	7
Fe	0.10	0.10	0.10	0.07
K	2.1	2.9	1.5	1.5
Mg	4	1.25	1.0	3.9
Na	19	8.7	4.50	8
P	0.15	0.15	0.25	0.15
SO_4	4.7	1.25	0.50	0.7
Si	4.7	5.55	4.5	3.6
Ag	0.001	0.001	0.001	0.001
As	0.001	0.001	0.001	0.001
B	0.15	0.17	0.07	0.1
Ba	0.003	0.002	0.002	0.002
Bi	0.001	0.001	0.001	0.001
Cd	0.0001	0.0001	0.0001	0.0001
Co	0.001	0.001	0.001	0.001
Cr	0.0010	0.001	0.001	0.001
Cu	0.001	0.001	0.001	0.001
Mn	0.001	0.002	0.001	0.001
Mo	0.001	0.001	0.001	0.001
Ni	0.001	0.001	0.001	0.001
Pb	0.001	0.001	0.001	0.001
Sb	0.001	0.001	0.001	0.001
Se	0.002	0.002	0.002	0.002
Sn	0.001	0.001	0.001	0.001
Sr	0.03	0.016	0.006	0.019
Th	0.001	0.001	0.001	0.001
Ti	0.001	0.001	0.001	0.001
Tl	0.001	0.001	0.001	0.001
U	0.001	0.001	0.001	0.001
V	0.001	0.001	0.001	0.001
Zn	0.002	0.0035	0.003	0.001
Hg	0.0003	0.0003	0.0005	0.0003
Cl	108	19.5	41.0	28
F	0.5	0.43	0.65	0.4
Total N	0.7	0.9	3.3	0.6

Notes: All values are in mg/L except pH

Appendix 2

Table C – Water Balance Model Results

Year	Groundwater inflow	Direct rain	Pit wall run off	Pit lake volume	evap
	m^3/day	m^3/day	m^3/day	m^3	m^3/day
0*	2943	41.76	1650	0.1	74.22
0.5	1537	285.9	405.8	456426	219.7
1	1982	0	499.4	740461	782
4	2054	0	779.5	2684000	1957
6	1891	0	290.5	3513000	2479
8	1756	2168	1115	4096000	2383
10	1628	0	371.6	4591000	2709
15	1441	0	459.6	5227000	2880
20	1340	311.8	912	5502000	2708
25	1264	0	485.2	5688000	2968
30	1277	0	421.5	5656000	2963
40	1294	0	1024	5616000	2726
50	1264	0	540.3	5686000	2967
60	1304	326	889.2	5586000	2718
75	1293	0	503.6	5618000	2958
100	1224	4677	823.6	5774000	2744
125	1258	0	827.8	5697000	2735
150	1238	0	812.4	5739000	2740
175	1238	0	732.3	5743000	2740
200	1201	0	956.2	5825000	2750
250	1225	2800	894.2	5770000	2743
300	1213	0	577.3	5797000	2746
400	1196	2027	1019	5838000	2753
500	1220	0	744	5783000	2745
750	1215	5542	837	5797000	2748
1000	1205	0	760.2	5817000	2750

*Using the upper limit for groundwater contributions during year 0 (i.e., 63%)

Table D – Select Geochemical Model Results

Parameter	WTS S10 predicted water quality in time (years)				NTD
	0	4	100	1000	4
pH	7.6 - 8.4	7.6 - 8.4	7.7 - 8.4	7.7 - 8.4	8.6
Ag	0.0007 - 0.001	0.0007 - 0.001	0.0007 - 0.001	0.0007 - 0.001	<0.0001
Al	0.031 - 0.004	0.005 - 0.0313	0.005 - 0.0313	0.005 - 0.0314	0.006
As	0.001 - 0.002	0.0010 - 0.0019	0.0010 - 0.0019	0.001 - 0.002	0.001
B	0.13 - 0.30	0.14 - 0.30	0.14 - 0.30	0.14 - 0.30	0.390
Ba	0.019 - 0.021	0.019 - 0.021	0.019 - 0.021	0.019 -0.021	0.017
Bi	0.0004 - 0.001	0.0004 - 0.001	0.0004 - 0.001	0.0004 - 0.001	<0.0005
Ca	4.35 - 17.57	4.9 - 17.6	5.2 - 17.6	5.3 - 17.54	80.0
Cd	0.0001 - 0.0001	0.0001 - 0.0001	0.0001 - 0.0001	0.0001 - 0.0001	<0.0001
Co	0.001 - 0.001	0.0009 -0.001	0.0009 - 0.001	0.001 - 0.001	<0.001
Cr	0.0007 - 0.001	0.0007 - 0.001	0.0007 - 0.001	0.0007 - 0.001	<0.001
Cu	0.0011 - 0.0020	0.0012 - 0.0020	0.0012 - 0.0021	0.0012 - 0.0021	<0.001
Fe	0.00004 - 0.00009	0.00004 - 0.00008	0.00004 - 0.00008	0.00004 - 0.00007	0.011
K	2.2 - 7.9	2. 3 - 7.9	2.3 - 7.9	2.3 - 7.9	28.0
Mg	4.9 - 64.3	5.5 - 64.5	5.7 - 64.7	5.9 - 64.9	140.0
Mn	7.5E-07 - 2.1E-06	7.5E-07 – 2.0E-06	7.5E-07 – 1.4E-06	7.5E-07 – 1.3E-06	0.010
Mo	0.0011 - 0.005	0.0011 - 0.005	0.001 - 0.005	0.001 - 0.005	0.002
Na	32.8 - 95.5	33.5 - 95.8	33.9 - 96.2	34.1 - 96.4	110.0
Ni	0.001 - 0.001	0.001 - 0.001	0.001 - 0.001	0.001 - 0.001	0.001
P	0.072 - 0.19	0.072 - 0.19	0.072 - 0.19	0.072 - 0.19098	0.040
Pb	0.0010 - 0.002	0.001 - 0.002	0.001 - 0.002	0.001 - 0.002	<0.001
S(6)	25.15 - 233.5	27.3 - 234.3	28.2 - 235.3	28.6 - 235.7	540.0
Sb	0.001 - 0.001	0.001 - 0.001	0.0007 - 0.001	0.001 - 0.001	0.001
Se	0.0023 - 0.0041	0.0023 - 0.0041	0.0023 - 0.0041	0.0023 - 0.0041	0.0011
Si	0.83 - 2.22	0.83 - 2.21	0.83 - 2.21	0.83 - 2.21010	6.1
Th	0.0004 - 0.001	0.0004 - 0.001	0.0004 - 0.001	0.0004 - 0.001	
Ti	0.0005 - 0.0013	0.0005 - 0.0013	0.0005 - 0.001	0.0005 - 0.001	<0.001
U	0.0007 - 0.0010	0.0007 - 0.0010	0.0007 - 0.001	0.0007 - 0.001	0.001
V	0.0005 - 0.0013	0.0005 - 0.0013	0.0005 - 0.0013	0.0005 - 0.0013	<0.001
Zn	0.0051 - 0.026	0.0053 - 0.026	0.0054 - 0.0264	0.0054 - 0.0265	0.021
Cl	51.84 - 147.5	52.86 - 147.9	53.5 - 148.5	53.7 - 148.8	270.0
Hg	0.0002 - 0.0004	0.0002 - 0.0004	0.0002 - 0.0004	0.0002 - 0.0004	<0.00005
F	0.53 - 0.56	0.53 - 0.56	0.53 - 0.56	0.53 - 0.56	0.6
N(5,3)	3.32 - 8.9	3.32 - 8.9	3.33 - 8.9	3.34 - 8.9	0.150
alkalinity	21.6 - 185.8	25.6 - 186.0	27.3 - 186.24	28.1 - 186.4	170
TDS	146.3 - 682.8	153.6 - 684.7	157.3 - 687.1	158.8 - 688.2	1100

Notes:

- All values are in mg/L except pH
- Values for the NTD pit lake are 2015 lab results and thus they presumably correspond to year 4 as the lake is assumed to have formed in 2011

Appendix 3

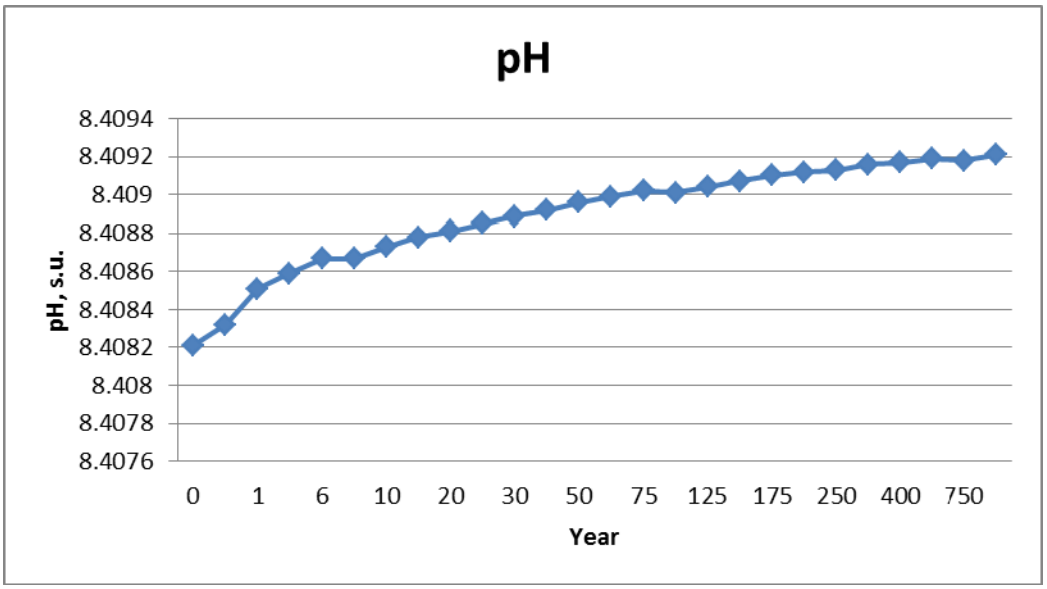


Figure 3 - Western Turner Syncline S10 pit lake pH in time

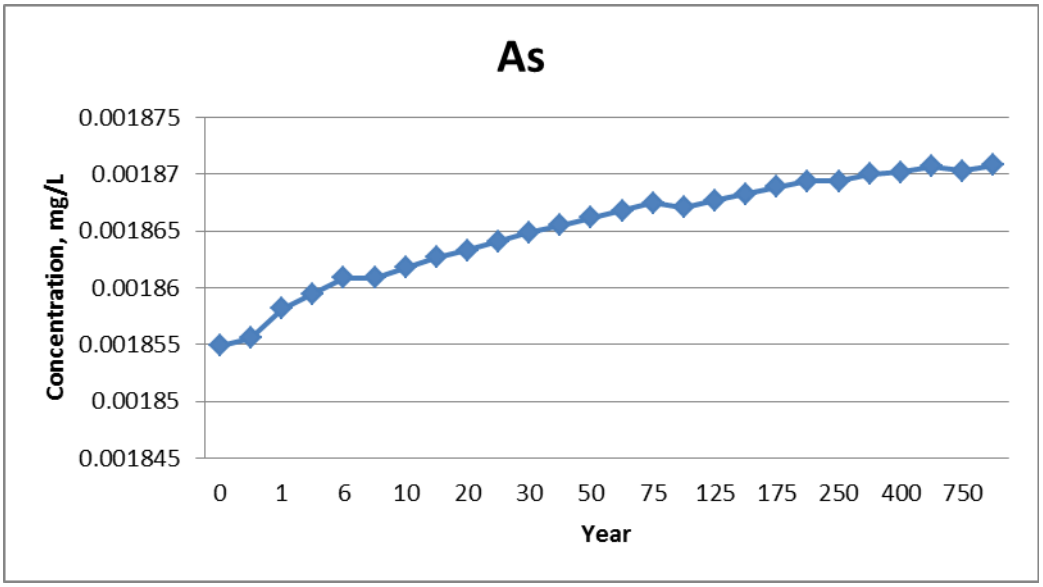


Figure 4 - Western Turner Syncline S10 pit lake arsenic concentrations in time

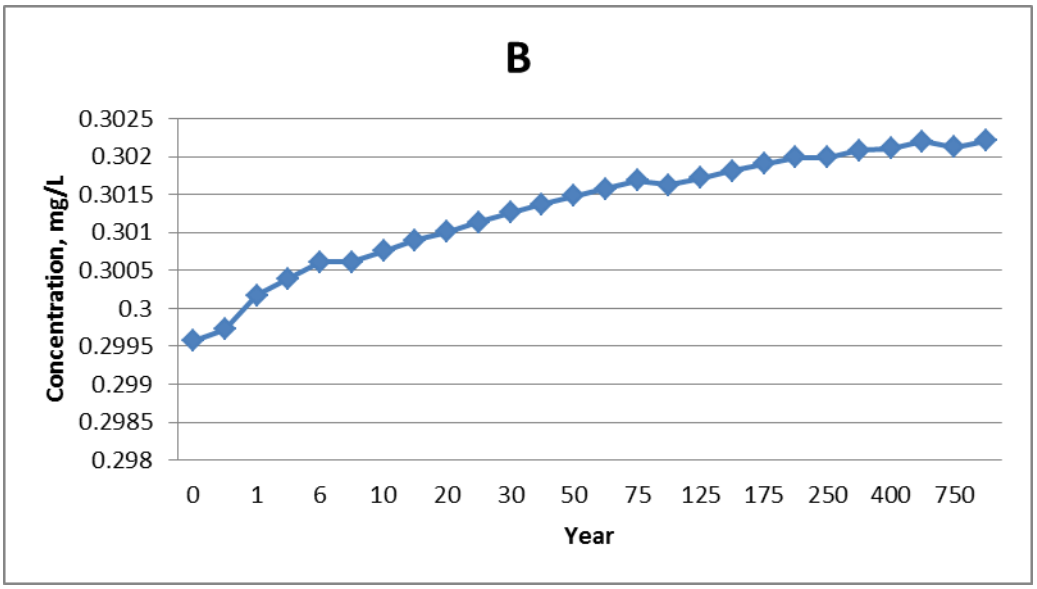


Figure 5 - Western Turner Syncline S10 pit lake boron concentrations in time

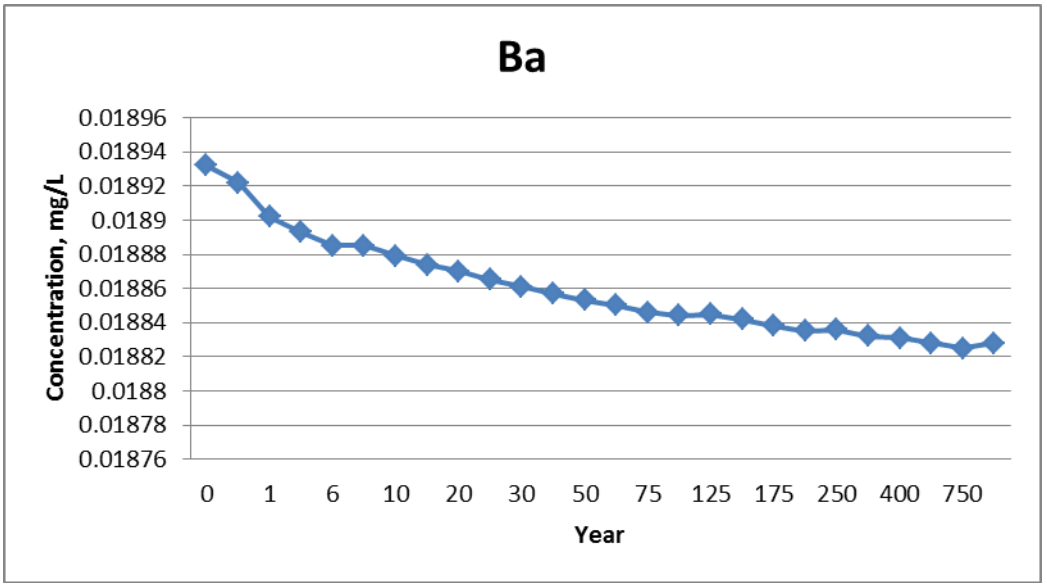


Figure 6 - Western Turner Syncline S10 pit lake barium concentrations in time

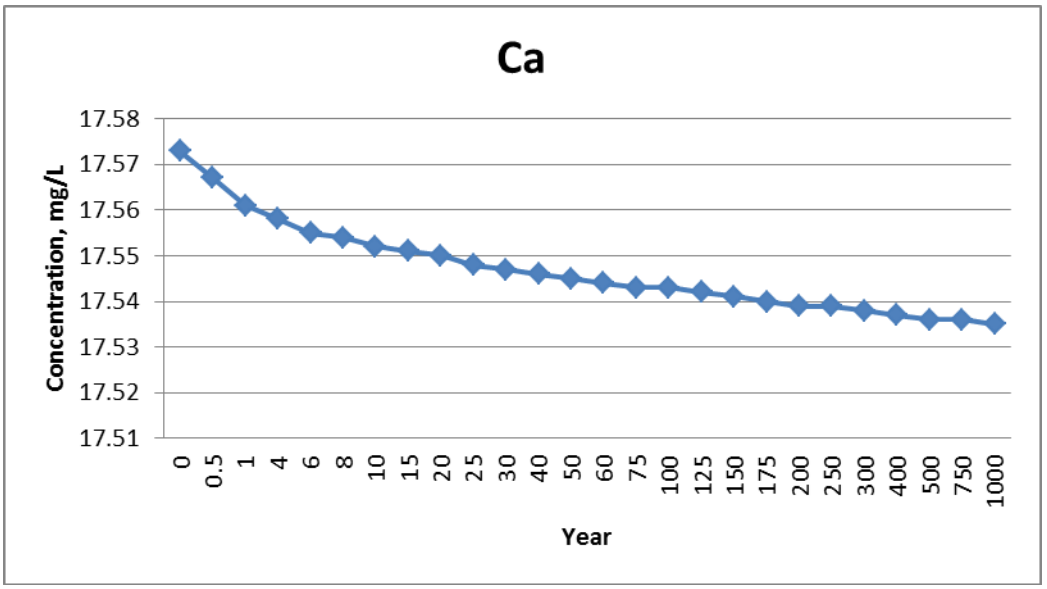


Figure 7 - Western Turner Syncline S10 pit lake calcium concentrations in time

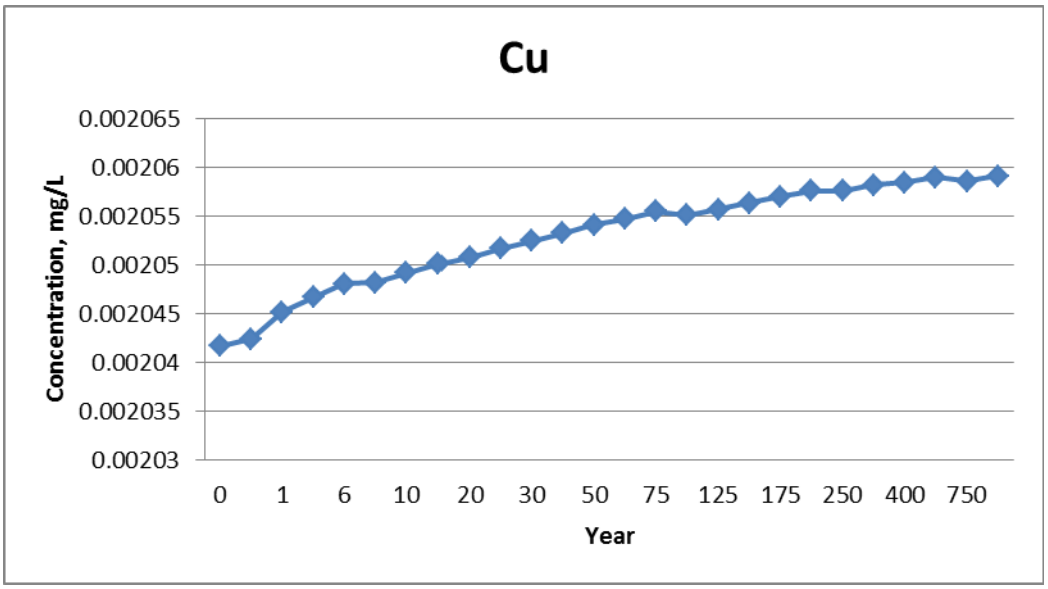


Figure 8 - Western Turner Syncline S10 pit lake copper concentrations in time

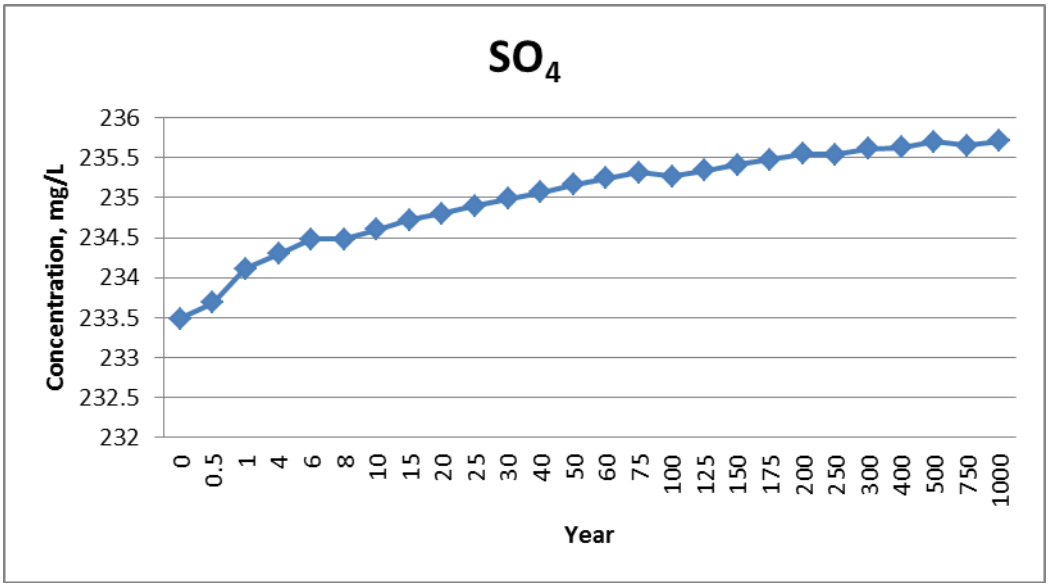


Figure 9 - Western Turner Syncline S10 pit lake sulfate concentrations in time

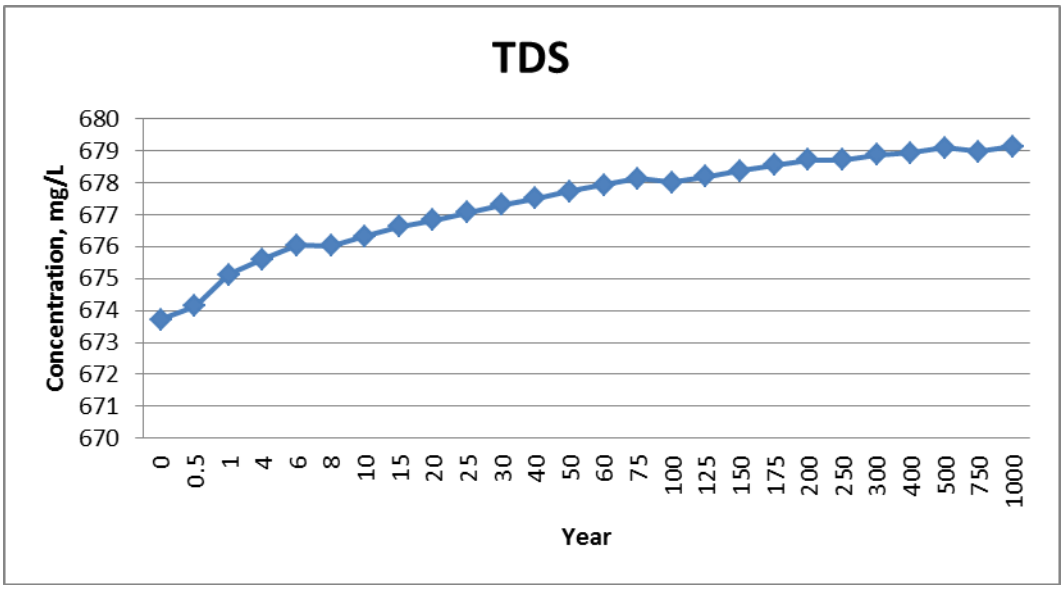


Figure 10 - Western Turner Syncline S10 pit lake total dissolved solids in time

Hamersley Iron Pty Limited

Western Turner Syncline mine closure plan

21 October 2015

FDMS No. RTIO-HSE-0251249

Mineral Field 47 – West Pilbara

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CORPORATE CLOSURE PLANNING STATEMENT

Hamersley Iron Pty Limited (**Hamersley**) is a wholly owned member of the Rio Tinto Group and part of Rio Tinto's global iron ore business. Rio Tinto's iron ore group (**Rio Tinto**) considers closure planning to be an integral part of its business. The process of preparing for closure begins in the early stages of project development, and continues throughout the life of the mine.

A team of in-house rehabilitation and closure planning specialists has been established within Rio Tinto to manage this aspect of our operations. A Rehabilitation and Closure Working Group has been established to facilitate integration of closure planning into the broader mine planning framework, and to oversee the research and improvement projects recommended in each closure plan. In this way, Rio Tinto aims to continually improve both its understanding of closure risks, and the strategies employed to mitigate them.

This plan documents the current closure knowledge base for Western Turner Syncline. It outlines the objectives that need to be met at closure, the strategies and plans to be employed to achieve them, and provides an indication of the criteria that will be used to assess closure success.

However, this is not a static document. Hamersley will continue to revisit its closure plans on a regular basis to ensure that the objectives to which it is working towards remain relevant and aligned to stakeholder expectations, and to revise its strategies and plans where appropriate to achieve improved closure outcomes.

Executive summary

Overview
Hamersley's Western Turner Syncline mine (**WTS**) is located in the western Pilbara region of Western Australia, approximately 20km north-west of the Tom Price mine site and 20km west of the town of Tom Price. WTS uses open cut, conventional drill-and-blast and load-and-haul mining methods to mine iron ore deposits positioned above and within the groundwater table. The iron ore is transported to Tom Price via a combination of road trains and conveyors, where the ore is processed and railed to market.

Scope
This closure plan has been prepared to support the Western Turner Syncline Iron Ore Project referral under Part IV of the *Environmental Protection Act* 1986 (**EP Act**). This closure plan is designed to address the closure requirements for WTS, including the three hub areas known as B1, Section 17 (**S17**) and Section 10 (**S10**). Closure is assumed to include progressive rehabilitation that will occur throughout the life of the mine. The goal of mine closure at WTS is to relinquish the site to the Government.

The closure plan has been developed to meet the requirements of the joint Office of the Environmental Protection Authority / Department of Mines and Petroleum Guidelines for Preparing Mine Closure Plans (2015) [1] (**Closure Guidelines**). As such, this closure plan includes closure approaches for prospective areas that are not intended for regulatory approval at this time[2]. These prospective areas are captured in the *Premature closure and other factors* section of this closure plan. Closure options presented in the *Premature closure and other factors* section are provided solely for the purpose of facilitating discussions with key stakeholders, as part of an integrated closure plan.

Primary obligations and commitments
WTS is subject to the *Iron Ore (Hamersley Range) Agreement Act 1963*, Ministerial Statement 807 and Ministerial Statement 946 under the EP Act. It is recognised that additional obligations may arise associated with the Western Turner Syncline Iron Ore Project referral.

Post-mining land use
The closure and rehabilitation strategy will focus on creating a safe, stable and non-polluting landscape vegetated with native vegetation of local provenance, to ensure the system remains compatible with general Pilbara land uses.

Closure objectives
The following closure objectives have been developed for WTS:
- Erosion does not threaten the long term stability of constructed landforms.
- Potential contaminants are managed such that no adverse impact to soil, surface water or groundwater is predicted.
- Vegetation on rehabilitated land is native and self-sustaining.
- The prevalence of invasive species is similar to that in nearby reference sites.
- Pit lakes do not represent a significant public liability, health or ecological risk.
- Measures to mitigate public safety hazards have been agreed with stakeholders and have been implemented.

Note that these objectives do not represent the full range of closure issues that may be present at the site. Rather the objectives reflect key issues against which closure performance will be assessed by government regulators.

Indicative completion criteria have been proposed within the closure plan, however further work is required to clarify and quantify the completion criteria.

Anticipated closure outcome
Post-closure, pit lakes are expected to develop in the S10 Body pit and B1 Main pit. Pit lake water modelling predicts that the water quality in both pits will progress from brackish to saline, owing to local groundwater quality and anticipated evapoconcentration processes. These pit lakes will be located high in the landscape,

[1] Department of Mines & Petroleum and Office of the Environmental Protection Authority (2015) Guidelines for Preparing Mine Closure Plans, June 2015.

[2] refer to Closure Guidelines Section 3.1, page 12, "…closure planning should start in the project feasibility stage (before project approvals)."

with limited connection to the surrounding environment. Egress from the lakes will be possible via the former haul roads; although access to the lake areas will be discouraged through the use of suitable barricades.

All other pits that extend below the pre-mining groundwater table will be backfilled to prevent the formation of permanent lakes. Backfill material will be sourced from the top lift(s) of the adjacent mineral waste dumps, if the pits are not progressively backfilled, to the required elevation, during the operating life of the mine.

Potentially acid forming (**PAF**) material is planned to be intersected at S17. PAF material exposed on the pit walls and floor will be covered with mineral waste, as part of an environmental risk reduction strategy. This will retard acid and / or metalliferous drainage (**AMD**) development and prevent further exposure of PAF materials as the pit walls erode, in order to maintain acceptable groundwater quality post-closure.

The eastern wall of the SE10 East MM 101 pit has been identified as a location where, over the long term, pit wall erosion and / or collapse has the potential to encroach into the adjacent creek floodplain and / or riparian vegetation. This location will be stabilised to prevent encroachment into the environment using a mineral waste buttress.

On closure, infrastructure will be removed and all disturbed areas outside of the mine voids, including waste dumps, will be rehabilitated to create stable landforms and vegetated with native species of local provenance. Waste dumps located inside the pits that have a connection to the adjacent environment, i.e. the mineral waste buttress in the SE10 East MM 101 pit, and all waste dumps containing PAF materials will also be rehabilitated.

Closure Guidelines checklist

Q	Mine Closure Plan (MCP) Checklist	Y/N/NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
1	Has the Checklist been endorsed by a senior representative within the operating company?	Y					
2	Are you aware that from 2015 all MCPs will be made publically available?	Y					
3	Is there any information in this MCP that should not be publicly available?	N					
4	If “Yes” to Q3, has confidential information been submitted in a separate document / section?	NA					
5	Does the MCP cover page include: Project Title, Company Name, Contact Details (including telephone numbers and email address) Document ID and version number, Date of submission (needs to match the date of this checklist)	Y					
6	State why the MCP is submitted (e.g. as part of a Mining Proposal, a reviewed MCP or to fulfil other legal requirement)			Referral under Part IV EPA Act	Y		Amalgamates and updates existing MCPs from existing approvals
7	Does the project summary include land ownership details, location of the project, comprehensive site plans and background information on the history and status of the project?	Y	17				
8	Does the MCP include a consolidated summary or register of closure obligations and commitments been included?	Y	20	Also see Appendix A			
9	Have all stakeholders involved in closure been identified?	Y	21				
10	Does the MCP included a summary or register of historic stakeholder engagement been provided, with details on who has been consulted and the outcomes?	Y	22				
11	Does the MCP include a stakeholder consultation strategy to be implemented in the future?	Y	21				

Q	Mine Closure Plan (MCP) Checklist	Y/N/NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
12	Does the MCP include agreed post-mining land use, closure objectives and conceptual landform design diagram?	Y	25	Conceptual landforms found after p48			
13	Does the MCP identify all potential (or pre-existing) environmental legacies which may restrict the post mining land use (including contaminated sites)?	Y	39				
14	Has any soil or groundwater contamination that occurred, or is suspected to have occurred, during the operation of the mine, been reported to DER as required under the *Contaminated Sites Act 2003?*	NA					
15	Does the MCP include an appropriate set of specific completion criteria and closure performance indicators?	Y	26				
16	Does the MCP include baseline data (including pre-mining studies and environmental data)	Y	29				
17	Has materials characterisation been carried out consistent with applicable standards and guidelines (e.g. GARD Guide)?	Y	36				
18	Does the MCP identify applicable closure learnings from benchmarking against other comparable mine sites?	Y		See Appendix B			
19	Does the MCP identify all key issues impacting mine closure objectives and outcomes (including potential contamination impacts)?	Y	48				
20	Does the MCP include information relevant to mine closure for each domain or feature?	Y	76				
21	Does the MCP include a gap analysis/risk assessment to determine if further information is required in relation to closure of each domain or feature?	Y	70				
22	Does the MCP include the process, methodology and has the rationale been provided to justify identification and management of the issues?	Y	70				

Q	Mine Closure Plan (MCP) Checklist	Y/N/NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
23	Does the MCP include a summary of closure implementation strategies and activities for the proposed operations or for the whole site?	Y	76				
24	Does the MCP include a closure work program for each domain or feature?	N		To be developed 5 years from closure			
25	Does the MCP contain site layout plans to clearly show each type of disturbance as defined in Schedule 1 of the MRF Regulations?	N		State agreement site not subject to MRF			
26	Does the MCP contain a schedule of research and trial activities?	Y	74				
27	Does the MCP contain a schedule of progressive rehabilitation activities?	N	77	Indicative closure schedule provided. Opportunities for rehab assessed annually			
28	Does the MCP include details of how unexpected closure and care and maintenance will be handled?	Y	82				
29	Does the MCP contain a schedule of decommissioning activities?	N		To be developed 5 years from closure			
30	Does the MCP contain a schedule of closure performance monitoring and maintenance activities?	N		To be developed 5 years from closure			
31	Does the MCP contain a framework, including methodology, quality control and remedial strategy for closure performance monitoring including post-closure monitoring and maintenance?	Y	84				
32	Does the MCP include costing methodology, assumptions and financial provision to resource closure implementation and monitoring?	Y	87				
33	Does the MCP include a process for regular review of the financial provision?	Y	87				

Q	Mine Closure Plan (MCP) Checklist	Y/N/NA	Page No.	Comments	Change from previous version (Y/N)	Page No.	Comments
34	Does the MCP contain a description of management strategies including systems and processes for the retention of mine records?	Y	88				

Corporate endorsement:
I hereby certify that to the best of my knowledge, the information within this Mine Closure Plan is true and correct and addresses the relevant requirements of the *Guidelines for Preparing Mine Closure Plans* approved by the Director General of Mines and Petroleum.



David Bloor
General Manager - Health, Safety and Environment

Date: 24/8/2015

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INTRODUCTION TO CLOSURE PLANNING

1 What is a closure plan?

A closure plan documents strategies to achieve the desired post-closure landform and avoid or mitigate potential social and environmental impacts associated with site closure, to an extent that is fiscally appropriate. As such, closure plans provide the framework for planning and implementing mine closure. Closure plans also document tasks the company has committed to undertake to improve closure outcomes.

Closure plans are intended to be used by site personnel to inform on-going planning decisions, and to ensure closure is integrated into operational activities. Closure plans are also one of the methods used by the business to communicate its closure strategy to stakeholders, including regulators.

2 The closure planning process

Closure plans are regularly updated to account for changes resulting from:

- amendments to the mine plan;
- improvements of the site closure knowledge base (e.g. through daily activities, technical studies and research actions, progressive rehabilitation);
- new or amended regulation;
- changes to surrounding land uses; and
- evolving stakeholder expectations.

Review processes bring experts together to discuss current performance, proposed mine changes and opportunities to improve closure outcomes. At the end of the review process, improvement actions are assigned and the closure plan is updated.

A key output of closure planning is the development of a closure cost estimate. Closure provisions are subsequently integrated into our business planning processes to ensure funds will be available to close the site effectively.

The detail of each closure plan increases as the knowledge base develops. When the site approaches scheduled closure, studies will be completed to define how infrastructure, decontamination, rehabilitation, the workforce and communications will be managed throughout the mine closure period (and beyond), specific to the site conditions at the end of mining. Stakeholder engagement and endorsement of the final completion criteria is facilitated at this time.

In the final closure plan update (also referred to as the Decommissioning Plan), location specific management plans are provided for each closure domain. These detailed plans cover the physical closure, dismantling and subsequent rehabilitation implementation requirements. The supporting technical reports that have been used within the closure plan to predict the post-closure outcomes are also appended to the final closure plan.

3 Closure terminology

This closure plan is accessed by various groups within Rio Tinto as well as external stakeholders, including Western Australian State Government regulator and advisory departments and Traditional Owner groups. The following clarification is provided to define how the following terms are used within this closure plan:

- A mine void refers to the cavity created in the natural geology in order to mine ore, which extends below the natural surface.

- A pit refers to total area from which material was removed. A pit may include shallow depressions, where material is removed for construction purposes e.g. a borrow pit, and / or quarries where no surface depression is created, but instead part of a rock outcrop is removed.

- Post-mining landform refers to the shape of the land that would be generated as a result of implementation of the current operational mine plan and standard operating practice. Issues that could potentially arise from this scenario, and strategies to manage them, are the focus of this closure plan.

- Final landform designs refer to the individual feature or domain-based landform shaping requirements required to achieve the closure objectives.

- Closure landform refers to the overall shape of all the land disturbed by mining activities after rehabilitation earthworks are complete.
- Post-closure landform encompasses the closure landform and the surrounding undisturbed land, to describe the wider catchment conditions.

PURPOSE AND SCOPE

4 Purpose

Planning for closure of a site is a critical business process that demonstrates Hamersley‘s commitment to sustainable development. The report follows the format and content requirements for mine closure plans as recommended in the Closure Guidelines and required by Ministerial Statement 946 Condition 8-1.

This closure plan has been prepared to support the Western Turner Syncline Iron Ore Project referral under Part IV of the EP Act.

This update consolidates the closure planning requirements for WTS, previously presented as separate S10 and B1/S17 closure plans, and:

- updates the predicted water quality outcomes in the B1 Main pit;
- updates the B1 waste dump construction strategy;
- includes the additional, proposed S10 mining areas; and
- includes prospective areas, for which closure planning has commenced. These options are presented for consideration in cumulative impact, integrated mine planning and to facilitate discussion with key stakeholders and are not intended to be approved by regulators for implementation.

This closure plan supersedes all previous closure, decommissioning and rehabilitation plans for WTS.

5 Scope

This plan covers the closure, rehabilitation and decommissioning of facilities and disturbed areas associated with all mining activities at WTS, including:

- open cut pits, mineral waste dumps, haul roads and associated ground disturbance;
- administration buildings, associated facilities and infrastructure, sealed and unsealed roads;
- dewatering borefield, pipelines, discharge outlets and associated infrastructure; and
- the main haul road to Tom Price, Tom Price lay down areas and associated conveyor infrastructure.

This mine closure plan update has been developed using information current as at June 2015.

PROJECT SUMMARY

6 Description of operation

6.1 Overview

WTS (Figure 1) is located in the western Pilbara region of Western Australia, approximately 20km north-west of the Mount Tom Price mine site and 20km west of the town of Tom Price. WTS mines iron ore from three areas or 'hubs': B1, S17 and S10. The iron ore deposits are associated with the Brockman Iron Formation, Marra Mamba Iron Formation and within general detrital geological units located above and within the groundwater table.

WTS is considered to be part of Hamersley's Greater Tom Price mining area. Ore from the WTS deposits is transported via road train and conveyors to the Tom Price mine for processing and export.

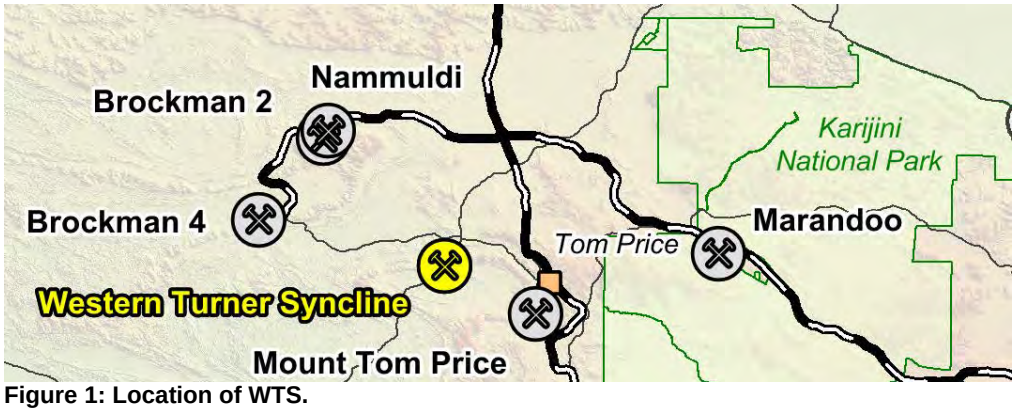


Figure 1: Location of WTS.

6.2 Closure plan review history

A closure management report was developed in 2008 to support the Western Turner Syncline, Section 10 Iron Ore Project referral, which was subsequently approved under Part IV of the EP Act, subject to Ministerial Statement 807.

A closure plan was developed in 2012 to support the Western Turner Syncline Stage 2 – B1 and Section 17 Deposits referral, which was subsequently approved under Part IV of the EP Act, subject to Ministerial Statement 946.

6.3 Mining layout

WTS utilises standard truck and shovel methods to develop open pit iron ore deposits. The mine layout is shown in Figure 2. The operation includes:

- open cut pits that mine to depths below the natural groundwater table in some deposits;
- mineral waste dumps developed outside and inside of the mine pits;
- a network of dewatering borefield, pipelines, discharge outlets and associated infrastructure to supply water and facilitate access to below water table (**BWT**) resources;
- haul roads and a conveyor network; and
- administration buildings, associated facilities, sealed and unsealed roads.

Note, a full site inventory is included in closure cost estimate reports for the site and is not reproduced in this report. It is assumed that all of the existing infrastructure and disturbance areas will be present at closure and will require decommissioning and subsequent rehabilitation.

Based on the current mine plan, the post-mining landform will consist of 19 mine voids and approximately 16 external waste dumps. Seven of the mine voids will extend into the groundwater table. It is expected that at least two of these BWT mine voids (S17 Pit 3 and S17 Pit 8) will be backfilled during the operation of the mine.

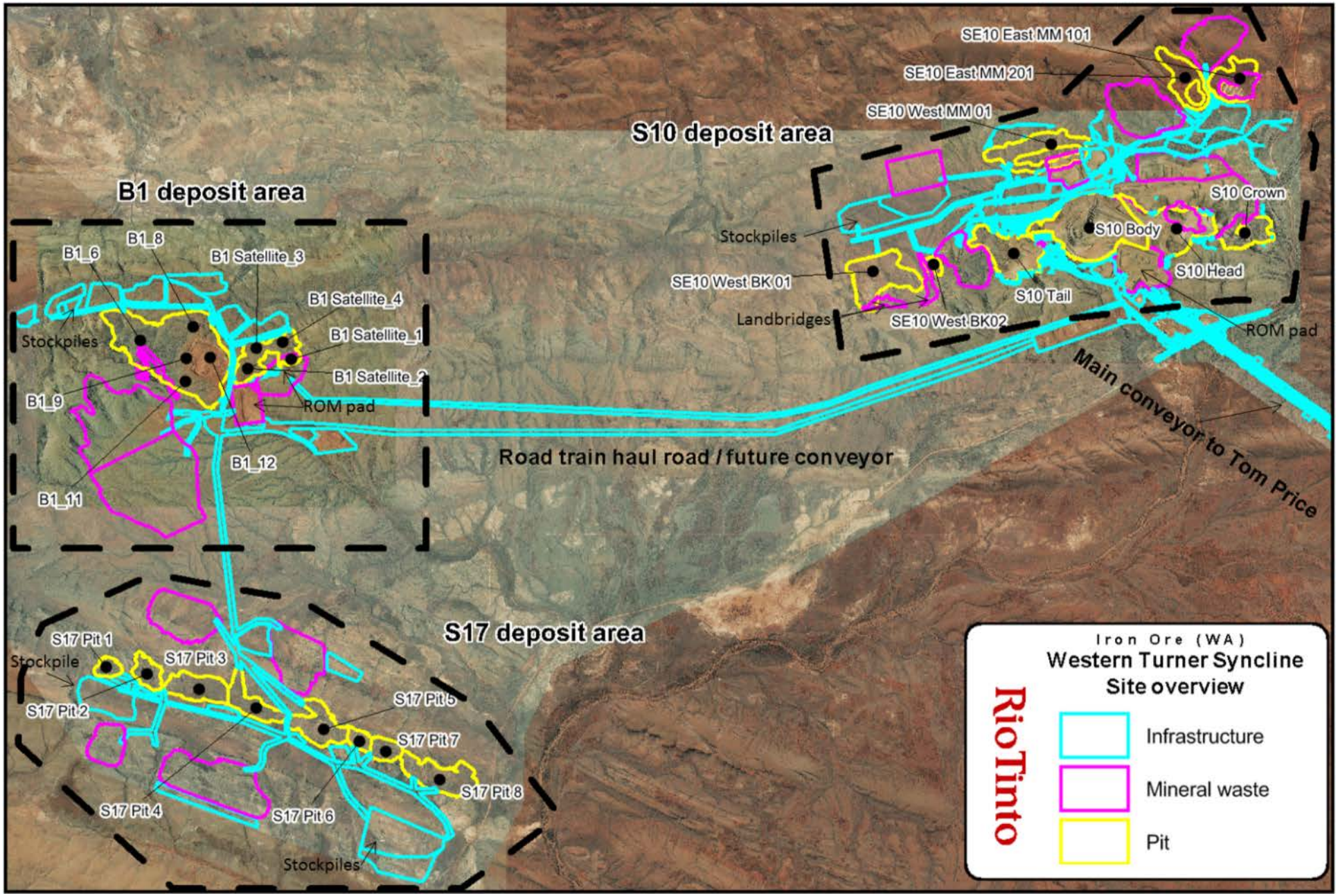


Figure 2: WTS mine layout.

6.4 Mining development and schedule

Ore was first transported from S10 in September 2010 and the first ore was transported from B1 in May 2015.

Major proposed milestones in the development and operation of the respective deposits are presented in Table 1 (locations of the individual deposits are illustrated in Figure 2). However it should be noted that mine plans undergo constant review and modification, and consequently this information should only be used as an indication of future mining and development.

Table 1: Indicative mining schedule

Deposits	Ore relative to water table	Indicative commencement
S10		
S10 Body (includes ULTWEST, ULTEAST, ULTNTHCB, RIDGE cutbacks)	Above and below	underway
S10 Head	Above	2015
S10 Crown	Above	2016
S10 Tail	Above	2015
SE 10 West BK 01	Above	2017
SE 10 West BK 02	Above	2017
SE10 East MM 101	Above and below	2017
SE10 East MM 201	Above and below	2020
SE10 West MM 01	Above and below	2023
B1		
B1 Main (B1 5-12)	Above and below	2015
B1 Satellite (1-4)	Above	2015
S17		
S17 Pit 1	All above	2023
S17 Pit 2	All above	2021
S17 Pit 3	Above and below	2021
S17 Pit 4	All above	2024
S17 Pit 5	All above	2023
S17 Pit 6	All above	2021
S17 Pit 7	All above	2023
S17 Pit 8	Above and below	2025

CLOSURE OBLIGATIONS AND COMMITMENTS

7 Legal obligations

A closure obligations register is presented as Appendix A, in accordance with the format prescribed in the Closure Guidelines. It contains a list of obligations from the following instruments:

- *Iron Ore (Hamersley Range) Agreement Act 1963*;
- Ministerial Statement 807 (Western Turner Syncline, Section 10 Iron Ore Project);
- Ministerial Statement 946 (Western Turner Syncline Stage 2 – B1 and Section 17 Deposits);
- relevant Native Vegetation Clearing Permits; and
- relevant leases held pursuant to *Land Administration Act 1997*.

The register also identifies legislation, standards and guidelines that may not apply to WTS specifically, but that may be relevant to closure of mine sites generally.

This closure plan has been prepared to support the Western Turner Syncline Iron Ore Project referral under Part IV of the EPA Act, and additional specific obligations may arise through these processes. These will be documented in the next update of the WTS closure plan.

STAKEHOLDER CONSULTATION

8 Stakeholder consultation

8.1 Consultation process

Stakeholder consultation is undertaken to ensure all stakeholders have their interests considered during closure planning. Hamersley has established processes and protocols for consultation with each of its key stakeholders; and most closure consultation is conducted within this existing framework.

Consultation is commenced in the early stages of the closure planning process, and continues through to site relinquishment. The consultation strategy used by Hamersley is designed to:

- identify stakeholders and interested parties;
- develop a targeted consultation plan to reflect the needs of the stakeholder groups and interested parties;
- integrate the consultation plan into the mine planning/closure planning process; and
- where practicable, work with communities to manage the potential impacts of mine closure.

Closure consultation is usually conducted within a broader consultation framework, as a component of on-going consultation forums. For example, consultation with State and Local Government stakeholders occurs as part of regular meetings held with individual agencies. Consultation on specific issues is also undertaken outside of these regular meetings as the need arises. Consultation with other stakeholders is conducted in a manner that is appropriate to the stakeholder and the specific issues requiring discussion.

The timing of discussions and discussion focus will change as the project matures or new deposits are discovered and developed. The focal areas for discussion are illustrated in Table 2.

Table 2: Closure discussion framework

Stage	Focus
Prior to deposit development	Undertake stakeholder identification and stakeholder mapping. Commence closure-specific discussions with key stakeholders. Discuss and agree (where relevant) key environmental, cultural and social values and closure objectives. (Usually undertaken in conjunction with environmental approval discussions.) Review public comments provided though public environmental review processes to identify additional stakeholders and / or concerns.
During operations	Ensure closure objectives and indicative closure criteria remain relevant and appropriate. Communicate outcomes of studies undertaken to improve the closure knowledge base, reduce closure risks or improve closure strategies, as part of the closure plan review process. Include closure in Traditional Owners liaison forums, established under the terms of Indigenous Land Use Agreements with relevant groups.
In the lead up to closure (development of Decommissioning Plan)	Undertake communication campaign to finalise completion criteria through key stakeholder consensus. Discussion future uses for infrastructure with other parties, i.e. for sale of equipment. Commence workforce communication strategy.
Post-closure	Establish a public awareness campaign to demonstrate progress of closure against completion criteria.

8.2 Communication register

Key stakeholders in the closure of WTS are listed in Table 3. This list is dynamic and is expected to evolve over time. The communications register in Table 4 summarises the discussions that have been held with stakeholders with respect to closure.

Table 3: Key stakeholders

Category	Stakeholder
State Government	Department of State Development (**DSD**)
	Department of Aboriginal Affairs (**DAA**)
	Department of Mines and Petroleum (**DMP**)
	Office of the EPA (**OEPA**)
	Department of Environmental Regulation (**DER**)
	Department of Parks and Wildlife (**Parks and Wildlife**)
	Department of Water (**DoW**)
	Department of Regional Development and Lands
	Department of Agriculture and Food WA
	Main Roads WA
	Pastoral Lands Board
Local Government	Shire of Ashburton
Community	Yinhawangka people
	Eastern Guruma people
	Tom Price town
	Bellary and Wakathuni communities

Table 4: Communication register

Stakeholders	Summary of discussion relevant to closure	Response
2007	**WTS S10 mining proposal**	
OEPA, DEC, DMP, DoW, DAA, DSD, Eastern Guruma, Yinhawangka, Shire of Ashburton	Hamersley provided a general overview of the WTS S10 above water table mining project to key stakeholder. Characteristics related to closure included: • Progressive rehabilitation to be integrated and maximised in the detailed mine plan. • Mineral waste initially directed to surface waste dumps and, thereafter, used in progressive backfilling of the eastern and western sections of the mine pit where practicable. • Areas of potential shale exposure to be identified during detailed mine modelling to be preferentially covered to prevent Acid Rock Drainage (ARD) generation.	Proposal accepted by stakeholders.
2012	**WTS Stage 2 (B1 and S17) mining proposal**	
DMP, OEPA, DEC (now Parks and Wildlife and DER), DoW	Hamersley presented the closure approach for the proposed Stage 2 expansion to the WTS mine. Retention of a pit lake at B1 was a key focus of discussion. DMP requested closure objectives be reviewed to ensure that they focus on outcomes rather than processes. DMP indicated that the closure plan should demonstrate that a capping of 1 m is sufficient on the B1 waste dumps, sufficient inventories of competent material are available to prevent erosion, the integrity of the B1 dumps would not be compromised by flood events and if fibrous materials present they must be managed. DEC indicated that pit lake modelling could be improved by considering the saline conditions expected post-closure.	A closure plan was prepared in accordance with DMP requirements as part of the mining proposal. Hamersley committed to continue to seek feedback from key stakeholders regarding approach to pit lake water quality monitoring.

Stakeholders	Summary of discussion relevant to closure	Response
Eastern Guruma	As part of the Hamersley presentation on the proposed Stage 2 expansion, Eastern Guruma voiced concern about B1 being retained as a pit lake.	Concern was noted by Hamersley
2014	**WTS revised proposal**	
Eastern Guruma	A brief, high level discussion with 6 Eastern Guruma representatives (and an anthropologist) regarding WTS closure on the 30th October 2014. Questions focused on the impact of mining to water quality and quantity after closure and how planning is undertaken. The importance of the large heritage site WTS-01 immediately adjacent to the S10 Marra Mamba deposit was communicated to Hamersley.	Hamersley committed to continuing the discussion to ensure concerns are understood and addressed where possible. Questions have been integrated into this closure plan.
DMP	A brief, high level overview was presented to DMP on the WTS closure strategy on 17th Feb 2015. The presentation included reference to the extent of proposed mining and likelihood of pit lakes. It was communicated to DMP that backfill of the deposits would occur if water quality and stability outcomes were not acceptable to the regulators. Stability issues and interactions with the general public were discussed in relation to safe post-mining land-use.	No response required.

8.3 Ongoing consultation synopsis

8.3.1 Aboriginal groups

The Yinhawangka People and Eastern Guruma People are the traditional custodians of the land identified in this closure plan. Members of these language groups are geographically dispersed with key locations being Wakathuni and Bellary near Tom Price, Onslow, Roebourne, Karratha and Port Hedland.

Consultation with Yinhawangka and Eastern Guruma peoples is undertaken through (separate) meeting processes, as provided for in agreements between Hamersley and the respective groups. These committees are a joint forum of Hamersley senior leaders and Yinhawangka Aboriginal Corporation, who represent the interests of the Yinhawangka People, and Wintawari Guruma Aboriginal Corporation, who represent the interests of the Eastern Guruma people. Closure may also be discussed, when appropriate, during ethnographic surveys and similar forums. Where appropriate, this engagement is documented as part of the Cultural Heritage Management System. The outcomes of these sessions and surveys are used to inform the development of closure strategies.

Eastern Guruma has expressed an interest in post-closure water, flora, fauna and landform stability outcomes, including:

- How will water levels and water quality in the lakes change over time?
- Will the pit water be safe for humans e.g. swimming?
- Which pit lakes will be accessible?
- Is creating a recreational area for the public to utilise once the mine is closed considered?
- What will happen to the aquifer when the mine closes?
- What are the long term impacts on the groundwater aquifers?
- What are the changes that will occur to local flora and fauna after closure?
- Why aren't pits backfilled instead of creating new external waste dumps?
- When is closure of WTS planned?

Other topics that have yet to be addressed with the Yinhawangka and Eastern Guruma peoples include:

- access to sites of cultural significance;
- repatriation of artefacts;
- integration of bush tucker, medicinal and other culturally significant plants into rehabilitation seed mixes; and
- removal of heritage fencing and signage at closure.

These topics are proposed to be discussed at future meetings with each group.

8.3.2 Regional community

Tom Price is the nearest town to WTS, located approximately 20 km from the S10 deposit. Tom Price is a modern mining town situated at the far-eastern boundary of the Shire of Ashburton, on the edge of the Hamersley Ranges and the Karijini National Park. Only a very small portion of the work-force resides in the town. In 2011 Tom Price had a population of approximately 5,500[3].

The top three industries of employment in Tom Price are mining, retail and education. Most of the Town's residents are employed directly by Rio Tinto and rental accommodation is included as part of their employment package. A baseline community assessment in 2008 estimated that mining accounts for 77 percent of the town's Gross Regional Product and up to 92.5 per cent of the town's economy when considering indirect impacts.

The two main Indigenous communities located near Tom Price are Wakathuni and Bellary Springs. Many Indigenous communities today are comprised of members from a number of different language groups. An example of this is Wakathuni, where members of the Yinhawangka, Kurrama, Banjima, Ngalawangka and Nyiyaparli reside. The Eastern Guruma People also occupy an area known as the White Quartz Lease, located adjacent to the White Quartz Road, 35km northwest of the Tom Price mine. Combined with Tom Price town (approximately 360 people), the indigenous population is around 500 people; a quarter of whom are employed locally[4].

Engagement with the community is undertaken through Hamersley's established processes and protocols for consultation. As mining rates decline and the site approaches closure, the Greater Tom Price workforce who operate WTS are expected to transition to other operations in Hamersley's Greater Tom Price mining area, in order to maintain production rates. Thus the community, employment opportunities and mine related services are not anticipated to be significantly impacted by closure of the mine.

[3] 2011 Australian Bureau of Statistics Census

[4] 121 Indigenous people reported being in the labour force in the week before 2011 Census.

POST-MINING LAND USE AND CLOSURE OBJECTIVES

9 Post-mining land use

The Pilbara is classified as an Extensive Land Use Zone. WTS ground disturbance will occur over tenure historically classified as Unallocated Crown Land. Land allocated to this classification in the Western Australian Pilbara region is dominantly used for the purpose of mining and associated activities.

Traditional Owners of the land, the Yinhawangka people and the Eastern Guruma people, regularly access culturally significant areas, in and around WTS, to maintain traditional law and connection to country. This connection to land is the basis for the formal recognition of Traditional Owner native title rights and interests.

Options for post-mining land use are limited in the Pilbara region, with mining and pastoralism the only industries that have historically proven viable. The closure and rehabilitation strategy will focus on creating a safe, stable and non-polluting landscape vegetated with native vegetation of local provenance, to ensure the system remains compatible with general Pilbara land uses.

10 Closure objectives

10.1 Hamersley's vision for closure in the Pilbara

Closure objectives for WTS have been developed with consideration of Hamersley's general vision for closure, to:

- Relinquish its mining leases to the Western Australian State Government.
- Preserve, protect and manage the cultural heritage values of the area in cooperation with the Traditional Owners and other stakeholders.
- Develop and implement strategies for closure which consider the implications on local communities.
- Achieve completion criteria which have been developed with stakeholders and agreed with Government.
- Develop landforms that are safe and stable and compatible with the surrounding environment and post-mining land use.
- Achieve environmental outcomes that are compatible with the surrounding environment.
- Implement a workforce strategy which addresses the impacts of closure on employees and contractors.
- Achieve successful closure in a cost effective manner.

10.2 WTS closure objectives

The ultimate goal of mine closure at WTS is to relinquish the site to the Government. This goal will be achieved once key stakeholders agree that the condition of the site is compatible with an agreed post-mining land use. Table 5 lists the closure objectives developed in consideration of the key stakeholder expectations for mine closure.

Table 5: WTS closure objectives

Number	Objective
1	Erosion does not threaten the long term stability of constructed landforms
2	Potential contaminants are managed such that no adverse impact to soil, surface water or groundwater is predicted.
3	Vegetation on rehabilitated land is native and self-sustaining.
4	The prevalence of invasive species is similar to that in nearby reference sites.
5	Pit lakes do not represent a significant public liability, health or ecological risk.
6	Measures to mitigate public safety hazards have been agreed with stakeholders and have been implemented.

COMPLETION CRITERIA

11 Completion criteria

Completion criteria can be defined as the indicators used to determine whether closure objectives have been met. They are used to measure the success of closure implementation against objectives, and to facilitate relinquishment of mining tenure.

The completion criteria, presented in Table 6, have been developed following consultation with stakeholders and in consideration of the predicted closure outcomes. Measurement processes, and the associated supporting data (evidence and / or metrics), that will be used to calculate or otherwise define the conditions at WTS are also described in Table 6.

The completion criteria are subject to ongoing review and update, informed by the outcome from studies identified in the closure task list (Table 27) and ongoing stakeholder consultation. As the site approaches scheduled closure the completion criteria will contain more measurable and time-bound parameters.

Table 6: Indicative completion criteria

Objective	Indicative completion criteria	Process	Evidence or metrics / data
1. Erosion does not threaten the long term stability of constructed landforms.	1a. Gully width or depth does not increase by more than 20 percent in the five year period prior to relinquishment.	Passive monitoring of rehabilitation slopes to identify potential erosional structures (e.g. aerial photography). Field validation of erosional structure size. Monitoring assessment of stability for erosional structures to demonstrate completion criteria achieved.	Annual aerial photography Field records of gully depth and width
2. Potential contaminants are managed such that no adverse impact to soil, surface water or groundwater is predicted.	2a. Acid drainage production from PAF dumps is assimilated into the environment at rates that maintain the pre-mining water quality pH range.	Identified PAF materials are adequately contained or covered to minimise acid drainage production. Contaminated transport modelling to predict water pH and quantity exiting waste dump. Contaminated transport impact assessment to predict water quality mixing impacts in natural environment.	Background water pH Column leach test results to define PAF material chemical properties
	2b. The pH of the soil in the top 20cm on PAF waste dumps and covers is similar to the soil pH on inert waste dumps.	Comparison of soil pH results from inert waste dumps, PAF waste dumps and PAF covers.	Field records of soil pH on rehabilitated waste dump landforms

Objective	Indicative completion criteria	Process	Evidence or metrics / data
	2c. Metal and hydrocarbon contaminant levels are below stakeholder agreed thresholds.	Thresholds for key contaminants are agreed with key stakeholders. Phase 1 environmental site investigation is completed to identify potential contaminants Phase 2 contaminated site investigation and associated remediation actions are completed to verify contaminant levels are below thresholds.	Contaminated site register Field sampling as required.
3. Vegetation on rehabilitated land is native and self-sustaining.	3a. Mean density of plants within rehabilitated areas is within the range demonstrated by reference sites.	Identification of key species for rehabilitation habitats / domains in seed selection. Comparison of plant density on rehabilitation areas with reference site statistics.	Field vegetation monitoring of species in reference sites to determine natural density range. Measurement of species density in rehabilitation areas.
	3b. Percentage of perennial cover within rehabilitated areas is comparable to reference sites.	Identification of perennial species for rehabilitation habitats / domains. Comparison of key species density variability with reference sites.	Field vegetation monitoring of species in reference sites to determine natural cover range. Field vegetation monitoring of species over 10 year period to determine cover variation over time.
	3c. Plants within rehabilitated areas are observed to flower and fruit	Records of key species during flowering and / or fruiting	Field vegetation monitoring of species in rehabilitation to sight flowers and/or fruit.
	3d. Recruitment of native perennial species is observed.	Records of perennial species seedlings in mature (>10 years old) rehabilitated areas.	Field vegetation monitoring of perennial species seedlings.
	3e. Native perennial vegetation within rehabilitated area is resilient to fire and drought.	Comparison of mean perennial plant density and mean perennial plant cover in fire or drought affected rehabilitation against pre-impact or reference site condition.	Measurements of species density and cover in impacted rehabilitation areas. Measurements of species density and cover pre-impact. Measurements of species cover in reference sites. Weather data and climate trends
4. The prevalence of invasive species is similar to that in nearby reference sites	4a. No new weed species are present in rehabilitated areas. 4b. Weed distribution and abundance within	List of weed species. Baseline weed conditions map.	Measurement of weed species and density in rehabilitation areas.

Objective	Indicative completion criteria	Process	Evidence or metrics / data
	rehabilitated areas is comparable to adjacent undisturbed areas.		
5. Pit lakes do not represent a significant public liability, health or ecological risk	5a. Water quality in pit lakes does not adversely impact local ecosystems.	Prediction of pit lake water quality and lake recovery conditions over time. Identification of location specific potential contaminant migration paths. Review of public liability, health and ecological risk factors Verification that the pit lake will not deteriorate the conservation status of significant species.	Lake water level and water chemistry Groundwater levels Weather data and climate trends Structural geology integration into hydrogeology model
	5b. Pit lakes likely to be accessed by the public have acceptable risk management profiles.	Identify lakes likely to be regularly accessed by the public. Define and agree water quality parameters for public access lakes with key stakeholders. Demonstrate predicted pit lake water quality and lake conditions over time are within acceptable parameters, considering likely land-use activities and interactions.	Geotechnical evaluation pit wall stability and erosion evolution Groundwater levels Weather data and climate trends Lake water level and water chemistry Lake enteric bacterial indicators
6. Measures to mitigate public safety hazards have been agreed with stakeholders and have been implemented.	6a. Key stakeholders are engaged in the process of defining potential hazards. 6b. Abandonment structures are erected outside geotechnical zone of instability to inhibit vehicle access to mine voids. 6c. Safe access to sites of cultural significance is implemented as agreed with key stakeholders. 6d. Abandonment signage is erected to describe potential hazards.	Identification of potential hazards to the public in the decommissioned area. Process for transfer of residual liabilities is agreed with stakeholders. Identification of cultural heritage sites that require access post-closure. Records of stakeholder engagement Independent audit(s) to confirm that hazard mitigation measures have been implemented.	Communications register Geotechnical evaluation report Fibrous materials audit Contaminated sites audit Electrical safety inspection Public access evaluation Traditional Owner cultural access requirements

COLLECTION AND ANALYSIS OF BASELINE DATA

The closure knowledge base (Appendix B) is a collection of baseline studies, models and interpretations, which are used to inform the closure planning process presented in this closure plan. The knowledge may be specific to the site or generally applicable to the Pilbara region; and includes information on the performance of closure-related trials completed at other Pilbara mining operations (when appropriate). At this stage of the closure plan development, only summaries of these reports are provided and the relevant information is summarised below. The relevant knowledge base reports will be included in the final closure plan.

12 Climate

Climatic information, particularly rainfall, rainfall intensity, cyclone frequency and evaporation is relevant to many aspects of mine closure. In particular, it potentially has a significant effect on the geotechnical and vegetative stability of final landforms including waste dumps.

The general climate of the Pilbara can be described semi-arid, characterised by a hot summer (October to April) and a mild winter (May to September).

12.1 Rainfall and significant weather events

The north / north-western coastline of Australia has experienced more tropical cyclones than anywhere else on mainland Australia. Most tropical cyclones are observed during the late summer, occurring between November and May. Tropical cyclones can produce damaging wind gusts in excess of 150 km per hour, with heavy rains resulting in regional flooding. On average, five tropical cyclones are expected off the coast of the Pilbara each year, with two expected to make landfall.

Precipitation is driven by summer cyclonic activity, with the months of August, September and October having the lowest average rainfall, and January, February and March the highest average rainfall (Figure 3). The mean annual rainfall as measured at the Tom Price weather station, located at the Tom Price mine 20 km away, is 397 mm, with a minimum of 114 mm (2010) and maximum of 765 mm (1999). Annual rainfall is also highly variable, as evidenced by the Tom Price rainfall record from 1999 to 2013 (Figure 4).

Temperatures at WTS are expected to range from an average maximum temperature of between 35 - 37^{o}C in summer to an average minimum temperature of between of 11 – 12^{o}C in winter. Monthly average temperatures recorded at Tom Price between 1999 and 2013 are presented in Figure 5.

Evaporation rates in the region greatly exceed rainfall. Point potential evaporation based on 30 year of Bureau of Meteorology climate data (1961 – 1990) is 3050 mm per year.

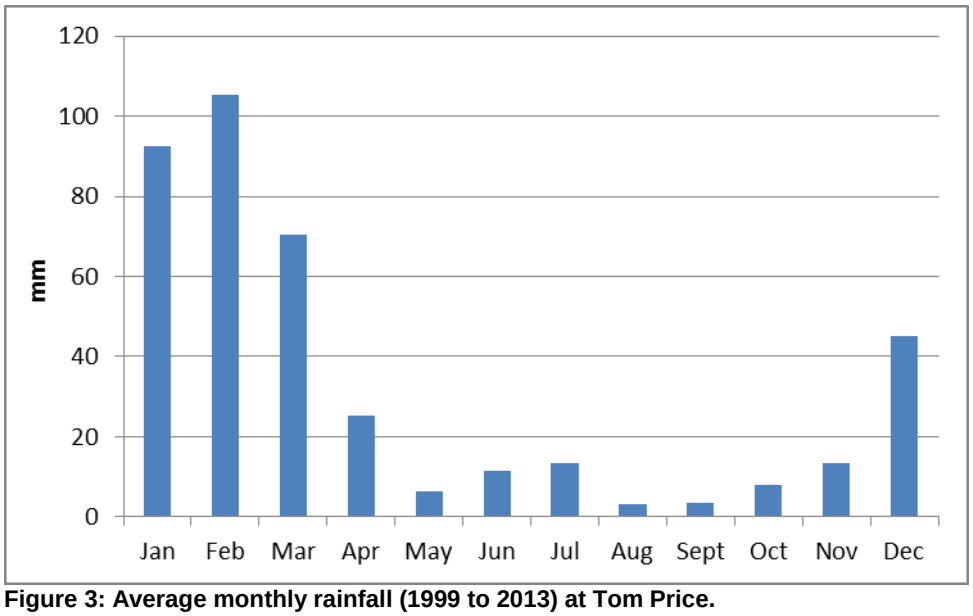


Figure 3: Average monthly rainfall (1999 to 2013) at Tom Price.

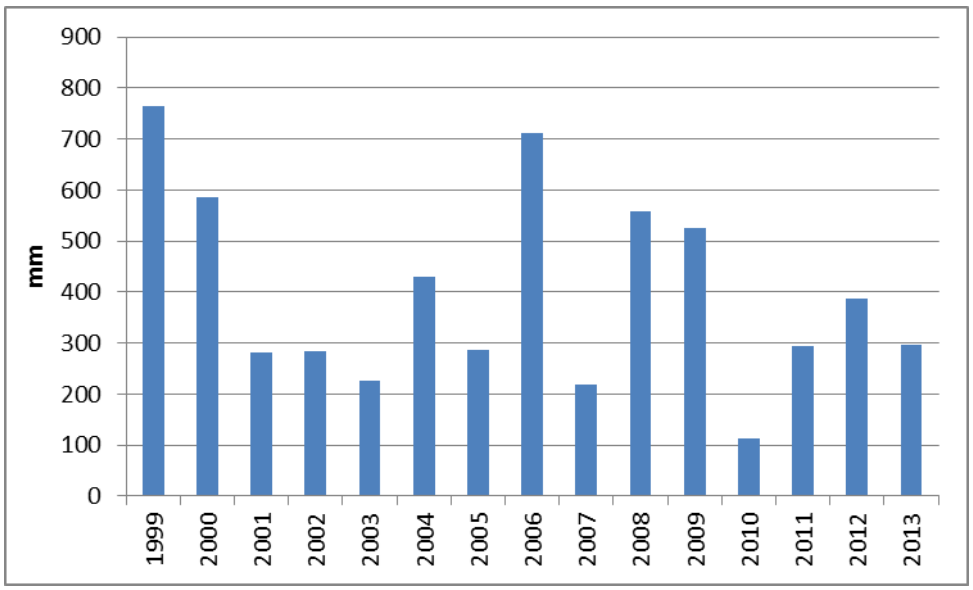


Figure 4: Historical annual rainfall (1999 to 2013) at Tom Price.

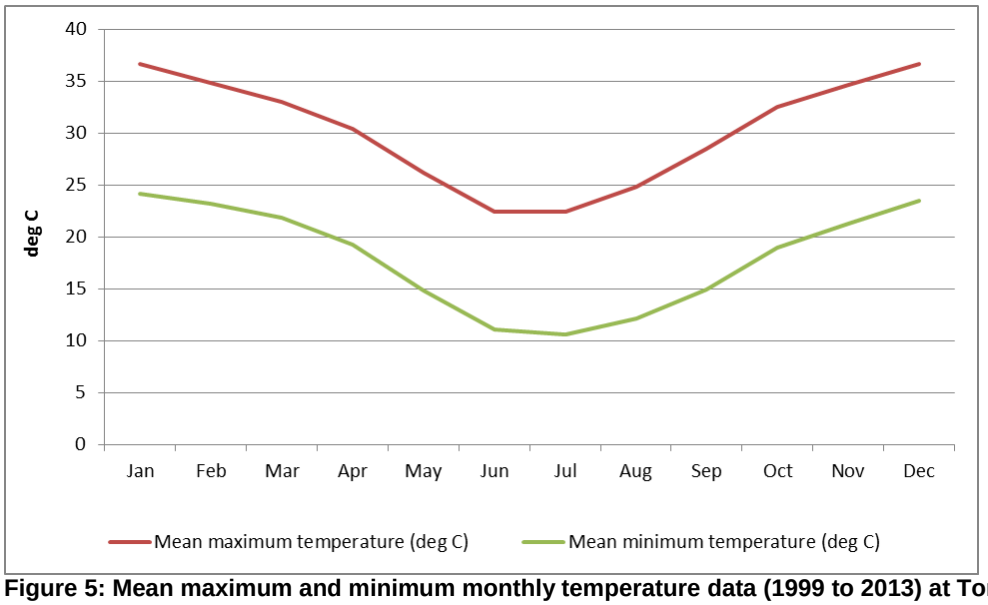


Figure 5: Mean maximum and minimum monthly temperature data (1999 to 2013) at Tom Price

12.2 Impact of climate change

The understanding of how climate will change in the future in the Pilbara is guided by the outcomes of climate modelling, commissioned privately by Rio Tinto and other Australian government agencies. The main climate drivers for the Pilbara are the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) ocean currents. However, these ocean currents are not well represented in most global climate models, and as a result climate predictions for the northwest of Western Australia vary significantly. Consequently the impact of climate change, the change in water availability and influence on ecosystems, in the Pilbara is still unclear.

The ENSO and IOD ocean currents are currently being researched by CSIRO. At the same time, modelling is being progressively improved by various Australian Government agencies to expand our understanding of the climate drivers in the southern hemisphere, to understand the associated impacts on water availability and to predict changes to existing ecosystems.

From the modelling completed to date, our understanding of Pilbara climate change suggests the region will experience the following climate trends:

- A shift in the historical tropical cyclone season, with an earlier start and potentially later finish.
  - For the period 2051 to 2099, compared to present day, tropical cyclone frequency could decrease by half, and the duration of a given tropical cyclone by 0.6 days on average. Projections also suggest that tropical cyclones could increase in size and intensity
- Continuation of the highly variable multi-decadal scale rainfall trends.

  - Projected rainfall reductions range from 1 to 24 percent for mid-century, and 9 to 24 percent for the end of the century
- A significant warming trend, influencing maximum temperatures, with the largest changes during the January to March period.
  - On average, maximum temperatures are expected to increase by 2.1 to 3.2 ˚C by mid-century and by a total range of 3.8 to 4.6 ˚C by the end of the century. For minimum temperatures the corresponding averaged increases are 1.9 to 2.4 ˚C (mid-century) and 4.1 to 4.6 ˚C (end of the century).

Changes to the climate conditions will need to be considered in pit lake water balance and water quality modelling.

13 Land

13.1 Geographic overview

13.1.1 Deposit setting

In a broader context, WTS lies within the Pilbara Craton, a bioregion defined by the Interim Biographic Regionalisation for Australia (IBRA). The Pilbara bioregion is divided into four subregions. WTS lies within the central section of the Hamersley subregion, with its relief defined as a “mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by gorges (basalt, shale and dolerite).” Six land systems are identified as occurring in and immediately adjacent to WTS, as listed in Table 7. Most of the disturbance will occur within the Newman, Platform and Rocklea land systems.

Table 7: WTS land systems and land units

Land system	Description
Newman	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands
Boolgeeda	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands
Platform	Dissected slopes and raised plains supporting hard spinifex grasslands
Robe	Low limonite mesas and buttes supporting soft spinifex, and occasionally hard spinifex, grasslands.
Table	Low calcrete plateaux, mesas, and lower plains supporting mulga and cassia shrublands and minor spinifex grasslands.

WTS is located on the Western Turner Syncline geological structure, which forms a ring of rounded hills and mountains that encircle a broad, expansive plain. Mineralisation occurs in the Brockman Iron Formation, Marra Mamba Iron Formation and within general detrital geological units.

Table 8 lists the dominant geological units and general landscape positions for the WTS deposits. In general, the deposits are located on or towards the top of the ridges, with only a few deposits located on the central plains area. Many of the deposits intersect and will mine out minor drainage lines and gullies.

Table 8: WTS deposit names and general setting.

Deposit	Dominant geology	Landscape position	Ore relative to water table
S10			
S10 Body	Brockman	Hill	Above and below
S10 Head	Brockman	Hill	All above
S10 Crown	Brockman	Hill	All above
S10 Tail	Brockman	Hill	All above
SE 10 West BK 01	Brockman	Hill	All above
SE 10 West BK 02	Brockman	Hill	All above
SE 10 East MM 101	Marra Mamba	Plains	Above and below

Deposit	Dominant geology	Landscape position	Ore relative to water table
SE 10 East MM 201	Marra Mamba	Plains	Above and below
SE 10 West MM 01	Marra Mamba	Plains	Above and below
B1			
B1 Main (5-12)	Brockman	Plains	Above and below
B1 Satellite (1-4)	Brockman	Hill	All above
S17			
S17 Pit 1	Brockman	Hill	All above
S17 Pit 2	Brockman	Hill	All above
S17 Pit 3	Brockman	Hill	Above and below
S17 Pit 4	Brockman	Hill	All above
S17 Pit 5	Brockman	Hill	All above
S17 Pit 6	Brockman	Hill	All above
S17 Pit 7	Brockman	Hill	All above
S17 Pit 8	Brockman	Hill	Above and below

13.1.2 Surface water

WTS is located in the headwaters of the Hardey River catchment. WTS is located close to the Hardey River, the northern branch of the Hardey River (**Northern Hardey River**) and the Beasley River (Figure 6); all ephemeral creek systems. Hardey River is located immediately to the south and west of WTS, the Beasley River about 6km to the west of B1, and the Northern Hardey River is located adjacent to S10. All three creeks have the potential to receive surplus water discharged from the site to facilitate below water table mining.

Local drainage lines within the WTS mine area are well defined due to the incised nature of the topography. Surface water flow is intermittent, generally occurring after significant rainfall events. There are no permanent or semi-permanent surface water pools in the local area.

The physico-chemistry of the Hardey and Beasley Rivers does not significantly vary between seasons, or upstream and downstream of WTS. Surface water quality in local ephemeral pools range from fresh (225 μS/cm) to brackish (4,710 μS/cm), depending on the time since the last significant rainfall event. Dissolved metal levels are naturally low, except for boron, copper, and zinc levels which exceeded the 99% ANZECC/ARMCANZ (2000) guidelines. Total nitrogen and total phosphorous concentrations can also exceed ANZECC/ARMCANZ (2000) guideline limits. Low dissolved oxygen levels of approximately 40% were also found in a number of pools during both wet and dry seasons, well below the day-time ANZECC/ARMCANZ (2000) guideline of 85 - 120%.

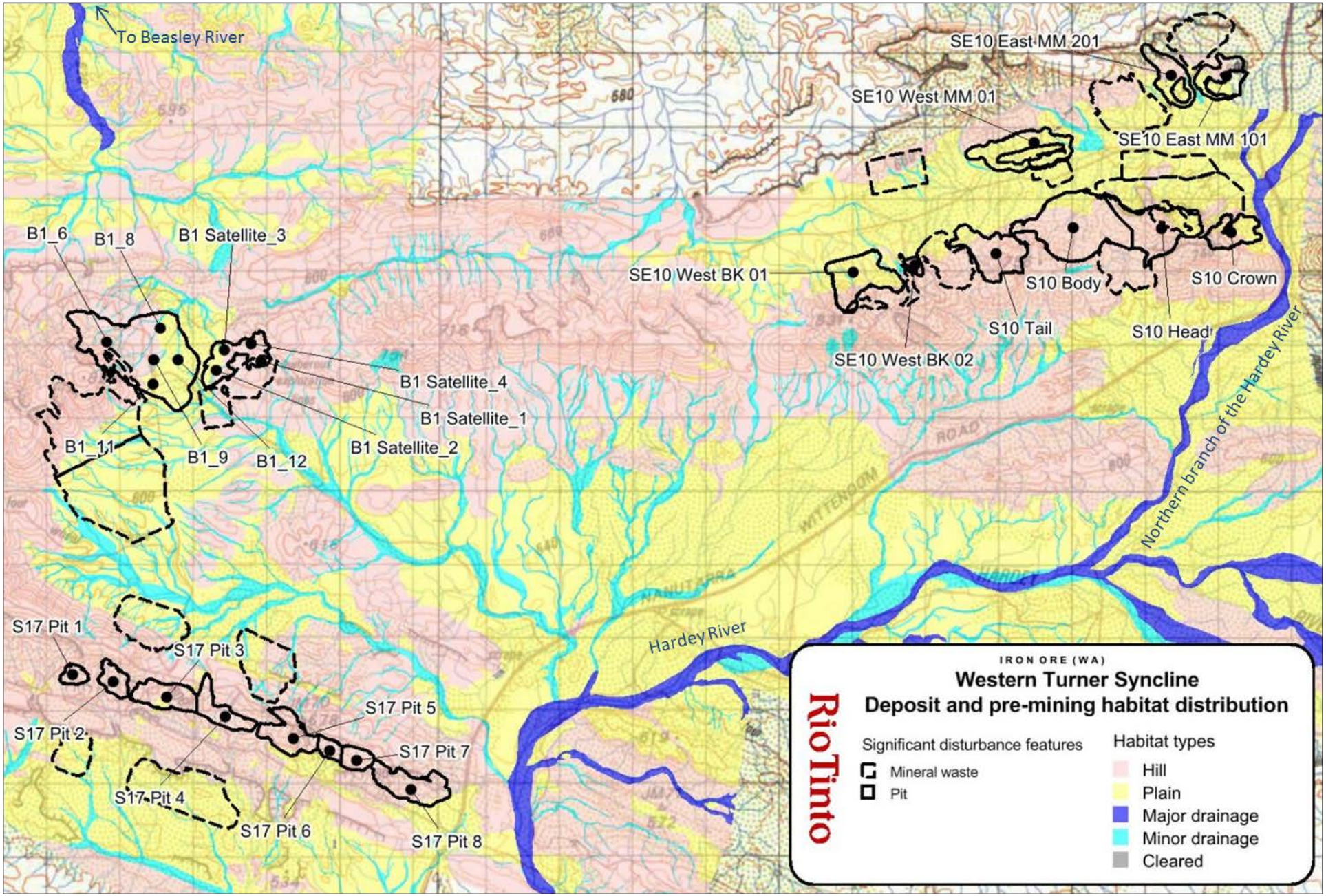


Figure 6: Topography and deposit locations.

13.1.3 Groundwater

The main aquifer and key hydrogeological concepts (Figure 7) at WTS include:

- Wittenoom Formation / Tertiary age sediments – characterised by locally cavernous, steeply dipping Wittenoom Formation overlain by tertiary calcretes/goethites and alluvial/colluvial sediments. This sequence is bounded to the north and south by the relatively impermeable banded iron formations.
- Brockman Iron Formation Ore Bodies – characterised by mineralisation and partial mineralisation and often high permeability. At B1 and Section 10 it is thought the aquifers in the ore bodies are separated from the Wittenoom Formation aquifer by the low permeability Mount McRae Shale.
- Marra Mamba Iron Formation Ore Bodies – characterised by mineralisation and partial mineralisation and often of high permeability and believed to be in hydraulic connection with the Wittenoom Formation aquifer.

Regional groundwater levels range from 555m AHD in the northeast to 490m AHD to the southwest where the Hardey River cuts through the southern limb of the Turner Syncline. Regional groundwater flow occurs in a broadly south-west direction sub parallel with the Turner Syncline axis.

At B1 the local groundwater table is relatively flat at approximately 535m to 540m AHD. The orebody aquifer is understood to be isolated from the Wittenoom Formation dolomite in the north by the low permeability units of the Mount McRae Shale and Mount Sylvia Formation, and isolated from the regional groundwater flow system in the south by the low permeability un-mineralised Brockman Iron Formation.

The groundwater table at S17 is nominally 500m AHD. This orebody aquifer is also understood to be separated from the regional groundwater flow system by low permeability Banded Iron Formation to the north and the Mount McRae Shale to the south.

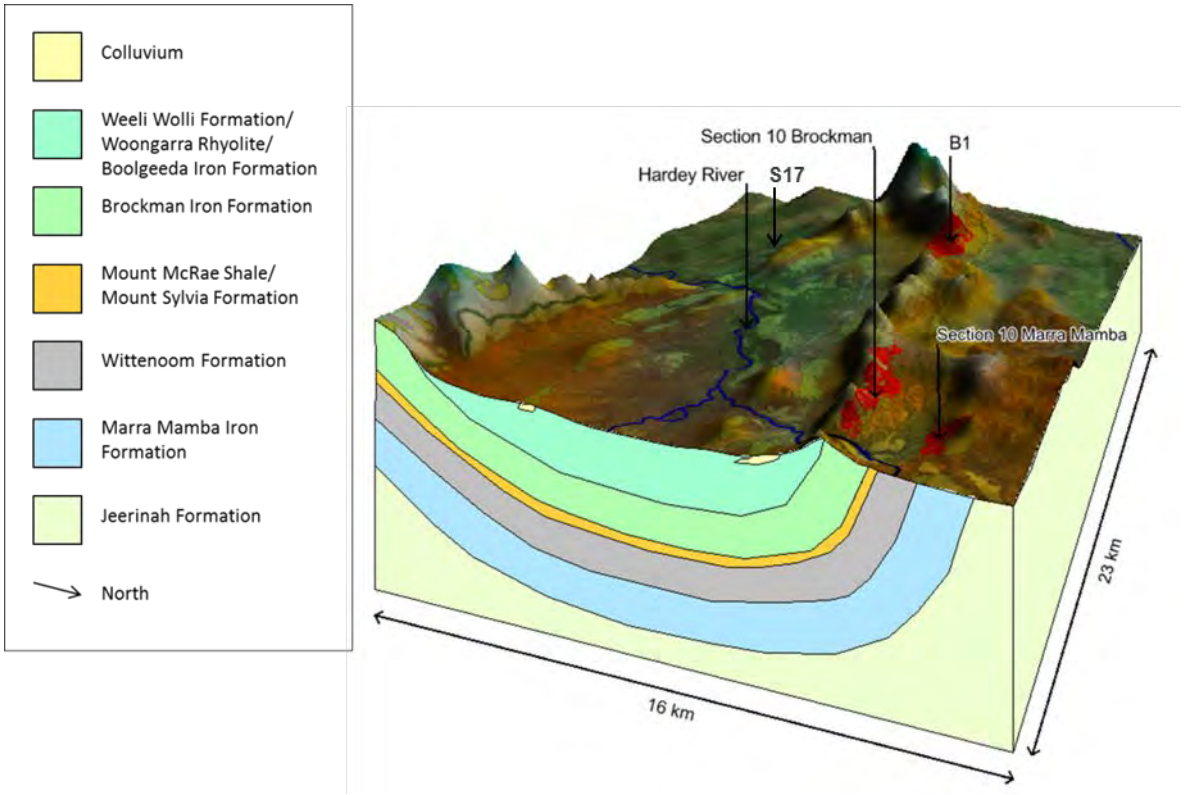


Figure 7: Hydrogeology conceptual cross-section at S10.

The groundwater table at S10 Brockman deposits is nominally 545m AHD. This orebody is located in the Dales Gorge Member of the Brockman Iron Formation. The deposit is underlain by unmineralised BIF in the south and low permeability Mount McRae Shale and Mount Sylvia Formation in the north, and is consequently believed to be separated from the regional groundwater flow system.

The groundwater table at the S10 Marra Mamba deposits has been influenced by water supply / demand from Hamersley's Mt Lionel borefield, which is located a few kilometres to the east of S10, east of the Northern Hardey River. The borefield commenced operation in 1976 to supply water to the Tom Price mine site. The aquifer system supporting the Mount Lionel Bore field is part of the regional aquifer and comprises locally cavernous, steeply dipping Wittenoom Formation overlain by Tertiary age calcretes / goethites and alluvial / colluvial sediments, with connection to the overlying Hardey River valley aquifer. The groundwater

table in the vicinity of the S10 Marra Mamba deposits is understood to have been lowered from a pre-disturbance level of around 555m AHD to the current level of around 530m AHD, demonstrating that there is a direct connection between the deposit and regional aquifer.

The Hardey River aquifer has developed in the Tertiary alluvial and chemical paleochannel sediments along the axis of the Turnersyncline. The sequence consists of Tertiary alluvial and colluvial clastic sediments incorporating chemically deposited goethite and calcrete overlying the Turee Creek Formation. Groundwater recharge is by infiltrated rainfall over the catchment area and direct infiltration of stream flow where the Hardey River and its tributary streams intersect the aquifer near the western end of the borefield.

Groundwater recharge rates across the aquifers are considered to be relatively low, with active recharge limited to the main creek channels. Based on the observed groundwater levels and water chemistry, average annual recharge in the WTS region is estimated to be less than 1% of the rainfall volume falling over the catchment.

The quality of groundwater at WTS is generally slightly brackish, the salinity of the groundwater is relatively consistent at <2000 us/cm and compatible with ANZECC/ARMCANZ (2000) livestock water quality guidelines.

There is no indication of shallow groundwater tables near the ore bodies owing to their aspect higher in the local topography.

13.2 Soil

13.2.1 Local soils

The soils of the area are generally red sandy clay loams with no observable structure. Soil depth varies from very shallow on the ridges and on the upper slopes, deepening on the stony plains and pediments. Coarse fragments are abundant on the surface and within the soil profile (Table 9).

Soils are generally acidic and not saline (Table 10) with low Exchangeable Sodium Percent (**ESP**). The soils can be hardsetting, which can provide an unfavourable environment for vegetation establishment.

Table 9: Particle size distribution of the topsoil at WTS.

Rock >45mm (%)	Pebbles 22-45mm (%)	Gravel 2-22mm (%)	Fine fraction <2mm (%)	Fine fraction			
				Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
1	8	71	20	47	24	1	21

Table 10: General properties of the topsoil at WTS.

pH	EC1:5	EC1:2	ESP	Potentially dispersive	Exchangeable cations (m.eq./100g)					ECEC
(-)	(dS/m)	(dS/m)	(%)		K	Ca	Mg	Na	Al	
6.0	0.03	0.07	16.3	Yes	0.64	4.42	1.13	0.46	0.0	6.65

Subsoil has physical properties suitable for plant growth and generally has chemical properties amenable to plant growth, although it does lack the nutrient content, organic matter, soil seed bank and mychorrhizal fungi properties of topsoil.

13.2.2 Soil inventory

Soil management practices aim to maximise topsoil recovery and retain soil viability and productivity, to improve future success of rehabilitation programs. Soil management implemented at WTS includes:

- stockpiling grubbed surface vegetation to provide a supply of additional seeds and organic matter for the soil;
- collecting more than the minimum 200 mm mandated quantity of topsoil where available;
- storage of topsoil in stockpiles no more than 2 m high (or one truck paddock dumped tip height, when using larger trucks) in sign posted, restricted access areas;
- collection of subsoil up to 600 mm where available;
- collecting additional subsoil where practicable / available;
- maintaining a soil inventory; and
- regularly reconciling the available and project soil requirements to the projected life of mine disturbance areas.

At WTS, like many sites in the Pilbara, the naturally shallow or rocky soil and topography make it difficult to recover the quantities of topsoil required to successfully rehabilitate all of the disturbed areas. Subsoil is notably absent across much of the deposit areas at WTS, resulting in the low predicted subsoil recovery volumes.

The soil inventory is provided in Table 11. This assessment is based on a total disturbance area of approximately 28,000,000 m^2, of which 21,000,000 m^2 is expected to require rehabilitation, applying soil at a uniform depth of 200mm. Soil has not been allocated to areas that will not be rehabilitated at closure, such as the pit walls and associated geotechnical zones of instability. This inventory will be updated throughout the life of the mine to reconcile closure requirements with soil stockpiles.

The soil inventory balance suggests that WTS will not recover sufficient topsoil in order to meet the rehabilitation soil target of 200 mm across the site. The prioritisation of topsoil use will need to be addressed as part of the revegetation plans.

Table 11: Soil balance for WTS

Deposit	Current (topsoil / subsoil) m^3	Predicted future recovery* (topsoil / subsoil) m^3
S10		
Body, Head, Crown Tail	121,000 / 59,000	194,600 / 584,000
SE 10 West BK 01 & 02		459,000 / 138,000
SE10 East MM 101 & 201		569,000 / 171,000
SE10 West MM 01		498,000 / 149,000
B1		
Main (5-12) & B1 Satellite (1-4)	396,000 / 44,000	935,000 / 253,000
B1 East BK 01 & 02		432,000 / 130,000
B1 West BK 01		150,000 / 45,000
B1 East MM 01 & 02		444,000 / 133,000
B1 Det Area 7 & 10		38,000 / 11,000
S17		
Pit 1-8		641,000 / 192,000
Estimate soil recovery		**3,800,000 m^3 top soil and 980,000 m^3 subsoil**
Estimated soil requirement for rehabilitation		**4,200,000 m^3**

* Based on recovery performance at S10 and B1.

13.3 Mineral waste characterisation

13.3.1 Physical characteristics

A description of mineral waste types expected to be encountered at WTS is provided in Table 12. The mineral waste materials include

- three geological members from the Brockman Iron Formation: Dales Gorge, Whaleback Shale and Joffre;
- all three members of the Marra Mamba Iron Formation: Nammuldi, MacLeod and Mount Newman; and
- other geological units including the Mount Sylvia Formation, Wittenoom Formation and Mount McRae Shale as well as generic hydrated iron materials, detrital materials, calcrete and dolerite.

Erodibility results assessed using a combination of site-specific geophysical test work and extrapolation from equivalent material at similar sites are summarised at Table 12. For example, physical testing of the detrital materials suggest the material has high erodibility i.e. it is unsuitable for placement in large volumes on the outer surface of waste dumps, unless very conservative waste dump design parameters are used.

The waste dumps, however, will be a combination of different geological units, depending on the inherent geological composition of the deposit and the sequence by which the waste material is removed. Table 13 lists WTS deposit types by erodibility class volume. This breakdown shows that a high proportion of the mineral waste at S10 Marra Mamba and B1 deposits will be highly erodible; while the majority of the waste material at the S10 Brockman and S17 deposits will have low erodibility.

Table 12: Mineral waste material descriptions

	Waste material type	Description	Erodibility
Marra Mamba Iron Formation	Nammuldi Member	Alternating yellow to yellow / brown chert and brown to black iron-formation mesobands	Low
	MacLeod Member	Integrated thin shale, chert and banded iron formation (BIF). The contact between the Nammuldi and MacLeod members is marked by a padded chert layer	Low
	Mount Newman Member	Dominated by BIF with thin shale intervals	Low
Brockman Iron Formation	Dales Gorge Member	Alternating sequences of BIF and argillite macrobands	Low
	Hydrated	Dales Gorge Member with high silica content	Low
	Whaleback shale Member	Interlayered chert and shale with 2 layers of BIF near the base	Medium
	Joffre Member	BIF with minor thin shale horizons	Low
Wittenoom Formation	West Angela Member	dolomite and dolomite argillite, with the later containing pyrite	High
	Paraburdoo Member	thin to thick bedded dolomite with some chert and argillite	High
	Bee Gorge Member	thinly laminated graphitic argillite along with subordinate thicknesses of carbonate, chert, volcaniclastic rock and iron formation	High
	Mount Sylvia Formation*	Shale, dolomitic shale and three prominent BIFs	Medium
	Mount McRae Shale*	Interlayered shale, dolomitic shale, chert and minor BIF	Medium
	Footwall zone	the upper unit of the Mount McRae Shale strand	Low
	Detritals	Secondary surficial ironstone, including include canga, limonite or unbedded goethite, pisolite	High
	Calcrete	Calcium-rich hardened material	Low
	Dolerite	Extremely hard volcanic rock	Low

*Potential geochemical hazard. Site specific test work is required to verify potential and define geochemical risk. For example, only unoxidised Mount McRae Shale is potentially acid forming.

Table 13: Approximate mineral waste erodibility characteristics by volume.

Deposit types	Erodibility (Mt)		
	Hard (Low)	Medium	Soft (High)
S10 Brockman deposits (Body, Head, Crown Tail, West BK 01 & 02)	86	25	25
S10 Marra Mamba deposits (SE 10 East MM 101 & 201, West MM 01)	36	0	25
B1 Brockman deposits (Main (5-12) & B1 Satellite (1-4))	77	32	41
S17 Pit 1-8	45	6	9

13.3.2 Geochemical characteristics

Hamersley has implemented an extensive program of geochemical testing, over several years, to understand the potential for acidification and / or metal enrichment to occur as a result of the various waste types common to mining operations in the Pilbara. Mineral waste that has been identified as posing a geochemical hazard is demarcated in Table 12.

Review of the geochemical properties of the WTS geology, including static (acid base accounting) and, if appropriate, kinetic testing of materials, has identified that the most significant geochemical risk at WTS is associated with sulfides, such as pyrite (FeS_2), which can form sulphuric acid when exposed to oxygen and water. Potentially acid forming (PAF) sulfides are present at WTS in the Mount McRae Shale and Mount Silvia Formation.

Sulfide bearing black shale within the Mount McRae Shale poses the greatest geochemical risk and is the only mineral waste type to regularly return sulfur values >0.3%. Materials with sufficiently high sulphur and organic carbon have the potential to spontaneously combust when exposed during mining. Sampling has

shown that the Mount McRae Shale within the B1 area, however, has relatively lower sulfur values than otherwise similar Mount McRae Shale samples collected from the S10 and S17 areas.

Pyrite can also occur in Banded Iron Formations. Other sulfate minerals present at the site, such as alunite and jarosite, in isolation may also pose a geochemical risk. However, these materials usually occur as isolated pockets and the surrounding rock containing sufficient neutralising capacity to limit any acid forming processes. As a result, at WTS the geology models indicate that this material can be treated as inert waste material.

Testing of calcrete (calcite) and dolomite (associated with the Wittenoom Formation) was found to have measured acid neutralisation capacity over 100 kg H2SO4/t, of which 60% of the neutralising capacity was readily available.

Some mineral waste materials also contain elements that pose a risk to ecosystem function and are enriched above mean crustal abundance and / or may be leached into the groundwater system under select water conditions. Across the deposits, mineral waste characteristics include:

- enriched (above mean crustal abundance) elements: Ag, As, B, Bi, Ca, Cd, Hg, Mo, N, Pb, S, Sb, Se, U and Zn;
- soluble elements Al, As, Cd, Co, Cr, Ni, Fe, Se, SO4, Zn and U;
- trace elements readily detectable in leachates included As, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Se, Sr, Th, U, V and Zn;
  - mild acid leaches (pH 2.4 to 4.6) resulted in elevated concentrations of Al, Fe, K, Si, Cr, Co, Ni, Mn and Zn compared to DI water leach tests (pH 6.1 to 9);
  - Mo and Se which were more readily leachable in the DI water leach tests (pH 6.1 to 9); and
  - Ag, As, Ba, Cu and Sr were present in higher concentrations in saline leaches.

Although PAF materials can be found within the geology surrounding all of the WTS deposits, the mine plan aims to avoid exposure of PAF materials within the S10 and B1 mine areas.

At WTS, the waste segregation process for material with potential geochemical issues uses sulfur content as an indicator of acid generation potential. Samples are collected from the network of drill holes surrounding and within the ore body, to enable geochemical characteristics to be applied to the geological block model and transferred into subsequent mining models.

The blocks are subsequently assigned to one of five categories, as described in Table 14, commensurate to the geochemical risk when considered as a bulk unit. This ensures materials with potential geochemical issues are identified prior to mining and managed as part of the mine planning process.

Geochemical risks are primarily associated with Category 2 and Category 3 materials. Category 2 materials (formerly referred to as ‘cold black shale’) are considered to have acid forming potential, while Category 3 materials (formerly referred to as ‘hot black shale’) have acid forming potential and a spontaneous combustion risk. Category 1 materials may contain sulphur but are considered to be non-acid forming (non-acid producing in bulk).

Table 15 provides an estimate of the total volume of waste segregated by geochemical material classes, based on the current pit design and geological models.

Table 14: Geochemical material categories.

Category	Description
0	All oxidised waste other than Mount McRae Shale and Whaleback Shale Member. No potential acid forming potential.
1	Oxidised Mount McRae Shale and oxidised Whaleback Shale Member. No acid forming potential.
2	Non-reactive black shale and sulfidic detritals and BIF (lower sulfur and / or lower organic carbon content)
3	Reactive black shale and lignite (high sulfur and organic carbon content)
4	Neutralising material. No potential acid forming potential.

Table 15: Geochemical material volumes by deposit.

Deposit	Category					Comment
	0	1	2	3	4	
S10 Body, Head, Crown Tail	109 Mt	16 Mt	none	none	2670 Mt	Pit designed to avoid Cat 2/3 materials
SE 10 West BK 01 & 02	2	1 Mt	none	none	74 Mt	No Cat 2/3 present
SE 10 East MM 101 & 201	49 Mt	none	none	none	none	No Cat 2/3 present
SE 10 West MM 01	70 Mt	none	none	none	none	No Cat 2/3 present
B1 Main (5-12) & B1 Satellite (1-4)	151 Mt	none	none	none	none	Pit designed to avoid Cat 2/3 materials
S17 Pit 1-8	56 Mt	6 Mt	1 Mt	<1 Mt	none	PAF anticipated on lower benches only

Note, the volumes and pit designs will be reviewed and refined throughout the mine life, when additional geological information becomes available.

13.3.3 Fibrous minerals

Naturally occurring silicate minerals can have fibrous habits. Fibrous minerals pose a risk when fibres of a respirable size become airborne and are inhaled. Respirable fibres are defined as being less than 3 microns wide, more than 5 microns in length and with a width to length ratio of greater than 3:1.

In the WTS region, the most commonly identified silicate minerals are the non-fibrous (massive) riebeckite and the asbestiform mineral crocidolite. Riebeckite is an indicator to the likely presence of crocidolite. Both minerals are usually associated with fresh, unweathered BIF.

Crocidolite has been encountered in regional drilling programs outside of the ore bodies, as well as some being identified on the surface within alluvium / colluvium associated with creek and natural drainage lines. To date, however, no fibrous minerals have been excavated at WTS, and are not expected to be excavated based on the current geological and mining models.

If fibrous materials should be encountered, management of the material will be guided by the Rio Tinto Iron Ore (WA) Fibrous Minerals Management Plan. This management plan requires risk assessments to be undertaken prior to entering or disturbing areas with potential fibrous risk, to ensure appropriate personal protection equipment is worn, and intersected / identified fibrous mineral waste to be encapsulated in 2 m thickness of non-fibrous mineral waste, in a location where the material will not be disturbed on closure.

13.4 Other potential contamination

Hamersley maintains a register of potentially contaminated sites for the WTS project. Areas identified, predominately include hydrocarbon storage or handling facilities. No locations have currently triggered reporting thresholds under the *Contaminated Sites Act 2003.*

Site closure will undoubtedly involve a change in land use, as such; the significance of any site contamination may change. A contaminated sites assessment will therefore be undertaken prior to closure, and specific plans developed, as part of the decommissioning process, to remove or manage contamination where appropriate.

The primary sources of contamination at WTS that may require management at closure include:

- localised hydrocarbon spills;
- putrescible materials at landfill sites; and
- sewage irrigation area.

14 Biodiversity

14.1 Flora and fauna

Surveys undertaken at WTS and the surrounding environment, prior to and during mining, include (as captured in Appendix B Closure knowledge database):

- terrestrial vegetation and flora;
- terrestrial and subterranean fauna (including Short-Range Endemic (SRE) invertebrates, troglofauna and stygofauna);
- riparian vegetation and flora; and
- aquatic fauna.

Table 16 and Table 17 list the significant fauna and flora (respectively) that were identified within the WTS mine lease prior to disturbance activities and their habitat relationships. (Note, subterranean fauna are not considered to constitute significant fauna due to the low population densities and limited species diversity.)

WTS is not expected to impact the conservation status of any flora or fauna species, populations or fauna habitat. This includes changes to abundance, species diversity, geographic distribution and / or productivity of flora at species or ecosystem levels.

Similarly no conservation significant habitats were identified that are analogous to any known Threatened Ecological Community (TEC), as an Environmentally Sensitive Area (ESA) or as a Priority Ecological Community (PEC).

As WTS will not impact the conservation significance of any species, ecosystem restoration activities and reintroduction of fauna are not planned as part of the rehabilitation activities at WTS.

Table 16: Significant fauna and its relationship to habitat across WTS mine lease.

Fauna species	Conservation status WA	EPBC Act status	Habitat occurrence	Comments
Rhinonicteris aurantia (Pilbara orange leaf-nosed bat)	Schedule 1	Vulnerable	Gullies Hilltop	Caves near water provide suitable roosts.
Liasis olivaceus barroni (olive python)	Schedule 1	Vulnerable	All hill habitats	Widespread in rocky areas, showing a preference for rocky habitats near water, particularly rock pools
Notoscincus butleri (lined soil-crevice skink)	Priority 4	-	Plains	Habitat for this species is spinifex dominated areas adjacent to riparian habitats
Pseudomys chapmani (western pebblemound mouse)	Priority 4	-	All hill habitats	Habitat for this species is rocky, hummock grasslands, with little or no soil. The western pebble-mound mouse occupies burrows beneath mounds of pebbles. Mounds are most common on the spurs and lower slopes of ridges
Macroderma gigas (ghost bat)	Priority 4	-	Gullies Hilltop	A single call of the Ghost Bat and the Orange Leaf-nosed Bat was detected, these calls indicate transient individuals and not the presence of roosting colonies. Roost in caves, rock piles and abandoned mines. Will travel 2 km from roost to hunt.
Ardeotis australis (Australian bustard)	Priority 4	-	Plains	Habitat preferred by this species lightly wooded country next to daytime shelter of thickets or long grass.
Leiopotherapon aheneus (Fortescue grunter)	Priority 4	-	Waterways	Found in freshwater streams and pools

Fauna species	Conservation status WA	EPBC Act status	Habitat occurrence	Comments
Hemicordulia koomina (Pilbara emerald dragonfly)	Priority 4	-	Waterways	Found around freshwater streams and pools
Eurysticta coolawanyah (Pilbara pin damselfly)	Priority 4	-	Waterways	Found around freshwater streams and pools
Merops ornatus (rainbow bee eater)		Migratory	All valley habitats	Found within open forests, woodlands and shrublands, and cleared areas. Open pit walls may be utilised to build nesting tunnels

Table 17: Significant flora and its relationship to habitat across the WTS mine lease.

Flora taxon	Conservation status WA	Habitat relationship
Grevillea saxicola	Priority 1	Breakaways and scree slopes, orange-brown loam soils
Hibiscus sp. Mt Brockman (E. Thoma ET 1354)	Priority 1	Upper scree slopes and crests
Sida sp. Hamersley Range (K. Newbey 10692)	Priority 1	Skeletal stony soils; rocky hills, breakaways
Pentalepis trichodesmoides subsp. *hispida*	Priority 2	Hummock grasslands
Spartothamnella puberula	Priority 2	Rocky loam, sandy or skeletal soils on hills or sandplains
Dampiera anonyma	Priority 3	Skeletal soil over banded ironstone. Hill summits, slopes (above 1000 m)
Eremophila magnifica subsp. *velutina*	Priority 3	Skeletal soils over ironstone on summits and breakaways
Goodenia sp. East Pilbara (A.A Mitchell PRP 727)	Priority 3	Red brown clay soil, calcrete pebbles. Low undulating plain, swampy plains
Gymnanthera cunninghamii	Priority 3	Sandy soils
Indigofera sp. Bungaroo Creek (S. van Leeuwen 4301)	Priority 3	Creeks and drainage lines
Nicotiana umbratica	Priority 3	Shallow soils. Rocky outcrops.
Ptilotus subspinescens	Priority 3	Gentle rocky scree slopes and bases; calcrete
Rostellularia adscendens var.*latifolia*	Priority 3	Creeks, rocky hills
Sida sp. Barlee Range (S. van Leeuwen 1642)	Priority 3	Skeletal red soils pockets. Steep slope.
Solanum kentrocaule	Priority 3	Hillsides, mountaintops and occasionally creek beds in skeletal red-brown soils over ironstone or on basalt at elevations between 700 -1250 m
Acacia bromilowiana	Priority 4	Skeletal loam soils on rocky hills, breakaways, scree slopes, gorges and creek beds
Eremophila magnifica subsp. *magnifica*	Priority 4	Rocky hillslopes, breakaways
Goodenia nuda	Priority 4	Wide alluvial plain or creek beds. Red brown clay loam, ironstone.
Ptilotus mollis	Priority 4	Stony hills

14.2 Terrestrial habitat

A habitat is made up of physical factors such as soil, moisture, range of temperature, shelter and availability of light as well as biotic factors such as vegetation, availability of food and the presence of predators. Habitats provide a simple method of dividing the land into areas with common characteristics.

On closure, the land will be returned to self-sustaining ecosystems using native species of local provenance. The physical factors associated with the closure landform provide a starting point to identify which habitat units could best be reinstated across the mine area, given the changes to the land resulting from mining activities, in order to establish native self-sustaining ecosystems.

Flora, fauna and vegetation survey (baseline) data has been used to understand and group the area's pre-mining biodiversity / ecosystem values into four broad habitat units. These habitat units, described in Table 18, include:

- Hill habitats units
  - hill top, slopes and gullies (gullies have been grouped with hill slopes habitats due to their low occurrence at WTS).
- Valley habitats units
  - plains
- Drainage habitats units
  - drainage lines, e.g. minor creeks
  - creeks, i.e. major unnamed and named creeks

Table 18: Pre-mining habitats across WTS.

Habitat name	Basic description
Hill habitats	
Hill	 Hills, ridges, plateaux remnants, gorges and breakaways of varied geological origin. Soil is generally skeletal sandy clay loams with greater than 80% stony detrital material. Under natural conditions this habitat zone is characterised by a scattered overstorey of Snappy gum *Eucalyptus leucophloia*, *Eucalyptus gamophylla* and/or *Acacia aneura* over *Acacia* spp. scattered shrubs over hummock grassland. Rocky, sheltered ridges and breakaways provide a suite of specialist plants or species more typical of lowlands. Pre-mining surveys indicate: • the average number (density) of plants is 29,000 plants per hectare; with • an average of 44% perennial cover. This habitat creates a diverse array of microhabitats and refugia. The habitat often contains rock shelters in the form of overhangs, cracks, crevices, caves and areas for water to pool during the wet season. Vegetation provides microhabitats in the form of logs, debris and hollows. This habitat zone will be present in undisturbed areas of the mine and may evolve around the edge of the disturbed mine area especially where the pit shell intersects local hills after erosion processes occur. However this habitat type will not be restored or rehabilitated as part of the closure plan.

Habitat name	Basic description
Valley habitats	
Plains	 Low and occasionally slightly undulating alluvial plains including outwash areas and broad drainage basins. Under natural conditions soils often consisting of sandy loam soils covered by rocky lag gravel. This habitat can be differentiated from hill slope habitats by the increased soil depth at WTS. The habitat is characterised by a high scrubland to low woodland of mixed Acacias over open hummock grassland and / or tussock grassland. Pre-mining surveys indicate: • the average number (density) of plants is 10,000 plants per hectare; with • an average of 45% perennial cover. This habitat type contains limited microhabitats with the dominant Acacia species providing no tree hollows, few logs, limited leaf litter and sparse vegetation. This habitat zone will be present in undisturbed areas of the lease. Characteristics of this habitat may be considered where there is the opportunity for deep soils to develop, i.e. on waste dumps.
Drainage habitats	
Drainage line	 A linear habitat that begins at the top of hills and runs to the surrounding plains, or encompasses small tributaries that eventually flow into larger river and major drainage habitat types. Vegetation composition is usually similar to the neighbouring habitat but with increase vigour and density due to sustained, elevated soil moisture following rainfall events. The drainage line habitats acts as wildlife corridor that help flora and some fauna disperse across the landscape. There is a moderate diversity of microhabitats with some logs, debris, occasional tree hollows and isolated pods of soft soils. Surface water is more likely to persist in this habitat after it has evaporated elsewhere, providing a refuge for fauna. This habitat zone will be present in undisturbed areas outside of the mine. It is likely that rehabilitation of some disturbed drainage line habitat will be required coincident with, or as part of, local drainage controls. It is possible that drainage line habitat could be introduced coincident to surface water runoff controls in the closure landform.

Habitat name	Basic description
Creek	 A linear habitat characterised by regular surface water flows, defined banks and associated riparian vegetation corridor. The creek habitat includes areas that are periodically flooded due to high surface water flow volumes (floodplains). Vegetation is characterised by a mixture of Eucalypt woodlands, Acacia shrublands and hummock grasslands, including riverine fringing vegetation of grasslands and herbs, including the presence of weed species such as **Cenchrus ciliaris*. Creek habitats act as wildlife corridors that help flora and fauna disperse across the landscape. There is a high diversity of microhabitats including logs, debris, tree hollows and soft soils, as well as temporary and permanent pools. This habitat zone will be present in undisturbed areas outside of the mine. Disturbed creek habitat, ie access roads and discharge related infrastructure, will be rehabilitated to return the land to functional creek habitat.

If only a low level of land disturbance has occurred, the land can usually be returned to the pre-mining habitat or closest equivalent from the surrounding area. For example, a laydown area built up with inert mineral waste over a former hill habitat area may be revegetated to a plains habitat as the land is now flat and is more likely to evolve a soil profile similar to the plains habitat units.

However, some mine related activities, such as the termination or modification of drainage flow paths and the introduction of new topographical features (waste dumps, mine voids etc.), can substantially change the physical habitat characteristics of the land. In these situations, it may be necessary to introduce alternate habitat types. These alternative habitats, listed in Table 19, aim to mimic habitats from the regional area, but which may not have been present in the immediate area prior to mining. Alternate habitats that may need to be introduced to the WTS area include pit lakes and terminal basin habitats.

Through the act of mining, there will also be areas associated with the pit development that cannot be rehabilitated due to safety and access issues. This usually includes the pit high walls and benches, and areas above the high wall where access is cut off as ore is mined. These areas are demarcated as cleared habitat units. Usually these areas have little to no soil cover, and are subject to erosion over time. Consequently, cleared habitat is always located within the geotechnical zone of instability.

Table 19: Habitats that may be introduced to WTS post-closure.

Other habitat	Basic description
Pit lake	 A water body created through the process of mining below the water table.

Other habitat	Basic description
	No effort will be made to establish an aquatic ecosystem. This habitat may attract fauna and is susceptible to weeds. Water quality may vary over time, and could become unpalatable or hazardous over time. Water quality will be within acceptable parameters. This habitat zone will be introduced in controlled locations, where the environmental impact is acceptable.
Terminal basin	 Land that due to its shape captures and holds surface water runoff. The landform shape facilities the settling of silts and sediments, often creating a clay pan or hard pan over time. Vegetation communities are designed to accommodate periodic, sustained flooding as well as periods of drought. As few vegetation species are capable of withstanding the extreme conditions, species diversity within and coverage across the habitat may be low. This habitat type can contain limited opportunity for fauna re-colonisation if the ground becomes a hard pan, preventing trees from establishing and thereby limiting log and leaf litter generation. This habitat zone will be introduced in constructed low lying topography within backfilled pit landforms, as part of the surface water management design. The terminal basin areas will capture and contain rainfall within the former pit areas, to minimise runoff and subsequent erosion across the backfilled landform.
Cleared	 Areas where vegetation and soil has been removed from the area, for the purpose of mining and related activities, and no effort will be made to establish vegetation or stabilise the landform. This habitat type is expected to have limited opportunity for fauna re-colonisation due to the lack of vegetation, substrate or shelter. This habitat zone will be present within highly disturbed areas without substrate suitable for plant growth, such as pit benches, pit floors, and areas of the mine that cannot be safely accessed.

The biodiversity significance of a habitat can be measured in terms of the range of habitat types, habitat coverage or with respect to the diversity or rarity of species within the individual habitats. Similarly, the consequence of mining may be strategically assessed through an understanding of the relative magnitude of habitat loss, linkage between habitats and / or the anticipated changes as a consequence on introducing of new habitat.

Of the habitat types identified at WTS, gully and creek habitats are of high value due to the diversity of microhabitats and potential to support conservation significant fauna species. Drainage line habitat is considered to have moderate habitat value due to the number of fauna that may utilise the area, while plain and hill crests / ridges have low value. All of these habitat types will be disturbed by mining activities; however, all of these habitat types are expected to be present in the environment, immediately outside the disturbance areas, on closure.

Cleared habitats provide little food, shelter, water or any other life essentials. As a consequence cleared habitat, land that will not be rehabilitated after mining, is considered to have little to no habitat value.

14.2.1 Reference sites

In 2013, six reference vegetation monitoring transects were established at WTS. Transects were established on the dominant plains and hill habitats. The key characteristics of the habitats are presented in Figure 8.

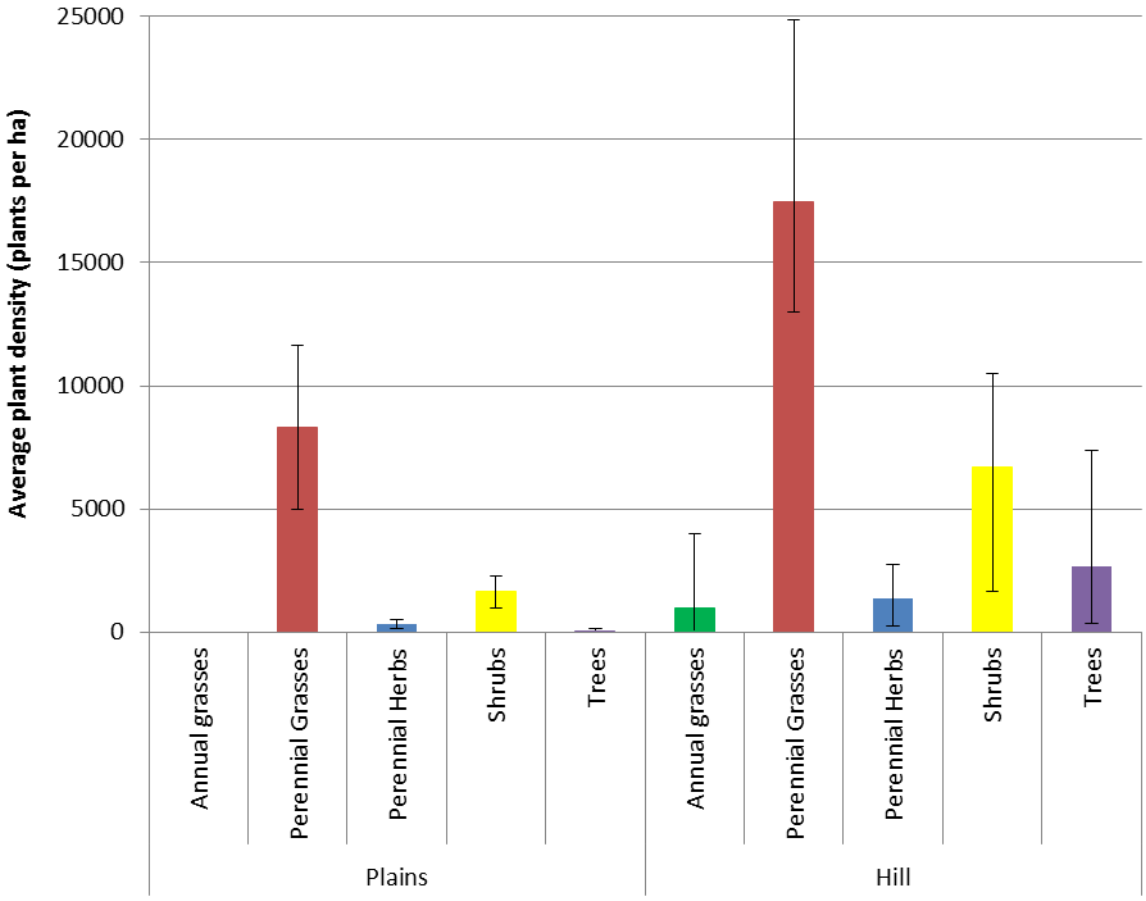


Figure 8: Average plant density (number plants/ha) on plains and hill habitat types.

Plains habitat was dominated by perennial grasses, with an average number (**density**) of plants around 10,000 plants per hectare. The hill habitat transects was also dominated by perennial grasses; however it also contains a higher abundance of shrubs, perennial herbs and trees than the plain habitat. The density of plants in the hill top habitat was around 29,000 plants per hectare, three times that of the plains habitat. It was also observed that plant cover was relatively uniform between the two habitats, with perennial cover estimated at around 45%.

Consequently, plains and hilltop habitats are differentiated by the density of plants per hectare, but show similar composition and perennial cover, e.g. many small plants in the hill top areas, and fewer larger plants in the plains habitat.

14.3 Weeds

A total of 18 introduced flora species (weeds) were recorded in the WTS area prior to disturbance (Table 19). None of these species are listed as Declared Plants for the Pilbara region under the *Agriculture and Related Resources Protection Act 1976*.

Across the 12,500 ha development envelope, prior to implementation of the WTS project, over 1150 weed occurrences were observed, approximately 10.9 weed occurrences/ha. The most common weeds were *Argemone ochroleuca subsp. Ochroleuca* (Mexican Poppy), *Bidens bipinnata (*Bipinnate Beggartick), *Cenchrus ciliaris* (Buffel grass), *Flaveria trinervia* (Speedy Weed) and *Malvastrum americanum* (Spiked Malvastrum).

Table 20: Weeds identified within the project envelope

Scientific Name	Common Name	Priority Classification
Acetosa vesicaria	Ruby Dock	Moderate
Melochia pyramidata		Moderate
Argemone ochroleuca subsp. Ochroleuca	Mexican Poppy	Low
Bidens bipinnata	Bipinnate Beggartick	Low
Cenchrus ciliaris	Buffel grass	Low
Cenchrus setiger	Birdwood Grass	Low
Cucumis melo subsp. Agrestis	Ulcardo Melon	Low
Datura leichhardtii	Native Thornapple	Low
Echinochloa colona	Awnless Barnyard Grass	Low
Flaveria trinervia	Speedy Weed	Low
Setaria verticillata	Whorled Pigeon grass	Low
Sigesbeckia orientalis	Indian Weed	Low
Sisymbrium orientale	Indian Hedge Mustard	Low
Solanum nigrum	Black Berry Nightshade	Low
Vachellia farnesiana	Mimosa Bush	Low
Euphorbia hirta	Asthma Plant	Negligible
Malvastrum americanum	Spiked Malvastrum	Negligible
Sonchus oleraceus	Common Sowthistle	Negligible

CLOSURE RELATED DATA AND ANALYSIS

15 Landform design

15.1 Mineral waste management

15.1.1 Inert mineral waste

The majority of the WTS mineral waste is expected to be inert.

It is recognised that in pit disposal of mineral waste will reduce mine disturbance and will result in improved environmental outcomes on closure. However, due to the mining sequence required for optimal ore quality recovery, it is not possible to mine out single pits then backfill the pits with the mineral waste from the next pit to be developed. In addition, many of the pits, at the end of the projected mine life, may still contain iron ore classified as low grade. This low grade ore, although uneconomic in the current market, may be a commodity in the future. To prevent the sterilisation of the ore and maximise value from the deposit, the majority of the mineral waste will be placed in waste dumps external to the mine voids (illustrated in Figure 10 and listed in Table 21) during the mine life.

Opportunities to dispose of mineral waste directly into neighbouring pit will be reviewed throughout the life on the mine. Some opportunities for in pit mineral waste disposal have been identified at:

- S10 Tail pit (Figure 9)
- SE10 East MM (from Pit 201-hill into Pit 101-creek); and
- SE10 West MM 01 pit.

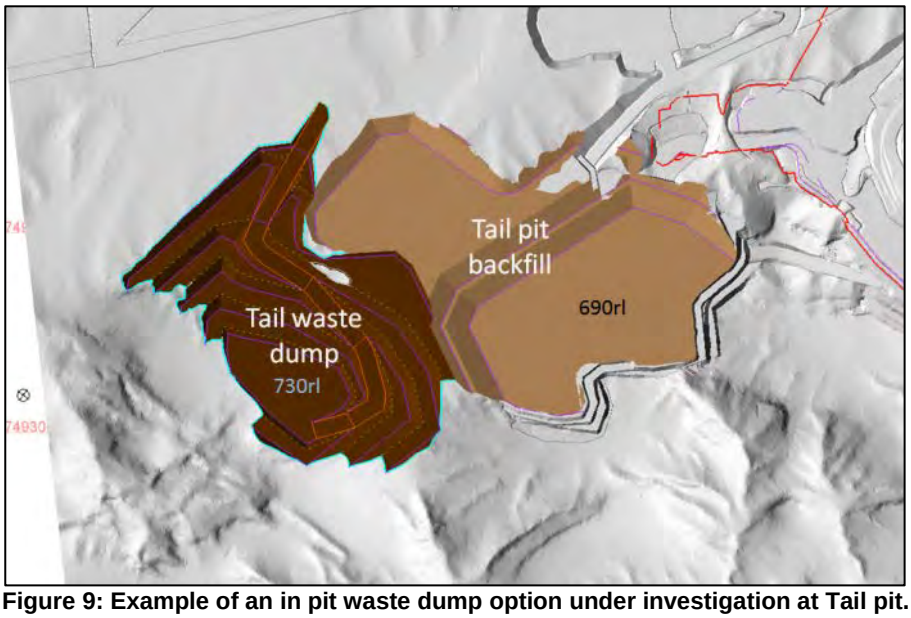


Figure 9: Example of an in pit waste dump option under investigation at Tail pit.

At the end of the mine life, the inert mineral waste dumps will provide a source of material for backfilling the pits to suppress the groundwater table, to cover or encapsulate exposures of PAF materials and will be used in the construction of abandonment bunds and water control structures.

Confirmation of the in pit disposal volumes and review of the environmental (landform and water condition) outcomes will be undertaken as the deposits are developed.

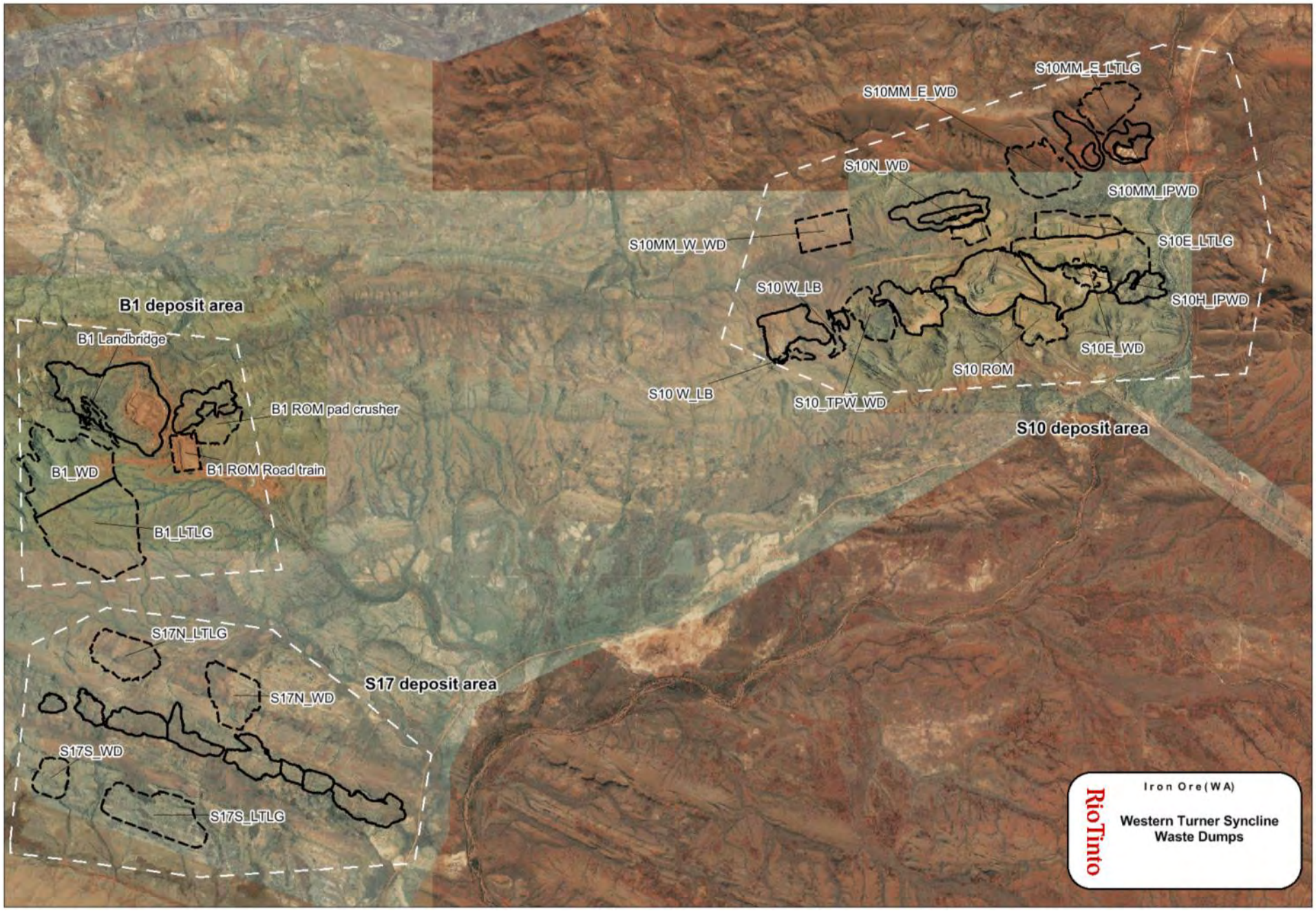


Figure 10: Waste dump locations are illustrated in dashed black lines. Pit outlines are shown in solid black lines. Please refer to Table 21 for waste dump naming conventions.

15.1.2 Geochemical mineral waste

Category 2 and Category 3 geochemical mineral waste requires management to limit water contact, for the long term minimisation and, where possible, prevention of acid and / or metalliferous drainage (**AMD**). Based on the current mine plan, mineral waste classified as Category 2 or 3 will only be excavated from the S17 deposit area.

Materials in geochemical Categories 2 and 3 will not to be used or encapsulated in earthworks, e.g. in windrows, construction fill, ramps, fantails, roads etc., and will only be stored in mineral waste dumps or as pit backfill (where the entire pit floor is uniformly covered). There is a preference for this material to be encapsulated in areas where PAF materials are already present, e.g. in pits or waste dumps already containing Category 2 / 3 geochemical waste materials, in order to minimise the long-term monitoring requirements.

Other selection and design criteria considered include:

- Avoiding areas that receive runoff from surrounding areas, which could increase infiltration into the waste dump (producing larger volumes acid).
- Avoiding locations where AMD leakage (if produced) could interact with the environment:
  - prioritising in-pit encapsulation opportunities before external; and
  - staying away from drainage lines and creeks; and
- If proposing to dispose of Category 2 or 3 geochemical waste material below the recovered water table, selecting locations where the groundwater table will recover quickly (naturally or through controlled water management / disposal) to minimise the potential for secondary salts to develop, which will later mobilise into the groundwater table.

All Category 2 and 3 geochemical mineral waste will be encapsulated within inert waste material, either within in-pit waste dumps or as part of a backfill sequence, in accordance with the following procedure:

- Sufficient inert waste rock placed against land surfaces so that Category 2 and 3 material is not located within 5 metres of any pit wall, pit floor, hillside, original land surface or groundwater recovery level[5] as measured both vertically and horizontally. This buffer will provide a preferential pathway for surface water runoff from the surrounding catchment to flow through to the groundwater without contacting the Category 2 / 3 geochemical waste materials.
- Category 2 material is dumped in 10 metre-thick lifts. No inert waste rock layer is needed between lifts. Machinery compaction of lifts is undertaken prior to construction of the next lift, to reduce pore spaces / cavities in the waste and thereby reduce oxygen movement within the waste dump.
- Category 3 material (has potential to spontaneously combust) is dumped in 2.5 metre-thick lifts if encapsulated in a waste dump or 5 metres if encapsulated in backfill, then covered by a minimum 2 metre-thick lift of inert waste rock, in order to smother the material and prevent spontaneous combustion while on the stockpile. Each lift is constructed using paddock dumping techniques. Machinery compaction of lifts is undertaken prior to construction of the next lift.
- Where Category 2 or 3 materials are stored above the water table, a minimum 2 metre-thick top lift of inert waste rock followed by a minimum 4 metre-thick store and release cover will be engineered(refer to Section 15.3), to minimise the volume of infiltration through the material, limiting the potential mobilisation of acid and secondary salts.
- Where Category 2 or 3 materials are stored in a pit that extends below the groundwater table, the material will be located:
  - i) at least 5m below[6] the lowest predicted post-mining groundwater recovery level; or
  - ii) 5 meters above the highest predicted post-mining groundwater recovery level; such that no materials are present within ±5m of the potential groundwater table recovery level.
- A minimum 5 metre-thick top lift of inert or net neutralising waste rock will be installed if all Category 2 and 3 material is encapsulated below the groundwater recovery level, to ensure secondary salts are not carried to the surface via capillary action.

The current mine plan aims to encapsulate Category 2 and 3 geochemical waste materials mined from the S17 pits in backfill within the S17 above water table pits, nominally within Pit 1 and Pit 2.

[5] Groundwater recovery level refers to the predicted steady state groundwater elevation estimated as part of a groundwater recovery model and accounting for future climate, rainfall and groundwater conditions. Also see guidance for below groundwater table storage instructions.

[6] Category 2 or 3 material will only be stored within the water table when there is a short timeframe (<10 years) between mining of the PAF and recovery of the groundwater table above the PAF material (or other means of saturating the PAF material). The time limit aims to minimise the volume of secondary salts generated within the mineral waste which have the potential to mobilise into the groundwater table on groundwater recovery.

Where in situ Category 2 or 3 geochemical materials are present in the pit, e.g. exposed on the pit walls in S17, the exposures will be covered with mineral waste as soon as practicable, to reduce oxygen supply to the sulfides. This will reduce the volume of acid drainage produced.

When the groundwater table recovers to a level that submerges the in situ Category 2 or 3 geochemical materials, some release of secondary salts is expected. However, the rate of the geochemical reaction is predicted to reduce further once the materials are fully saturated. Consequently the volume of salts produced in associated with the pit wall exposures is expected to be minimal, transient and unlikely to have an impact on the regional groundwater system as a result of this backfill management strategy.

Monitoring of groundwater quality will be required to demonstrate that the management strategy has been successful.

15.2 Waste dump design

Waste dumps that will be rehabilitated at closure include those:

- located outside of the mine voids or have a direct connection to (abut) rehabilitated or undisturbed land;
- constructed for the purpose of providing landform stability; or that
- contain Category 2 or 3 geochemical mineral waste.

Table 21 summarises the waste dump design criteria that will be implemented to rehabilitate the waste dumps. The design criteria conform to the Rio Tinto Iron Ore (WA) Landform Design Guidelines, which outlines a process for developing waste dump designs to take into account:

- specific mineral wastes present in each dump;
- climatic conditions present at the site;
- location, including in pit disposal / backfill and surface water considerations;
- maximum dump height and footprint constraints;
- shape of waste dump, preferably to minimise surface area to volume ratio;
- shaping options for the top of the waste dump.

Siting of the waste dump also considers the estimated geotechnical zone of instability, to ensure waste dumps located external to the mine voids are not compromised by pit wall subsidence and / or collapse.

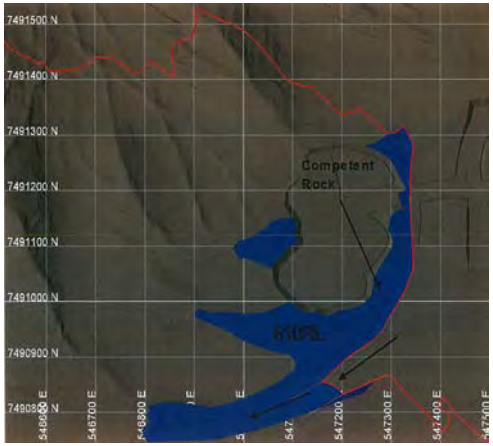
Slope angles that conform to the guidance are predicted to have an average erosion rate (averaged over the entire slope length) of <5 t/ha/y, together with a predicted maximum erosion rate at any point on the slope of <10 t/ha/y, such that rilling, and consequently gullying potential will be minimised. Erosion rates on the final landforms may differ from these values, due to variations in waste types, surface treatments, plant growth and drainage controls.

The final landform design is reviewed by a multi-disciplinary team and includes lift height, slope angle, minimum berm width and supplementary measures, i.e. selective material management, surface treatment and drainage management, for factors that cannot be resolved through landform shaping alone.

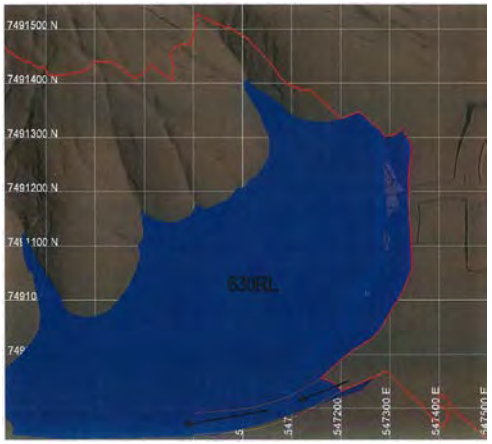
Table 21: Waste dump inventory and design information.

Waste dump		Predicted erodibility	Lift height (m)	Rehab berm width (m)	Batter slope angle (degrees)	Indicative max height (m)	Indicative elevation (m RL)	Comments
S10E_WD	SE10 Eastern waste dump	Low / hard	20	10	20	80	680	Selective material management required to place erodible material away from final face
S10E_LTLG	SE10 Eastern LTLG	Low / hard	n/r	n/r	n/r	80	680	Material merges with SE10 Eastern Waste Dump if still uneconomic by closure. Material may be removed before closure if change in ore grade occurs
S10N_WD	SE10 Northern waste dump	Low / hard	n/r	n/r	n/r	40	640	Remove waste dump (behind geotechnical instability zone) to develop S10 MM West pit. Remaining material to be used to construct closure structures i.e. abandonment bunds.
S10H_IPWD	SE10 Head BF	High / soft	5	15	20	70	670	In pit waste dump. May receive highly erodible material from SE10 MM East 101 pit. If waste dump extends above the lip of the void, waste dump design parameters for highly erodible material will be applied.
S10MM_E_LTLG	SE10MM East long term low grade	Low / hard	20	10	20	45	660	Minimal highly erodible material to be stored at this location. If required, highly erodible waste to be encapsulated in centre of dump. Includes long term low grade (sub-economic) ore stockpile.
S10MM_E_WD	SE10MM East waste dump	Low / hard	20	10	20	50	670	Minimal highly erodible material to be stored at this location. Highly erodible material from SE10 MM East 201 pit to be sent to SE10 MM East 101 pit / S10MM_IPWD. If required, highly erodible waste to be encapsulated in centre of dump.
S10MM_IPWD	S10MM 101 pit buttress	TBC	-	-	-	45	580	Buttress structure constructed from mineral waste inside SE10 MM East 101 pit. Material source to be confirmed. Will be constructed at closure.
S10MM_W_WD	SE10 West WD	Moderate	10	15	20	TBC	TBC	Waste dump positioned to facilitate future expansion opportunities. Height to be confirmed.
S10_TPW_WD	S10 Tail pit waste dump	Moderate	10	15	20	90	720	
S10_W_Landbridge	S10 West BK 02 landbridge	Moderate	10	15	20	70	805	Landbridge location and design to be confirmed.

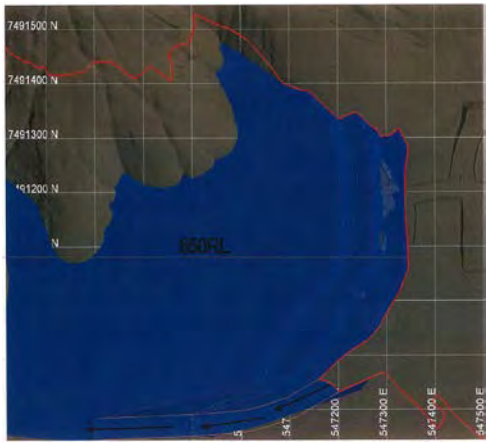
Waste dump		Predicted erodibility	Lift height (m)	Rehab berm width (m)	Batter slope angle (degrees)	Indicative max height (m)	Indicative elevation (m RL)	Comments
B1_WD	B1 waste dump	Moderate	20	10	20	150	750	Highly erodible waste to be encapsulated in centre of dump and against natural surface, to prevent material from being exposed on rehabilitation.
B1_LTLG	B1 long term waste dump	Moderate	20	10	20	60	650	Highly erodible waste to be encapsulated in centre of dump and against natural surface, to prevent material from being exposed on rehabilitation. Material may be removed before closure if change in ore grade occurs
S17N_LTLG	SE17 north long-term low grade	Low / hard	20	10	20	80	650	Low erodible material. Material may be removed before closure if change in ore grade occurs
S17S_LTLG	SE17 south long-term low grade	Low / hard	20	10	20	60	595	Low erodible material. Material may be removed before closure if change in ore grade occurs.
S17N_WD	SE17 north waste dump	Low / hard	20	10	20	105	670	Low erodible material
S17S_WD	SE17 south waste dump	Low / hard	20	10	20	45	590	Low erodible material



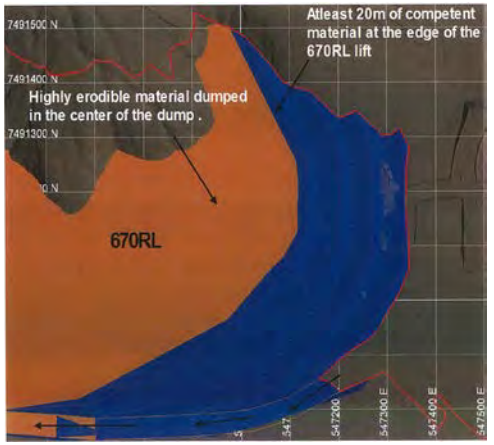
610RL development (~2015)



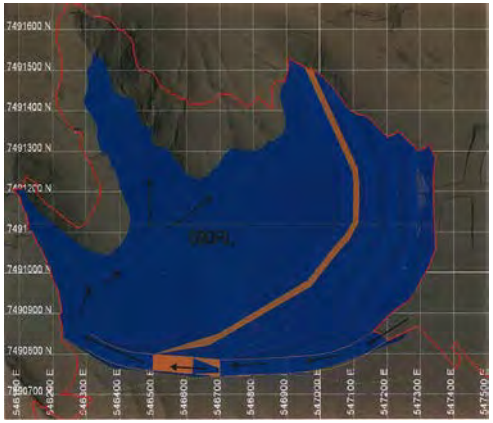
630 RL development (~2015)



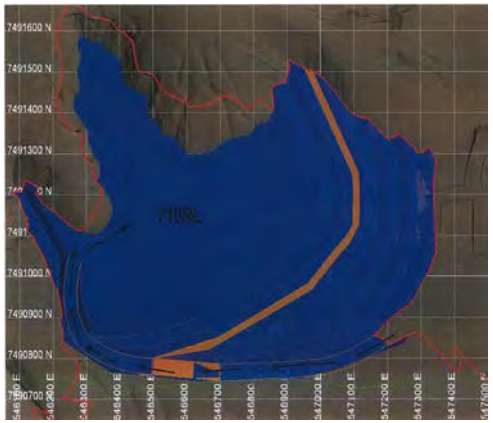
650 RL development (~2015)



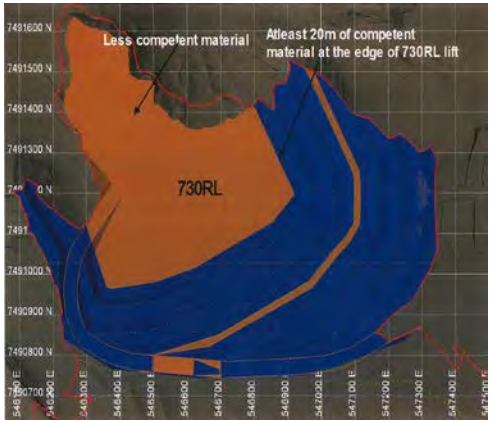
670 RL development (~2018-2019)



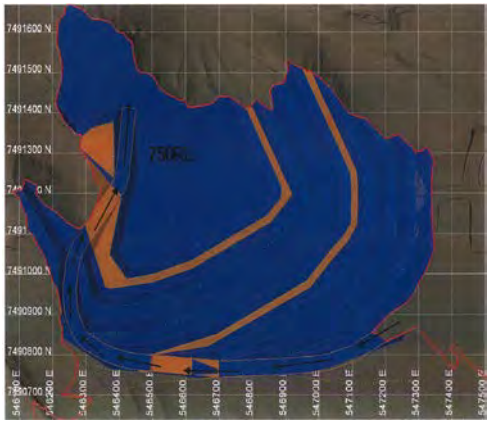
690 RL development (~2020-2021)



710 RL development (~2022)



730 RL development (~2023-2024)



750 RL development (~2025)

Figure 11: Planned waste dump progression at B1, illustrating encapsulation / waste segregation plan. Dark blue indicates competent material, orange is highly erodible material.

In the S10 MM and B1 areas where highly erodible material may be encountered, the highly erodible mineral waste will be selectively dumped; either in-pit (preference) or in locations, to ensure that the highly erodible waste will not present on the final face of the rehabilitated landform. This 'encapsulation'-style approach supersedes previous management approaches that relied on capping with competent waste at the end of the mine life to stabilise the waste dumps for rehabilitation.

Figure 11 illustrates how the highly erodible waste at B1 will be encapsulated. The majority of the highly erodible material is expected to present in the pit in 2018, 2019, 2023 and 2024. This material will be placed 20m back from the edge of the lift to enable competent material to be placed on the outer edge of the waste dump. When the waste dump is rehabilitated, all of the highly erodible material is encapsulated within the waste dump (Figure 12).

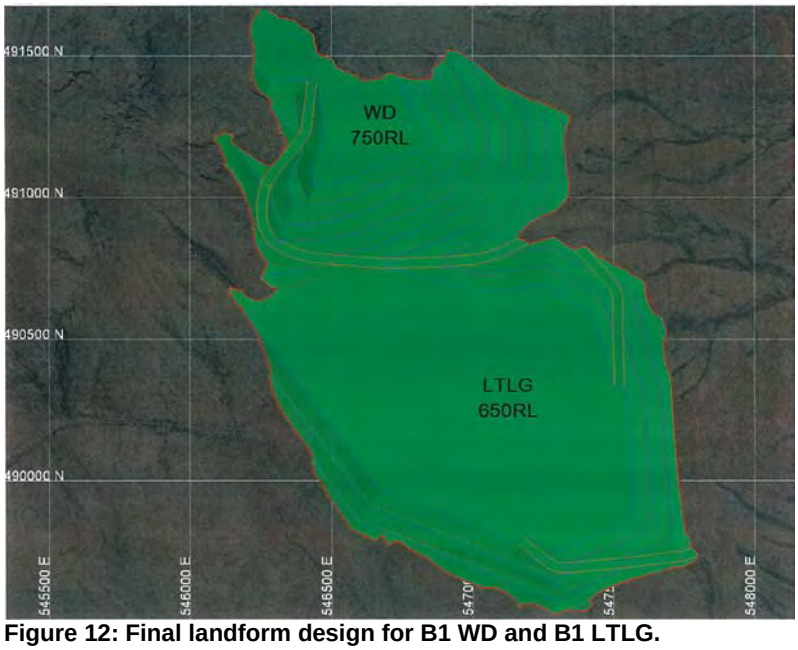


Figure 12: Final landform design for B1 WD and B1 LTLG.

Similar waste segregation is already underway at S10. As illustrated in Figure 13, as of 2014 mineral waste has been segregated into four different categories. Competent materials that may have some future economic benefit are shown in pink, yellow and blue. Mineral wastes with no potential economic benefit, including all of the highly erodible materials, are shown in brown.

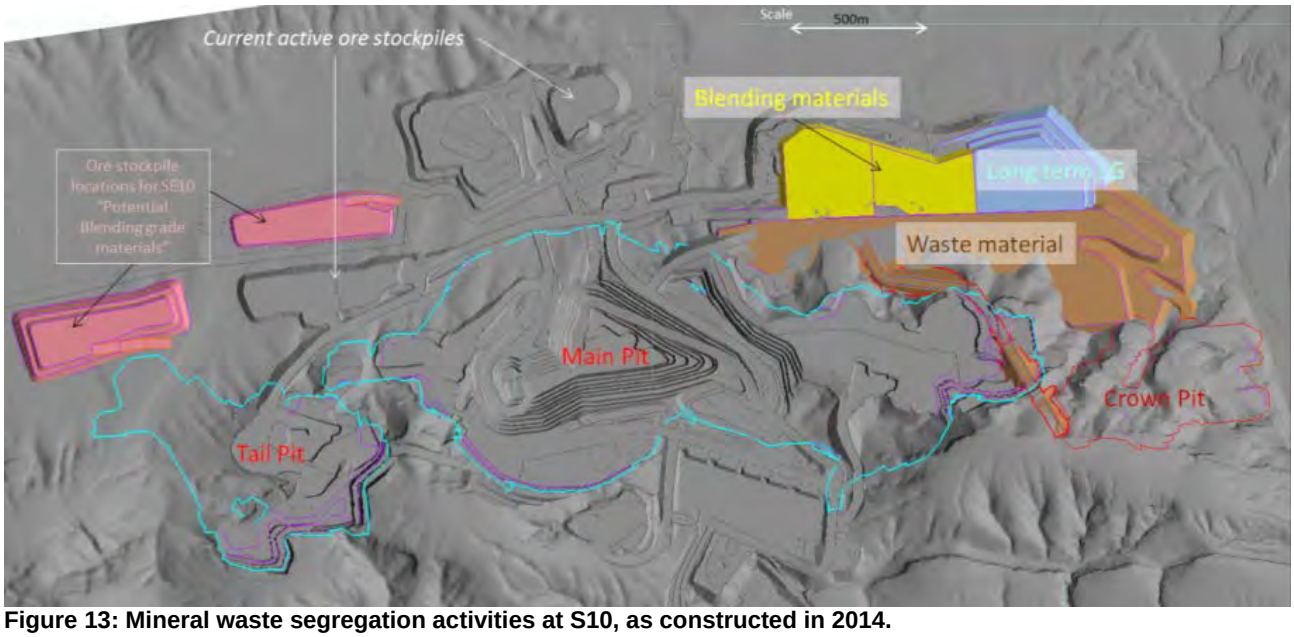


Figure 13: Mineral waste segregation activities at S10, as constructed in 2014.

The segregation ensures that materials with potential economic benefits are easily accessible in the future, while highly erodible, non-economic waste is placed against the natural topography. The current indicative closure landform design for S10 (Figure 17) assumes this material is not used in the mining process, and will

be rehabilitated in situ, used in the construction of abandonment bunds or utilized for backfill / buttress activities.

Across the WTS operation, when mineral waste is recovered from a waste dump for use in developing the closure landform, i.e. for in-pit backfill, the waste will be recovered from the upper most lifts only. An example of this concept is provided in Figure 14. This process will ensure that less component material encapsulated within the waste dump is not exposed on the batter slopes of the rehabilitated landform.

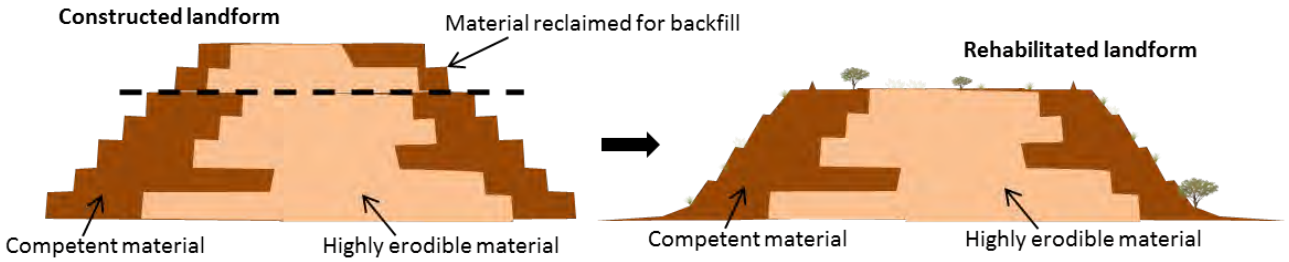


Figure 14: Reclamation of mineral waste for backfill use.

Waste dump criteria will be reviewed over time and reconciled against actual mineral waste characteristics presenting on the waste dumps.

Closure implementation requirements for each dump are highly variable and dependent of the level of construction difficulty. This includes battering to design slopes from angle of repose, capping where required, construction of appropriate grade on contour berms and top, construction of windrows and installation of drainage. Waste dump specific implementation plans will be developed prior to rehabilitation. No implementation plans have been developed to date.

15.3 Store and release covers

Store and release covers are designed to limit infiltration into the underlying waste rock by maximising the evapo-transpiration of incident rain water, and thereby minimise acid drainage production from Category 2 and 3 geochemical mineral wastes. The cover is designed to store water near the surface during the wet season so that the water can be removed from the cover material and returned to the atmosphere during the dry season by evaporation and plant transpiration. Covers will be implemented where Category 2 and 3 geochemical waste materials are encapsulated in S17 Pits 1 and 2.

Store and release covers are constructed from waste rock that contains sufficient fine-grained material to have high moisture retention capacity, relatively low permeability and chemical properties (salinity, pH) suitable to support native vegetation, for example inert waste rock containing oxidised shale.

Well-graded clayey, silty, sandy gravel or clayey silty gravely sand makes the best store and release cover material. As a rough guide, suitable cover material contains more than 1/3 coarse sand size and finer particles (< 5 mm), but no large boulders.

Store and release covers should be constructed as follows:

- Paddock-dump selected store and release cover material on the top lift of a machinery compacted surface so that the average depth of the cover material is greater than 2 metres.
- Using a dozer knock down the crest of each paddock dump pile to fill in the depressions between piles to create a trafficable surface.
- Paddock-dump a second layer of store and release cover material on top of the first lift so that the average depth of the second lift is greater than 2 metres. Machinery compaction completed on the top of the first store and release cover layer.
- Again, using a dozer knock down the crest of each paddock dump pile in the second layer to fill in the depressions between piles. The surface should be shaped in accordance with the rehabilitation design.
- Place topsoil on top of the second store and release cover layer. Rip and seed the surface in accordance with rehabilitation requirements.

15.4 Mine voids

Mining activities at WTS will leave 19 mine voids on closure (Table 22), seven of which extend into the groundwater table. Table 22 provides a summary of the void management.

Table 22: Mine void closure conditions.

Water interactions	Landscape position	Deposit (void) name	Management	Closure outcome
Extends below water table	Hill slope	S10 Body	Avoid PAF exposure	Pit lake, no rehabilitation
		S17 Pit 3	Backfill to 515m RL	Void
		S17 Pit 8	Backfill to 515m RL	Void
	Plains	SE10 East MM 101	Backfill to 545m RL and support buttress	Void, rehabilitate backfill and buttress
		SE10 East MM 201	Backfill to 545m RL	Void
		SE10 West MM 01	Backfill to 550 m RL	Void
		B1 Main (5-12)	Avoid PAF exposure	Pit lake, no rehabilitation
All located above water table	Hill slope	S10 Head	Opportunistic waste disposal	Void, rehabilitate waste dump
		S10 Crown	None	Void
		S10 Tail	None	Void
		SE 10 West BK 01	None	Void
		SE 10 West BK 02	None	Void
		B1 Satellite (1-4)	Opportunistic waste disposal	Void
		S17 Pit 1	Will receive PAF waste	Void, rehabilitate floor
		S17 Pit 2	Will receive PAF waste	Void, rehabilitate floor
		S17 Pit 4	None	Void
		S17 Pit 5	None	Void
		S17 Pit 6	None	Void
		S17 Pit 7	None	Void

For the above water table pits: S10 Crown, S10 Tail, SE 10 West BK 01, SE 10 West BK 02, B1 Satellite and S17 pits 4 to 7, the voids will not be revegetated on closure. Management of these voids will focus on public safety, to minimise inadvertent access to the zone of geotechnical instability.

For the above water table pits: S17 Pit 1 and S17 Pit 2 (Figure 15), which contain excavated and encapsulated Category 2 and 3 geochemical waste materials, the pit floors will be revegetated (as part of the store and release cover implementation) on closure. Management of these voids will focus on public safety, to minimise inadvertent access to the zone of geotechnical instability.

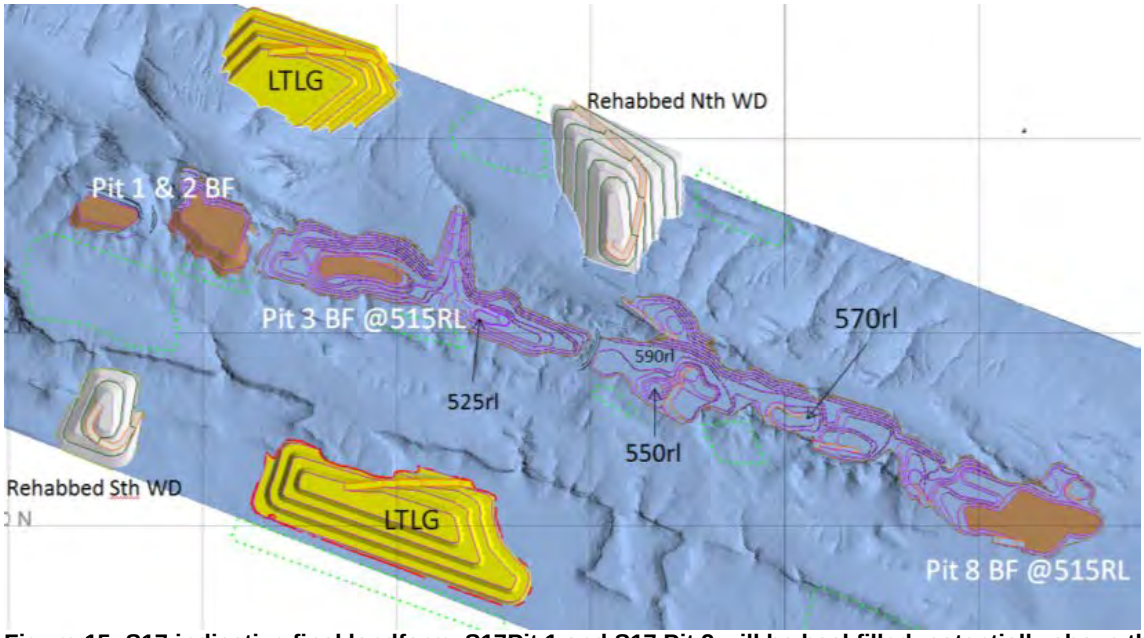


Figure 15: S17 indicative final landform. S17Pit 1 and S17 Pit 2 will be backfilled, potentially above the pit crest in sections, to create in pit waste dumps. Areas at the base of S17 Pit 3 and S17 Pit 8 will be backfilled to cover any potential acid forming material exposed in the pit wall and to suppress the groundwater table. Long term low grade (LTLG) will be rehabilitated if not utilised during operations.

Hamersley has committed to backfill mine voids to suppress the groundwater table at SE10 East MM 201, SE10 West MM 01, S17 Pit 3 (Figure 15) and S17 Pit 8 (Figure 15). Backfill targets have been established +5m above the predicted groundwater recovery level to accommodate subsidence. In the S17 pits, where Category 2 or 3 geochemical waste materials are expected to present (in situ) on the pit walls, an additional +5m has been included in the backfill target to ensure salts are not drawn to the surface via capillary action.

If backfill is not completed during mining operations, backfill material will be sourced from the upper lifts of the adjacent inert mineral waste dumps. For example, S17 Pit 3 is planned to be backfilled using mineral waste generated by the development of S17 Pit 4. However, S17 Pit 8 is expected to be the last pit to be developed, and mineral waste from the S17N_WD will be used to backfill this pit.

Once backfill is completed, the voids will be managed as though they are above water table voids, with closure management focusing on public safety, to minimise inadvertent access to the zone of geotechnical instability.

At SE10 East MM 101 (Figure 16) Hamersley has also committed to backfill the mine void to suppress the groundwater table. However, an additional in pit buttress will be required to stabilise the eastern pit wall adjacent to the floodplain. A preliminary design of the buttress (S10MM_IPWD) has been produced, based on constructing an in pit waste dump, extending from the backfilled surface to the lip of the pit immediately adjacent to the floodplain, using conservative rehabilitation parameters. Further detailed design will be required once the backfill material source is confirmed.

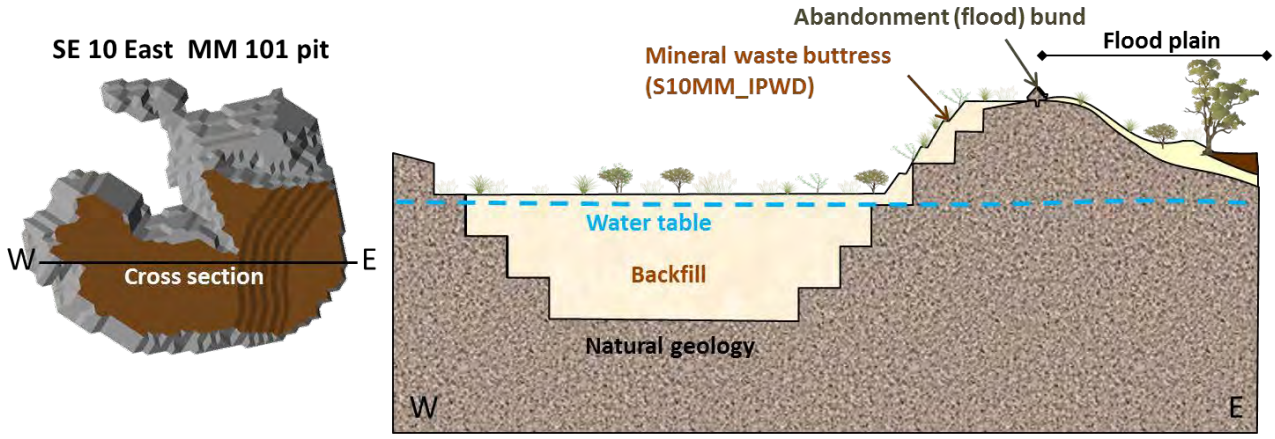


Figure 16: Cross section of the final landform design concept through the S10 East MM 101 pit.

The buttress reduces the geotechnical zone of instability in SE10 East MM 101 pit to zero metres (stable) immediately adjacent to the floodplain. An abandonment bund may not be required adjacent to the buttress, as the surface is considered to be stable. However, the buttress will be subject to significant erosion if water floods overs the pit edge during very large flood events (e.g. greater than 100 year flood events). Consequently, if on closure flood modelling still demonstrates that there is potential for very large flood events to overtop the pit crest, an abandonment bund designed to withstand and deflect flood water will be constructed outside the flood plain adjacent to the pit crest. An abandonment bund will be constructed around all other open edges, where topographically appropriate, to minimise inadvertent access to the zone of geotechnical instability.

The S10 Body pit and B1 Main pit will not be backfilled, unless the water quality proves to be unacceptable to stakeholders (refer to *Water Management* section for water quality outcome predictions). The groundwater table in these pits will be allowed to recover to create pit lakes. Safe egress from the S10 Body lake (Figure 17), and access for water quality sampling, will be provided via the eastern haul road ramp. This ramp exits the void on the southern high wall. Safe egress from the B1 Main lake (Figure 18), and access for water quality sampling, will be provided via the northern haul road ramp. Access to pits via all other haul roads will be blocked on closure.

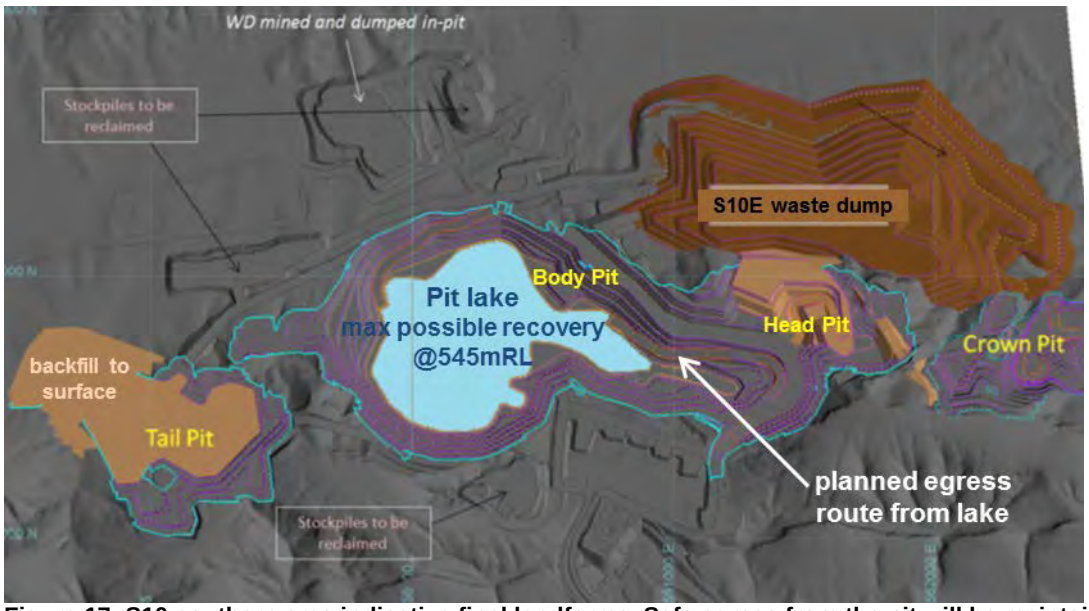


Figure 17: S10 southern area indicative final landforms. Safe egress from the pit will be maintained via the south via the eastern haul road. Note the pit lake illustrated is the maximum possible water levels in the void, considering a wet future climate. Recovery level is expected to be around 530 m RL after 100 years.

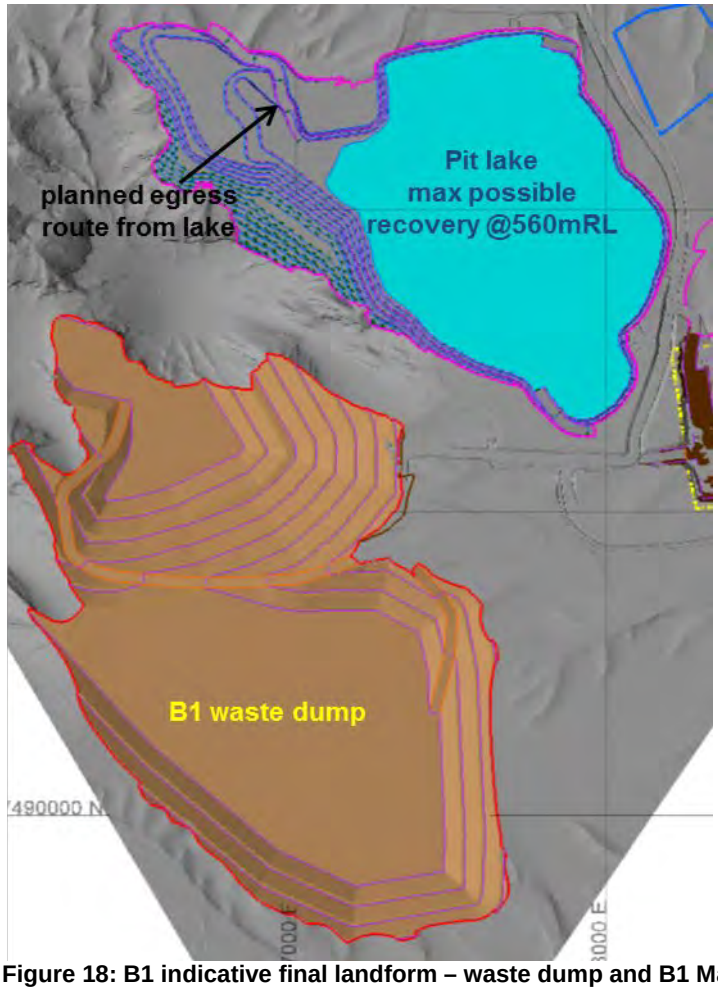


Figure 18: B1 indicative final landform – waste dump and B1 Main pit lake. Safe egress from the pit will be maintained via the northern haul road. Note the pit lake illustrated is the maximum possible water levels in the void, considering a wet future climate. Recovery level is expected to be around 525 m RL after 100 years.

15.4.1 Safe working environments

The closure strategy for WTS will require people to re-enter pit areas after mining activities have ceased, e.g. to undertake backfill, rehabilitation, water sampling etc. As pits are developed, safe working conditions within those open pits is a priority for the operation, and maintenance is undertaken regularly to remove or manage potential health and safety hazards, i.e. loose rocks.

However, there can be a time lag between the completion of mining activities and the closure activities. During this period, the groundwater table may recover, which can have an effect on pit wall stability. Similarly, as no one is currently working within those pit areas, general safety maintenance within the pits may not be undertaken on a regular basis.

Location specific management plans will be developed to minimise health, safety and environmental risks associated with unstable landforms during the pre-closure, decommissioning and post-closure phases.

15.5 Flat and undulating areas

The majority of the infrastructure areas can be described as flat or undulating areas. This includes areas such as laydown areas, haul roads, building sites and bitumen roads. Rehabilitation of these areas is subject to detailed design, expected to be undertaken immediately prior to rehabilitation, in accordance with the following guidelines:

- Any steep slopes that have been artificially constructed will be dozed or shaped to less than 20 degrees or rock armoured to prevent erosion, unless it can be demonstrated that the structures are stable in the long term. (High disturbance areas)
- Areas with less than 1m relief will be re-contoured, to control runoff and so that the landform blends in with the surrounding landscape. If the area is large with a slight slope, then shallow windrows may be constructed on the contour approximately every 50m to prevent erosion from large sheet water flows. (Moderate disturbance)
- Where practical, areas will be ripped or scarified to remove compaction and encourage water infiltration and plant growth. On slopes, areas will be ripped parallel to the topographic contours. Roads are usually ripped along their length if they are not wide enough for contour ripping. Compacted areas such as haul roads require deep ripping (e.g. dozer Tyne at depth of ~1 m).

16 Water management

16.1 Minor drainage

Environmental management plans have been implemented at WTS to respond to any impacts relating to the modification of major creek system or associated riparian vegetation communities. This includes potential impacts and mitigation associated with creek discharge. Consequently, drainage management at closure is expected to be limited to:

- removing roads, culverts and floodways across creeks and minor drainage lines,
- following the removal of infrastructure, reinstating minor drainage lines / surface water flow systems and repairing creek beds, banks and associated vegetation, and
- implementing localised surface water controls on / around waste dumps, e.g. runoff from ridge lines onto waste dumps.

These minor drainage works will aim to:

- ensure the long term safety and stability of engineered landforms e.g. considering local climate and climate change;
- ensure local drainage is reinstated in such a way that impacts on local hydrology is limited e.g. maintain flows, minimise erosion and sedimentation; and to
- ensure the latest design practice and monitoring evidence are used to guide design.

Minor drainage design works require a comprehensive understanding of the local long-term landforms. As a result closure drainage designs cannot be effectively generated until the future landform is known and no further land disturbance is proposed. Consequently drainage design activities for these minor drainage works will only be undertaken as part of progressive rehabilitation activities or immediately prior to closure.

Drainage will be preferentially reinstated along natural flow paths. However, due to changes to the landscape as a result of mining, it may not be possible to restore minor drainage lines along their pre-mining flow paths. In which case, new drainage flow paths will need to be established with consideration of local environmental effects and impacts. These changes will be reviewed with key stakeholders as part of the decommissioning plan development. In general, re-instated and constructed drainage will be designed in accordance with the following guidelines:

- The final profile of the constructed drainage line will consist of a flat base and sloped banks to allow for free drainage. Depth should not exceed 0.5m.
- The channel width will be determined based on the estimated volume of water that is anticipated to flow down the channel. In areas where friable, easily erodible material exists, or where there is the potential for high flow velocities, it may be necessary to cover the base of the constructed channel with BIF rock material or available equivalent.

- Where possible, the channel will be designed to meander such that the constructed channels have characteristics similar to the surrounding region, e.g. are not all linear features.
- The constructed channel will be blended in with any natural drainage lines.

16.2 Groundwater systems

Due to the low reliability of the pre-mining water conditions and in the absence of a regional groundwater understanding of the closure impacts, it is not possible to conclude what the post-closure water conditions will be across WTS. In the absence of extensive field data, the groundwater systems have been modelled based on Rio Tinto's experience of mining and dewatering similar geological units in the region.

The modelling suggests that the groundwater table within the S10 Marra Mamba aquifers could recover to within 5 m of the pre-mining levels. However, the connectivity of the groundwater within the S10 Marra Mamba deposits and the regional aquifer is speculative. Full recovery of the water table was also possible, depending on the future climate conditions; such that water level recovery is dependent on future rainfall.

Preliminary groundwater investigations suggest groundwater within the S10 Body pit, B1 main pit and S17 deposits is isolated from the regional groundwater systems. There is less confidence that the water levels in the S10 Body pit area, B1 Main pit are and S17 deposits will recover to pre-mining levels.

Further field and modelling work is required to confirm the groundwater levels, groundwater system connectivity and the groundwater quality at each deposit.

16.3 Pit lake formation and water quality

Preliminary water quality modelling (Table 23) has been completed for the B1 Main pit lake and S10 Body pit lake. It is acknowledged that further work is required to define how contaminant concentrations in water in the pit lake will change with time, and the subsequent impact pathways for those contaminants, including:

- the behaviour of oxyanionic metal and metalloid species that are likely to be absorbed on these minerals and desorbed under conditions where the alkalinity and sulfate concentrations in the pit lake increases with time.
- occurrence of naturally elevated nutrients in some groundwater aquifers, which if present in pit lakes has the potential to generate algal blooms and eutrophic conditions.

It is expected that discussions with stakeholders will occur over the life of the mine to define, review and refine the water quality parameters (completion criteria) used to define "acceptable water quality". Acceptable water quality parameters are expected to encompass public liability, health and ecological risk. It is expected that predictions of the post-closure water conditions and ecological interactions will be refined sufficiently ahead of mine closure so as to enable informed discussion and resolution of the strategy prior to decommissioning.

If an acceptable lake outcome cannot be resolved with regulators, the closure strategy for the affected pit will be reviewed and consider backfill to prevent the formation of a permanent lake.

16.3.1 B1 Main pit lake

The B1 Main pit lake (Figure 18) is located high in the landscape, away from public view, at the base of the mine void. The pit lake is expected to reach quazi steady state level (90% recovered) of around 525 m RL, a depth of over 100 m and 10 m below the pre-mining groundwater level approximately, 60 years post-dewatering (~100 years to steady-state). The lake will be a groundwater sink, such that salts and aqueous elements will not move outside the lake area. The lake is also expected to be meromictic, such that the water column is subject to partial mixing with a stagnant, anoxic layer across the lake bottom.

The pit walls are expected to collapse on closure and there is the potential for low geochemical risk material to be transported into the lake. Geochemical equilibrium modelling indicates the water would maintain a circum-neutral pH with the entire water column mixing at least once a year as a result of seasonal overturn. Total dissolved solids (TDS) are predicted to be elevated due to evaporation of water and concentration of the dissolved constituents. The high TDS values are largely due to elevated concentrations of calcium, potassium, magnesium, sodium, sulfate, and chlorine.

Hydro-geochemical modelling is an advancing science. Model inputs derived from further geochemical test work and improved understanding of the groundwater systems are expected to significantly improve the hydro-geochemical model predictions prior to closure. Based on the current predictions, however, the water quality of the B1 pit lake is predicted to be, in general, of an acceptable quality to the majority of stakeholders.

Management options, such as in pit barriers, have not been considered as part of the most recent modelling scenarios. There is the potential that the water quality could be further enhanced by controlling the movement of low geochemical risk material. This assumption will be reviewed as further geochemical test work is completed.

16.3.2 S10 Body pit lake

The S10 Body pit lake (Figure 17) is located high in the landscape, away from public view, at the base of the mine void. As with the B1 Main pit lake, the S10 Body pit lake is expected to recover to a quazi steady state level (90% recovered) of around 530 m RL, a depth of 50 m, after 100 years. This level is approximately 15m below the pre-mining water table. As with B1 Main pit lake, the S10 Body pit lake will be a groundwater sink; however the water column within the lake will be fully mixed, such that oxygen is available throughout the water column.

The results indicate that the WTS S10 pit lake will be fresh and moderately alkaline with pH values around 8 and total dissolved solids (TDS) around 690 mg/L. Consistent with this pH, most metals and trace elements will be low with only boron and copper barely approaching or slightly exceeding ANZECC guidelines for aquatic ecosystems. Most parameters display increasing trends in time due primarily to evapoconcentration effects. Parameters such as barium, calcium and others display decreasing concentrations as geochemical controls known to exist for them were imposed in the model.

Based on the current predictions, however, the water quality of the S10 pit lake is predicted to be, in general, of an acceptable quality to the majority of stakeholders.

Table 23: Hydro-geochemical modelling results for the S10 and B1 pit lakes. BDL is used to identify parameters predicted to be below the detection limits.

Parameter	S10 (ug/L)	B1 (ug/L)	Comment
pH	8.4	7.3	
Ag	0.7	27	S10 exceeds some ecosystem guidelines, but are within Pilbara background levels. B1 levels require further validation, above some ecosystem trigger values.
Al	31	7	
As	2	BDL	
B	300	26,900	B1 levels require further validation, above some ecosystem trigger values
Ba	19	9	
Bi	0.4	22	B1 levels require further validation, above some ecosystem trigger values
Ca	18,000	830,000	B1 levels are below ANZECC stock drinking water guidelines
Cd	0.1	BDL	
Co	1	0.018	
Cr	0.69	BDL	
Cu	2.1	BDL	S10 levels are below ANZECC highly disturbed ecosystem 80% trigger value
Fe	0.04	0.15	
K	7,900	624,000	
Mg	65,000	1,260,000	
Mn	BDL	0.086	
Mo	0.48	1.4	
Na	96,400	4,127,000	B1 levels require further validation, potential over-estimation due to model configuration
Ni	1	BDL	

Parameter	S10 (ug/L)	B1 (ug/L)	Comment
P	71.9	BDL	
Pb	2.3	BDL	
S(6)	240,000	4,280,000	S10 and B1 levels require further validation, above some health and ecosystem trigger values
Sb	1	100	
Se	4.1	160	B1 levels require further validation, above some ecosystem trigger values
Si	830	7,200	
Th	0.4	22	
Ti	0.5	24	
U	0.7	87	B1 levels require further validation, above some ecosystem trigger values
V	0.5	BDL	
Zn	26.5	BDL	
Cl	150,000	8,800,000	B1 levels require further validation, above some ecosystem trigger values
Hg	0.18	0.79	
F	530	30,000	
N(5,3)	3,300	140,000	B1 levels require further validation, above some ecosystem trigger values
alkalinity	190,000	26,000	
TDS	690,000	20,000,000	B1 levels require further validation, above some ecosystem trigger values

17 Plant and soil development

17.1 Habitat planning

When disturbed areas are no longer required to support mining activities, the areas may be progressively closed and rehabilitated. The habitat plan (Figure 19) provides the strategic vision to assist with the local planning activities. (Descriptions of the habitats are provided in Table 18 and Table 19.)

Habitat elements that are considered as part of the rehabilitation include:

- selection of vegetation characteristics of the desired habitat unit e.g. known to provide preferred food or shelter preference;
- ability to reuse retained woody debris, to provide fauna refuge and microhabitats;
- ability to integrate rocky features, i.e. oversized waste burden or scree slopes, into the design for aesthetics and fauna use;
- requirements for rapid generation and retention of leaf litter using small-scale topography (e.g. furrows created from ripping);
- establishing soil depth and considering opportunities to use subsoil or inert mineral waste to build habitat for burrowing fauna;
- preserving connectivity with unmined areas, and maintaining the quality of these habitats; and
- managing feral predators and herbivores across both reference and rehabilitated areas.

As fauna species are not proposed to be introduced to the area on closure, natural migration of fauna species into rehabilitated land will be encouraged by selecting seed mixes that produce vegetation communities that are linked to pre-mining habitat units. Most post-mining habitat units are also connected to similar undisturbed habitat, which helps fauna to migrate.

It is expected that the majority of the site will be rehabilitated as part of mine closure.

17.2 Revegetation

Topsoil will be spread over reconstructed landforms and ripped into the underlying substrate. Due to the anticipated topsoil deficit, the rate of topsoil application will need to be prioritised. For example, stockpiled subsoil will be blended with topsoil to provide a minimum 200 mm deep quality surface growth media. Stockpiled vegetation is then returned to the area.

Monitoring has shown that in small disturbed areas adjacent to existing vegetation or in areas where fresh topsoil can be utilised (e.g. borrow pits), appropriate species are generally re-establish without the need for additional seed. This is because the seed bank in the fresh topsoil remains viable, resulting in good germination and growth, and in very small areas seeds can ingress from surrounding vegetation.

In most cases, however, locally collected seed is needed to assist in revegetation and the creation of a self-sustaining ecosystem. Over time the viability of seeds in stockpiled topsoil decreases, and thus the quality of the topsoil deteriorates. In addition the topsoil that was salvaged prior to disturbance may not contain seeds of all the target species of its new location / habitat.

Revegetation activities and replacement of topsoil should ideally be timed so that rehabilitated areas are completed prior to the summer wet season, usually commencing in November. This should give the seeds in the rehabilitation area the best chance of germination and survival.

Seed mixes for rehabilitation are preferentially of local provenance. Specific seed mixes are selected to provide a range of species appropriate to the desired habitat (see Figure 19, Table 18), taking into consideration landscape position and slope. In areas where erosion risks are identified, seed mixes may be modified to include or increase the portion of species that provide rapid cover.

Seed mixes may also include species of cultural significance to Traditional Owners, such as bush tucker and medicinal plant, if and when identified through ongoing consultation with Traditional Owners.

17.3 Invasive species management

17.3.1 Weeds

A Weed Management Plan will be developed prior to closure. The Weed Management Plan will build on the Weed Management Plan implemented during operation of the site, and include procedures to:

- identify, control and eradicate target weeds, in accordance with Parks and Wildlife weed species ranking action response recommendations;
- weed hygiene activities for vehicle and earthmoving machines to minimise the distribution of weeds; and
- monitor the effectiveness of weed control measures to minimise the spread of weed species, prevent the introduction of new weeds, and control and / or eradicate high and very high risk weeds across the rehabilitated area.

17.3.2 Invasive animals

Feral carnivores (e.g. cats, dogs, foxes) can create locally increased predation pressure on native fauna as well as increase competition with native species for resources such as space (territory), water and food.

Feral herbivores (e.g. cattle, camels, donkeys) can also have a significant impact in Rangeland areas, such as the Pilbara. In dry times, grazing pressure reduces the abundance of palatable native species, impacting biodiversity and can create conditions that encourage weeds to grow. Foot traffic impacts the soil conditions, and in combination with over grazing, can encourage erosion. Foot traffic has also been the cause of damage to cultural landmarks and Aboriginal sites. Overgrazing and damaged soils has a low-on effect to native fauna species that rely on this vegetation for food and shelter.

Strategies for post-closure management of invasive animals will be developed as the site approaches closure, building on successful strategies implemented during the site operation.

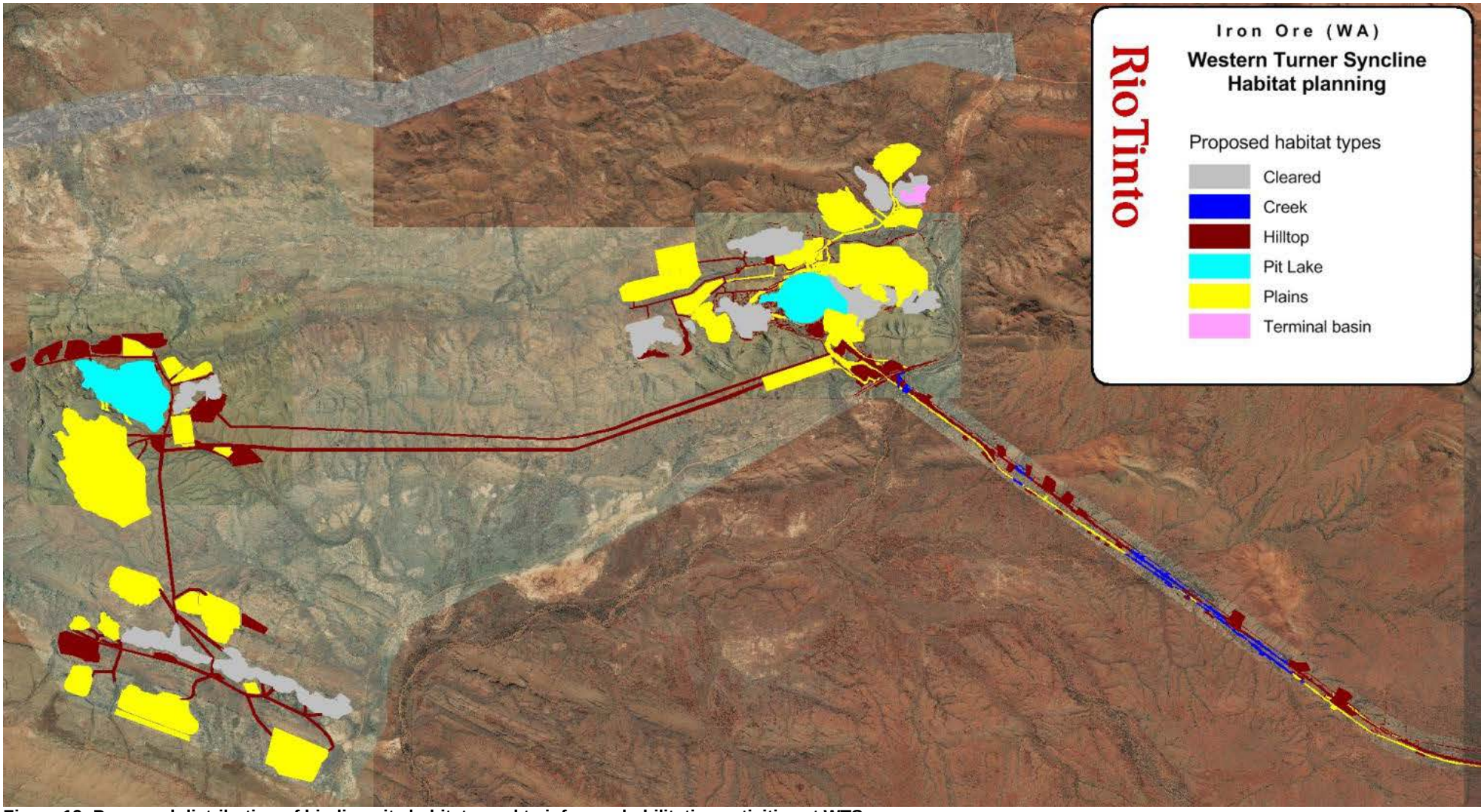


Figure 19: Proposed distribution of biodiversity habitat, used to inform rehabilitation activities at WTS.

17.4 Progressive rehabilitation performance

17.4.1 Rehabilitation at WTS

WTS is a new operation and consequently progressive rehabilitation has been limited. Since 2010, 48 ha of borrow pit and track rehabilitation has been undertaken along the infrastructure corridor between the WTS S10 deposit and Tom Price. This rehabilitation was completed by recontouring, ripping and replacing the recently disturbed topsoil. No supplementary seeding was applied.

For example, borrow pit BP3_1 (Figure 20) was completed in 2012. This area consists of skeletal sandy soils and is regarded as a hilltop habitat. Both species density (13,500 plants/ha) and perennial cover (12%) are lower than density and cover targets for a hilltop habitat density (29,000 plants/ha and 45% perennial cover). However this is a young rehabilitation site and plant density has continued to increase since 2013. Cover and densities are expected to continue to improve with time. No weeds have been recorded at this site.



Figure 20: Vegetation growth after 2 years at a former borrow pit 2013_WTS_BP3_1.

17.4.2 Comparison of rehabilitation success at other operations

The soil and mineral waste properties at Mount Tom Price mine are similar to WTS. Rehabilitation of the Tom Price MME1 in pit waste dump (completed in 2012), trial areas on the NEBC waste dump (completed in 1999) and South Section 6 waste dump (completed in 2001) were undertaken using the rehabilitation techniques proposed in this closure plan. Rehabilitation works included re-profiling, topsoil replacement, ripping and seeding.

The 2014 rehabilitation monitoring data (Table 24) shows that the plant density target established for WTS plains habitat (the habitat outcome proposed for waste dumps at WTS and Mount Tom Price), of 10,000 plants/ha, has been achieved in the Mount Tom Price rehabilitation areas. However, the perennial vegetation cover percentages varied. This variation may be due to location specific conditions and adjacent mining activities. Nonetheless, the results demonstrate that it will be possible to achieve the WTS indicative completion criteria using the rehabilitation techniques proposed in this closure plan.

Table 24: Comparison between the WTS indicative completion criteria for plains habitat rehabilitation and similar plains style habitat rehabilitation at Mount Tom Price.

	WTS plains habitat indicative completion criteria	Mount Tom Price waste dumps		
		MME1	NEBC	South Section 6
Age of rehabilitation	-	2 years	15 years	13 years
Plant density (plants / ha)	10,000	12,750	23,500	32,000
Perennial cover (%)	45%	41%	31%	60%

18 Safety structures

18.1 Zones of instability and abandonment bunds

Abandonment bunds will be constructed around the perimeter of mine voids to prevent inadvertent access to the zone of geotechnical instability around the mine voids. Figure 21, Figure 23 and Figure 24 illustrate where the zone of geotechnical instability is likely to be at closure. Further assessment, based on topographic accessibility and final wall stability, will be undertaken to confirm the locations for the abandonment bunds.

Abandonment bunds will be constructed from inert mineral waste, with a height of at least 2 m, width of at least 5 m at the base, and side slopes greater than 15 degrees (depending on the material type characteristics). At SE10 East MM 101, where the pit is located outside the 100 year flood plain but is inside the probable maximum flood (PMF) extent, PMF water may peak at 1.9 m high against the bund, flowing with a peak velocity of 2 m/s. To manage this impact, facing class rock will be required along the length of the bund within the PMF plain (shown in green on Figure 21). This material can be quarried from the developed mine pits.

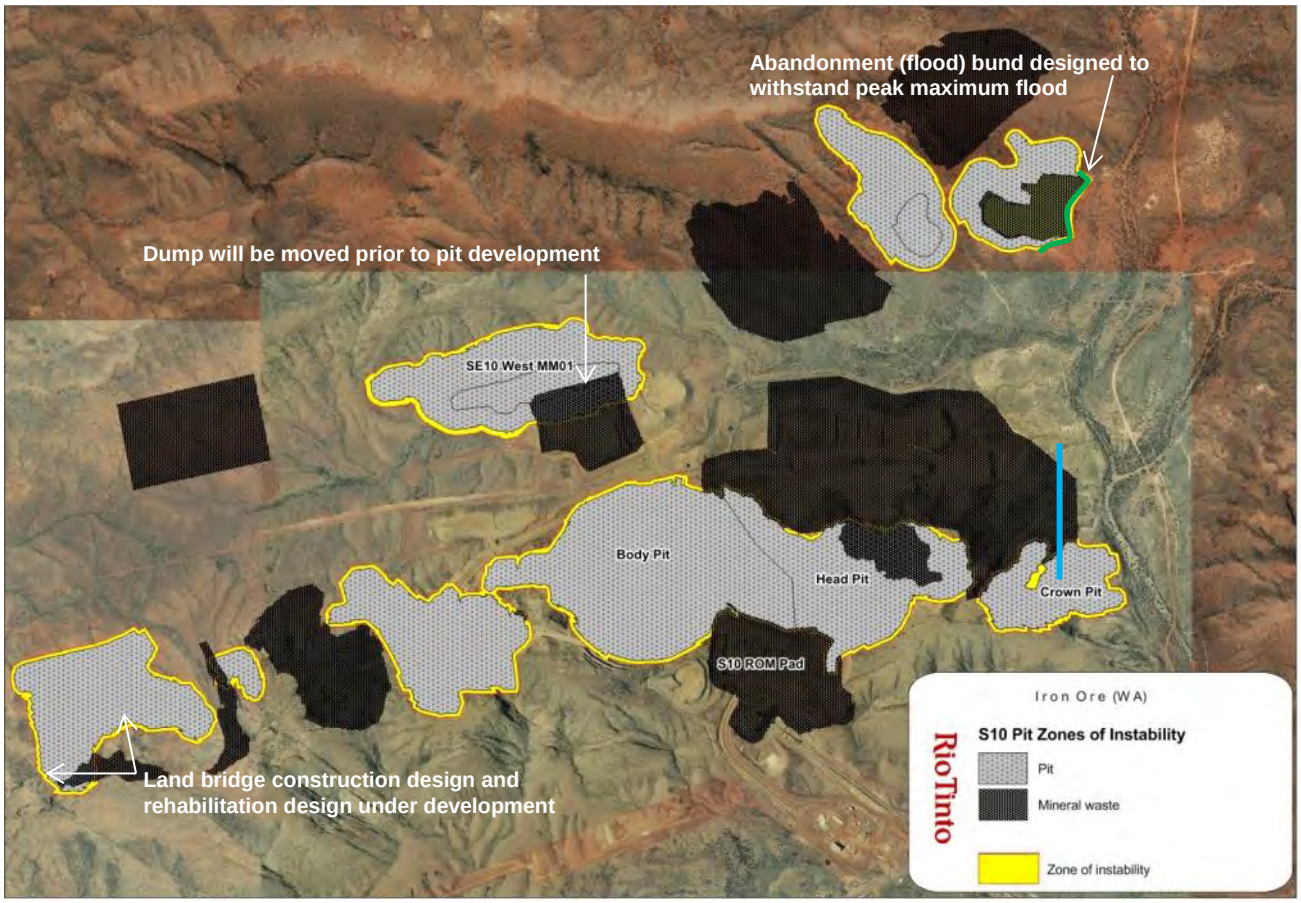


Figure 21: Indicative abandonment bund locations for S10 deposits (red line outside of yellow area). Yellow area includes zone of instability and 10m setback. The blue line indicates where the cross section in Figure 22 is located.

It is recognised that waste dumps in Figure 21 intersect geotechnical zones of instability in some locations surrounding the S10 Body, Head and Crown pits. Figure 22 provides a typical cross-sectional view through the pit, the natural geology and the waste dump at these intersect locations. As Figure 22 shows, the potential zone of collapse only extends approximately 10 m into the upper lift of the waste dump. As such, while the waste dumps are located within the geotechnical zone of instability, the structural integrity of the S10 waste dumps are not considered to be at risk of failure if the pit walls collapse.



Figure 22: Position of geotechnical zone of instability relative to waste dumps at WTS S10. The geotechnical zone of instability extends approximately 10m back from the pit crest.

Land bridge haul roads, highlighted in Figure 21, will be required to access the upper benches of the SE10 West BK 01 pit. It is expected that the land bridges will be constructed from mineral waste. However, the location and construction methods are still subject to further design review. The proximity to the geotechnical zone of instability will be considered as part of the rehabilitation design for this haul road.

In the B1 deposit area, the conveyor laydown and ROM pad will be built over the edge of the B1 satellite pit, in order to minimise further land disturbance. These structures will be rehabilitated on closure, although further design refinement is required, prior to construction, to ensure landform stability post-closure.

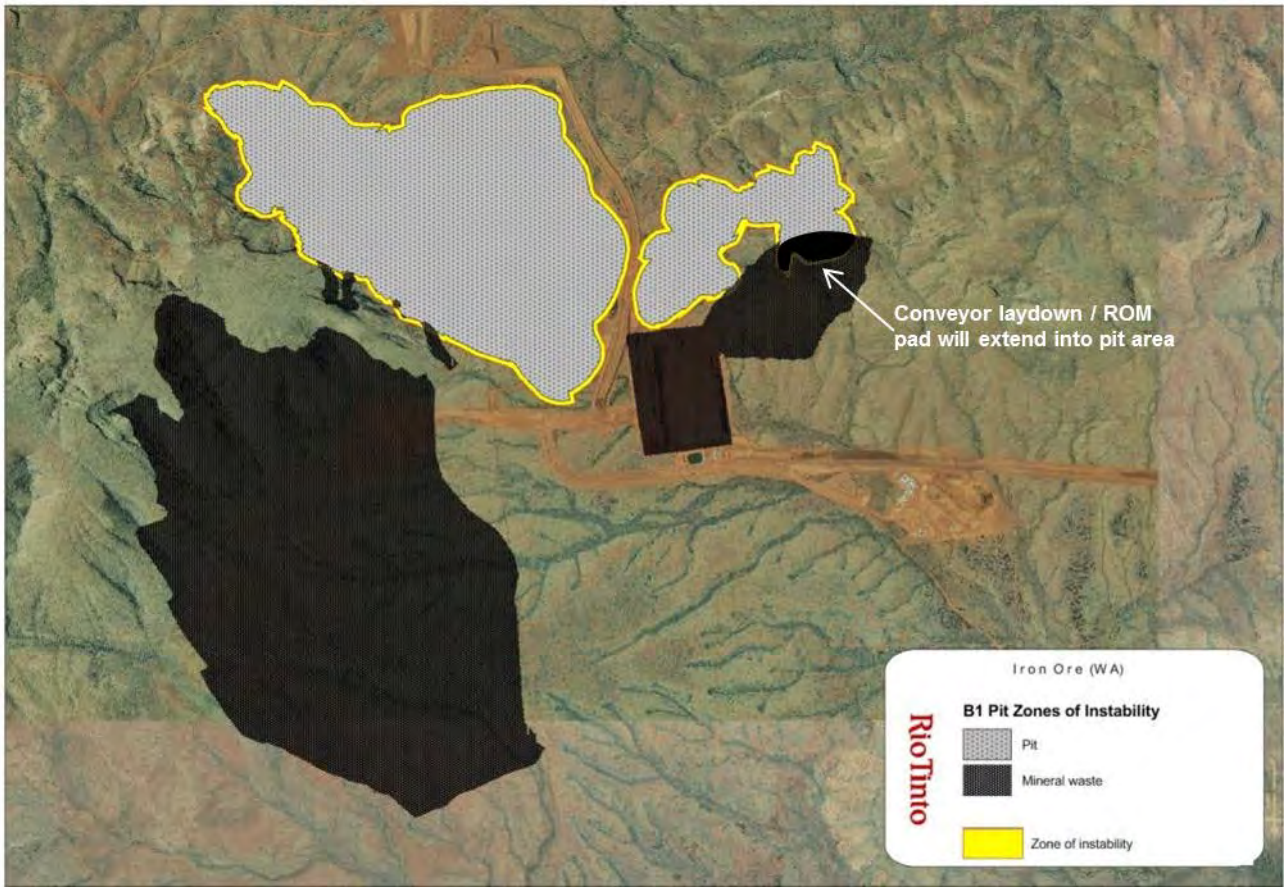


Figure 23: Indicative abandonment bund locations for B1 deposits (red line outside of yellow area). Yellow area includes zone of instability and 10m setback.

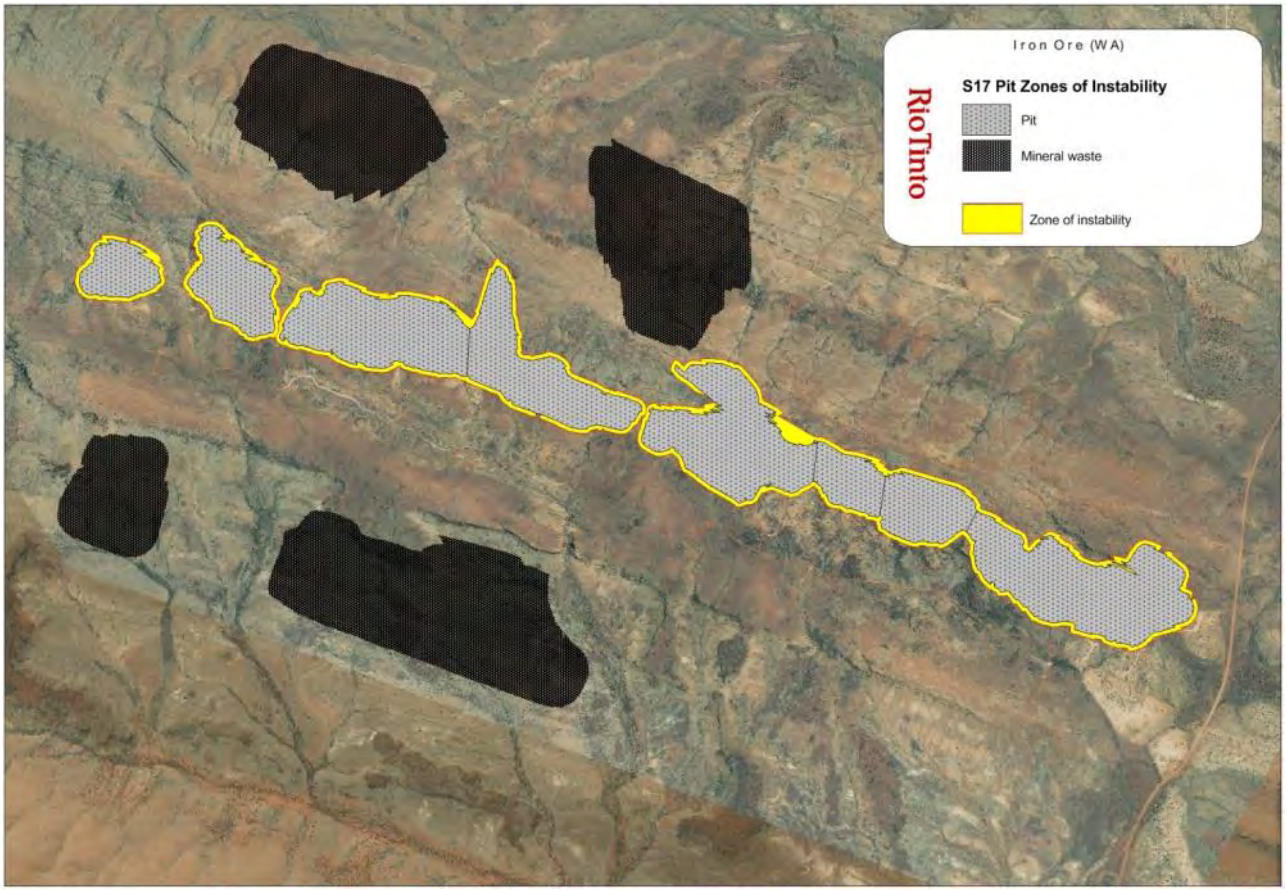


Figure 24: Indicative abandonment bund locations for S17 deposits (red line outside of yellow area). Yellow area includes zone of instability and 10m setback.

18.2 Signage

Safety signs are subject to strict control and legislation from the standards operating within Hamersley, as well as by local legislation. Signage will be developed in consultation with the relevant authorities as part of the studies completed immediately prior to closure.

IDENTIFICATION AND MANAGEMENT OF CLOSURE ISSUES

19 Issues evaluation

A closure risk assessment was completed on the proposed closure strategy for WTS. The risk register developed from the risk assessment is included in Appendix C. The assessment was completed by a panel of multi-disciplinary subject matter experts with the aim of:

- identifying hazards, aspects and opportunities that could influence the successful closure of the site;
- evaluating the resulting risks to people, property and the environment; and
- defining the actions required to reduce the risk to below the risk acceptance threshold.

19.1 Hazard / aspect identification

The context and acceptability criteria for the risk analysis was established by reviewing baseline studies, stakeholder consultation, learnings from work undertaken at other sites, and research etc. to identify any knowledge gaps.

Controls and commitments that are currently in place to manage each hazard were subsequently identified. This identification process included a review of the effectiveness of current management plans, procedures, work practice guidelines etc. to identify any management gaps.

Table 25 summarises the topics raised / discussed during the evaluation session(s). Aspects reviewed as part of the closure risk evaluation included:

- mineral waste characterisation;
- pit lakes and ground water;
- landform stability;
- surface water implications;
- decontamination;
- biodiversity;
- visual amenity;
- cultural heritage; and
- local communities, communication and consultation.

Table 25: Closure context for WTS risk evaluation process.

Aspect	Current status
Mineral waste characterisation	• Waste material includes a range of competent and highly erodible material. • Geochemical characterisation indicates PAF materials in area, although geochemical characterisation not complete in all pits. • Plan is to avoid intercepting PAF at S10 and B1 deposits but will be mined at S17 with subsequent potential for AMD generation • Excavated Category 2 and 3 materials will be encapsulated within in-pit waste dumps / backfill. • Management plan in place to encapsulate fibrous materials if encountered.
Landform stability	• Waste dump designs require selective placement of highly erodible material in centre of dumps to achieve long term stability. • Some waste dumps abut topography (have catchment run-on) and may require additional drainage management controls to prevent erosion. • Buttresses built from mineral waste required against east wall of S10 MM 101 pit to prevent wall collapse, which could lead to encroachment into the adjacent creek floodplain and riparian vegetation. • Safe egress from pit lake areas is required to be formalised in the pit design and review process. Egress expected to be maintained via haul roads. • Some unconsolidated materials (over-blast) have been pushed over the pit edge and exist outside the pit area at S10. Area is challenging to stabilise / rehabilitate i.e. management is currently unresolved.

Aspect	Current status
Water	• Groundwater in Brockman-style deposits is mostly compartmentalised (disconnected from regional aquifer). • Groundwater in Marra Mamba-style deposits is connected to the regional aquifer. The regional aquifer flows from the east to west. Preliminary modelling suggests natural evaporation processes associated with the backfilled pits could create a local groundwater depression that extends approximately 100 m to the east and west of the S10 MM pits. • Pit lakes are proposed to develop post-closure in the S10 Body and B1 Main pits. Preliminary water quality modelling has been completed. Results suggest water quality will not adversely impact the ecosystem in the short or long term. Further data to be collected to verify model predictions. • Closure strategy includes contingency to prevent formation of permanent pit lakes (backfilling) if regional groundwater quality will be impacted. • Although mine activities cross major creek with minor riparian disturbance, no modification of named or major creek systems is anticipated. Some creek restoration and minor drainage line management will be required. • Discharge to creeks to be managed during operations to prevent / mitigate impacts. Discharge to creek expected to cease well in advance of mine closure.
Biodiversity	• Comparison of rehabilitation performance on similar landforms at neighbouring mine sites suggest WTS landforms can be successfully rehabilitated using standard practice. • Pit lakes will be isolated / disconnected from surrounding ecosystems, in deep pools at base of deep voids. Thus lakes will not be rehabilitated, opportunistic colonisation only anticipated i.e. stygofauna.
Cultural heritage	• Heritage surveys still to be completed across the development area. Some heritage sites associated with caves may be identified and require management. To be resolved through standard processes. • Heritage sites identified located outside S10 MM pits. Closure strategy not expected to impact on sites, but will follow protocols to ensure no impact. • Ongoing dialogue required to address pit lake and water queries.
Decommissioning	• Fixed assets are standard and unlikely to present potential complications to demolition strategy. • Standard management measures considered sufficient to manage minor hydrocarbon contamination issues (if they arise).
Other stakeholders	• Minimal impact to local communities as site is not located adjacent to population centres. • Workforce expected to transition back to Tom Price mine at end of mine life • Closure criteria are similar to previous approvals and believed to address all known stakeholder concerns. Detailed targets are still to be resolved for some of the completion criteria.

19.2 Risk evaluation

Risk was evaluated on the basis of the maximum reasonable outcome consequence and the likelihood of that consequence occurring, e.g. rare, unlikely, possible, likely or almost certain. Risks were evaluated inclusive of current management and commitments, and represent current residual risk. A summary of the risk titles and evaluated risk class are provided in Table 26.

Consequences included in the evaluation were:

- **Health**: reversible health effects of little concern (very low) to multiple fatalities (very high);
- **Personal safety**: inconvenient first aid treatments (very low) to multiple fatalities (very high);
- **Environment**: reversible impact (very low) to widespread, long-term impacts (very high). As some environmental impacts can escalate if immediate identification and remediation is not possible, environmental consequences are also evaluated by:
  - **On-site**: referring to impacts that occur during the pre-closure and decommissioning phases, when staff are able to utilise site equipment and quickly react to remediate impacts; and
  - **Off-site**: referring to impacts that occur during the post-closure phase, when remediation may not immediately follow impact identification, due to a need to bring equipment and experts back to site to remediate.
- **Community trust**: mistrust amongst a small section of the wider community (very low) to widespread mistrust with key stakeholders (very high); and
- **Compliance**: non-conformance to internal requirements (very low) to prosecution for breach of regulatory licence(s) (very high).

Risks resolved from the evaluation were classified as follows:

- **Low** (Class I): Risks that are below the risk acceptance threshold and do not require further management.
- **Moderate** (Class II): Risks that lie on the risk acceptance threshold and require regular review to ensure management remains adequate and fit-for-purpose.
- **High** (Class III): Risks that, based on the current level of knowledge, could exceed the risk acceptance threshold and require proactive management and / or resolution of knowledge gaps.
- **Critical** (Class IV): Risks that, based on the current level of knowledge, will exceed the risk acceptance threshold and need urgent and immediate attention to develop an alternative approach.

Actions were assigned to risks that exceeded the risk acceptance threshold. Actions were also assigned to address knowledge gaps and assigned where subject matter experts requested the performance of existing controls and commitments be re-evaluated at some later date. These actions are captured in Appendix C.

Table 26: Summary of closure risks at WTS.

	Maximum reasonable consequence evaluation		
Risk title	Likelihood	Consequence	Risk
Under-estimated general contaminant clean up requirements	Unlikely	Moderate	Class II
Under-estimated acid and / or metalliferous drainage management requirements during operations (pre-closure) & decommissioning phase	Possible	Low	Class II
Acid and / or metalliferous drainage generation (after closure) creates a contaminated site	Unlikely	High	Class III
Human health impacts from in situ fibrous material exposures	Rare	Moderate	Class II
Lake and / or lake fringe habitat has undesirable impacts on general ecosystem function.	Unlikely	High	Class III
Lake poses public liability and / or health risk	Unlikely	Moderate	Class II
Degradation of regional groundwater quality or levels	R Rare	Moderate	Class II
Wall failure within mine void compromises closure outcomes	Rare	High	Class III
Built landforms (excluding mine void areas) erode and / or collapse	Possible	Low	Class II
Surface treatment on landforms limits vegetation growth	Unlikely	Moderate	Class II
Vegetation is not self-sustaining	Unlikely	Moderate	Class II
Access through area post-closure poses public liability risk	Unlikely	Low	Class I
General environment outside of approved mine disturbance areas is adversely impacted	Unlikely	Moderate	Class II
Adverse impact to flora or fauna with conservation status or wider regional impact to high value environment	Rare	Very low	Class I
Heritage site condition / cultural value is degraded as a result of implementing the closure plan	Unlikely	Moderate	Class II
Consultation fails to identify stakeholder concerns	Unlikely	Moderate	Class II
Closure outcomes do not meet stakeholder(s) / community expectations	Possible	Low	Class II
A stakeholder's expectations conflict with that of another stakeholder, causing delays to plan approval and / or closure	Unlikely	Low	Class I
Closure strategy prevents or limits future exploitation of resources	Likely	Very low	Class II
Mine closure has a significant, long-term detrimental impact on local communities	Rare	Moderate	Class II
Closure is not implemented in accordance with the approved closure plan	Rare	Moderate	Class II

19.3 Key risks

Of the 21 risks evaluated three high (Class III) risks we identified. These risks were associated with:

- AMD generation;
- undesirable impacts of the pit lakes on general ecosystem function; and
- pit wall failure compromising closure outcomes.

A summary of the Class III risks and required future work is provided below. Implementation of the identified actions will reduce the Class III risks to Class II.

19.3.1 Acid and / or metalliferous mine drainage

PAF materials have been identified in the mineral waste surrounding the Brockman-style iron ore deposits at S10, B1 and S17. Pit designs have been developed for S10 and B1 which allow the ore to be mined without intersecting Category 2 or 3 geochemically problematic mineral wastes (also known as hot and cold black shales).

Category 2 and 3 geochemically problematic mineral wastes could not be avoided in the S17 area. However, these PAF materials are located only on the lowest benches of the voids. The mining sequence will enable the PAF materials to be encapsulated in-pit in adjacent above water table pits. In-pit encapsulation is believed to reduce oxygen supply to the PAF (compared to ex-pit encapsulation options) and thereby provide the lowest potential for AMD generation.

However, when encapsulated as backfill, the PAF may inadvertently receive runoff from the newly created pit catchment. Further detailed mine planning will be required prior to the excavation of PAF at S17 to ensure surface water is diverted away from encapsulation areas (during operations and post-closure).

Store and release covers are proposed to be installed over PAF encapsulated waste materials. It is recognised that the environmental conditions within the pit may limit plant growth. Further studies are required to identify which plant species are best suited to in-pit conditions for the purpose of a functioning store and release cover. Completion criteria pertaining to the wider site revegetation performance are not expected to be applied to these in pit areas.

Pit wall PAF exposures in the S17 pits will be covered with inert mineral waste on closure. The pits will also be backfilled to target level 10m above the groundwater recovery level, to accommodate ground subsidence and to prevent secondary salts from rising to the surface via capillary action. Backfill is expected to occur immediately after the PAF is exposed, consequently no significant water quality issues (e.g. due to PAF exposures intersecting rainfall run-off) are anticipated.

Acid and / or metalliferous mine drainage risk reduction activity:

Reference	Task
WTS-16	Ensure learnings from modelling and in situ measurements at Pilbara mines are used to review and revise PAF management activities prior to PAF removal in S17.

19.3.2 Pit lakes

Pit lakes are expected to develop in the S10 Body and B1 Main pits post-closure. Both lakes will be sustained by groundwater, and will be a local expression of the groundwater table. However, hydrogeological investigations suggest the aquifers associated with groundwater table in the vicinity of S10 Body and B1 Main are isolated from the regional groundwater systems. As such, groundwater table recovery will depend on future climate conditions and local rainfall recharge mechanisms. Based on the current future climate predictions, groundwater recovery is expected to be slow and it could take over 100 years before a steady state level within the lakes is achieved.

Geochemical equilibrium studies have been completed for both pit lakes. Generally the water quality is predicted to be acceptable. Nevertheless, hydro-geochemical modelling is an evolving science. Further study of many of the input parameters, including groundwater recovery, evaporation rates, alkalinity consumption mechanisms, trace element concentrations and implications of stratifications, are recommended to improve the accuracy and reliability of the predicted out comes.

Pit lakes risk reduction activities:

Reference	Task
WTS-03	Review of pit lake water quality modelling to incorporate improved knowledge base
WTS-10	Assess the ability of pit lake water to sustain aquatic flora and fauna
WTS-11	Update pit lake ecological risk assessment as knowledge develops, including the potential for biological attenuation

19.3.3 Landform stability

Physical characteristics have been developed for all expected waste types. As the geology and subsequent waste types are similar across most of the Pilbara, mineral waste characterisation has been extrapolated from neighbouring deposit types where physical test work has been completed. If, through standard resource definition processes, waste material types are found to differ from expectation, further test work will be undertaken.

Some mineral waste units are expected to be highly erodible. Management options for highly erodible waste material at WTS have been reviewed with respect to the mine sequence, considering frequency of occurrence for highly erodible waste material, availability of pits for in-pit backfill, availability of materials for capping and stockpile requirements for capping. The review concluded that encapsulation of highly erodible material within the waste dump during construction / mining requires less re-work on closure and is more likely to result is the desired closure landform. Waste dump designs have been modified to accommodate encapsulation of highly erodible mineral waste. Performance of (and ability to conform to) the new designs will be reviewed during the life of the mine.

Mining in the S10 MM 101 pit will occur close to, but outside the floodplain of the Northern Hardey River. This pit is also located close to an area of cultural significance regularly visited by the local community. As disturbance of the creek floodplain and riparian corridor could have an impact on the environmental, social and heritage values of the area, it is proposed to stabilise the eastern wall of the pit using a buttress. The buttress will extend from the floor of the pit to the lip of the pit, and will be constructed from mineral waste material and rehabilitated. Designs for the buttress will be refined immediately prior to closure, giving consideration to the physical conditions within the pit, the pit wall and the mineral waste used to construct the buttress.

Landform stability risk reduction activities:

Reference	Task
WTS-07	Review and verify the pit wall stability management requirements for the S10 MM pit wall below local creek
WTS-15	Refine design of S10 MM pit wall buttress stabilising structure based on selected material waste characteristics

19.4 Research and investigation task list

Table 27 summarises the actions identified through the risk evaluation process that require research or form part of significant ongoing investigations. It is not expected that this list includes all of the mine activities undertaken that relate to closure, only the key activities that are necessary to manage or prevent unacceptable closure risks.

Table 27: WTS closure task list.

Aspect	Reference	Task	Due date
Ongoing reviews and updates	WTS-17	Review data collected and information developed through the operation life. Use data / information to improve models, interpretations and verify predictions.	Ongoing
	WTS-19	Development of HSE management methodology for closure	Prior to commencing closure activities
	WTS-18	Integrate management of inactive mine areas into Life of Mine plan	Ongoing
Acid and / or metalliferous drainage	WTS-01	Undertake geochemical analyses (eg leach testing) of non-acid forming material with neutralisation capacity to understand buffering capacity for waste dump AMD and pit lake water quality assessments.	Ongoing
	WTS-16	Ensure learnings from modelling and in situ measurements at Pilbara mines are used to review and revise PAF management activities prior to PAF removal in S17.	Ongoing
Water	WTS-03	Update pit lake water quality modelling to incorporate improved knowledge base	Prior to end of mining at individual pits

Aspect	Reference	Task	Due date
Closure landforms	WTS-05	Review water management for waste dumps that abut the landscape to minimise run-on to dumps at closure.	As part of individual design reviews
	WTS-07	Review and verify the pit wall stability management requirements for the S10 MM pit wall below local creek.	Prior to commencing closure activities
	WTS-15	Refine design of S10 MM pit wall buttress stabilising structure based on selected material waste characteristics.	Prior to commencing closure activities
	WTS-20	Review and revise controls for preventing inadvertent access to the pit, considering geotechnical instability, surface water management and topography	Prior to commencing closure activities
	WTS-21	Review conformance to waste dump encapsulation design during construction	Next update
	WTS-08	Investigate processes for reclaiming / rehabilitating over-blast areas.	Prior to commencing closure activities
Biodiversity	WTS-10	Assess the ability of pit lake water to sustain aquatic flora and fauna.	Prior to commencing closure activities
	WTS-11	Update pit lake ecological risk assessments as knowledge develops, including the potential for biological attenuation	Prior to commencing closure activities
Community	WTS-12	Conduct visual amenity assessment of final landform options.	Next update
	WTS-13	Undertake closure specific consultation with TOs to determine cultural management closure requirements	Prior to next update
	WTS-14	Consult with key stakeholders to gauge their expectations in regards to post closure land-use, objectives and criteria.	Ongoing

CLOSURE IMPLEMENTATION

20 Closure implementation

20.1 Removal of infrastructure

Decommissioning is anticipated to commence at the cessation of mining activities, as most areas of the mine, mine equipment and infrastructure will be fully utilised until the end of the mine life. However, as with progressive rehabilitation, opportunities to decommission areas in advance and facilitate rehabilitation will be reviewed through the mine planning process.

Hamersley has generic strategies for the removal of infrastructure, and develops location specific decommissioning plans as the mine approaches closure. Strategies involve:

- negotiating with Government prior to the removal of infrastructure as required under State Agreement requirements;
- actively seeking opportunities to recycle or reuse infrastructure that is to be removed;
- removing any environmentally hazardous materials in accordance with Controlled Waste Regulations; and
- where recycling and reuse opportunities are not available or viable, demolishing inert infrastructure and burying it onsite.

The decommissioning requirements for infrastructure at WTS are outlined in Table 28.

Table 28: Decommissioning requirements for WTS.

Category	Strategy
General	• Any equipment, steel structures or material that is not suitable for reuse are to be completely removed to an approved disposal site. • If encountered, any asbestos-containing building product or pipe work is to be disposed appropriately.
Above ground structures (e.g. buildings, tanks, rail)	• Brick, block work and steel frame structures are to be dismantled and salvaged or appropriately disposed. • Any container or tank that has held hazardous materials is to be drained/emptied and then disposed. • Bullet tanks and storage tanks 4 m diameters and less will be disposed of whole. Bins and storage tanks greater than 4 m diameter will be cut into transportable sizes for removal.
Reinforced soil walls	• Remove any structures, footings, slabs and equipment supported by the wall and its backfill. • Dismantle wall and remove backfill back to a natural surface profile. Any part of the wall that will be more than 1m below the finished ground surface can remain in place.
Concrete or sleeper-type retaining walls	• Remove any structure, footings, slabs and equipment supported by the wall. • Excavate soil from back of wall to a depth sufficient to allow the next two steps to be safely accomplished. • Remove any tiebacks and deadmen that are within 1 m of the finished ground level.
Ground slabs	• Remove all attached steelwork, block work, services and equipment. • Break up and dispose of the concrete and full removal is practicable / required. • Otherwise leave the slab in place and cover with earth to a natural profile, and with minimum cover of 1 m.
Footings and associated pedestals	• Remove all attached steelwork and equipment. • If the footing and associated pedestals are less than 2 m^3, remove and dispose of them. • Otherwise cut and remove pedestals if required, and cover with earth to a natural profile, and with minimum cover of 1 m.
Above-ground concrete plinths (e.g. pump plinths) and structures (e.g. crusher blocks)	• Remove all attached steelwork and equipment. • Where practicable, remove concrete intact to disposal. • Otherwise, break concrete items and remove to disposal.
Culverts	• Remove all fill back to natural surface profile. • Remove culvert.

Category	Strategy
Sedimentation basins, ponds and reservoirs	• Dispose of liquid and sediments prior to deconstruction. • Break up and remove all concrete.
Roads and hardstand areas	• Remove any bituminous material to a disposal pit. • If roads were treated with salt or an acid based dust suppressant then clean fill maybe required over the road so that plant germination is not suppressed
Below ground infrastructure	• Services and infrastructure less than 1 m below ground level to be removed. • Services and infrastructure greater than 1m below ground level to be left in situ.
General areas	• Dispose of rubbish and any other decommissioning debris in an appropriate manner. • Remove any contaminated soil or designated hazardous materials that area to be remediated separately.

20.2 Closure domains

Closure domains are used to group areas with common features, rehabilitation and decommissioning requirements. Closure domains that have been established for WTS include:

- generic site areas, as described in Table 29, that may be rehabilitated on an ad hoc basis, when the disturbed area is no longer required to support the operations. No rehabilitation schedule is available for these areas; and
- constructed landforms, as described in Table 30, that have the potential to be rehabilitated once mining ceases in the local area. An indicative schedule indicating when the associated subdomains would be available for rehabilitation is provided.

The distribution of closure domains is illustrated in Figure 25. Refinement of the closure domains and associated detailed plans for the rehabilitation and decommissioning of these areas will be developed as areas become available or alternatively developed immediately prior to closure.

Table 29: WTS general area implementation strategies by closure domain.

Domain	Closure method
Borrow pits	• No backfill required • Reshape to a self-draining landform and contour to blend with local landscape. • Respread topsoil windrows and stockpiled vegetation onto disturbed area. Deep rip and seed, if required.
Landfill	• Cap with least 2 m of competent inert material. • Respread topsoil windrows and stockpiled vegetation onto disturbed area. Deep rip and seed.
Highly disturbed area	• Demolish or dismantle built structures to footing level. Remove bitumen and concrete. Dispose of demolition material to an appropriate waste site. • Undertake extensive earthworks and reshaping of areas to create a compatible landform consistent with the surrounding natural relief and landforms. • If the area is very compacted additional ripping may be required • Natural drainage lines to be re-established where practicable. • Topsoil, rip, seed treatment and spread stockpiled vegetation
Moderately disturbed area	• Demolish or dismantle built structures to footing level. Remove bitumen and concrete. Dispose of demolition material to an appropriate waste site. • Contour to either return the area to natural relief or create a compatible landform consistent with the surrounding natural relief and landforms. • Natural drainage lines to be re-established where practicable. • Topsoil, rip, seed treatment and spread stockpiled vegetation
Low level disturbance	• Scatter any dead vegetation or rocks over the rehabilitated surface to increase habitat diversity and reduce wind and water erosion. • Natural drainage lines to be re-established where practicable. • Where top soil has not been removed and compaction is limited to two wheel tracks the area will be left to rehabilitate naturally. Other tracks should be ripped. • On slopes, rip parallel to contours. • Topsoil (as required), rip, seed treatment and spread stockpiled vegetation.

Table 30: WTS void and waste dump implementation strategies and schedule by closure domain. (Please refer to Table 6 for relevant completion criteria references.)

Domain	Closure method	Relevant completion criteria	Sub-domain areas	Indicative closure schedule
Voids				
Inert AWT pits	• No backfill required. • Opportunistic in pit waste disposal. • Identify and implement means to restrict public access i.e. abandonment bund outside zone of instability • Bare rock areas will not be rehabilitated. (See waste dump domains for in pit rehabilitation requirements).	6b, 6d	S10 pits • S10 Crown • S10 Head • S10 Tail • SE 10 West BK 01 • SE 10 West BK 02 B1 pits • B1 Satellite (2-4) S17 pits • S17 Pit 4 • S17 Pit 5 • S17 Pit 6 • S17 Pit 7	 2023 2018 2023 2025 2025 2034 2024 2024 2024 2025
Backfill pits	• Preference for opportunistic backfill during mining. • Validate backfill levels based on latest hydrogeological investigations. • Verify source of material for backfill. Consider recovery of material from upper lifts of adjacent waste dumps and areas where as-built waste dumps require significant waste movement to re-shape to stable landform. • Backfill to nominated above groundwater recovery levels to prevent permanent lake formation: – SE10 East MM 101 @ 545m RL (5m above water table) – SE10 East MM 201 @ 545m RL (5m above water table) – SE10 West MM 01 @ 550m RL (5m above water table) – S17 Pit 3 @ 515m RL (10m above water table) – S17 Pit 8 @ 515m RL (10m above water table) • Identify and implement means to restrict public access i.e. abandonment bund outside zone of instability • Bare rock areas and backfill disconnected from the local environment by more than 10 m of bare rock will not be rehabilitated. (See waste dump domains for in pit rehabilitation requirements).	6b, 6d	S10 pits • SE10 East MM 101 • SE10 East MM 201 • SE10 West MM 01 S17 pits • S17 Pit 3 • S17 Pit 8	 2019 2021 2027 2022 2028

Domain	Closure method	Relevant completion criteria	Sub-domain areas	Indicative closure schedule
PAF backfill (In pit PAF waste disposal)	• Encapsulate material as described in Section 15.1.2 during construction. • Identify appropriate materials for construction of store and release cover (refer to Section 15.3). • Develop and purchase appropriate local provenance seed mix for location, based on store and release cover properties and seed species availability. Consider plant root depth and climate conditions at base of pit. • Build store and release cover on top of waste ensuring a 5m buffer remains between PAF cells and final rehabilitated surface (refer to Section 15.3). • Topsoil and mulch spread over the dump surface to a maximum depth of 200mm. Deep rip and seed.	2a, 2b, 3a, 3b, 4a, 4b	S17 Pit 1 S17 Pit 2	2025 2023
Lake pits	• Verify pit lake water quality modelling predicts acceptable outcomes. Further engagement with stakeholders will be required if unacceptable outcomes are possible; and contingency plans to backfill voids may be required. • Identify and stabilise, where required, safe egress routes to future lake areas. Consider future monitoring, public access (if any) and drainage management requirements. • Identify and implement means to prevent inadvertent access to area, i.e. abandonment bund outside zone of instability	5a, 5b, 6b, 6d	S10 Body B1 Main	2023 2034

Domain	Closure method	Relevant completion criteria	Sub-domain areas	Indicative closure schedule
Waste dumps				
Inert waste dumps	• Verify as-built conditions including waste dump slope material erodibility characteristics. • Develop implementation strategy to re-shape as-built waste dump according into rehabilitation design parameters (Table 21). • Integrate local surface water management elements into rehabilitation design. • Identify surface treatment options, based on top soil availability and any drainage armouring requirements. • Develop and purchase appropriate local provenance seed mix for location, based on required habitat outcome and seed species availability. • Commence landform shaping once appropriate approvals are in place. Contour rip outer surface of waste dump. • Topsoil and mulch spread over the dump surface to a maximum depth of 200mm. Deep rip and seed.	1a, 3a, 3b, 4a, 4b	S10 waste dumps • S10MM_E_LTLG • S10MM_E_WD • S10E_LTLG • S10E_WD • S10N_WD (remaining material) • S10MM_W_WD • S10_TPW_WD • S10_ROM B1 waste dumps • B1_WD • B1_LTLG • B1 ROM pad crusher • B1 ROM Road train S17 waste dumps • S17N_LTLG • S17N_WD • S17S_WD • S17S_LTLG	 2023 2023 2023 2023 2023 2023 2023 2023 2034 2034 2034 2034 2030 2030 2030 2030
In pit wall structures	• Verify source of material for structure construction. Consider recovery of material from upper lifts of adjacent waste dumps to prevent encapsulated high erodibility materials from being exposed on rehabilitation surfaces. • Develop implementation strategy to build waste dump according to material erodibility properties. Guidance for rehabilitation design parameters located in Table 21. • Integrate local surface water management elements into rehabilitation design. • Identify surface treatment options, based on top soil availability and any drainage armouring requirements. • Develop and purchase appropriate local provenance seed mix for location, based on required habitat outcome and seed species availability. Consider final material type properties and the impact of plant root structures on structural integrity. Optimise plant species selection for stability over biodiversity. • Build landform once appropriate approvals are in place. • Topsoil and mulch spread over the dump surface to a maximum depth of 200mm. Deep rip and seed.	1a, 3a, 3b, 4a, 4b	S10MM_IPWD	2021

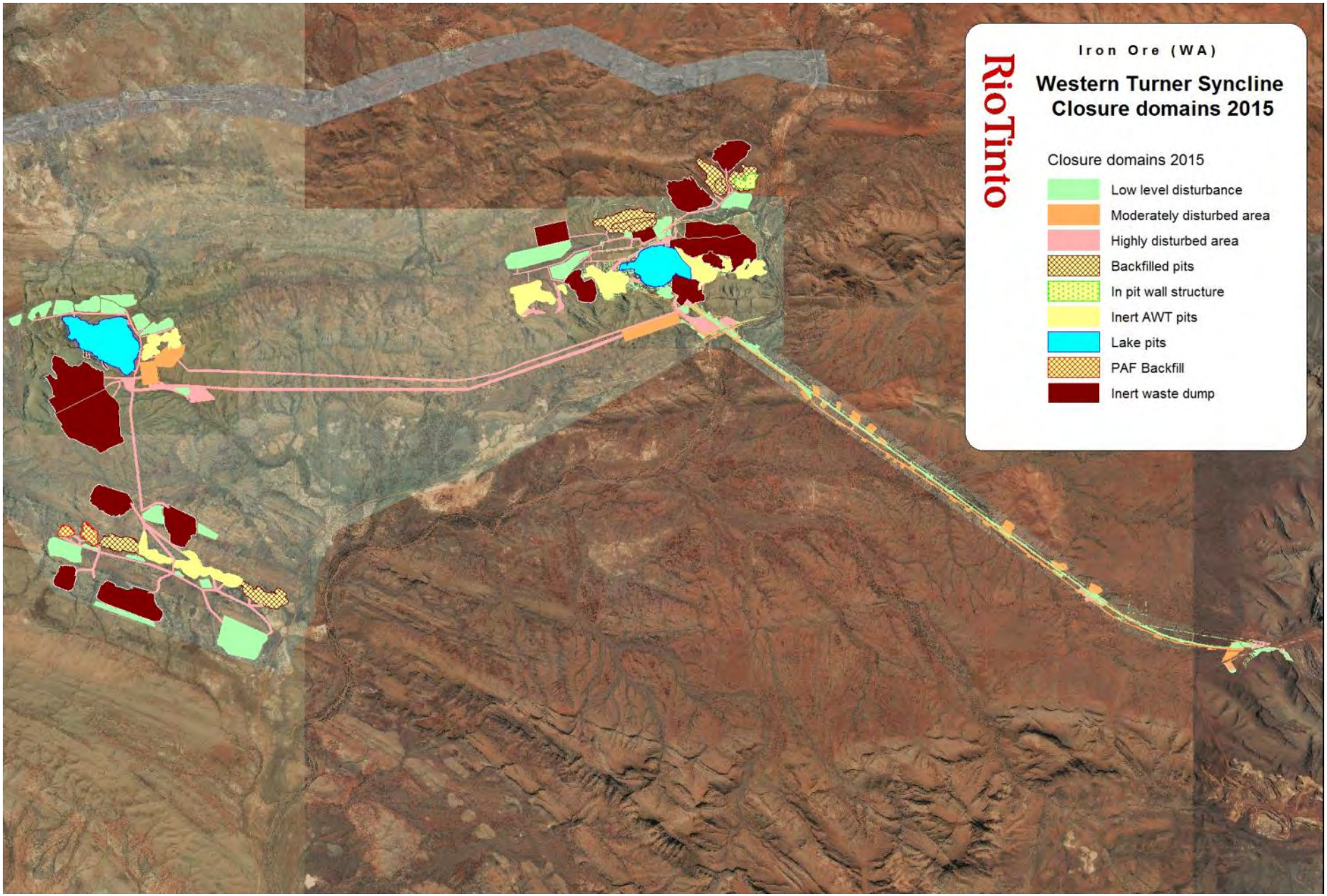


Figure 25: WTS closure domains. (Note Landfill and Borrow pit domains are too small to appear on maps)

21 Premature closure and other factors

The closure implementation schedule may be influenced by factors outside of the current mine plan. These factors include:

- suspension of operations under care and maintenance; this could occur if production costs exceed product value e.g. due to commodity price changes;
- unexpected closure; this could occur if there was major change in global demand for iron ore; and
- future proposals; these could occur if iron ore deposits of appropriate quality are identified adjacent to the existing deposits.

21.1 Care and maintenance

In the event of temporary closure, measures will be undertaken to transfer the site from operations into a care and maintenance regime and relevant authorities notified. A Care and Maintenance Plan will be developed prior to the care and maintenance period which demonstrates how on-going environmental obligations associated with the site will continue to be met during the period of care and maintenance. Social obligations and responsibilities will also be addressed in this plan.

21.2 Unexpected closure

Whilst Hamersley considers the risk of unexpected closure to be minimal, there are numerous factors that could force early closure of one or several sites. Even if some level of contraction were to occur, it is reasonable to assume that Hamersley would continue to operate in the Pilbara and that it could continue to manage closure of its sites. It should be noted that Hamersley is one group within the global Rio Tinto group of companies, which further mitigates this risk.

In the event of unplanned or sudden closure, Hamersley will notify all relevant authorities including the DMP. The existing closure plan for the site would then be revised and a Decommissioning Plan prepared and submitted to the DMP and other relevant authorities within three months of notification of closure. The Decommissioning Plan will include undertaking detailed consultation with stakeholders. Once the plan is approved by the relevant authorities, work will commence on closure implementation activities.

21.3 Future proposals

As illustrated in the Western Australian Government *Guidelines for Preparing Mine Closure Plans,* planning for mine closure, including stakeholder and regulator consultation should commence during the exploration stages of the project. Basic information relevant to these prospective deposits is provided in this section in order to facilitate discussions with key stakeholders, and is not intended for regulatory approval at this time.

There are several deposits between B1 and S10 (Figure 26) that are reported as part of the ore reserves for the WTS operations. Table 31 lists the deposit setting, landscape position and relationship to the groundwater table. Development of these deposits would prolong the mine life of WTS.

Table 31: WTS prospective deposit names and general setting.

Deposit	Dominant geology	Landscape position	Ore relative to water table
S10			
SE10 West MM 02	Marra Mamba	Plains	All above
SE10 West BK02	Brockman	Hill	All above
B1			
B1 East BK 01	Brockman	Hill	All above
B1 East BK 02	Brockman	Hill	All above
B1 West BK 01	Brockman	Hill	All above
B1 East MM 02	Marra Mamba	Hill	All above
B1 East MM 01	Marra Mamba	Hill	Above and below
B1 Det Area 7	Detrital	Hill	Above and below
B1 Det Area 10	Detrital	Hill	Above and below

Detailed closure planning for these prospective deposits will be developed as and if mining studies progress, prior to regulatory approval to mine these deposits being requested.

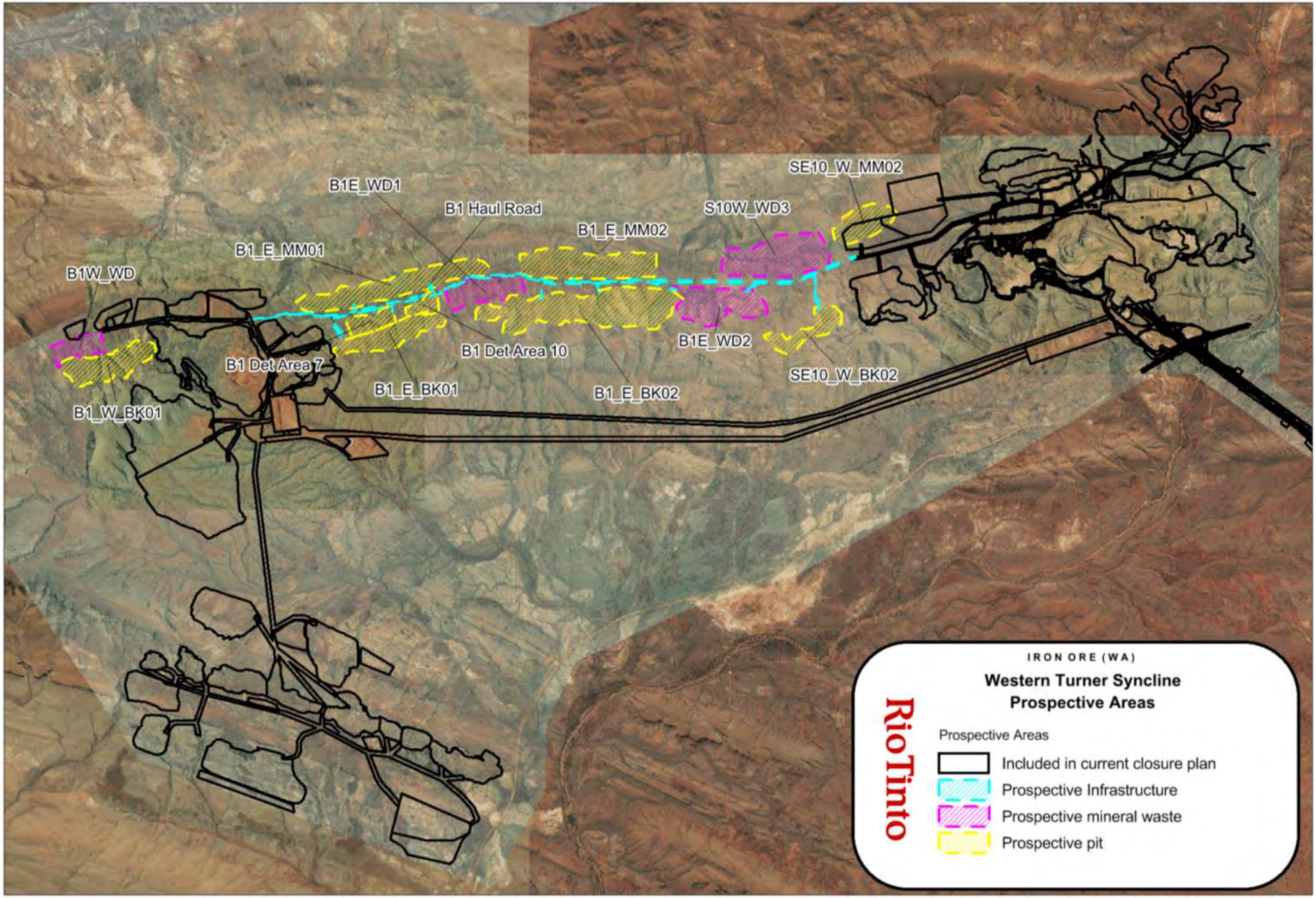


Figure 26: Prospective areas that could lead to the expansion of the WTS operation.

CLOSURE MONITORING AND MAINTENANCE

22 Closure monitoring programs

An environmental monitoring program is underway at WTS to track the performance of the operation, identify potential environmental impacts and to better understand the environment surrounding the mine in order to avoid or minimise future environmental impacts. This includes:

- baseline monitoring, which is conducted as operations expand into new mining areas; and
- operational monitoring, which occurs throughout the life of the mine, in line with regulatory requirements and the Rio Tinto operational standards.

Results from the operational environmental monitoring program that are relevant to closure are summarised in this closure plan.

A phased approach to closure monitoring, consistent with other Hamersley sites, is proposed for WTS:

- **Pre-closure monitoring**: occurs as the site approaches closure to establish post-mining baseline conditions (where required). Aspects that may need to be collected to establish the post-mining conditions include water levels outside the active mine area, riparian vegetation condition, and potentially terrestrial fauna;
- **Decommissioning monitoring**: conducted during the period of active site decommissioning and rehabilitation. This monitoring plan will be developed as part of the final closure plan, to ensure the activities do not adversely impact the environment; and
- **Post-closure monitoring**: conducted on a scheduled basis until the completion criteria have been met. This monitoring plan will be developed as part of the final closure plan.

The monitoring aspects expected to be undertaken at each phase of monitoring are listed in Table 32. This monitoring is undertaken to inform Hamersley internal quality control and assurance processes as well as to demonstrate that closure objectives have been met. It is expected that the monitoring programmes will be sufficiently flexible to enable adjustments to be made if results indicate that more or less monitoring is warranted at any particular phase. Completion criteria monitoring will continue until stakeholders agree that the completion criterion has been achieved.

Table 32: Expected components of the closure monitoring program

Monitoring aspect	Phase		
	Pre closure	**Decommissioning**	**Post closure**
Vegetation	✓	✓	✓
Fauna			✓
Erosion	✓	✓	✓
Weeds	✓	✓	✓
Ecological function	✓		✓
Water quality and contaminant	✓	✓	✓
Heritage	✓	✓	

22.1 Vegetation monitoring

Vegetation monitoring tracks the progress and evaluates successional development of rehabilitation areas. This information is used to assess progress towards long term rehabilitation objectives and to improve rehabilitation techniques.

Vegetation characteristics will be recorded by quadrat at intervals along transects at established rehabilitation and associated reference sites. Qualitative assessment of soil surface, perennial vegetation cover, species richness and general condition will also be recorded.

The monitoring program is expected to include:

- number of plants by species;
- percentage cover by species;
- bare areas in quadrat;

- percentage of perennial cover;
- percentage of spinifex cover;
- percentage of grass cover (excluding spinifex);
- percentage of native perennial shrub cover (0.5m to 2m);
- percentage of litter cover;
- percentage of tree cover >2m;
- presence of annuals;
- presence of weeds species; and
- if burnt since last monitoring.

Monitoring will be scheduled annually for the first three years after establishment, biennially from years five to nine and (approximately) triennially thereafter, until sufficient information is gathered to validate the performance of the rehabilitation.

22.2 Fauna monitoring

Invertebrates have a major role in the success of rehabilitation efforts because they facilitate a variety of ecosystem processes, such as litter decomposition and nutrient cycling, herbivory, seed dispersal, soil aeration and drainage, pollination and provision of a source of food for vertebrate predators. Invertebrates can be encouraged by providing areas of thick, widespread litter cover over part of the area, logs and standing dead wood. Vertebrates are usually the last to recolonise, once complex vegetation assemblages and invertebrate prey are established.

Fauna monitoring will be undertaken in conjunction with vegetation monitoring schedule. Fauna monitoring will review transects as a whole to record:

- number of logs (>10cm diameter and >30cm long);
- number of rocks (>15cm diameter);
- presence of scat;
- presence of ants;
- general animal sighting (including tracks, burrows and nests);
- flowering and fruiting species; and
- extent of grazing.

As with rehabilitation monitoring, fauna monitoring will continue until sufficient information is gathered to describe the environmental conditions with respect to fauna.

22.3 Erosion monitoring

Monitoring involves the examination of transects for the number of rills and gullies, recording their width and depth. These measurements are compared over time to determine if the landform has stabilised; for example erosion rates are within the accepted completion criteria range or rill and gully geometry is similar to the surrounding landscape. If a landform fails to stabilise, further management / intervention will be applied.

22.4 Weed monitoring

Weed management programs will be developed for each phase of closure immediately prior to closure, to reflect the different work programmes and associated risks. These programs will define procedures to identify, control and eradicate target weeds and monitor weed control measures to minimise the spread of weed species, prevent the introduction of new weeds and control and/or eradicate both noxious and environmental weeds across the rehabilitated area.

For example, the pre-closure weed management program will focus on annual weed eradication and control, as mining and associated disturbance activities will still be occurring in the area. During the decommissioning phase, weed management will emphasise weed hygiene, in order to minimise the spread of weeds with the significant increase in vehicle and earth movement activities. During the post-closure phase, weed management will focus on monitoring, which will be undertaken as part of the rehabilitation monitoring activities, with inspection and trigger / response remediation actions.

22.5 Ecological function

Targeted monitoring of select ecological functions may be required to ensure that biological, geological and chemical interactions associated with lake water quality and lake fringe vegetation have evolved as predicted. Monitoring requirements for validating these ecological functions will be resolved with key stakeholders prior to closure.

22.6 Water quality and contaminants monitoring

Water monitoring networks will be established during the life of the mine and during the decommissioning phase to validate groundwater and surface water predictions. It is expected that monitoring for water level, pH, EC, alkalinity/acidity, major cations and anions including sulfate and metals will be undertaken every six months until sufficient information is gathered to validate the water recovery and quality predictions.

22.7 Heritage

Heritage will continue to managed and monitored in accordance with the Cultural Heritage Management System until the land tenure is relinquished to the State Government.

FINANCIAL PROVISION FOR CLOSURE

23 Principles of Rio Tinto closure cost estimation

Closure cost estimates are determined in accordance with internal accounting policy methods, with the level of accuracy increasing as the site approaches closure. During the life of the operation, two closure costs will be developed:

- A Present Closure Obligation (**PCO**) which is indicative of costs associated with closure of the mine given its current footprint; and
- A Total Projected Closure (**TPC**) cost which predicts the cost (in current terms) associated with closure at the end of the life of the mine. The TPC includes areas that are not currently approved, but that feature within the life of mine plan and that are considered likely to be developed in the future.

The cost estimates consider the following components:

- Decommissioning (i.e. removal of infrastructure)[7];
- Final landform construction;
- Rehabilitation and biodiversity management;
- Heritage management;
- Workforce management (i.e. training costs and redundancy payments)[8];
- Monitoring costs;
- Costs associated with the development of a Final Decommissioning Plan;
- Costs associated with undertaking a final shutdown of operations;
- Allowance for failed rehabilitation or pollution that may necessitate rework of rehabilitation areas;
- Assignment of indirect costs in accordance with Rio Tinto Accounting Policy; and
- A contingency allowance.

The amount recognised for closure at any given time will be determined by using the best and most recent estimate of the expected cost at that time.

The PCO estimate is revised on an annual basis, whilst the TPC estimate is revised whenever a formal closure plan review is conducted. Note that for commercial reasons the actual estimate is not documented in this closure plan.

[7] The decommissioning cost estimate assumes that infrastructure will be demolished and buried on site. However; opportunities for salvage and recycling will be sought as the site approaches closure.

[8] Workforce management costs are only included in the TPC.

MANAGEMENT OF INFORMATION AND DATA

24 Data and information management

24.1 Iron Ore Document Management System (IODMS)

Hamersley operates a comprehensive document management system, with electronic records of all key information and data. The document system, known as Iron Ore Document Management System (**IODMS**) is linked to other business units within the Rio Tinto group of companies, and processes are in place to ensure that the data contained within this system is appropriately backed up and protected. Each document stored within this system is given a unique document number which identifies the document and enables it to be accessed. This system will continue to operate following site closure, and all relevant data will be retained accordingly.

An audit will be conducted prior to closure to ascertain whether there is any additional information stored in hard copy form at the site. Such data will be scanned and entered into IODMS to ensure that it is appropriately retained post-closure.

Hard copies of confidential information stored at the site (such as employee records) will be destroyed at the time of closure.

24.2 Closure knowledge base

The closure knowledge database is a knowledge management process designed to bring closure related research and monitoring outcomes together into one searchable location. It uses a single entry form to capture where the report is stored, and how and where the research can be applied for all new ongoing and completed closure related studies. This information is then managed by the Closure team within a secure database.

24.3 EnviroSys

EnviroSys is a desktop application, with a web based interface, that manages environmental and hydrogeological parameters collected in the field and their logical context. The tool is used to store, monitor and analyse those parameters and report trends on data collections.

Data collected includes:

- groundwater – biological, chemical, field, levels, production;
- marine water – biological, chemical, field;
- soil chemistry;
- surface water – biological, chemical, field, levels, production;
- tonnes and moisture;
- water meters; and
- weather (rainfall, temperatures etc.).

EnviroSys is used to support the building of closure knowledge bases, as well as ensure compliance with operating licenses pertaining to data management.

24.4 Legal and other requirements system

The Legal and Other Requirements System (LAORS) is used by Hamersley to manage the following:

- Approval and Legislation Reports which provide a high level snapshot of approvals and legislation and is used to check the status and expiry dates of approvals.
- Approval and Legislative Requirements Reports which lists
  - accountabilities for specific conditions within approvals and clauses within legislation;
  - required actions to comply with approvals and or legislation; and
  - due dates for specific requirements.
- Statutory Position Appointed Persons reports which list individuals appointed to a statutory position.
- Statutory Position Accountabilities Reports which identify clauses of legislation that the statutory position is accountable for.

APPENDIX A – REGISTER OF KEY CLOSURE OBLIGATIONS

WESTERN TURNER SYNCLINE CLOSURE OBLIGATIONS REGISTER

Legal Obligations

Ministerial Statement 807	
Condition No.	**Closure conditions**
9-1	Prior to commencement of mining the proponent shall have conducted surveys of the proposal area to collect baseline information on the following: 1. soil profiles; 2. groundwater levels; 3. surface water levels; 4. plant communities and flora; and 5. landscape and landforms
9-2	Waste dumps and other artificial landforms shall be constructed so that their shape, size, stability, soil profiles ability to support native vegetation, and response to surface water flows are comparable to natural landforms in the area.
9-3	Waste dumps, artificial landforms and other disturbed areas outside the pit, shall be progressively rehabilitated with native plant species of local provenance.
9-4	Within five years of mine closure, the percentage cover of native vegetation shall be comparable with that of natural landforms in the area.
9-5	No new noxious or environmental weed species shall be introduced into the area as a result of the implementation of the proposal.
9-6	Within five years of mine closure the distribution and abundance of weeds shall be no greater than the distribution and abundance of weeds prior to the implementation of the proposal.
9-7	Within five years of mine closure the proponent shall submit a report of rehabilitation performance monitoring to the CEO of the department of Environment and Conservation and the Director general of the Department of State Development and shall address in the report the following: 1. progress towards meeting the criteria required by conditions 9-2 to 9-6 inclusive; and 2. contingency management measures in the event that criteria are unlikely to be met.

Ministerial Statement 946	
Condition No.	**Closure conditions**
8-1	Within 6 months following commissioning of the first Western Turner Syncline Stage 2 pit, or as otherwise agreed by the CEO, the proponent shall prepare a Western Turner Syncline Stage 2 - B1 and Section 19 Deposits mine Closure Plan in accordance with the Guidelines for Preparing Mine Closure Plans, June 2011, in consultation with the DMP, and undertake any updates of the Mine Closure Plan to the requirements of the CEO on advice of the DMP.
8-2	The Mine Closure Plan required by condition 8-1 shall ensure that closure planning and rehabilitation are carried out in a coordinated, progressive manner and are integrated with development planning, consistent with current best practice, and the agreed land uses.
8-3	Within 12 months following commission of the first Western Turner Syncline Stage 2 pit, or as otherwise agreed by the CEO, the proponent shall implement the Western Turner Syncline Stage 2 _ B1 and Section 17 Deposits Mine Closure Plan required by condition 8-1 and any subsequent approved revisions and continue implementation until otherwise agreed by the CEO.
Schedule 1	Backfilling of mine pits 3 and 8 at Section 17: Mine pits are to be backfilled so that the final surface levels are at a higher elevation than the predicted post development groundwater levels to prevent the formation of pit lakes.

WESTERN TURNER SYNCLINE CLOSURE OBLIGATIONS REGISTER

Legal Obligations

Iron Ore (Hamersley Range) Agreement Act 1963	
Clause No.	**Closure obligations**
1. Interpretation	Nothing in this Agreement shall be construed: (a) to exempt the Company from compliance with any requirement in connection with the protection of the environment arising out of or incidental to its activities under this Agreement that may be made by or under the EP Act;
11(e)	that on the cessation or determination of any lease license or easement granted hereunder or pursuant hereto by the State to the Company or (except as otherwise agreed by the Minister) to an associated company or other assignee of the Company under clause 20 hereof of land or held pursuant hereto for the Company's wharf for any installation within the harbour for the Company's railway or for housing at the port or port townsite the improvements and things erected on the relevant land and provided for in connection therewith shall remain or become the absolute property of the State without compensation and freed and discharged from all mortgages and encumbrances and the Company will do and execute such documents and things (including surrenders) as the State may reasonably require to give effect to this provision. In the event of the Company immediately prior to such expiration or determination or subsequent thereto deciding to remove its locomotives rolling stock plant equipment and removable buildings or any of them from any land it shall not do so without first notifying the State in writing of its decision and thereby granting to the State the right or option exercisable within three months thereafter to purchase at valuation in situ the said plant equipment and removable buildings or any of them. Such valuation shall be mutually agreed or in default of agreement shall be made by such competent valuer as the parties may appoint or falling agreement as to such appointment then by two competent valuers one to be appointed by each party or by an umpire appointed by such valuers should they fail to agree;

Mining Act 1978	
Miscellaneous Licence L47/209. Purposes: Road; powerline; conveyor system; taking water; communications to service a mining	
Condition No.	**Closure conditions**
18.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum.
19.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.
23.	At the completion of operations, all buildings and structures being removed from site or demolished and buried to the satisfaction of the Director, Environment Division, DMP.
Miscellaneous Licence L47/210. Purposes: mine-site administration buildings; workshop and vehicle facilities and equipment and fuel storage areas; road	
Condition No.	**Closure conditions**
N/A	Nil

Miscellaneous Licence L47/342. Purposes: road; pipeline; power line; tunnel; bridge; taking water; pump station; bore; water management facility; communications facility; storage or transportation facility for minerals or mineral concentrate; minesite administration facility; workshop and storage facility	
Condition No.	**Closure conditions**
13.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum.
22.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.
25.	All topsoil being removed ahead of all mining operations from sites such as pit areas, waste disposal areas, ore stockpile areas, pipeline, haul roads and new access roads and being stockpiled for later respreading or immediately respread as rehabilitation progresses
26.	At the completion of operations, all buildings and structures being removed from site or demolished and buried to the satisfaction of the Director, Environment Division, DMP.
Miscellaneous Licence L47/552. Purposes: a bore; a communications facility; a pipeline; a power line; a pump station; a road; a storage or transportation facility for minerals or mineral concentrate; a workshop and storage facility; taking water	
Condition No.	**Closure conditions**
3.	When surface disturbance activities are proposed on the licence which are not associated with development or construction proposals, the prior written approval of the Environmental Officer, DMP must be obtained before the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for the proposed surface disturbance activities. Following approval, all topsoil being removed ahead of operations and separately stockpiled for replacement after backfilling and/or completion of operations.
6.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum.
13.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.

Miscellaneous Licence L47/645. Purposes: a bore; a communications facility; a conveyor system; a minesite administration facility; a pipeline; a power line; a pump station; a road; a storage or transportation facility for minerals or mineral concentrate; a workshop and storage facility; taking water	
Condition No.	**Closure conditions**
3.	When surface disturbance activities are proposed on the licence which are not associated with development or construction proposals, the prior written approval of the Environmental Officer, DMP must be obtained before the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for the proposed surface disturbance activities. Following approval, all topsoil being removed ahead of operations and separately stockpiled for replacement after backfilling and/or completion of operations.
7.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum.
14.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.
20.	At the completion of operations, all buildings and structures being removed from site or demolished and buried to the satisfaction of the Director, Environment Division, DMP.
24.	On the completion of operations or progressively when possible, all waste dumps, tailings storage facilities, stockpiles or other mining related landforms must be rehabilitated to form safe, stable, non-polluting structures which are integrated with the surrounding landscape and support self sustaining, functional ecosystems comprising suitable, local provenance species or alternative agreed outcome to the satisfaction of the Executive Director, Environment Division, DMP.
Miscellaneous Licence L47/646. Purposes: a bore; a bridge; a communications facility; a drainage channel; a pipeline; a power line;	
Condition No.	**Closure conditions**
2.	When surface disturbance activities are proposed on the licence which are not associated with development or construction proposals, the prior written approval of the Environmental Officer, DMP must be obtained before the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for the proposed surface disturbance activities. Following approval, all topsoil being removed ahead of operations and separately stockpiled for replacement after backfilling and/or completion of operations.
7.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum

14.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.
Miscellaneous Licence L47/668. Purposes: a bore; a communications facility; a drainage channel; a pipeline; a power line; a pump station; a road; taking water	
Condition No.	**Closure conditions**
3.	When surface disturbance activities are proposed on the licence which are not associated with development or construction proposals, the prior written approval of the Environmental Officer, DMP must be obtained before the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for the proposed surface disturbance activities. Following approval, all topsoil being removed ahead of operations and separately stockpiled for replacement after backfilling and/or completion of operations.
11.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum.
19.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.
Miscellaneous Licence L47/698. Purposes a bore; a communications facility; a pipeline; a power generation and transmission facility; a power line; a pump station, a road, a storage or transportation facility for minerals or mineral concentrate, a water management facility, a workshop and storage facility, taking water	
Condition No.	**Closure conditions**
3.	When surface disturbance activities are proposed on the licence which are not associated with development or construction proposals, the prior written approval of the Environmental Officer, DMP must be obtained before the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for the proposed surface disturbance activities. Following approval, all topsoil being removed ahead of operations and separately stockpiled for replacement after backfilling and/or completion of operations.
7.	All topsoil that may be removed ahead of pipelaying operations to be stockpiled for replacement in accordance with the directions of the Environmental Officer, Department of Mines and Petroleum.

19.	On the completion of the life of mining operations in relation to this licence the holder shall: Remove all installations constructed pursuant to this licence; Cover over all wells and holes in the ground to such degree of safety as shall be determined by the Environmental Officer, Department of Mines and Petroleum; and On such areas cleared of natural growth by the holder or any of its agents, the holder shall plant trees and/or shrubs and/or any other plant as shall conform to the general pattern and type of growth in the area and as directed by the Environmental Officer, Department of Mines and Petroleum and properly maintain same until the Environmental Officer advises regrowth is self supporting; unless the Mining Registrar or Minister responsible for the Mining Act 1978 orders or consents otherwise.
24.	At the completion of operations, all buildings and structures being removed from site or demolished and buried to the satisfaction of the Director, Environment Division, DMP.
28.	On the completion of operations or progressively when possible, all waste dumps, tailings storage facilities, stockpiles or other mining related landforms must be rehabilitated to form safe, stable, non-polluting structures which are integrated with the surrounding landscape and support self sustaining, functional ecosystems comprising suitable, local provenance species or alternative agreed outcome to the satisfaction of the Executive Director, Environment Division, DMP.
General Purpose Lease G47/1258. Purpose: Facilities for erection, operation and storage of plant, machinery and equipment, mineral ore, tailing, topsoil and waste transport, processing and storage facilities, and infrastructure including roads, water and laydown and storage areas and other purposes permitted pursuant to the Iron Ore (Hamersley Range) agreement Act 1963, including in connection with approved proposals.	
Condition No.	**Closure conditions**
8.	All topsoil and vegetation being removed ahead of all mining operations and being stockpiled appropriately for later respreading or immediately respread as rehabilitation progresses.
9.	At the completion of operations, all buildings and structures being removed from site or demolished and buried to the satisfaction of the Director, Environment Division, DMP.
13.	On the completion of operations or progressively when possible, all waste dumps, tailings storage facilities, stockpiles or other mining related landforms must be rehabilitated to form safe, stable, non-polluting structures which are integrated with the surrounding landscape and support self sustaining, functional ecosystems comprising suitable, local provenance species or alternative agreed outcome to the satisfaction of the Executive Director, Environment Division, DMP.
General Purpose Lease G47/1260. Purpose: Facilities for erection, operation and storage of plant, machinery and equipment, mineral ore, tailing, topsoil and waste transport, processing and storage facilities, and infrastructure including roads, water and laydown and storage areas and other purposes permitted pursuant to the Iron Ore (Hamersley Range) agreement Act 1963, including in connection with approved proposals.	
N/A	Nil
Exploration Licence E47/1411	
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion
2.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.

3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
4.	Unless the written approval of the Environmental Officer, DoIR is first obtained, the use of scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations
Exploration Licence E47/2948	
Condition No.	**Closure conditions**
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion
2.	All costeans and other disturbances to the surface of the land made as a result of exploration, including drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Industry and Resources (DoIR). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DoIR.
3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
4.	Unless the written approval of the Environmental Officer, DMP is first obtained, the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations.
Exploration Licence E47/2951	
Condition No.	**Closure conditions**
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion
2.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
4.	Unless the written approval of the Environmental Officer, DMP is first obtained, the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations.
Exploration Licence E47/2952	
Condition No.	**Closure conditions**
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion

2.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
4.	Unless the written approval of the Environmental Officer, DMP is first obtained, the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations.
Exploration Licence E47/2953	
Condition No.	**Closure conditions**
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion
2.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
4.	Unless the written approval of the Environmental Officer, DMP is first obtained, the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations.
Exploration Licence E47/2954	
Condition No.	**Closure conditions**
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion
2.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
Prospecting Licence P47/1709	
Condition No.	**Closure conditions**
1.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion

2.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
3.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
4.	Unless the written approval of the Environmental Officer, DMP is first obtained, the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations.
Prospecting Licence M47/1135	
Condition No.	**Closure conditions**
2.	All surface holes drilled for the purpose of exploration are to be capped, filled or otherwise made safe immediately after completion
3.	All disturbances to the surface of the land made as a result of exploration, including costeans, drill pads, grid lines and access tracks, being backfilled and rehabilitated to the satisfaction of the Environmental Officer, Department of Mines and Petroleum (DMP). Backfilling and rehabilitation being required no later than 6 months after excavation unless otherwise approved in writing by the Environmental Officer, DMP.
4.	All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings being removed from the mining tenement prior to or at the termination of exploration program.
5.	Unless the written approval of the Environmental Officer, DMP is first obtained, the use of drilling rigs, scrapers, graders, bulldozers, backhoes or other mechanised equipment for surface disturbance or the excavation of costeans is prohibited. Following approval, all topsoil being removed ahead of mining operations and separately stockpiled for replacement after backfilling and/or completion of operations.
Mineral Lease 4SA.	
Condition No.	**Closure conditions**
N/A	Nil

Native Vegetation Clearing Permit	
Permit No. 4413/1 (mineral exploration)	
Condition No.	**Closure conditions**
4	Retain vegetative material and topsoil, revegetation and rehabilitation The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within six months following completion of clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for the purpose for which they were cleared under this Permit by: (i) re-shaping the surface of the land so that it is consistent with the surrounding five metres of uncleared land; and (ii) laying the vegetative material and topsoil retained under Condition 4(a). (c) within four years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 4(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 4(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.
Permit No. 4581/1 (mineral production)	
Condition No.	**Closure conditions**
7	Retain and spread vegetative material and topsoil The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within 12 months following clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for the purpose for which they were cleared under this Permit by: (i) re-shaping the surface of the land so that it is consistent with the surrounding 5 metres of uncleared land; and (ii) laying the vegetative material and topsoil retained under Condition 7(a). (c) within 4 years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 7(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 7(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.

WESTERN TURNER SYNCLINE CLOSURE OBLIGATIONS REGISTER

Legal Obligations

Permit No. 4746/1 (mineral exploration)	
Condition No.	**Closure conditions**
9	Retain and spread vegetative material and topsoil The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within 12 months following clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for the purpose for which they were cleared under this Permit by: (i) re-shaping the surface of the land so that it is consistent with the surrounding 5 metres of uncleared land; and (ii) laying the vegetative material and topsoil retained under Condition 9(a). (c) within 4 years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 9(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 9(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.
Permit No. 4780/3 (access and early works)	
Condition No.	**Closure conditions**
9	Retain and spread vegetative material and topsoil The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within 12 months following clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for the purpose for which they were cleared under this Permit by: (i) re-shaping the surface of the land so that it is consistent with the surrounding 5 metres of uncleared land; and (ii) laying the vegetative material and topsoil retained under Condition 9(a). (c) within 4 years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 9(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 9(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.

Permit No. 4915/3 (mineral exploration)	
Condition No.	**Closure conditions**
8	Retain and spread vegetative material and topsoil The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within 12 months following clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for the purpose for which they were cleared under this Permit by: (i) ripping the ground on the contour to remove soil compaction; (ii) re-shaping the surface of the land so that it is consistent with the surrounding 5 metres of uncleared land; and (iii) laying the vegetative material and topsoil retained under Condition 8(a). (c) within 4 years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 8(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 8(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.
Permit No. 4993 (geotechnical investigations)	
Condition No.	**Closure conditions**
10	Retain vegetative material and topsoil, revegetation and rehabilitation The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within 12 months following clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for future scheduled and approved development by: (i) ripping the ground on the contour to remove soil compaction; and (ii) laying the vegetative material and topsoil retained under Condition 10(a) on the cleared area(s). (c) within 2 years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 10(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 10(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.

Permit No. 5657 (mineral exploration)	
Condition No.	**Closure conditions**
8	Retain and spread vegetative material and topsoil The Permit Holder shall: (a) retain the vegetative material and topsoil removed by clearing authorised under this Permit and stockpile the vegetative material and topsoil in an area that has already been cleared. (b) within 12 months following clearing authorised under this permit, revegetate and rehabilitate the areas that are no longer required for the purpose for which they were cleared under this Permit by: (i) re-shaping the surface of the land so that it is consistent with the surrounding 5 metres of uncleared land; and (ii) laying the vegetative material and topsoil retained under Condition 8(a). (c) within 4 years of laying the vegetative material and topsoil on the cleared area in accordance with Condition 8(b) of this Permit: (i) engage an environmental specialist to determine the species composition, structure and density of the area revegetated and rehabilitated; and (ii) where, in the opinion of an environmental specialist, the composition structure and density determined under Condition 8(c)(i) of this Permit will not result in a similar species composition, structure and density to that of pre-clearing vegetation types in that area, revegetate the area by deliberately planing and/or direct seeding native vegetation that will result in a similar species composition, structure and denisty of native vegetation to pre-clearing vegetation types in that area and ensuring only local provenance seeds and propogating material are used.

WESTERN TURNER SYNCLINE CLOSURE OBLIGATIONS REGISTER

Formal Commitments

Stakeholder Name	
Date	**Commitment**
n/a	No further formal commitments relevant to closure identified

CLOSURE OBLIGATIONS REGISTER

Relevant Legislation

Closure planning and implementation requires consideration of general legislative requirements beyond those that apply to a specific site. A list of potentially relevant legislation is provided below, but is not necessarily exhaustive. A comprehensive legal review will be required as closure approaches to ensure that all relevant legislative requirements are identified.

Australian Commonwealth Legislation

Environmental Protection and Biodiversity Conservation Act 1999
Native Title Act 1993
Aboriginal and Torres Strait Islander Heritage Protection Act 1984
Workplace Relations Act 1996

Western Australian State Legislation

Environmental Protection Act 1986
Environmental Protection Regulations 1987
Environmental Protection (Controlled Waste) Regulations 2004
Environmental Protection (Unauthorised Discharges) Regulations 2004
Contaminated Sites Act 2003
Contaminated Sites Regulations 2006
Conservation and Land Management Act 1984
Mining Act 1978
Mining Regulations 1981
Parks and Reserves Act 1895
Rights in Water and Irrigation Act 1914
Wildlife Conservation Act 1950
Aboriginal Heritage Act 1972
Aboriginal Affairs Planning Authority Act 1972
Mines Safety and Inspection Act 1994
Mines Safety and Inspection Regulations 1995
Occupiers Liability Act 1985
Criminal Code Compilation Act 1913

CLOSURE OBLIGATIONS REGISTER

Relevant Guidelines and Standards

Closure planning and implementation requires consideration of relevant guidelines and standards, some of which may have regulatory consequence through being referenced in regulatory documents. A list of key guidelines and standards that are routinely considered is provided below, but is not exhaustive due to the breadth of the closure planning discipline. This closure plan has been prepared so as to be considered with relevant content of these guidelines and standards.

Guideline or Standard	**Author**
Guidelines for the Preparation of Mine Closure Plans (2015)	Western Australian Department of Mines and Petroleum and Environmental Protection Authority
Leading Practice Sustainable Development Program for the Mining Industry - Mine Closure and Completion (2006)	Commonwealth Department of Industry Trade and Resources
Mine Rehabilitation Handbook (1998)	Minerals Council of Australia
Guideline for the Assessment of Environmental Factors: Rehabilitation of Terrestrial Ecosystems (2006)	Western Australian Environmental Protection Authority
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)	Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council
Mine Void Water Resource Issues in Western Australia (2003)	Western Australian Water and Rivers Commission
Contaminated Sites guideline series	Western Australian Department of Environmental Regulation
Environmental Notes on Mining: Acid Mine Drainage (2009)	Western Australian Department of Mines and Petroleum
Environmental Notes on Mining: Waste Rock Dumps (2009)	Western Australian Department of Mines and Petroleum
Safety Bund Walls Around Abandoned Open Pit Mines (1997)	Western Australian Department of Industry and Resources
Global Acid Rock Drainage Guide (2014)	International Network for Acid Prevention
Australian Standard 2601: The Demolition of Structures (2001)	Standards Australia
Australian Standard 4976: The Removal of Underground Petroleum Storage Tanks (2008)	Standards Australia
Demolition Work Code of Practice (2015)	Safe Work Australia

APPENDIX B – CLOSURE KNOWLEDGE DATABASE

Rio Tinto Western Turner Syncline closure knowledge database

The closure knowledge database is a summary of the technical reports that directly or indirectly contribute to the development of the closure plan. These documents do not form part of the report and are for indicative purposes only.

The knowledge and understanding of closure issues and management strategies evolve and improved over time, coincident with the development of the mining operation. As a result, some components of some reports and studies may be superseded by new research or studies. While the closure plan addresses the current state of understanding and strategy for closure, the closure knowledge database captures the historical development of closure knowledge, and demonstrates how experience and knowledge developed at other Rio Tinto sites has been considered during the development of the closure plan and across the life of the operation. Accordingly, some information presented in the closure knowledge database may be obsolete.

Technical reports supporting the closure of the operation will be presented as part of the last plan produced prior to the implementation of closure (the Decommissioning Plan).

CONFIDENTIAL

Climate

Climate Change Adaptation Project, Rio Tinto Climate Change Impacts in the Tom Price – Paraburdoo Region of the Pilbara, Western Australia **2007**

This study was undertaken to provide a future climate analysis, spanning the period from 2000 to 2060 for the inland west Pilbara region of Western Australia, with particular emphasis given to the Tom Price region.

Internal reference: RTIO-HSE-0046946

Over the coming decades out to the year 2060, the numbers of tropical cyclones do not appear to change dramatically, with the magnitude of the inter-decadal climate variability overshadowing the slight changes in the frequency of the total numbers of tropical cyclones for this region. The modelling points to an increased likelihood of more intense tropical cyclones forming over the waters off the Pilbara coast. Extreme maximum temperatures are expected to rise by at least 4.4oC for the summer season. Annual rainfall is predicted to decline by 30% from 1970 values. The impact is likely to increase the frequency of drier years, but with further extreme heavy rainfall events. The lengthening of the return periods for the extreme rainfalls can be attributed to the predicted gradual decline in the frequency of tropical cyclone events near this location and a reduction in the frequency of the middle level cloud bands during the autumn and winter months. Potential for increased severe thunderstorm activity, particularly in the form of severe wind squalls was also identified.

Geochemical characterisation

Review of Waste Rock Geochemistry a.General Overview of Acid Base Accounting **2006**

This report contains a general overview of acid base accounting and a summary of the geochemical test work that has been previously completed for various sites and lithologies.

Internal reference: RTIO-PDE-0021130

There are large discrepancies in the total sulfur concentration measured using XRF and LECO machines. The XRF machine underestimates the sulfur concentration at values greater than 2%. Materials with total sulfur concentrations less than 0.1% can contain low capacity PAF material, however, it is considered only to be low additional acid and metalliferous risk if the boundary for inert material and potentially acid forming material is shifted from 0.02%S to 0.1%S. A paste pH result of less than 7 should be sent to the black shale dump and a paste pH result of greater than 7 can be sent to an inert material waste dump.

Implications of the Radioactivity Content of Iron Ore Waste **2007**

This report highlights the possible radiological risk, or lack of risks, associated with waste ore solid samples of black shale from the Mt McRae formation from the Western Turner Syncline deposit.

Internal reference: RTIO-PDE-0047317

The concentration of radionuclides in the iron ore waste was considerable below trigger values and would not be considered radioactive. There are no grounds to expect a radiological risk from the concentrations of naturally occurring radionuclides observed in waste.

Western Turner Syncline (B1), Hope Downs 1 North and East Angeles - Geochemical Characterisation and ARD Assessment of Drill Chip Samples **2007**

An acid and metalliferous drainage assessment was undertaken on drill chip samples from the Western Turner Syncline, Hope Downs 1 and East Angeles projects. Western Turner Syncline results only are summarised below.

Internal reference: RTIO-PDE-0034855

Approximately two thirds of the Western Turner samples were classified as non-acid forming (NAF) and one third were classified as potentially acid forming (PAF). The results suggest that the BIF/Shale lithology is NAF; Shale/Pyrite mainly NAF but with some PAF-LC; and the Shale/Chert/Pyrite PAF. The majority of PAF samples had no lag period before acid generation. Ag, As, Hg, Pb, Sb and Se were significantly enriched in one or more samples. Soluble elements included Al, As, Ba, Co, Cu, Fe, Ni, SO4 and U.

Western Turner Syncline Section 17 Geochemical Characterisation and ARD Assessment of McRae Shale Samples **2007**

This report documents the results and findings of the geochemcial test work, likelihood of ARD and recommendations for materials handling at WTS S17 project.

Internal reference: RTIO-HSE-0036017

The results indicate that one third of the samples are non-acid forming (NAF) and two thirds were classified as potentially acid forming (PAF). The PAF materials will have no lag or a very short lag of days to weeks before onset of acid generation. The solids were found to be enriched in Ag, As, B, Bi, Ca, and metals/metalloids such as Al, As, Cd, Co, Fe, Se, SO4, Se and U were soluble and potential elements of concern for site water quality management.

Western Turner Syncline, Section 10: Geochemical Characterisation and ARD Assessment of Waste Rock **2008**

An acid and metalliferous drainage assessment was carried out on drill chip samples from Western Turner Syncline, Section 10.

Internal reference: RTIO-PDE-0054550

Of thirty three samples, one third were classified as potentially acid forming and two thirds were non acid forming. Results indicate that total sulfur can be used to identify acid and metalliferous drainage rock types. Ag, As, B, Bi, Cd, Hg, Mo, N, Pb, S, Sb, Se, U and Zn were significantly enriched in a least one of the samples and that Al, As, Co, Cr, Cu, Fe, Ni, SO4, Se and Zn were soluble.

Mineralogical Analysis of Potentially Acid Forming Materials **2008**

Quantitative mineralogy (QEM-Scan) for samples of rock collected from Tom Price, Channar, West Angelas, Brockman, Paraburdoo, East Extension, Western Turner Syncline and Hope Downs 1 North was undertaken. Comparisons were made between two methodologies use to characterise potentially acid forming materials; acid base accounting and mineralogical analysis.

Internal reference: RTIO-PDE-0053725

All samples contained elevated total sulfur concentrations and the lithologies were either shale, banded iron formation or dolomite. Pyrite was the dominant mineral contributing to acidity and the dominant sulfate secondary mineralisation consisted of alunite and jarosite.

Determination of ARD potential of Rio Tinto Iron Ore (WA) Waste Rock Samples **2008**

This report investigates the use of mineralogy to predict acid and metalliferous drainage potential. Analysis of numerous rocks was undertaken using QEM-SCAN.

Internal reference: RTIO-PDE-0051613

Areas of waste rock which have underdone oxidation can be identified where sulfur-bearing minerals vary between samples in the form of pyrite, alunite and jarosite. The variability of gangue mineral phases suggest that some areas of composite waste rock pile may provide some neutralising potential while other areas will have no neutralising potential. Variable textural and mineralogical controls on sulfide mineral occurrence result in decreased accessibility of pyrite to oxidising fluids.

Western Turner Syncline SE10 Deposit ARD and Geochemical Risk Assessment **2010**

The 2010 risks associated with acid and metalliferous drainage (AMD) has been investigated.

Internal reference: RTIO-PDE-0073331

The overall AMD risk is moderate for the SE10 deposit. It is expected, according to current designs, that almost 1% of the pit shells surface area will comprise sulfidic black Mt McRae Shale (MCS) exposures upon closure. In the potentially acid forming MCS samples Ag, As, B, Bi, Cd, Hg, Mo, N, Pn, S, Sb, Se, U and Zn may be enriched. Al, As, Co, Cr, Cu, Fe, Ni, SO4, Se and Zn are soluble and potential elements of concern for potentially acid forming material.

Contaminant Leaching from Non-Sulfidic Waste Material **2011**

The available leach extract data and information pertaining to the distribution of metals and metalloids in non sulfur materials at neutral pH was reviewed. Based on this review conceptual models for controls on their leaching and mobility were developed.

Internal reference: RTIO-HSE-0145041

The review found that contaminant leaching from non-sulfidic materials was generally very limited. Usually the pH in leach tests was near-neutral (pH 6 to 8), and dissolved contaminant concentration were at or below detection limits. It is believed that a primary leachable contaminant source is the oxidation of sulfide minerals. Release from oxidising sulfides leads to release of soluble reaction products. Under neutral pH conditions, there is the potential for release of these contaminants when those products dissolve.

Environmental Status of Selenium (Se) in the Pilbara Region of Western Australia – Potential Risk from Iron Ore Mining **2011**

This report includes information about Selenium geochemistry, distribution in the environment, occurrence in rocks in the Pilbara and potential risks to the environment.

Internal reference: RTIO-PDE-0103857

The Selenium (Se) content of shales containing significant pyrite should be recorded as part of the overall risk assessment for acid and metalliferous mine drainage. However, it should also be noted Se solubility is far less constrained by pH than in the case of metals and near neutral drainage may contain significant Se concentrations in solution. It would be most useful to study the Selenium budget of the wetlands in the Pilbara as, apart from the chance poisoning of livestock from the consumption of plants that have taken up high concentrations of Selenium, impacts are most likely to be felt in wetlands receiving mine site drainage.

Contaminant Leaching from Low-Sulphur Waste Minerals (Summary) **2011**

Internal reference: RTIO-PDE-0090689

RTIO's Geochemical Database was reviewed and based upon this data, conceptual models for controls on the leaching and mobility of a range of metals and metalloids were developed. This summary also describes potential controls on the amount of dissolved element that may be released. This is a summary of a comprehensive report RTIO-PDE-0100104.

For most contaminants, dissolved concentrations at circum neutral pH (pH 6 to 8) were very low, typically at or below detection limit. Geochemical modelling indicates that water-rock interactions are controlled by equilibrium, for salt, carbonates and sulphates this equilibrium is often source term limited whilst hydroxyl-sulphates and hydroxides are solubility controlled. Results also indicate that sorption plays an important role in solute concentration; weak (but detectable) sorption occurred for selenium and zinc whilst the strongest sorption was evident for cobalt. The review suggested that storage waste facilities containing low-sulfur materials pose a low level of environmental risk however, there is a small risk of increased in mobility of some contaminants if acidic conditions arise. Acidic conditions can sometimes arise from the interactions between iron and aluminium hydroxyl-sulphates and hydroxides.

Static Geochemical Characterisation of Material from the B1 and Section 10 Deposits at Western Turner Syncline **2012**

Internal reference: RTIO-PDE-0101686

An interim report which documents the findings of static geochemical test work carried out on samples from the Western Turner Syncline S10 and B1. For a subset of samples, further stages of kinetic test work are ongoing and will form the subject of a future report.

The majority of samples (156) were classified as non-acid forming (NAF), whilst 13 samples were classified as potentially acid forming (PAF) and 39 as uncertain. Those that were PAF were mainly from the Mt McRae Shale (MCS) and MTS stratigraphy which were determined to be highly acidic with short lag times for acid onset. As, Fe, Sb and U were significantly enriched in most samples. For the majority of samples minor and trace element leachability was low, either being close to or below the limit of detection. Readily detectable dissolved concentrations were often associated with materials from the MCS and MTS stratigraphies. Metals such as Co, Cu, Ni, Pb and Zn had higher dissolved concentrations were in acidic leach solutions, however, higher dissolved concentrations of As, Cr, Mo, V and Se were associated with near-neutral leach solutions.

Western Turner Syncline B1 and Section 17 AMD Risk Assessment **2012**

Internal reference: RTIO-PDE-0102517

This updated assessment (from Feb 2012) takes into account the new pit shell for the B1 project area as well as the results from recently completed geochemical test work. The purpose was to determine the acid and metalliferous drainage (AMD) risk for the Western Turner Syncline B1 and S17 deposits and to identify enriched concentrations of elements which pose an environmental risk.

The B1 deposits pose a moderate acid and metalliferous drainage (AMD) risk based on the current pit shell design. Based on the current model and available data, it is unlikely that significant volumes of black Mt McRae Shale (MCS) will be exposed during mining at B1. If black MCS is exposed, it is possible that it will be classified as cold black MCS. The S17 deposit poses a low-moderate AMD risk based on the current pit shell design. It is unlikely that significant volumes of black MCS will be exposed during mining, but if exposed in Pit 3 or Pit 8, it is likely that this material would be hot black shale. In both sites most elevated-sulfur samples are located within close proximity to the surface, indicating that the sulfur may be in the form of the sulfate mineral gypsum or potentially alunite.

Geochemical Characterisation of Material from Western Turner Syncline **2012**

Internal reference: RTIO-PDE-0103459

This report documents the findings and results of further stages (Phase 3) of kinetic test work undertaken on 17 samples.

AMIRA leach column results on black shale (not proposed to be minded as part of the WTS development) indicate that the solute release from the columns was still variable, therefore more time will be required before the columns reach a pseudo steady state. Bottle roll test work results indicate that the pH of the leachate was greater than from the AMIRA test work, however the pH of the solutions is comparable in all the tests, ranging between 3.9 and 4.8.

Western Turner Syncline - Comparison of Geochemistry within the S10, B1 and S17 Project Areas **2013**

Internal reference: RTIO-PDE-0117051

The purpose of this internal memo is to summarise the assessment of geochemical data associated with the WTS S10, B1 and S17 project areas.

The AMD risk at S10 and B1 project areas is moderate and at the S17 area it is low-moderate. The geochemical characteristics of rock types highlighted as posing a potential acid generation risk have been assessed. The Detrital (DET) waste, Dolerite (DOR) waste, Joffre Member (JOF) Hydrated material, Whaleback Shale Member (WS) waste, WS ore material, WS Hydrated material, Dales Gorge Member (DG) Hydrated material, and the oxidised Mount McRae Shale (MCS) intersected within the B1, S10 and S17 project areas are considered to be geochemically similar. An exception is the black MCS intersected within the B1 project area, which has relatively lower sulfur values than thos black MCS samples intersected in the S10 and S17 project areas.

Western Turner Syncline - Supplemental Leach Test Programme **2014**

Internal reference: RTIO-PDE-0119214

This report documents the results for 18 samples from WTS S10 and B1 that were selected to undergo various leach tests including Kinetic leach columns, Multi-step DI Leaches, Mild Acid leaches and Sequential extraction leaches.

Samples were submitted for AMIRA leach column tests confirmed the classification of 4 samples as PAF, 1 sample as NAF and resulted in two samples being re-classified as PAF-LC. The sulfate release rates were found to be proportional to the sulfide sulfur content. The highest rates of elemental release were associated with SO4, Ca, K, Mg, Na, N, Si, Al and Fe. Trace elements readily detectable in leachates included As, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Se, Sr, Th, U, V and Zn. High release rates were associated with acidic leachates, although Mo and Se were released in higher rates under circum-neutral conditions. The Whaleback shale samples EPO496 was submitted for multi-step DI leach to compare with the results of the AMIRA leach tests. Overall the results were comparable even with the different test durations. The results of the mild acid leaches (final pH between 2.4 and 4.6) resulted in higher concentrations of major elements (Al, Fe, K and Si) and trace elements (Al, Cr, Co, Fe, Ni, Mn and Zn) when compared to the corresponding DI water leach tests (final pH between 6.1 and 9). The exceptions were Mo and Se which were more readily leachable in the DI water leaches. Results of the DI water leach and mild sulfuric acid leaches were also compared with the corresponding DI and acetic acid leaches in the sequential extraction tests. Similar elements were found to be readily detectable in the DI water leachates, though the concentration and range of elements were greater in the acetic acid leach compared with the mild sulfuric acid leach.

Geochemical Assessment of Tailings from Yandi, Paraburdoo, Tom Price, Brockman 4 and Mesa J **2014**

Internal reference: RTIO-PDE-0123030

This report presents the results from geochemical testing and saline solution extraction of tailings samples from Yandi, Paraburdoo, Tom Price, Brockman 4 and Mesa J deposits.

Overall the tailings from these operations are unlikely to generate acid and are not expected to leach significant levels of metals under oxidising or saline conditions.

Geochemical Characterisation of Material from Western Turner Syncline - Section 17 Deposit **2014**

Internal reference: RTIO-PDE-0120354

This report comprises ongoing geochemical characterisation for 67 waste rock samples from six stratigraphies, from Section 17 of the Wester Turner Syncline deposit.

65 samples were classified as non-acid forming (NAF), the bulk of which had negligible neutralising capacity. Only two samples from the MCS were designated potentially acid forming (PAF). These two PAF samples have high levels of sulfur present as pyrite. Fe and Si were the dominant elements measured in the samples with Ag, As, B, F, Hg, Mo, N, Pb, S, Sb, Se and Zn present at levels greater than the average crustal abundance. Once again the MCS had the greatest range of elemental enrichment. Leach tests were carried out on the samples and included variation of contact ratios and salinity. The main elements leached include Ca, Cl, K, Mg, Na and N along with the trace elements Al, Ba, Cu, Fe, Mn and Sr. No firm trends were seen with differing salinities although Ag, As, Ba, Cu and Sr were present in higher concentrations in saline leaches. Free draining leach columns were carried out on two MCS samples, and have been in operation for 20 weeks. The leachate from the samples was immediately acidic confirming the PAF classification.

Oxidation and solute accumulation in dewatered pit wall rocks **2014**

Internal reference: RTIO-PDE-0109045

Dewatering and removing the water table may result in de-saturation of sulphide-bearing lithologies. This study was undertaken to review how oxygen ingress and consequent sulphide oxidation of Mount McRae Shales could impact water quality when the groundwater table rebounds after mining.

West Turner Syncline Section 10 AMD risk assessment **2014**

Internal reference: RTIO-PDE-0124005

This report determines and updates the AMD risk at the Western Turner Section 10 deposits, including the proposed Marra Mamba pits.

The WTS S10 Brockman deposits are expected to pose a Moderate AMD risk. In particular only the main pit is expected to encounter black shale. The WTS S10 Marra Mamba pits are expected to pose a low-moderate AMD risk. No sulfides are expected to be encountered however there is a lack of information with regards to surface water management and mine planning which raises the risk. It is expected that the risk would lower as additional information is collected, and the uncertainty changes. Characterisation undertaken on the black McRae Shale indicates that it will pose a moderate to high risk and will require management during operations as per the SCARD management plan. Calcrete mined on site could potentially be used to offset/neutralise any acid produced from the black shale. Overall Fe, As, Sn, Co, Cr, Cu, Mn, Ni, Pb and Zn were determined to be enriched in WTS Section 10 area. The geochemical characterisation undertaken indicates that these elements are not expected to leach at appreciable levels with the exception of black McRae Shale where the elements are expected to leach in significant quantities under low pH conditions.

Large Scale Column Construction Procedure and Initial Chemistry **2014**

Internal reference: RTIO-PDE-0123894

Large scale column experiments have been constructed to examine the reactivity of hot and cold black shale material in an operational environment. The memo describes the construction of the columns and the first geochemistry data collected after small rainfall events at Rhodes Ridge.

Initial results suggest that effluent water retains the chemistry of the incident rainfall. Constituents to note in the initial chemistry include nitrate and ammonia detected in the hot black shale effluent. This study provides an important comparison between laboratory characterisation studies and field reactivity of waste rock. Data from the large scale column tests can be applied to reactivity of in pit waste/talus as well as waste rock dumps. It can be used as an intermediate to predict long term reactivity of waste rock.

Water contacting PAF material at Western Turner Syncline Section 10 **2014**

This study was undertaken to provide guidance on the volume of runoff water than may be generated on an annual basis over the life of the pits relative to the exposure of potentially acid forming (PAF) MCS by using a probabilistic method based on Monte Carlo simulation of daily rainfall and runoff.

Internal reference: RTIO-PDE-0128523

From 2020 the pit shell may intersect black shale. Based on the final pit design, it is likely that the majority of runoff from the black shale exposure could be contained in a small section of the pit and, without a cover, the potential for acidification is likely to be relatively low.

Geochemical characterisation of Material from Western Turner Syncline - Section 10 MM deposit **2015**

This study was undertaken to determine the geochemical (including AMD) characteristics of waste and low grade material

Internal reference: RTIO-PDE-0128434

The total sulfur content of the samples was general low (less than 0.1%), with one detrital samples containing 0.95% sulfur. The sulfur was present as the sulfate minerals gypsum and bassanite. Acid neutralisation capacity of the samples was generally low (<10 kg H2SO4/t) although seven calcrete samples had high ANC values (>100 kg H2SO4/t), dominated by calcite and dolomite. 60% of the neutralising capacity was readily available. Overall the samples were either classified as Non-acid forming (NAF) (44) or Uncertain (NAF) (5). The remaining sample was classified as Potentially Acid Forming in a low capacity (PAF-LC). This sample had low sulfur levels (0.1%) with the sulfur expected to be present as sulfate minerals alunite or jarosite. All samples were dominated by Fe and Si with enriched levels of the following elements (above crustal abundance levels):As, B, Bi, Cd, Fe, S, Sb, Se, Te and Zn. The detrital samples had the greatest range of elemental enrichment. In terms of leaching most elements were close to or below the limit of detection.

Geochemical Characterisation of Material from Western Turner Syncline (Section 17 Deposit) Kinetic Leach Testing **2015**

This report summaries the findings of AMIRA kinetic column leach test work carried out on two samples over a period of 48 weeks. The samples were carbonaceous shales from the Mt McRae Shale stratigraphy.

Internal reference: RTIO-PDE-0132529

The leach testing confirmed the classification of the samples as PAF, with the pH remaining at or below 2 for the duration of the tests. Highest release rates associated with Fe, SO4, lower release rates for AL, As, Si, Co, Cu, Mg, N, Na and Ni.

Physical characterisation

Soil Characterisation Assessment of the Western Syncline Open Pit Project **2010**

This report summaries the baseline soil characteristics at WTS S10.

Internal reference: RTIO-HSE-0096973

The soils are sandy and have no observable structure. Soils were slightly acid to neutral, with the subsoils being moderately alkaline. Soil salinity was low for all soils sampled. The soils pose no risk of clay dispersion. Total available N, P and S are all low.

Western Turner Syncline Phase 2 - Closure Inventory and Topsoil Balance **2012**

The memo summaries the total volume of material required for rehabilitation of the waste rock dumps and pits for WTS Phase 2.

Internal reference: RTIO-HSE-0139437

The total volume of topsoil required to rehabilitate WTS Phase 2 is approximately 820,000 m3. The potential volume of topsoil to be collected totals 1,400,000 m3, therefore there may be an excess of usable material for rehabilitation.

Western Turner Syncline Stage 2 Visual Impact Assessment **2012**

The report details the results of the Visual Impact Assessment undertaken for the WTS Stage 2 project.

Internal reference: RTIO-HSE-0159656

The overall visual impact of the Project ranged from None where the Project is Not Evident to Level 1 where the Project was assessed as a Prominent impact. The Level 1 impacts are confined to Nanutarra Munjina Road. The visual impact as a result of WTS Stage 2 is likely to be minimal on the landscape values and view experiences within the Hamersley Ranges Landscape Character region.

Soil Characterisation Assessment of the Western Turner Syncline Stage 2 Project **2013**

This report summaries the baseline soil characteristics for the B1 and S17 project.

Internal reference: RTIO-HSE-0186384

Three different soil types were identified, type A (a very gravelly, dark red sandy clay loam), D (a gravelly, red, calcareous sandy clay loam) and F (a very gravelly, shallow, dark red sandy clay loam). Soil pH is variable but predominately acidic, soil salinity is low and does not change with soil depth; and most soils within the project are have topsoil and subsoil pH and salinity levels not likely to cause adverse impacts to vegetation. Soil chemical fertility is low, in particularly Total P, available P and total N.

Performance Monitoring Report for the Period January to December 2012, Tom Price Operations, ARD Control Cover System Trials **2013**

Internal reference: RTIO-PDE-0112371

The field performance of the 'store and release' cover system trials on the Marra Mamba waste rock dump between January and December 2012 are summarised in this report.

Based on data from the monitoring period it was concluded that both cover systems are effectively storing moisture following rainfall events and subsequently releasing it to the atmosphere via evapotranspiration during dry periods. Both cover systems showed a positive gain in moisture storage during the monitoring period. Estimated net percolation was 39mm (6% of rainfall) at TP#1 and 25 mm (4% of rainfall) at TP#2. Estimated actual evapotranspiration (AET) was 494mm at TP#1 and 530mm at TP#2 for the Year 9 monitoring period.

Net solute load response to the installation of infiltration limiting dry cover systems over acid forming waste piles **2014**

Internal reference: RTIO-PDE-0128431

This work was conducted to verify the central design concept of store-and-release covers over sulfidic above water table waste dumps that is, whether limiting net percolation volume through the cover results in a lesser sulfate and acidity load being realised generated and passing through the dump.

The results from this thesis project confirm that the central aim of store-and-release covers to reduce net percolation volume is a valid measure for reducing the net loading of sulfate and acidity. The mechanism through which decreasing net percolation (applied water volume) results in a lesser sulfate and acidity load was identified, however further work in a site context is needed to assess how this relationship between percolation volume and loading persists in the real-world environment.

Groundwater

Section 10 Mt Lionel Groundwater Modelling Simulations **2008**

Internal reference: RTIO-PDE-0062665

This report outlines the physical extent and volume of dewatering activities at s10 using a numerical groundwater model.

In 1976, prior to commissioning of the Mt Lionel borefield, the groundwater level was 557mRL. Long term abstraction from the alluvial and Wittenoom Formation aquifers in the Mt Lionel borefield has resulted in an elongated cone of depression, which is constrained by the relatively impermeable Marra Mamba Formation to the north and the Brockman Iron Formation to the south. The Section 10 deposit has been partially dewatered by the abstraction activities associated with the Mt Lionel borefield. Water levels in the Section 10 deposit prior to dewatering were around 543mRL. Dewatering activities at Section 10 will reduce the abstraction volumes utilised from Mt Lionel borefield. This may enable the water table at Mt Lionel borefield to recover slightly.

Western Turner Syncline Section 10 Groundwater Modelling for Closure and Backfill Options **2011**

Internal reference: RTIO-PDE-0087486

This report summarises the groundwater modelling results from three options developed to manage pit lake formation and black shale exposure at the end of mine life.

Backfilling to either the 545mRL or 535mRL is unlikely to result in the formation of a permanent pit lake. Under both scenarios ephemeral lakes were likely to occur during the wet season. If the pit was not backfilled, and only minor, localised encapsulation of the black shale on the pit wall was undertaken, then a pit lake would form. The water levels within this pit lake are expected to range between 510mRL to 556mRL.

WTS2 Groundwater Quality - updated data **2012**

Internal reference: RTIO-HSE-0166326

This memo summaries the water quality of the B1 and S17 ore body aquifers, ephermeral pools in the WTS area and surrounds, and regional surface water. Updated with 2012 data.

Analysis of data from the orebody aquifers indicates all parameters are less than the ANZECC drinking water and livestock water quality guidelines. As bores at S17 were not cased or purged results not discussed in the report. B1 will be the primary source of dewatering discharge. Cr and Zn were higher in the B1 orebody aquifer than the ephemeral pools in the WTS area. Nutrient concentrations N_total and N_NOx were higher in the B1 aquifer than the ephemeral pools.

Western Turner Syncline B1 - Feasibility Studies Groundwater Modelling: Dewatering and Closure **2013**

Internal reference: RTIO-PDE-0104666

The report presents an update and refinement of the PFS numerical groundwater model developed by RTIO in 2012. This internal report summaries the dewatering strategies and predicted pit-lake levels post-closure based on the new pit shell (2012) and previous 2011 mine schedule.

The model shows that the groundwater level starts to rebounds immediately after cessation of dewatering and that water level in the pit lake will form a groundwater sink and recover to a quazi-constant level 10 m below premining levels (between 524.8 mRL and 525.1 mRL) after 60 years. Elevated sulfur material is expected to remain above the recovery water level and a small exposure of black shale is expected to be permanently inundated at the 525 mRL steady state water level (following recovery).

Surface water

Floodplain estimation for local creek traversing proposed long term waste dumps — 2012

Internal reference: RTIO-PDE-0098041

The objective of the report was to define the flood extent of a local creek within the B1 and S17 mine areas for a range of rainfall events to ensure that the long term waste dumps were ouside the floodplain.

The three waste dumps currently proposed to the south of Mt Turner Creek occur outside the 100 yr, 500 yr and probable maximum flood extents. Mt Turner Creek will not affect the stability of the proposed waste dumps to its south.

Conceptual Water Management Design for Waste Dump Closure at the Western Turner Syncline B1 and S17 — 2012

Internal reference: RTIO-PDE-0100839

This report describes concepts for the management of surface water runoff arising from local catchment contribution from above the WTS waste dumps.

Three concepts were considered: an armoured interface between the waste dump and topography to shed the run-on, an upslope diversion drain, and a purpose-built rock-armoured channel at the interface. This purpose-built channel option was preferred and involves reshaping the surface of the waste dumps to direct surface runoff towards the interface between the waste dumps and the natural topography, and the construction of an armoured channel across the crest and down the valleys at the interface.

Baseline Hydrology Assessment for Local Creek Discharge from WTS B1 — 2012

Internal reference: RTIO-PDE-0095090

This report summaries the results of modelling of the extent of dewatering discharge downstream of the proposed discharge point located north of the B1 main pit.

A saturated discharge footprint of 18 km was estimated for the maximum modelled discharge rate of 30 ML/day. Based on the model results, it was determined that water released into the local creek and Beasley River would be contained within the low flow channel, therefore overtopping of the creek beds is not expected. Local ecological cycles triggered by flood events would be unlikely to be activated or impacted.

Surface hydrology in the vicinity of the WTS2 infrastructure corridor between WTS B1 and S10; assessment and modelling of natural surface flows — 2012

Internal reference: RTIO-PDE-0103316

This internal memo describes the results of modelling of surface hydrology undertaken to provide a quantitative analysis of surface hydrology and flow regimes in the proximity to the infrastructure corridor.

The modelling demonstrated channelized flow is the predominant surface flow mechanism in the study area. Some areas of limited and localised overland flow were evident, particularly in areas of subdued relief in the central WTS. The corridor was considered highly unlikely to have a significant detrimental effect on overland flow.

WTS Phase II Surface Water Management — 2013

Internal reference: RTIO-PDE-0101051

The report summaries the interaction between natural surface water runoff, the local environment and the WTS Phase II study area.

There are no catchments that contribute significant runoff to the pits (i.e. greater than 0.4 km2), therefore no creek diversion around the pit are proposed. Waste dump locations have avoided intercepting signficant catchment areas and thus diversion infrastructure is not recommended. Some protection bunds are required at the toe of the waste dumps and topsoil stockpiles to prevent from water pooling against the toe, which could otherwise contribute to stability issues. The infrastructure corridor will require creek crossing culverts to maintain the hydrological regime in the area. (Note: These will be removed on closure.)

Western Turner Syncline - B1 Water Balance - Feasibility Study 2014 — 2014

Internal reference:

This internal memo summarises the results of the water blance update and assessment of beneficial use options for surplus dewatering for the WTS Stage 2 Feasbility study.

Surplus discharge water from B1 will be transferred via a pipeline to S10, excess discharge water not utilised at S10 will be discharged into the Beasley River. Model results suggest that water released into the creek will be contained within the low flow channel, and overtopping of the creek banks is not anticipated. If no water is utilised at B1 or S10 and all is discharged to the river, the volume is significantly smaller than the volume generated by the catchment during flood events, dicsharged water would be contained within the local flow channel.

Water interactions and pit lakes

The Impact of Wind Sheltering on Mine Lake Stratification Dynamics and Evaporation at Mount Tom Price — 2009

Internal reference: RTIO-PDE-0081596

The effects of wind sheltering experienced by a potential mine lake at Mount Tom Price was investigated using a hydrodynamics model DYRESM.

With the presence of wind sheltering there is a reduced penetration of wind mixing along the depth of the mine lake and increased stratification, and reduction in evaporation losses in the lake. This is likely to benefit the containment of contaminants.

Western Turner Syncline Water Quality Assessment- Stage 2 **2012**

Internal reference: RTIO-HSE-0145681

A water quality model was constructed using GoldSim and PHREEQC for the Western Turner Syncline B1 pit to evaluate the potential post-closure water quality of the pit lake. Note: These modelling results have been largely superceded by the WTS B1 Predictive Water Quality Assessment RTIO-PDE-0102103

Modelling results indicate that the pit lake will reach a steady state elevation of ~490mRL after ~150 years and that a groundwater sink is likely to form in the pit void. Based on simulations that suggest groundwater flow will always be towards the pit lake, the impact of the Western Turner Syncline 2 B1 pit on the surrounding environment is expected to be low. Evaporation is the primary water balance driver in the Western Turner Syncline 2 B1 pit lake, with an average rate of 2000m3/day at steady-state compared to 1350m3/day for the steady state groundwater inflow. Independent of geochemical processes, the WTS B1 pit will act as an evaporative system with ongoing evaporative concentration of elements.

Western Turner Syncline Water Quality Assessment **2012**

Internal reference:

The report presents the results of a water quality model for WTS B1 pit to predict post-closure water quality, based on a proposed mining pit shell from 2011.

Following external review the results of this model were found to be inaccurate, and further modelling was commissioned superseding this report.

Western Turner Syncline B1 Predictive Water Quality Assessment **2013**

Internal reference: RTIO-PDE-0102103

This report summaries the results of the predictive water quality model completed for the WTS B1 Pit lake using current water balance and geochemistry in 2013, based on the 2012 pit model.

The predictive pit lake model generated shows that a terminal sink pit lake will form with a steady state water level occurring 100 years after mining ceases. The maximum depth of the pit lake is estimated to be 184 meters, with elevation of 534meters amsl. Groundwater chemistry and evaporation are the main drivers influencing the pit lake chemical character. Predicted pH values are circumneutral (8.1 year 100, 7.3 year 1,000) and TDS are predicted to be elevated (20,116 mg/L) due to evaporation. The high TDS values are largely due to elevated concentrations of Ca, K, Mg, Na, SO4 and Cl. Limnology studies suggest that the entire water column may be subject to mixing events that will introduce oxygen into deeper portions of the lake.

Western Turner Syncline (WTS) S10 Pit Lake Model **2015**

Internal reference:

This report summaries results of the geochemical model developed to predict the chemical composition of the WTS S10 pit lake over time.

The results indicate that the WTS S10 pit lake will be fresh and moderately alkaline with pH values around 8 and TDS around 690 mg/L. Most metals and trace elements will be low with only boron and copper barely approaching or slightly exceeding ANZECC guidelines for aquatic ecosystems.

Western Turner Syncline Section 10 Groundwater Modelling for Closure and Backfill Options **2015**

Internal reference: RTIO-PDE-0132867

This report assesses the closure and backfill options of the Brockman Main Pit and the Marra Mamba pits.

It was found for the Brockman Main Pit groundwater levels will recover to the 530 mRL assuming no backfill. To ensure a non-perennial lake forming in the pit void backfilling to the 535 mRL will be required. Similarly for the Marra Mamba Pits simulated water levels suggest backfilling to the 540 mRL and to the 545 mRL for the east and west pits respectivtly to avoid a non-perennial lake forming.

Flora

Monitoring of unmined hillslope vegetation at Tom Price, Paraburdoo and Marandoo **2001**

Internal reference: RTIO-HSE-0016088

This study obtained baseline information on various parameters from unmined hillslopes in the West Pilbara areas of Marandoo, Tom Price and Paraburdoo, to facilitate comparison of vegetation established on sloping rehabilitation areas.

Vegetation on hillslopes fell into three broad structural groups: slopes dominated by a spinifex hummock grassland with an open cover of scattered shrubs; slopes supporting a relatively dense shrubland over a moderate amount of spinifex; or slopes supporting a tall shrubland (usually dominated by Mulga) over large amounts of annual grasses with little or no spinifex. There was considerable variability in the floristic composition of unmined hillslope vegetation, with none of the transects showing any particular trend. Fire appears to be the dominant influence, with unburnt transects grouping out as dissimilar from burnt transects.

A Vegetation and Flora Survey of the West Turner Section 10 Area and Infrastructure Corridor **2007**

Internal reference: RTIO-HSE-0063557

This report describes the initial vegetation and flora survey of the Section 10 area and associated infrastructure corridor completed in 2007.

28 vegetation types were defined for the Section 10 area and infrastructure corridor. None of the vegetation types recorded represent TEC's. The riverine woodlands vegetation type was considered to be of high conservation significance. Riverine woodlands is associated with major drainage channels for the area, and is likely to support species restricted to such habitat. 8 vegetation types were considered to be of moderate significance, with the remainder of the vegetation types identified as low conservation significance. One DRF species, Lepidium catapycnon, and 6 priority flora species were recorded in the infrastructure corridor.

Flora and Vegetation on the Hope Downs 4 Lease Area **2008**

This report describes the results of flora and vegetation surveys conducted between 2004 and 2007.

Internal reference: RTIO-HSE-0044175

No DRF or threatened plant taxon were recorded. A total of 6 priority flora species were recorded, one Priority 1 (Goodenia omearana), one Priority 2 (Olearia fluvialis), three priority 3 (Gymnanthera cunninghamii; Themeda ?sp. Hamersley Station; Goodenia purpurascens) and one Priority 4 species (Eremophila youngii subsp. lepidota). 4 introduced species were recorded. 17 plant communities were defined, none of these communities are considered TEC's.

Botanical Survey Work for Western Turner Section 10 and Infrastructure Corridor **2008**

The report summarises results from flora survey completed in May 2008.

Internal reference:

Only one DRF was recorded, Lepidium catapycnon, and three priority species were recorded. The recordings were restricted to a valley located adjacent to the Tom Price mine site and a calcrete outcrop close to the Nanuturra-Wittenoom road.

Western Turner Syncline S10 Expanded Vegetation and Flora Survey Report **2011**

This report summaries the biological survey of two additional areas adjacent to existing surveyed areas at S10. The report provides a consolidated vegetation map of the S10 project area.

Internal reference: RTIO-HSE-0123440

The vegetation units defined for the additional areas, are similar to those mapped for the adjacent S10 project area. None of the vegetation units recorded from the additional areas comprise of TECs or PECs. No DRF were recorded. Three priority flora species were recorded: (1) Eremophilia magnifica subsp. velutina (2) Goodenia sp. East Pilbara (3) Sida sp. Barlee Range.

Potential Impacts of mining operations on groundwater-dependent vegetation **2012**

This report provides an assessment of potential groundwater-dependent vegetation in the WTS area.

Internal reference: RTIO-HSE-0159544

Only vegetation that occurred on creeks, flowlines and floodplains were considered to be potential groundwater dependent vegetation (GDV) within the proposed mining footprint. Community types that included Eucalyptus camaldulensis subsp. refulgens and/or Eucalyptus victrix were the only potential GDV at WTS stage 2. Dewatering associated with the B1 pit is unlikely to impact on any GDV as the vegetation types are outside the predicted/modelled extent of groundwater drawdown.

Potential impacts of mining operations on overland flow dependent vegetation **2012**

This report provides an assessment of potential overland-flow dependent vegetation in the WTS area, and potential impacts of infrastructure corridor.

Internal reference: RTIO-HSE-0159807

Mulga communities on the valley floor are potentially dependent on overland-flow water delivery. These communities occur in association with the major drainage feature, within the perimeter of the site and at a significant distance downslope of the proposed infrastructure. Most flow supplying to the mulga woodland community is likely to be highly channelised. Therefore the planned infrastructure is unlikely to impact on this community if suitable culverts are installed in association with the major drainage lines.

West Turner Syncline Phase 2 Vegetation and Flora Report **2012**

This report describes the vegetation and flora survey for Phase 2 (B1 and S17) completed in 2012 and consolidates all existing survey data over the entire WTS area surveyed from 2007 - 2011.

Internal reference: RTIO-HSE-0164513

A total of 52 vegetation units were described, these can be classified into three groups based on the associated landform: (1) Vegetation of Stony Plains and Low Spurs; (2) Vegetation of Stony Hills and Slopes; (3) Vegetation of Creeks, Flowlines, Floodplains and Gullies. None of the vegetation units are TECs or PECs. Three vegetation units of relevance to the study area: lower slope mulga, valley floor mulga and all major ephemeral water courses, could be classified as "ecosystem at risk". One vegetation unit comprising scattered riparian Eucalypts on a major creek and two vegetation units from gullies and gorges are considered to be of conservation significance. The majority of the vegetation was ranked as being in very good condition. No threatened flora species wre recorded, one, Priority 1 species, seven Priority 3 species and two Priority 4 species were recorded. 21 weed species were recorded.

West Turner Syncline Vegetation and Flora Report: 2007 - 2013 **2013**

This report details the combined results of two-phase field vegetation and flora surveys of the West Turner Study area, which has been surveyed from 2007-2013.

Internal reference: RTIO-HSE-0195242

None of the vegetation units comprise listed TECs or PECs. A total of 6 vegetation units described from the study area are considered as "ecosystems at risk" within three categories: (1) lower slope mulga, (2) valley floor mulga, and (3) major ephemeral water courses. Three additional vegetation units of conservation significance were identified, however they appear to be widespread at the regional level. No Threatened flora species were recorded, with 18 Priority flora species recorded.

West Turner Syncline Creeks Survey: Hardey River Riparian Vegetation **2013**

Internal reference: RTIO-HSE-0218302

This report summaries the findings of baseline riparian vegetation and flora surveys of the Hardey River and associated tributaries. The report compares the results with survey results from the Beasley River and associated tributaries.

The vegetation condition ranged from excellent to very poor with the majority of the quadrats in very good condition. Eight introduced species were found. The morphology of creeks supporting vegetation types along the Hardey River were generally similar to the morphology of creeks supporting the same vegetation types along the Beasley River.

Western Turner Syncline - Rehabilitation Monitoring Report 2013 **2013**

Internal reference:

This report contains the analysis and summary of results from the 2013 WTS rehabilitation monitoring program. The report describes the findings from two vegetation transects (ODA1 and BP3-1) rehabilitated between 2010 and 2012, compared with two reference sites (TCS1 and TCS3) from the Tom Price mine area established in 2001.

The percentage vegetation cover and total number of vegetation species is greater at the reference sites compared to the rehabilitated sites. However, monitoring results for the two rehabilitated sites indicate that vegetation on both sites is estalishing well with no erosion recorded. Future monitoring and reference sites will be established following rehabilitation works at WTS.

West Turner Syncline Creeks Survey: Beasley River Riparian Vegetation **2013**

Internal reference: RTIO-HSE-0204117

The report summaries the findings of baseline riparian vegetation and flora surveys of the Beasley River and associated tributaries conducted to date (2012 - 2013).

The vegetation condition ranged from completely degraded to excellent, with the majority of the quadrats being in poor or very poor condition. The vegetation profile has remained constant over the baseline monitoring period. No threatened flora species were recorded and none are expected to occur. Three priority flora were recorded. 17 introduced species were recorded, this is an increase from 13 recorded in 2012.

Western Turner Syncline Rehabilitation Reference Site Establishment and Monitoring **2014**

Internal reference: RTIO-HSE-0210250

In 2009, transects were established in undisturbed areas to be used as reference sites. This report summarises the data collected in 2013 on six reference site transects installed at Western Turner Syncline.

Data was collected on a range of vegetation parameters, as well as bare ground and soil analyses. 64 plant taxa from 31 plant genera and 15 plant families were recorded. No priority flora, no declared species and no introduced species were recorded. Total density values tended to reflect perennial grass density, with the hilltop landscape unit having the highest density followed by the midslope landscape unit, followed by the flat landscape unit. Perennial grass cover showed an inverse trend to that shown for perennial grass density. Total cover values did not show the same trend as found for density, with all three landscape units having similar total cover. Three Triodia species dominated the vegetation.

Western Turner Syncline Stage 2 Weed Survey Report **2014**

Internal reference: RTIO-HSE-0220109

The report presents results of a baseline weed survey of riparian habitat in the Beasley River System between September 2012 and July 2013.

Twenty weed species were recorded during the survey. The weeds detected were mostly commonly occurring Pilbara species. One declared pest (Mexican poppy) was recorded. Overall the baseline condition was considered consistent with areas of the Pilbara subject to historical pastorl disturbance.

Western Turner Syncline - Rehabilitation Monitoring Report 2014 **2014**

Internal reference:

This report contains the analysis and summary of results from the 2014 WTS rehabilitation monitoring program. The report describes the findings from two vegetation transects (ODA1 and BP3_1) rehabilitated in 1985 and 2012 respectively, compared with two reference sites (2013_WTS_Flat_C3 and TCS3) established in 2013 and 2001. Another borrow pit, BP1, rehabilitated in 2012 was monitored using the qualitative Borrow Pit Monitoring Procedure.

Total numbers of species recorded at rehabilitated site BP3_1 were within the range of values recorded in the two reference sites and only marginally lower for ODA1, indicating good species diversity in the rehabilitated sites. Plant density increased in both rehabilitated sites between 2013 and 2014. Buffel grass (Cenchrus ciliaris) was recorded at BP3_1, no weeds were recorded at any other site.

Western Turner Syncline Section 10 Below Water Table and Satellite Ore Bodies Flora and Vegetation Survey **2014**

Internal reference: RTIO-HSE-0246926

The report describes findings from an additional flora and vegetation survey of MM Project area at S10, completed in 2014.

One additional priority three species was identified in this survey Solanum kentrocaule (Grevillea saxicola name change from Grevillea sp. Turee). No threatened flora species were recorded. None of the vegetation units comprise listed TECs or PECs. One additional weed species was recorded, Sonchus asper (Rough Sowthistle).

Western Turner Syncline Creeks Monitoring 2014 **2014**

Internal reference: RTIO-HSE-0244932

This report documents the findings of the riparian flora and vegetation surveys of the Beasley River and associated tributaries conducted by Biota to date (2012 - 2014)

The creek morphology of each sites within each Zone was relatively similar with two main morphology types described: narrow creeks with a distinct channel, and broad and shallow creeks with poorly defined channels in zones 2. No Threatened flora species were recorded, two Priority flora taxa, Bothriochloa decipiens var. cloncurrensis (Priority 1) and Ipomoea racemigera (Priority 2), were recorded in 2014. Rostellularia adscendens var. latifolia (Priority 3) was recorded in 2013, and Indigofera sp. Bungaroo Creek (Priority 3) was recorded in 2012 and 2013. A total of 18 weed species have been recorded to date. One of the weed species Argemone ochroleuca subsp ochroleuca, is listed as a declared pest for WA under the BAM Act. The majority of quadrats were considered to be in poor or very poor condition in 2014, due to high levels of cattle activity and invasion by weeds.

Western Turner Syncline Section 10 Below Water Table Groundwater Dependent Vegetation Assessment **2015**

Internal reference:

This report provides an assessment of the potential impacts of groundwater drawdown on groundwater dependent vegetation (GDV) due to dewatering to enable below water table mining at WTS S10.

One of the vegetation units was dominated by the phreatophytic species Eucalyptus camaldulensis, another was dominated by Eucalyptus victri, a mesophytic species (potentially uses groundwater), both have been classified as a GDV. For the phreatophic vegetation: A drop of 5-10 m is unlikely to adversely affect this GDV, lowering of the water table by 10-20 m may result in the stress and potential loss in the drawdown areas and lowering the water table by greater than 20 m will affect this species at MM east. For the mesophytic vegetation, lowering the water table by less than 20 m is unlikely to lead to loss of this GDV, greater than 20 m drawdown could lead to some loss of this GDV depending on duration of drawdown.

Fauna

West Turner Syncline Section 10 Potential Short Range Endemic Fauna Species Risk Assessment **2008**

Internal reference: RTIO-HSE-0064546

This report summarises the impacts on the potential terrestrial and subterranean Short Range Endemic (SRE) fauna at WTS s10.

Two singleton records were made of potential SRE fauna. One of these records was of a mygalomorph spider which is considered to be a potential SRE taxa, however the issue arises of this taxon's wider distribution beyond the impact area, as it is difficult due to the general state of knowledge on the taxonomy, ecology and distribution at species level for Pilbara trapdoor spider. The assessment indicated a low risk of species extinction occurring as a result of the s10 proposal as the vegetation type where this species occurred is extensive, thereby a large habitat is retained.

West Turner Syncline Section 10 Subterranean Fauna Assessment **2008**

Internal reference:

The purpose of this report was to determine the potential for subterranean fauna to occur within the WTS s10 ore body and surrounds through a habitat-based assessment and preliminary field survey results. The impacts to subterranean systems from the project were also reviewed.

The desk top review suggest that there is a low likelihood of subterranean fauna occurring in the habitats that would be directly affected by the WTS s10 pit area. Bores sampled within the project impact area did not yeild any troglofauna, indicating low risk of the project having a significant impact on troglobitic biodiversity values. Similarly no stygofauna were collected from the confined aquifer of the S10 ore body, or the surrounding Mt Lionel or Hardey River borefields. Whilst process water abstraction and pit mining will affect the aquifer habitats, it appears unlikely that any species of stygofauna will be placed at risk as a result of the project.

West Turner Syncline S10 Development Two-Phase Fauna Survey **2009**

Internal reference: RTIO-HSE-0123438

This report summaries results of fauna assessment undertaken during 2007 and 2008, at WTS S10.

Three species of conservation significancewere recorded within or adjacent to the S10 study area: (1) Pilbara Olive Python, (2) Western Pebble-mound Mouse, and (3) Rainbow Bee-eater. Scree slopes, breakaways and escarpments were noted to provide potiential habitats for the schedule listed northern quoll, pilbara olive python and Peregrine Falcon.

A Two-Phase Fauna Survey of the West Turner Syncline Area **2009**

Internal reference: RTIO-HSE-0063545

The is report summarises results from fauna assessment completed during 2007 and 2008. This report does not include S10.

Three Priority 4 fauna species were recorded: (1) Western Pebble-mound Mouse, (2) Australian Bustard, and (3) Notoscincus butleri, along with one listed migratory species the Rainbow Bee-eater. Scree slopes, breakaways and escarpments were noted to provide potiential habitats for the schedule listed northern quoll, pilbara olive python and Peregrine Falcon.

West Turner Targeted Fauna Survey **2011**

Internal reference: RTIO-HSE-0131480

This report documents the results of a targeted fauna survey of an additional area at WTS in September 2011.

Two vertebrate fauna species of conservation significance were recorded during the survey, (1) Orange Leafnosed bat and (2) Western Pebble-mound Mouse. Potential Short Range Endemic species collected (1) mygalomorph spider, (2) terrestrial snail and (3) millipede groups.

Western Turner Syncline: Baseline Assessment of Aquantic Fauna and Water Quality. Wet and Dry 2011 Survey **2012**

Internal reference: RTIO-HSE-0134269

The key objectives of this report were: (1) sample aquatic fauna and water quality in recieving and reference creeklines in the WTS region; (2) Characterise the seasonal variation in fauna-water quality relationships; (3) Document existing biodiversity and conservation value of the aquatic biota of the Beasley River and Hardey River; (4) Report water quality data against ANZECC water qaulity guidelines.

There were no significant differences in physico-chemistry between upstream and downstream or between seasons. TN and TP concentrations exceeded ANZECC/ARMCANZ (2000) guidelines at most sites, whilst B, Cu and Zn also exceeded the guidelines at some sites. The only significant differences in regards to macro and microinvertebrates were as follows: (1) Significant difference in microinvetebrate taxa richness between Beasley River Western Channel reach and Hardey River reach and (2) Significant difference in macroinvertebrate assemblage composition recorded between seasons. Two internationally listed macroinvertebrate species (the Pilbara emerald dragonfly and the Pilbara pin damselfly) were recorded at both reference sites and potentially exposed sites along the the Beasley River. Fish diversity and abundance thoughout the study area was slightly lower than other semi-perment and seasonal Pilbara systems. It is considered that the potential risk of significant impacts on the downstream aquatic systems due to potential dewatering/discharge operations is low, under the current water quality conditions.

West Turner Syncline Stage 2 B1 and Section 17 Deposits Subterranean Fauna Survey **2012**

Internal reference: RTIO-HSE-0159400

This report summaries the findings of the sampling for troglofauna and stygofauna within the B1 and S17 project area.

Results suggest that subterranean fauna populations occur in low densities and limited diversity at WTS. 19 subterranean fauna were recorded consisting of 15 troglomorphic fauna and 4 stygobitic fauna. None of the troglomorphic taxa collected at WTS are considered true troglobites, but instead troglophiles. Troglophiles are at minimal risk of conservation impacts due to local scale development proposals. No significant groundwater fauna occurs in the locality, and there is minimal risk or any short-range spatial restrictions in the stygofauna of WTS.

West Turner Syncline Fauna Survey Summary Report **2012**

Internal reference: RTIO-HSE-0164353

Summary of results of four fauna surveys conducted within the WTS project.

7 fauna considered as conservation significant fauna were recorded within the WTS area: Orange Leaf-nosed Bat, Pilbara Olive Python, Notoscincus butleri, Western Pebble-mound Mouse, Australian Bustard, Ghost Bat, and Rainbow Bee-eater. Eight potential SRE taxa and one formally described non-SRE species were collected.

West Turner Syncline Stage 2 Extension Fauna Survey **2013**

Internal reference: RTIO-HSE-0188455

The report summaries results of a single-phase terrestrial fauna survey of an additional area, WTS Stage 2 Extension located to the west of the existing project in October 2012.

Four conservation significant fauna were recorded in the study area: (1) Orange Leaf-nosed Bat; (2) Ghost Bat; (3) Western Pebble-mound Mouse; and (4) Australian Bustard. Five species of mygalomorph spider were recorded from the study area, one species has not previously been collected outside the study area and is considered to represent an SRE species. One species of snail is also regarded as a SRE species.

Western Turner Syncline: Baseline Assessment of Aquatic Fauna and Water Quality. Wet and Dry 2012 Survey **2013**

Internal reference: RTIO-HSE-0196216

The report presents findings from sampling during the wet and dry seasons of 2012, it also compares data from current study, with that recorded in 2011.

Analysis of data recorded to date has highlighted the natural seasonal and temporal variation in macroinvertebrate and fish species richness and abundance data. The water quality of the WTS waterbodies were characterised by neutral to slightly basic pH (7.16 to 8.7), and predominantly fresh to brackish (225 to 4240 us/cm). A number of sites recorded total N and Total P levels in excess of the ANZECC/ARMCANZ guidelines. B, Cu and Zn also exceeded the guidelines at the majority of sites. Two internationally listed macroinvertebrate species the Pilbara emerald dragonfly, and the Pilbara pin damselfly were recorded at both reference and potentially exposed sites. The fish species the Fortescue grunter is listed as Lower Risk Near Threatened and was recorded in both the Beasley and Hardey River.

West Turner Fauna Integration Report **2013**

Internal reference: RTIO-HSE-0195046

This report consolidates the results of a series of vertebrate fauna surveys completed in the WTS project area by Biota.

Seven species of conservation significance were recorded with the WTS study area. However only one was recorded from within the proposal boundary, the Western Pebble-mound Mouse. Habitat for the Olive Python, Notoscincus butleri, Australian Bustard and Rainbow Bee-eater was also present within the proposal boundary, so these species are likely to occur.

Western Turner Syncline Project. Baseline Trace Element Concentrations in Fish Fauna **2014**

Internal reference: RTIO-HSE-0220306

The report provides a baseline dataset of concentrations of 10 elements of ecotoxicolgical interest in water, sediment and fish species along the Beasley River and Hardey River in the wet and dry seasons of 2013.

Natural bioaccumulation of mercury in perch and rainbowfish muscle tissue has reached levels found to exceed guidelines for safe consumption by a 65 kg person at all reaches in both seasons.

West Turner Syncline Section 10 Below Water Table and Satellite Ore Bodies Targeted Terrestrial Fauna Survey **2014**

Internal reference:

This report describes the results of a targeted terrestrial fauna survey for the S10 BWT and MM project.

Of the targeted vertebrate fauna, only the Orange Leaf-nosed Bat was detected at a single location via two echolocation calls, most likely representing a transitory individual, no evidence of suitable roost caves. The Northern Quoll, Pilbara Olive Python and Ghost Bat were not recorded within the study area. 12 mygalomorph spiders were recorded. Three millipedes were collected.

Western Turner Syncline Stage 2. Baseline Aquatic Fauna and Water Quality Surveys 2011 - 2013 **2014**

Internal reference:
RTIO-HSE-0241713

This report presents the combined results of all the baseline data collected to date, this includes suveys completed in wet and dry seasons in 2011, 2012 and 2013.

Surface waters were fresh-brackish (median 720 - 3110 us/cm), hard to extremely hard (median 190 - 880 mg/L CaCO3), alkaline (median pH 7.9-9.7) and with moderate to high day-time dissolved oxygen (median 79 - 122% saturation). No microinvertebrate species were listed for conservation significance. Three priority 4 species were recorded: the Pilbara emerald dragonfly, the Pilbara pin damselfly and the Fortescue grunter fish.

Conceptual Assessment of Closure Scenarios for Pit Voids at Western Turner Syncline **2015**

Internal reference:
RTIO-PDE-0129538

A conceptual hydrogeological assessment of the closure scenario for each of the deposits/pits that have been identifed as being below water table at WTS.

The following pits will become a saline sink on closure: SE10 East MM101, SE10 East MM201, SE10 West MM01, B1 East MM01, B1 Det Area 7, B1 Det Area 10. S10 Body will also become a saline sink, with pH circum neutral. B1 Main will be a pit lake, with the entire water column likely to mix at least once a year, TDS are predicted to be elevated and pH is anticipated to be circum-neutral. At S17, pits 3 and 8, no permanent pit lake is anticipated.

Biodiversity improvement studies

Evaluation of mine waste materials as alternative rehabilitation growth medium **2010**

Internal reference:
RTIO-HSE-0109961

This study reviewed the physical and chemical properties of soil, tailing and mineral waste from select Pilbara mining operations, to identify waste material and material combinations for use as a topsoil substitute or supplement.

The study showed plant-available nutrients held within the waste materials, although variable, was characteristically low and comparable to natural soils in the region. The majority of the waste materials had macro and micro nutrient concentrations within the range or above the levels measured in benchmark Pilbara topsoil and rehabilitated soils. The pH and phosphorus buffering index of most waste materials were also comparable to that of the benchmark topsoil materials. However, some of the waste types and tailings may need to be mixed with rocky material due to poor physical / erodibility characteristics.

Irrigated seed orchard trial **2011**

Internal reference:

Commencing in 2011 (and still ongoing), a trial irrigated seed orchard was established at the Hamersley Agriculture Project (Marandoo). The purpose of the trial was to identify an alternate method of addressing seed deficits. If successful, the project may be implemented at other Rio Tinto operations, such as the Nammuldi agriculture project.

Genetic diversity in Eucalyptus leucophloia across the Pilbara: Provenance zone implications **2011**

Internal reference:
RTIO-HSE-0108843

This study was undertaken to define the provenance seed collection zones for a common species of the Pilbara, Eucalyptus leucophloia (Snappy Gum). This report details information on genetic analysis conducted on E. leucophloia. Collections of E. leucophloia were made from 20 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in E. leucophloia was high and was typical of that found in other eucalypt species with wide spread distributions. Across the species the level of population differentiation was low and the majority of the diversity was maintained within populations with only 6% of variation partitioned between populations. Genetic variation in E. leucophloia showed little structure across the Pilbara with no clustering of populations based on any geographical proximity or in association with obvious topographical, physiogeographical or geological features such as the Hamersley or Chichester Ranges. Populations towards the edges of the species distribution within the Pilbara showed greater levels of differentiation from populations within the species main range. The high levels of genetic diversity and low levels of differentiation within E. leucophloia implies that seed resources for rehabilitation can be selected from a wide range within the Pilbara.

Genetic diversity in Acacia ancistrocarpa across the Pilbara: Provenance zone implications **2011**

Internal reference: RTIO-HSE-0119260

This study was undertaken to define the provenance seed collection zones for Acacia ancistrocarpa (Fitzroy Wattle). This report details information on genetic analysis conducted on Acacia ancistrocarpa. Collections were made from 24 populations across the Pilbara bioregion and genetic analysis was conducted on 16 populations using microsatellite markers.

Genetic diversity in A. ancistrocarpa was high but lower than that in E. leucophloia, another widespread species in the Pilbara. Across the species Pilbara range the level of population differentiation was low and the majority of the diversity was maintained within populations with only 3% of variation partitioned between populations. Genetic variation in A. ancistrocarpa showed little structure across the Pilbara with no clustering of populations based on geographical proximity or in association with obvious topographical, physiogeographical or geological features. Populations towards the edges of the species distribution within the Pilbara showed greater levels of differentiation from populations within the species main range. The high levels of genetic diversity and low levels of differentiation within A. ancistrocarpa implies that seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide range within the Pilbara

Root hydraulic conductance and aquaporin abundance respond rapidly to partial root-zone drying events in a riparian Melaleuca species **2011**

Internal reference: RTIO-HSE-0252171

This study examined partial root zone drying (PRD) responses of Melaleuca argentea.

The results demonstrate that PRD can induce rapid changes in root hydraulic conductance and aquaporin expression in roots, which may play a role in short-term water uptake adjustments, particularly in species adapted to heterogeneous water availability.

Baseline Terrestrial Fauna Assessment of Pilbara Rehabilitation Areas **2012**

Internal reference: RTIO-HSE-0134168

In 2011 a fauna survey was conducted within established rehabilitation areas at Brockman 2 and Tom Price mine sites, with the aim of identifying whether fauna is recolonising rehabilitation sites in assemblages comparable to reference sites.

The study found that at least 85 species of native vertebrate fauna, as well as representatives from each of six major groups of invertebrate fauna, are using rehabilitation areas at Brockman 2 and Tom Price, with species compositions that were broadly similar to reference sites. Ant collections were typical of the Pilbara bioregion, with an absence of invasive ant species. The study found greater data correlation between monitoring sites at a particular mine site (Tom Price or Brockman 2) than between rehabilitation and reference sites, indicating the importance of selecting local reference sites. The study concluded that the best candidates for bio-indicators are ants and reptiles.

Genetic diversity in Aluta quadrata:Implication for management and provenance zone **2012**

Internal reference:

This study was undertaken to define the provenance seed collection zones for Aluta quadrata. This report details information on genetic analysis conducted on Aluta quadrata. Collections were made from 8 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in A. quadrata was moderate and lower than in the other two more widespread Pilbara species, E. leucophloia and A. ancistrocarpa. The findings suggest that its populations may have fluctuated significantly in size over time with genetic drift and possibly inbreeding resulting in a reduction in genetic variability, particularly in rare alleles. Despite the narrow geographic range, the level of population differentiation in A.quadrata was relatively high with 25% of the genetic variation maintained between populations and 19% due to differences between the three different locations. This significant genetic structure indicates that A. quadrata consists of three conservation or management units, Western Ranges, Pirraburdoo and Howie's Hole.

Genetic diversity in Acacia atkinsiana across the Pilbara: Provenance zone implications **2012**

Internal reference:

This study was undertaken to define the provenance seed collection zones for Acacia atkinsiana (Atkins wattle). This report details information on genetic analysis conducted on Aluta quadrata. Collections were made from 16 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers.

Genetic diversity in A. atkinsiana was low and lower than that observed in its congener Acacia ancistrocarpa, a widespread species across northern Australia. The level of population differentiation was high and 30% of the diversity was partitioned between populations across the range of A. atkinsiana. Genetic variation in A. atkinsiana showed some structure across the Pilbara with clustering of populations in the western part of the distribution and from the Hamersley Range, along with other populations that were divergent from these groups. The low levels of genetic diversity and high levels of differentiation within A. atkinsiana implies that seed for land rehabilitation and mine-site revegetation programs should be restricted to specific zones. For rehabilitation of sites within the Hamersley Range we recommend seed collections be restricted to that region. Similarly, for rehabilitation in the part of the distribution west of Pannawonica, seed collections should be restricted to that area.

Rehabilitation Quality Metric (RQM) Project **2012**

Internal reference: RTIO-HSE-0164020

Western Australia has no formal process to measure habitat quality and as such RTIO has needed to design its own customised metrics. Vegetation condition scoring has previously been developed by RTIO through a Biodiversity Net Positive Impact Assessment, but a more precise metric was needed. The Rehabilitation Quality Metric (RQM) project was developed to provide a repeatable method to assess rehabilitation quality against pre-determined reference sites, on a site by site basis, to predict rehabilitation ecosystem quality at the time of relinquishment.

The RQM methodology employs seventeen parameters to characterise the landscape, including vegetation, fauna habitat, fauna presence, erosion, and ecosystem function. Parameters are tailored to be an applicable measure for both rehabilitation and native vegetation (reference sites). Parameters are scored, based on measured or observed characteristics, with a value between 0 and 1, with 1 being functional (terrestrial ecosystem is functioning for the maintenance of biodiversity values at a local or property scale) and 0 being dysfunctional (terrestrial ecosystem is failing; indicators of ecosystem function have scored below acceptable levels). Both rehabilitation areas and reference sites are scored. Scores are subsequently determined for the entire mine lease, based on the condition of the land before mining (extrapolated from the reference sites, area weighted) and the likely post-mining conditions (extrapolated from the rehabilitation areas and expected closure domain distribution, area weighted, ie pits with no rehabilitation score 0). The difference between the pre-mining and post-mining scores represents the residual impact of mining.

Propagation of Pilbara spinifex (Triodia sp.) **2012**

Internal reference: RTIO-HSE-0169744

Triodia has often been observed to have very poor establishment from broadcast seed. This project investigated alternatives to growing Triodia (spinifex) from seed, focussing on ways to propagate seedlings from wild harvested material.

The project found the most successful propagating material was stolons. Greatest propagation success was achieved when Triodia were collected when semi to fully dormant (mid Winter-Spring). The 'Moist Root Induction Method' recommended by previous researchers was less successful than the standard propagation techniques employed in this project. Success varied notably between populations. Consequently, any future collections of propagating material should target multiple populations to maximise potential for success.

Pilbara Seed Science Project, Part 2 Final Report Jan 2012 **2013**

Internal reference: RTIO-HSE-0174944

Undertaken between 2009-2012, this seed research investigated germination, biology, dormancy classification and treatments for dormancy alleviation for a range of species from the Pilbara.

The *Acacia atkinsiana, Indigofera monophylla and Sida echinocarpa* seed lots have physical dormancy. Heat treatments and mechanical scarification improved germination on dormant seeds, however, heat treatments killed non-dormant seeds. The treatments used for *Goodenia stobbsiana* seeds failed to overcome dormancy, suggesting deep physiological dormancy. The *Hakea lorea/ chordophylla* seed lots were found to be non-dormant, with very high germination results in the controls. As such, they will not require any pre-treatments prior to direct seeding. The florets surrounding the *Triodia pungens* and *T. wiseana* seeds were found to restrict germination, however, many of the freshly extracted seeds out of the florets were found to be physiologically dormant. Treatments for dormancy include mechanical scarifier to rupture seed coat, hot water (noting potential damage to immature or non-dormant seeds) and increases to germination through wet / dry cycling and / or temperature cycling.

Morphological variation in the western rainbowfish (Melanotaenia australis) among habitats of the Pilbara region of northwest Australia. **2013**

Internal reference: RTIO-HSE-0252169

The aim of this honours thesis was to determine and quantify the extent of morphological variation present in M. australis and relate this to environmental variables, which will provide the first step to understanding how the species copes with environmental change.

This results of this thesis found that there was limited evidence that fish morphology correlated with environmental variables

Patterns of water use by the riparian tree Melaleuca argentea in semi-arid northwest Australia **2013**

Internal reference: RTIO-HSE-0249538

This thesis examines the water use physiology of the riparian tree Melaleuca argentea, and the ways in which this species may respond to anthropogenic disturbances to hydrologic processes.

M. argentea displays highly plastic root-level responses to heterogeneous water availability and to waterlogging, facilitating high rates of water use and growth in the riparian wetland habitats of the Pilbara. Mature M.argentea trees appear to tolerate groundwater drawdown of at least several metres, most likely by employing the same plastic root strategies to access deeper water. M.argentea can also withstand short periods of severe drought, by adopting a 'waiting' strategy of ceasing growth and shedding leaves to avoid moisture loss, a state from which they can then recover. M. argentea populations are unlikely to thrive under large and prolonged reductions in water availability.

Priority Species Seed Quality and Germination Final Report **2013**

Internal reference: RTIO-HSE-0207487

This study investigated the quality and germination biology of a range of priority and keystone (Triodia) plant species from the Pilbara.

Eremophila magnifica subsp. Magnifica has physical & physiological dormancy. Propagation methods other than seed may be more successful. Geijera salicifolia and Olearia mucronata has physiological dormancy. Temperature cycling may be required to stimulate germination. Indigofera ixiocarpa and Indigofera sp. Bungaroo Creek has physical dormancy or is non-dormant. Mechanical scarification may be required. Ptilotus subspinescens is non-dormant and will germinate easily without removal from the perianth sheath. However, seed is likely to lose viability with a few years. Sida echinocarpa and Sida sp. Barlee Range has physical dormancy. Seeds should be removed from the mericarp and then scarified in order to germinate. Triodia pungens has T. wiseana non-deeep or deep physiological dormancy. Germination of de-husked seeds can be improved by applying gibberellic acid or 1% smoke water and wet/dry cycling.

Early physiological flood-tolerance and extensive morphological changes are followed by slow post-flooding root recovery in the dryland tree Eucalyptus camaldulensis subsp. Refulgens **2014**

Internal reference: RTIO-HSE-0252170

This study investigated physiological and morphological response to flooding and recovery in Eucalyptus camaldulensis subsp. Refulgens, a riparian tree species from a dryland region prone to intense episodic flood events.

E. camaldulensis subsp. Refulgens underwent considerable morphological changes during flooding, including extensive adventitious root production, increased root porosity and stem hypertrophy. Physiologically, net photosynthesis and stomatal conductance were maintained for at least 2 weeks of flooding before declining gradually. Despite moderate flood-tolerance during flooding and presumably high environmental selection pressure, recovery of reduced root mass after flooding was poor.

Priority Species Project Progress Report 2013 **2014**

Internal reference: RTIO-HSE-0207486

The Priority Species Project, initiated in 2012, aims to improve knowledge of priority plant species and develop methods to successfully germinate and establish priority species, to enable priority plant species to be integrated into Rio Tinto rehabilitation programmes. This work is being undertaken in conjunction with the Department of Parks and Wildlife.

13 plant species were selected as being potentially suitable for establishment in rehabilitation: Eremophila magnifica subsp. magnifica, Indigofera sp. Bungaroo Creek, Indigofera sp. gilesii, Acacia bromilowiana, Sida sp. Barlee Range, Ptilotus subspinescens, Ptilotus mollis, Acacia subtiliformis, Isotropis parviflora, Grevillea sp. Turee, Hibiscus sp. Canga, Themeda sp. Hamersley Station, and Aluta quadrata. Indigofera sp. Bungaroo Creek and Ptilotus subspinescens were found to readily germinate in laboratory conditions, and a field trial was established at Brockman 4 late in 2013.

Regional Variation in Metal Concentrations of Pilbara Fish in Relation to Concentrations in Water and Sediments **2014**

Internal reference: RTIO-HSE-0216967

This study aimed to characterise and document natural, background metal concentrations in freshwater fishes from different locations across the Pilbara in order to understand how local geology may affect baseline metal levels in fish tissues and surface waters. Metal concentrations were analysed from water, sediment and muscle and liver tissues from fish collected from up to 13 sites as yet unimpacted by mining across the Pilbara during October (dry season) of 2012.

Levels of dissolved metals from water samples were generally low. However, some elevated concentrations of Boron, Copper and Zinc were recorded. Concentrations of heavy metals in sediments were variable across the Pilbara. Generally, sediment concentrations were well below the Interim Sediment Quality Guidelines (ISQG). However, metal concentrations in excess of ISQG TVs were recorded for Chromium and Copper at some sites. There was no relationship between metal concentrations in sediment and those in water. Metal concentrations in fish tissue (muscle and liver) varied between species with some significantly higher in some particular species. The study concluded that variation in metal concentrations in water, sediment and fish across pools in the Pilbara was likely to be mainly dictated by the local geological setting in which the pool occurs.

Marandoo Native Pivot. Scope 2 Monitoring. Final Monitoring Report **2014**

Internal reference:

The Native Pivot Project involves a series of scientific trials into the effect of fertigation on plant species native to the Pilbara region. This report details the results from the first year of monitoring.

Fertigation is resulting in measurable differences to soil properties. Soil moisture was higher in the '2x' and the '1x treatments than the '0.5x' and the '0x' treatments. Soil moisture was observed to converge in all treatments during the wet season in Jan/Feb 2014. The germination of target species was low in the seeded species trial component, the presense of non-target native species is thought to have affected germination. The fertigation treatments were determined to have had a significant effect on the abundance, cover and health scores of native vegetation in the Pivot trials.

Dampier Port Rehabilitation Trials **2014**

Internal reference: RTIO-HSE-0246218

This report presents the results of a final monitoring survey of two rehabilitation trials established at the Dampier Port. The aim of the trials was to evaluate the effect of a range of mulch and soil treatments on the success of rehabilitation.

The outcome of the trial in terms of informing rehabilitation methods for the dredge spoil areas, is that the soil properties in both locations support native vegetation growth without treatment or amelioration (the soil has no properties that are considered inhibitive or detrimental to the growth of Pilbara native species). In addition the treatments were shown to have no significant effect and therefore won't be incorporated into future rehabilitation. Salinity and sodicity of the dredge spoil decreased over time and it is likely it will continue to decrease with time, which is considered an improvement in soil properties to enable native vegetation growth

Progress Report 2014, Ecological responses of native fishes to dynamic water flows in northwest arid Australia **2014**

Internal reference: RTIO-HSE-0246021

This three year Australian Research Council linkage Project commenced in 2013 and aims to increase understanding of the effects of altered stream flows on the Pilbara freshwater aquatic environment. Project aims: 1. Quantifying fish biodiversity and population structure in relation to hydrological and environmental parameters to identify thresholds of ecological concern for water management; 2. Determine the fundamental physiological, morphological and behavioural adaptations of fishes to variations in water quality using experimental manipulations; and 3. Examine spatial scales of gene flow to determine if increased flows increase genetic connectivity relative to natural-flow sites.

To date work has focuses on characterisation of baseline physicochemical parameters across aquatic habitats within the Fortescue River catchment (Aim 1), analysis of variation in rainbow fish morphometrics and mechanosensory lateral line systems in response to geographic region and water management regime (Aim 2), and extraction of DNA samples from 17 populations across the Fortescue River catchment (Aim 3). The project will culminate in the development of a predictive model for stream restoration relevant to future closure scenarios for above and below-groundwater mines. Results from an honours thesis indicate that rainbow fish body shape varies according to geographic region but fish from a dewatered site (WW Ck) were more streamlined than other populations from the upper Fortescue catchment. This statement of results has been superseded by the results of the actual thesis report RTIO-HSE-0252169.

Landform design

Results of flume investigations of the stability of rock mulches **1998**

Internal reference: RTIO-HSE-0109221

This study assessed the potential for rock mulches to be stripped from the soil surface by overland flows.

Although 150-300mm diameter BIF was not removed by simulated overland flows, even for 100mm/hr simulated runoff on 55% gradients, considerable scour of the spoil between the rocks was observed, indicating potential for long-term development of rills or gullies if the level of rock cover was less than 100%. Large reductions in sediment concentrations were observed when finer rocks were mixed with BIF. The data indicate that it is crucial for any rock mulch to cover a wide range of particle diameters, including a component of finer rocks. The resulting mixed rock created a framework of large rocks that resist movement by flows, while the smaller rocks reduce erosion being anchored within the larger (framework) rock. For rock mulches with a mixture of rock diameters, 80% cover produced acceptable erosion rates. Sediment loads were slightly higher for 40% cover by rock of mixed diameters, and it was speculated that this may also achieve acceptable erosion rates with the addition of vegetation.

Final Landform Design Criteria for Use During Mine Planning **2012**

Internal reference: RTIO-PDE-0159989

Rio Tinto Iron Ore WA have historically designed closure landforms for waste materials with berms ~10 m, lifts ~20 m and ad hoc alterations to batter gradients where erosion rates have been perceived to be unacceptably high. This report integrates recent advances in characterisation and modelling of materials, climate and erosion processes to provide appropriate final landform batter characteristics for key Pilbara mineral wastes and soils.

Material properties of mineral wastes were assessed and classified for the range of mineral wastes found across Rio Tinto Pilbara sites. Climate sequences were used to model and test potential erosion rates for a range of batter configurations (shapes (linear, concave), heights, gradients, berm capacity) and validated against existing slopes for which material and climate data were available. This information was used to develop a searchable waste dump batter database for all major mineral wastes and soils, intended for use during mine planning design.

Simulation of Seven Years of Field Performance Monitoring at Rio Tinto Iron Ore, Mount Tom Price Mine using Soil-Plant-Atmosphere Numerical Modelling **2012**

Internal reference: RTIO-PDE-0101771

Numerical modelling was undertaken to simulate field responses measured at the two field trials at Tom Price to develop a set of calibrated model inputs, which could then be used to develop a better understanding of long-term cover system performance.

Simulating the measured field responses is a challenging process because of the numerous variables influencing soil-plant-atmosphere flow regimes. Despite these difficulties, the calibrated models were able to acceptably simulate field responses, with TP1 and TP2 having coefficient of determination values of 0.86 and 0.92, respectively, over the period. These calibrated model inputs were then used to estimate how the cover systems would perform over a 100-year period. The 100-year simulations estimate that both cover systems limit net percolation to less than 5% of average annual rainfall.

Contamination

Impact of Nitrogen from Explosives on Mine Site Water Quality — **2008**

Internal reference: RTIO-PDE-0054638

The likely issues associated with the use of nitrogen based explosives on mineral waste and any leachate water are explored in this report. The amounts of explosives used on site are described, along with nitrogen chemistry and toxicity. Nitrogen concentrations for various mine sites and specific lithologies are presented which includes concentration in rock assays and liquid extracts.

It was concluded that the largest risk of nitrogen contamination is likely to arise from the discharge of surface waters that have been in contact with blasted materials and are discharged off site into creeks or waterways. This becomes a more significant issue if the water is also acidic. Algae (ie cyanobacteria) plumes have been identified in acidic water at Tom Price

Control Measures for Potentially Acid Forming Pit Wall Rocks — **2010**

Internal reference: RTIO-PDE-0079541

Desktop study of potential strategies to manage exposed sulfidic materials and find viable options for management was conducted with a focus on the Hope Downs 1 and Tom Price sites.

Chemical treatments have the potential to be effective only in the short-term and only for minor water quality issues. Grouting of the pit walls is expected to have limited applicability, although grout curtains behind the wall may have success (untested). Cover technologies have the greatest potential to be effective over the long term, but would need to be resistant to puncture by underlying rocks, resistant to weathering and UV damage ie shotcrete, geomembranes. For long term performance the exposed surface need to be as stable and free of loose material as possible. Treatment effectiveness will also depend on the site conditions, eg chemical less effective at Tom Price.

Bioremediation of Rio Tinto Iron Ore Pilbara Pit Lake Water – Stage 2 — **2011**

Internal reference: RTIO-PDE-0080610

Characterisation of organic materials (green waste and sewage sludge) was undertaken and the role of carbon forms of different bioavailability was evaluated through a microcosm experiment.

Results indicated that sewage was much more effective at stimulating sulfate reducing bacteria bioremediation than ethanol. As the sewage sludge concentration increased the bioremediation also increased. There is no measured beneficial effect when sewage was added at concentrations >60g/L.

Bioremediation as a potential treatment to improve iron-ore pit lake water quality in the Pilbara; Stage 3 Interim Report — **2012**

Internal reference: RTIO-PDE-0094629

The changes in microbiological, geochemistry and breakdown of organic materials during and at the conclusion of bioremediation were examined. This is an interim report based on the first 3 months of data.

Results indicate that Sulfate Reducing Bacteria bioremediation is a practical treatment for South East Prongs (SEP) and may be able to solve the acidity and metal contamination problems. It was found that SEP mine water which had a low pH (4.0) initially could be turned neutral following treatment with both Tom Price and Beenyup sewage.

Workshop Summary and Desktop Review: Dewatering and Sulfate Accumulation — **2012**

Internal reference: RTIO-PDE-0101903

This is a summary of a workshop held to determine the risks of dewatering sulphides within the pit wall. The outcomes from this workshop will be used to develop models to estimate the mass of sulfate produced as a consequence of dewatering activities.

There are many processes that contribute to poor pit water quality. Most of these processes are known and accounted for in existing models. However, the science of fluid flow in fractured rock is not well developed and this lack of knowledge restricts the outcomes of studies on pit water quality. There is a general lack of empirical data for estimating parameters used in models, creating a large degree of uncertainty in predictive models. Sensitivity analysis can be used to overcome some of these challenges.

Development of a conceptual model: Sulfate accumulation as a consequence of pit dewatering activities, memo — **2012**

Internal reference: RTIO-PDE-0101903

Mine dewatering and the consequent lowering of the water table may result in desaturation of sulfide bearing lithologies. The objective of this work was to develop a conceptual model of the associated processes: where sulphide bearing rock intersects the pit walls, and where the sulphide bearing rock is located behind the pit walls but not directly exposed on the pit wall face.

The conceptual model developed estimates the mass of sulfate produced as a consequence of dewatering activities, considering processes during operations and after operations cease, and using sensitivity analysis where parameter inputs are uncertain. The model output provides the basis for an assessment of potential impacts on water quality for general risk assessment applications. Further work was identified to improve parameterisation of the model, including the collection of additional empirical data for pit wall fracturing, saturation of pit wall fractures and sulfide oxidation rates in talus and on pit walls.

Ethnographic or archaeological values

Water and Indigenous People in the Pilbara: A Preliminary Study, CSIRO: Water for a Healthy Country **2011**

Internal reference:
RTIO-HSE-0218222

Water resources are vital to Indigenous identities, beliefs, environmental philosophies and livelihoods. This report provides a broad-scale scoping study of Indigenous relationships to water in the Pilbara and considers the potential impacts of Indigenous water values.

Indigenous belief systems perceive water as an elemental part of the broader cultural landscape, held and managed under customary systems of law. Water sources were derived during the Dreaming and are the most important features in the Pilbara cultural landscape. Interviews raised issues of long term drying, obstruction of water flow, over-extraction, inappropriate discharge from de-watering and access restrictions.

APPENDIX C – CLOSURE RISK ASSESSMENT

Ref.				Risk Description Evaluated 21 of 21 risks		
Risk Type (T=TI	Category	Subcategory	Item	Threat Title	Potential causes (Triggers / Indicators)	Existing Controls and Commitments
T	**A**			**Planning and knowledge**		
T	**A**	**01**		**Contaminated sites**		
T	A	01	01	Under-estimated general contaminant clean up requirements	• Use of chemicals and hydrocarbons during operations • Housekeeping practice and maintenance of work areas and equipment	• Regular maintenance / inspection / audit of work place procedures • Spill management kits readily available • Contaminated sites register maintained across life of operation
T	A	01	02	Under-estimated acid and / or metalliferous drainage management requirements during operations (pre-closure) & decommissioning phase	• Potential for acid / alkaline / metalliferous / neutral / saline drainage generation during operation of mine, PAF will be intersected in S17 only • Water management, storage and monitoring practices • Water quality prior to return to environment e.g. via infiltration or discharge	• Business has committed to encapsulate PAF is exhausted pits and backfill all below water table areas to suppress groundwater table. • Business has committed not to mine PAF at B1. • Wet season management plans • Groundwater operating management plan to monitor groundwater quality, low pH would allow AMD seepage to be identified, trigger management . • SCARD management plan to guide encapsulation management of potentially acid forming (PAF) materials • Mine block models flag PAF materials for disposal
T	A	01	03	Acid and / or metalliferous drainage generation (after closure) creates a contaminated site	• Interaction of water and mineral waste could generate acid / alkaline levels that leach metals / salts from the mineral waste or local environment • Presence of temporary or permanent open water bodies, enabling evapoconcentration to occur with creation of alkaline / hypersaline water quality • Ability of metals / salts to move through environment to impact a sensitive receptor, to meet definitions in Contaminated Sites Act 2003	• Business has committed not to mine PAF at B1. Assumes PAF not mined at S10. • PAF will be mined at S17. Business has committed to encapsulate PAF is exhausted pits and backfill all below water table areas to suppress groundwater table.
T	A	01	04	Human health impacts from in situ fibrous material exposures	• Hazardous fibres exposed in situ by mining, mined and moved to encapsulated areas or naturally present in soils disturbed by mining / rehabilitation activities • Erosion of materials containing hazardous fibres post-closure	• Physical materials characterisation, some fibres present in mineral waste materials, surface alluvials and associated with infrastructure installation (cuts through non-mined geology) • Fibrous materials management plan enacted
T	**A**	**02**		**Void management**		
T	A	02	01	Lake and / or lake fringe habitat has undesirable impacts on general ecosystem function.	• Open water bodies in Pilbara naturally attract fauna (feral and native species) for food/ water/ refuge, safe access to water required • Concentration of natural groundwater or mineral waste derived salts through evapoconcentration in open water bodies • Release of metals from natural geology or mineral waste into water (infiltration or groundwater flow) • Water provides opportunity for plant /weed growth, good and bad (toxic algal blooms, noxious weeds) • Certain plant / animal species bio-accumulate / magnify toxic metals • Instability associated with saturated, unconsolidated ground, can be increased by high trafficability	• Void closure management guidance • Geochemical waste characterisation, good understanding of water chemistry / reaction chemistry • Physical waste characterisation • Rehabilitation handbook • Landform design guidance • Safe access to lake edges established via adjacent waste dumps • Aquatic fauna research underway to understand natural levels of toxic metal accumulation / impact on native species
T	A	02	02	Lake poses public liability and / or health risk	• Lake(s) in a location that is easily accessible by the general public e.g. near or visible from a public road • Lake(s) is near an existing attraction e.g. area of cultural significance or tourist attraction • Access to the lake edge is not via a dedicated, safe path • Contaminants well above recreational guidelines • Strongly acidic or alkaline lake water, or releases noxious gases • Toxic algal blooms and / or noxious weeds • Waterborne pests and disease e.g. mosquitos	• Void closure management guidance • Geochemical waste characterisation, mineral waste does not contain toxic minerals • Water quality modelling ongoing, preliminary results identify areas of potential high salinity
T	A	02	03	Degradation of regional groundwater quality or levels	• Concentration of natural groundwater or mineral waste derived salts through evapoconcentration in open water bodies • Groundwater flow through pit lake or mineral waste with connection to regional aquifer • Density driven saline groundwater flow from groundwater sink-style pit lakes • Downstream groundwater users (people, plants or animals)	• Void closure management guidance, WTS closure strategy includes backfill to suppress groundwater table in all void connected to regional aquifers • Environmental surveys include regional groundwater dependent ecosystem • Geochemical waste characterisation and column leach tests • PAF / AMD management developed for S17

Ref.					Risk Evaluation								
Risk Type (T=Th	Category	Subcategory	Item	Site specific overview	Evaluation Rationale (Maximum reasonable consequence)	Likelihood	Health	Safety On-site	Environment Off-site	Environment Community	Trust	Compliance	Risk Management	Detailed Action Descriptions
T	A	01												
T	A	01	01	• Potential for hydrocarbon contamination has been identified around the workshops and washbays. Decontamination expense has been accounted for as part of the decomissioning plan.	Signficant additional contamination is identified during decomissioning of site infrastructure.	U			M				II	
T	A	01	02	• Geochemical characterisation of waste material identified hot black shale, cold black shale and that some waste contains elevated sulfur material. Material is acid forming in bulk and expected to produce acid drainage if mined. PAF waste blocks won't be mined in S10 and B1 deposit areas. • PAF expected to be encountered in S17. SCARD plan to be implemented at site. PAF blocks have been identified and disposal locations identified. • Existing approval for WTS S10 AWT enable mining of PAF. Proposal is to change mine plans such that no PAF is mined at S10. • Wet season management plans used to control run off, includes management of water in contact with PAF wall exposures. Impacted water volues expected to be very small, would be sumped inside the mine void. Insitu treatment possible, but not considered likely to be required. No offsite disposal proposed. • Groundwater from operation to be discharged to local creeks. Discharge water quality monitored. Includes sampling and trigger / response requirements. PAF impacted water will not be disposed off-site. No treatment plant at site.	PAF matieral is excavated during mining. But not immediately encapsulated. Rainfall and surface water runoff enter the wast dump and mobilise the AMD. AMD enters the groundwater table and requires treatment to achieve acceptable closure outcomes	P			L				II	WTS-01. Undertake geochemical analyses (eg leach testing) of non-acid forming material with neutralisation capacity to understand buffering capacity for waste dump AMD and pit lake water quality assessments.
T	A	01	03	• No PAF materials are expected to be exposed on final landform surfaces. • Pit lakes will remain at B1 and S10 body. • Material behind the pit walls in pit lake areas will contain PAF material, but only exposed if there was a signficant earth movement (considered unlikely). • Potential for AMD generation increased if PAF blasted (not mined), but considered low risk of generating AMD. • Some elevated sulfur-style material could be exposed in pit walls and could enter pit lakes, considered of moderate AMD risk. • PAF encapsulate in pit floor of S17 poses highest AMD risk. Pit voids at S17 will focus surface water runoff to base of pit, over PAF storage area. If PAF material is encapsulated under the lowest point in the pit floor, some additional AMD generation could be experienced. Additional detailed planning for PAF placement and encapsulation required prior to excavation of PAF material.	PAF material is inadvertantly exposed in the pit wall during mining. The wall exposures create AMD which leaches into the pit lake. Acidity of the water changes and leads to an increase in metal contamination in pit lake water, which in turn leads to an impact on avifauna. The contignecy plan to bacfill the pit is required to be implements to stop the interaction between avifauna and impacted water.	U			M	H			III	WTS-16. Ensure learnings from modelling and in situ measurements at Pilbara mines are used to review and revise PAF management activities prior to PAF removal in S17.
T	A	01	04	• There is a low potential to encounter fibrous material while mining; however, management plans are in force for construction activities on the alluvial areas north of S10 Brockman pits. • It is expected that fibrous material management may be necessary during decommissioning.	Hazardous fibrous materials are disturbed during decommissioning activities without appropriate protection equipment being used. A stop work order is issued until the hazardous area and appropriate protection equipment are used.	R	M						II	WTS-09 Ensure hazardous fibrous materials in alluvials (if identified) can be adequately managed in accordance with the (new) Fibrous Material Management Plan.
T	A	02												
T	A	02	01	• Pit lakes will be left to develop in the B1 main and S10 body pits. • Detailed hydrogeology information is not available for the area, but is expected to be developed during the life of the operation. • Premliminary modelling, based on available information and assumptions, suggested pit lakes will have fresh to brackish water quality with some elevated metals. • It is likely that the water will not be fit for human consumption, but may be suitable for other land uses. • The lake water is expected to have limited interaction with the local environment, interaction requires access up ridge and down into the pit areas. • Lake littoral zones are not expected to form due to seep pit sides. This will minimise bioological activity within lake, and will discourage further food chain development / dependance. • Some fauna may access lake water periodically for water supply, i.e. birds, especially during drought.	Lake water develops high metal concentrations which lead to minor but long-term health impacts in local (non-protected) fauna species.	U				H			III	WTS-03. Review of pit lake water quality modelling to incorporate improved knowledge base WTS-10. Assess the ability of pit lake water to sustain aquatic flora and fauna. WTS-11. Update pit lake ecological risk assessment as knowledge develops, including the potential for biological attenuation
T	A	02	02	• Pit lakes will be left to develop in the B1 Main and S10 Body pits will be difficult for the public to access. Closure management strategies include means to discourage use of lakes i.e. no roads to lakes, abandonment bund • Lakes not visible from public access roads, but are near regularly accessed TO heritage sites. • Water quality may be suitabe for recreation use. Further model prediction validation required to confirm health risks. • Pit walls not designed to be stable, however significant wall collapse / mass material movement is not expected. Small wall movement, i.e. rosk fall, could pose public liability risk.	Pit lake becomes a regular tourist location. A pit wall collapses while people are using the areas, placing lives at risk.	U	L	M			M	M	II	WTS-03. Review of pit lake water quality modelling to incorporate improved knowledge base
T	A	02	03	• Borefields in area used for pastoral use, have already lowered regional groundwater table in some areas compared to natural (undisturbed) conditions. • Groundwater in WTS believed to be compartmentalised. Only new (no PAF) S10 MM pits connected to regional aquifer, will be backfilled on closure. • Preliminary integrated ground-surface water modelling (with recovery) completed. Dewatered areas may not recovery to pre-mining levels, localised depression in regioanl aquifer expected to form due to capiliary actions in S10 MM pits, however impact is localised and regional groundwater levels expected to recover. • Regional aquifer has brackish water quality. Dewatering and groundwater recovery not expected to influence regional groundwater quality.	Groundwater salinity increases such that bores are no longer suitable for pastoral use.	R				M	L	L	II	

Risk Type (T=TI	Ref. Category	Ref. Subcategory	Ref. Item	Risk Description Evaluated 21 of 21 risks Threat Title	Potential causes (Triggers / Indicators)	Existing Controls and Commitments
T	A	02	04	Wall failure within mine void compromises closure outcomes	• Influence of erosion, subsidence, seismicity, wall slip • Influence of groundwater recovery and surface water flow on stability. • Creek system neighbouring or within zone of instability, potential stream capture • Poor communication of zone of instability to facilitate identification of important features	• Geotechnical assessments for wall stability and zone of collapse as part of mine design reviews, as required • Pit walls design factor of safety 1.3, geotechnical assessment show zone of collapse for high risk locations (near creeks, infrastructure etc.) • Conceptual location for abandonment bunds established
T	**A**	**03**		**Closure landforms**		
T	A	03	01	Built landforms (excluding mine void areas) erode and / or collapse	• Physical material properties considered in design • Drainage and erosion management • Design and construction of landforms / waste dumps • Sensitive receptors identified downstream • New waste types present requiring characterisation • Waste types erodibility characteristics differ from expected performance	• Physical materials characterisation completed for expected waste types • Multi-disciplinary pit and waste dump design sign-off processes, considers landform design guidelines and provides rehabilitation designs where appropriate • RTIO Rehabilitation handbook used for general rehabilitation activities • Rehabilitation designed to be stable without vegetation
T	A	03	02	Surface treatment on landforms limits vegetation growth	• Availability of top soil stockpile soil / poor stockpile management e.g. soil washed away • Low moisture retention i.e. hydrophobic soils development, very rocky materials • Chemical properties of materials on waste dump / rehab surface e.g. salt circulation, alkalinity • Poor quality topsoil resulting from excess rehandling	• Physical and geochemical materials characterisation complete for expected waste material types. • Topsoil and subsoil collected as disturbance occurs throughout mine life • Annual stockpile reconciliation of top soil and sub soil stockpiles, return of 200mm to create quality surface growth media • Rehabilitation handbook provides direction on alternate surface treatment options
T	A	03	03	Vegetation is not self-sustaining	• Vegetation established, but does not re-seed in same abundance • Weed competition • Species selection / insufficient species diversity • Animal interference i.e. feral animals eating new growth • Changes to soil water conditions e.g. salinity, water logging etc	• Rehabilitation handbook provides guidance on seed selection for appropriate diversity • Top soil stockpiles provide seed bank
T	A	03	04	Access through area post-closure poses public liability risk	• Post-closure access / land-use requirements, e.g. for stock, people, heritage, environmental monitoring, adjacent mining activities etc. • Potential for general public to create their own access if appropriate access not provided.	• Regular review and integration of stakeholder feedback into closure plan updates.
T	**A**	**04**		**Other regional considerations**		
T	A	04	01	General environment outside of approved mine disturbance areas is adversely impacted	• New (previously unidentified) environmental sites, not considered in existing environmental impact assessment • Changes to environmental conditions due to cessation of artificial support / mitigation activities, e.g. water supplementation • Change to drainage patterns on closure e.g. removal of temporary diversions, drains etc.	• Internal ground disturbance approval request system to prevent inadvertent disturbance • Baseline biological / ecosystem health surveys and existing monitoring to define post-mining status • GIS system includes results from all flora, fauna, vegetation surveys • Operational management plan for discharge includes actions relating to water quality and discharge extent targets, to ensure environmental issues are managed during operations • Significant species management plan implemented during operation to minimise impact to select species • Vegetation management plan implemented during operations to monitor and manage impacts to vegetation (riparian, understorey and weeds)
T	A	04	02	Adverse impact to flora or fauna with conservation status or wider regional impact to high value environment	• Scheduled, listed or declared rare and / or threatened species of flora or fauna present in/adjacent to site • Downstream regional area of high value • Environmental conditions post-closure differ significantly from pre-mining conditions • Post-mining land use differs from pre-mining land use	• Internal ground disturbance approval request system to prevent inadvertent disturbance • Baseline biological / ecosystem health surveys and existing monitoring to define post-mining status • GIS system includes results from all flora, fauna, vegetation surveys • Operational management plan for discharge includes actions relating to water quality and discharge extent targets (proximity to Fortescue Marsh), to ensure environmental issues are managed during operations • Significant species management plan implemented during operation to minimise impact to select species • Vegetation management plan implemented during operations to monitor and manage impacts to vegetation (riparian, understorey and weeds)

Ref.					Risk Evaluation								
Risk Type (T=Th	Category	Subcategory	Item	Site specific overview	Evaluation Rationale (Maximum reasonable consequence)	Likelihood	Health	Safety	On-site Environment	Off-site Environment	Community Trust	Compliance	Risk Management	Detailed Action Descriptions
T	A	02	04	• Some surface water drainage expected to flows into some pits. This could increase the geotechnical instability in these locations. Water management or alternate bunding strategies may be required in these locations. • In S10 MM 101 pit the pit wall adjacent to the creek floodplain will be buttressed to stabilise the ground above the pit wall (zero zone of instability), to ensure the creek is not captured within the pit in the future. • Geotechnical zones of instability have ben established for the pits based on simple parameters. Further understanding of geological structural issues will be resolved during the life of the mine, and zones will be updated accordingly.	After management is in place, the riparian corridor is impacted due to erosion resulting from in-pit mass movement (and associated erosion). Repair to environment and bunds are required.	R				H	M		III	WTS-07. Review and verify the pit wall stability management requirements for the S10 MM pit wall below local creek. WTS-15. Refine design of S10 MM pit wall buttress stabilising structure based on selected material waste characteristics. WTS-20. Review and revise controls for preventing inadvertent access to the pit, considering geotechnical instability, surface water management and topography
T	**A**	**03**												
T	A	03	01	• There is a high proportion of erodible material on site. • Waste dumps have been designed to landform design guidelines, consider highly erodible materials, but rely on waste segregation to achieve long-term stability, e.g. encapsulation and / or transportation of highly erodible materials to in pit backfill. • Encapsulation of highly erodible materials expected to have better stability outcomes than capping. Capping of waste material with competent waste material no longer required, reduce risk of re-work at end of mine life. • Construction conformance to waste dump design is not at prefered performance levels. Some re-work expected on existing waste dumps to achieve long-term stable landforms. • There are no environmental significant features near waste dumps. • Protection of the Northern Hardey River floodplain requires buttress and erosion protection to ensure structure remains stable (if flood overtops bund) and no subsidence occurs within floodplain (leading to creek capture). (Risk considered under void management - not rated under "built landforms")	Waste dump erodes (due to surface water flows or rainfall) and compromises structural integrity of landform, post-closure repair required.	P				L			II	WTS-05. Review water management for waste dumps that abut the landscape to minimise run-on to dumps at closure. WTS-21. Review conformance to waste dump encapsulation design during construction.
T	A	03	02	• Mineral waste characterisation suggests most waste material is inert and in general is expected to be acceptable growth media. • Waste includes problematic material for growth, i.e. calcrete and PAF. Rehabilitation performance of calcrete is unknown; but is only of small volume and specific to S10 MM area. Additional surface treatment on waste dumps may be requird to ensure good growth if materials are present on outer surfaces. • As limited rehabilitation / revegetation has been completed at WTS. Available data from Tom Price suggests standard rehabilitation practice can achieve revegetation. But difficult to conclude that standard rehabilitation techniques will achieve WTS closure completion criteria. • Blasting at S10 has resulted in rock material being deposited on undisturbed, inaccesssible ground. Rehabilitation of these overblast area may be extremely challenging. • Top soil recovery has been limited due to rocky terrain. WTS topsoil reconcilitation in closure plan considers current performance success, concludes topsoil shortage likely. Subsoil may ned to be blended with topsoil to achieve 200mm targets.	Soil chemical properties inhibit plant development requiring investigation and treatment, i.e. mulch, fertilisers, gypsum etc.	U			VL	M			II	WTS-08. Investigate processes for reclaiming / rehabilitating over-blast areas.
T	A	03	03	• Most revegetation activities will occur at closure. Soil stockpiles will be kept for a long time, and there is a potential for soil quality to degrade. • Seeds tested for germination as standard. Seeds sourced from reliable suppliers. • No underlying pastroral land use, so problematic cattle not expected to impede vegetation growth. • Invasive species management plan to be developed as part of closure activities.	Vegetation fails to establish and re-work is required post-closure.	U				M			II	
T	A	03	04	• No access requirements have been identified with stakeholders	Requirements for a track through the former mine area is identified during the decommissioning study	U					L		I	
T	**A**	**04**												
T	A	04	01	• Discharge has the potential for disturbance outside the mine area. Discharge impacts will be monitored during the operation and mitigated during the operation; not expected to require resolution during closure • No adverse impact off site are anticipated through the implementation of the project.	Ecosystems fail to recover from the cessation of surplus water discharge. Recruitment fails and existing plants die. Invasive weed species take over and reduce biodivsity value. Extensive weed management campains and a rehabilitation programme is required to restore vegetation community to suitable level.	U				M			II	
T	A	04	02	• Environmental avoidance areas in mine area (priority species or high value species / vegetation communities) • No species with conservation status or high environmental value is expected to be impacted through the implementation or closure of the project.	Priority species is identified in the mine disturbance area and requires change in landform design to avoid impact.	R				VL			I	

Risk Type (T=TI	Ref. Category	Subcategory	Item	Risk Description Evaluated 21 of 21 risks Threat Title	Potential causes (Triggers / Indicators)	Existing Controls and Commitments
T	A	04	03	Heritage site condition / cultural value is degraded as a result of implementing the closure plan	• New (previously unidentified) heritage sites, not considered in existing assessment, discussions, agreements or with authority to disturb • Changes to landforms on closure have potential to alter conditions at downstream sites, e.g. consider drainage, landform footprint, erosion implications • Cessation of maintenance of / to heritage site	• Internal ground disturbance approval request system ensures heritage sites identified prior to disturbance. S18 processes followed. • GIS system includes results from heritage surveys to promote avoidance where possible • Ongoing consultation with Traditional Owners on LoM planning through Eastern Guruma Monitoring and Liaison Meetings
T	**B**			**Stakeholders**		
T	**B**	**01**		**Consultation**		
T	B	01	01	Consultation fails to identify stakeholder concerns	• Large number of stakeholders in the project • Clarity of explanation / prediction of closure outcomes, communication styles, long term engagement of agreed outcomes through generational change. • Stakeholder expectations change over time, due to changing global benchmarks for mine rehabilitation success, intergenerational change, regulatory changes etc. • Stakeholders do not endorse site closure as their issues / concerns were not addressed	• RTIO stakeholder engagement practice with key stakeholders i.e. Traditional Owner M&L, etc. • Ad hoc consultation with key stakeholders • Detailed engagement planned during decommissioning study • Stakeholder engagement register
T	**B**	**02**		**Key stakeholder expectations**		
T	B	02	01	Closure outcomes do not meet stakeholder(s) / community expectations	• Absence of rehabilitation trial or data to support predicted outcomes, closure activties fail to achieve completion criteria • Communication of anticipated closure outcomes and post-closure land use needs i.e. wrong plant species established • Unrealistic expectations for economic potential opportunities / post-closure land use capability i.e. aquiculture in pit lakes	• RTIO stakeholder engagement practice with key stakeholders • Monitoring established for water, rehabilitation trials started • Numerical completion criteria established for some aspects
T	B	02	02	A stakeholder's expectations conflict with that of another stakeholder, causing delays to plan approval and / or closure	• Conflicting stakeholder expectations or areas of authority e.g. different regulators for environment, heritage, health, economic, tourism • Conflicting legal obligations e.g. State Agreement and EPA • Interactions between catchment land uses, including mining developments, at different points in time	• RTIO stakeholder engagement practice with key stakeholders
T	B	02	03	Closure strategy prevents or limits future exploitation of resources	• Backfill sterilises ore reserves • Lakes or habitat restoration prevent / limit future access to adjacent resources	• RTIO stakeholder engagement practice with key stakeholders • Integration of potential expansion deposits into current closure plan options • Internal approval process to commence backfill of pits
T	**B**	**03**		**Other expectations**		
T	B	03	01	Mine closure has a significant, long-term detrimental impact on local communities	• Local communities receive direct support from operation for basic community services e.g. doctor • Significant proportion of community are directly or indirectly employed by operation	• Ongoing communication with stakeholders • Mining will transition back to Tom price operations, workforce retained
T	**C**			**Obligations**		
T	**C**	**01**		**Agreements and commitments**		
T	C	01	01	Closure is not implemented in accordance with the approved closure plan	• Mine development changes prevent closure plan from being implemented as planned • Closure plan proves to be overly challenging to implement or implementation results in a different outcome than anticpated	• Integration of closure plan with LoM report
T	**C**	**03**		**Governance (internal only)**		
T	C	03	01	Management of closure related issues during life of mine leads to increased closure complexity	• Unsafe working conditions evolve prior to rehabilitation e.g. reduce maintenance, pit / landform stability changes over time, groundwater recovery prior to completion of in pit closure activities, hazardous fibres exposed with erosion, sulphides gases • Lack of experience, i.e. staff skills or trial areas/activities, use of inefficent management processes / practice, high degree of re-work • Ambiguity of risk / issue / action ownership to appropriately resource & resolve prior to key mining decisions, increased cost & lost opportunities	• Mine safety inspections • Operational pit permitting system • Development of risk register

Ref.					Risk Evaluation									
Risk Type (T=Th	Category	Subcategory	Item	Site specific overview	Evaluation Rationale (Maximum reasonable consequence)	Likelihood	Health	Safety	On-site Environment	Off-site Environment	Community Trust	Compliance	Risk Management	Detailed Action Descriptions
T	A	04	03	• Heritage sites located in / near mine area. Mine planning has avoided sites where possible to ensure sites a represerved post-closure. Consultation with TO's will continue throughout life of mine, and requirements for repatriation can be integrated into design at any stage. • No artifact repatriation requirements have been identified to date.	Closure plan implementation disturbs environmental or heritage site without approval.	U					M		II	
T	**B**													
T	**B**	**01**												
T	B	01	01	• Key regulators already engaged in discussions. • Eastern Guruma TO's already engaged in discussions. • Local Government aware of development, but not closure specific.	Stakeholder perceptions change over time and current plan is no longer accepted, requiring changes to the closure strategy during decommissioning	U					M		II	WTS-13. Undertake closure specific consultation with TO's
T	**B**	**02**												
T	B	02	01	• Pastoral lease only on a small area of mining lease. Expect land to revert to unallocated crown land; requires native vegetation growth and stable landforms for post-closure land-use compatibility. • 3D post-closure visualisation is not available. Landscape vision and potential vegetation communities have not been discussed with all stakeholders in detail.	Longer post-closure monitoring period than anticipated is required to demonstrate ecosystems are self-sustaining	P					L		II	WTS-12. Conduct visual amenity assessment of final landform options. WTS-14. Consult with key stakeholders to gauge their expectations in regards to post closure objectives and criteria.
T	B	02	02	• No conflicts have been identified. Communication with stakeholders will occur throughout mine life to identify and address potential conflicts.	Stakeholder requirements for environmental management conflict, and one stakeholders needs can't be met	U					L		I	
T	B	02	03	• Backfill is part of closure strategy and will cover some resources. Approval to backfill over resource will be confirmed prior to undertaking activity • The majority of the low grade resource is expected to be exhausted prior to closure of pits identified as future pit lakes. • Further resource definition drilling is underway in the area. Subsequent mining studies could influence mine sequencing, but are not expected to significantly alter the expected closure outcomes at WTS. • Further discussion with key stakeholders and regulatory approvals are required before any expansion deposits can be mined.	Closure of the site is delayed, causing some disgruntlement within some stakeholder groups.	L					VL		II	
T	**B**	**03**												
T	B	03	01	• No detrimental impacts are anticipated. If schedule changes and mining at Tom Price finishes before WTS, closure plan will be updated.	Mining at Tom Price ceases before mining at WTS and adequate provision for community transition from RTIO dependence is unavailable.	R					M		II	
T	**C**													
T	**C**	**01**												
T	C	01	01	• Implementation of the closure plan will influence site mineral waste management activities. Communication with / approval from regulators may be required prior to implementing changes to the mine plan. • Closure plan expected to require 3 yearly updates approved by EPA.	Regulator identifies an inconsistency in closure implementation and requires re-work to achieve acceptable outcome	R					M	M	II	WTS-17. Review data collected and information developed through the operation life. Use data / information to improve models, interpretations and verify predictions.
T	**C**	**03**												
T	C	03	01	• Mine manager and site GM have yet to be engaged with closure planning. • LoM planning team have been highly engaged in closure planning, and LoM plan / design currently aligns with closure plan. • Backfill of voids has been requested to be implemented as part of operations. Delay to backfill could result in pit wall instability an may increase closure complexity.	Pit walls start to collapse or haul road conditions deteriorate prior to backfill requirements being implemented, putting people in line of fire.	U	L	M					II	WTS-19. Development of HSE management methodology for closure WTS-18. Integrate management of inactive mine areas into LoM plan

Western Turner Syncline

Riparian Vegetation Monitoring and Management Plan

RTIO-HSE-0259018

Hamersley Iron Pty Limited
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October 2015

Disclaimer and Limitation

This report has been prepared by Rio Tinto Iron Ore (Rio Tinto), on behalf of Hamersley Iron Pty Limited, specifically for the Western Turner Syncline Project. Neither the report nor its contents may be referred to without the express approval of Rio Tinto, unless the report has been released for referral and assessment of proposals.

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Rev	Author	Reviewer/s	Date	Approved for Issue	
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1 SUMMARY

This Environmental Management Plan (**EMP**) is submitted in accordance with Ministerial Statement No. [X] for the Western Turner Project by Hamersley Iron Pty Limited.

Table 1-1 Environmental criteria to measure achievement of environmental outcome

Title of proposal	Western Turner Syncline Project
Proponent	Hamersley Iron Pty Limited
Ministerial Statement Number	[X]
Purpose of this EMP	The Western Turner Riparian Vegetation Monitoring and Management Plan is submitted to fulfil the requirements of condition [x-x] of the above Statement.
EPA's environmental objective for the key environmental factor	Maintain representation, diversity, viability and ecological function at the species, population and community levels.
Condition environmental outcome or proposed measurable outcome	Ensuring that dewatering required for the WTS Project, and any mitigation measures implemented, does not adversely impact the riparian vegetation, particularly the eucalypt overstorey associated with the Beasley River and Hardey River systems.
Early response criteria	*Early response criterion 1: Overstorey vegetation* ±15 percent change in mean foliage cover relative to baseline, in excess of change in reference sites. *Early response criterion 2: Understorey vegetation* 15 percent decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference sites.
Trigger criteria	*Trigger criterion 1: Overstorey vegetation* ±25 percent change in mean foliage cover relative to baseline, in excess of change in reference sites. *Trigger criterion 2: Understorey vegetation* 20 percent decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference sites. *Trigger criterion 3: Introduced (exotic) species.* Introduced species recorded at an impact site, which has not previously been recorded within the project area and/ or significantly increased since baseline or significantly different from reference sites.
Threshold criteria	*Threshold criterion 1: Overstorey vegetation* ±40 percent change in mean foliage cover relative to baseline, in excess of change in reference sites *Threshold criterion 2: Understorey vegetation* 30 percent decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference sites *Threshold criterion 3: Introduced (exotic) species* Introduced species not previously recorded within the project area, and classified by the department of Parks and Wildlife as having High Ecological Impact and Low Feasibility of control and exceeds 60 percent of total understorey cover at impact sites.

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2 CONTEXT AND SCOPE

2.1 WESTERN TURNER SYNCLINE PROJECT

Hamersley Iron Pty Limited (**the Proponent**) manages and operates the Western Turner Syncline Project (**WTS Project**) approved under the Environmental Protection Act 1986 (**EP Act**) by the Minister for the Environment. The WTS Project is integrated into the current Rio Tinto Greater Tom Price mining operation, located within the Shire of Ashburton (Pilbara region), approximately 20 km west to the Tom Price Township (Figure 2-1).

Karijini National Park is situated 18 km east of the WTS development envelope and is the only location registered on the Australian Heritage Database in the vicinity of Tom Price. No Heritage Council of Western Australia listed sites occur within the vicinity of the WTS Project.

The WTS Project encompasses Section 10 (**S10**) deposits and B1 and Section 17 (**S17**) deposits (Figure 2-2). Surplus dewatering from the S10 deposit is discharged to the south of the deposit, in Hardey River and surplus dewatering from B1 deposit is discharge to the north, into a tributary joining the Beasley River approximately 9.5 km upstream.

2.2 KEY ENVIRONMENTAL FACTORS

A key environmental factor of the WTS Project is the dewatering discharge in the Beasley River and Hardey River and the consequential potential adverse impact on flora and vegetation within these river systems. As a precautionary measure, the Environmental Protection Authority (**EPA**) set an environmental condition which required a riparian monitoring program with associated trigger and threshold values and management actions.

The focus of this Western Turner Syncline Riparian Monitoring and Management Plan (**WTS MMP**) is on the environmental objective of ensuring that dewatering required for the WTS Project, and any mitigation measures implemented, does not adversely impact the riparian vegetation, particularly the eucalypt overstorey associated with the Beasley River and Hardey River systems.

This objective is aligned with the EPA's broader environmental objective for flora and vegetation of: "*Maintain representation, diversity, viability and ecological function at the species, population and community levels*".

2.3 REGULATORY REQUIREMENTS

This Western Turner Syncline Riparian Monitoring and Management Plan (**WTS MMP**) describes the monitoring and management of dewatering discharge from the WTS Project to the riparian vegetation, as required by its Ministerial Statement No [X].

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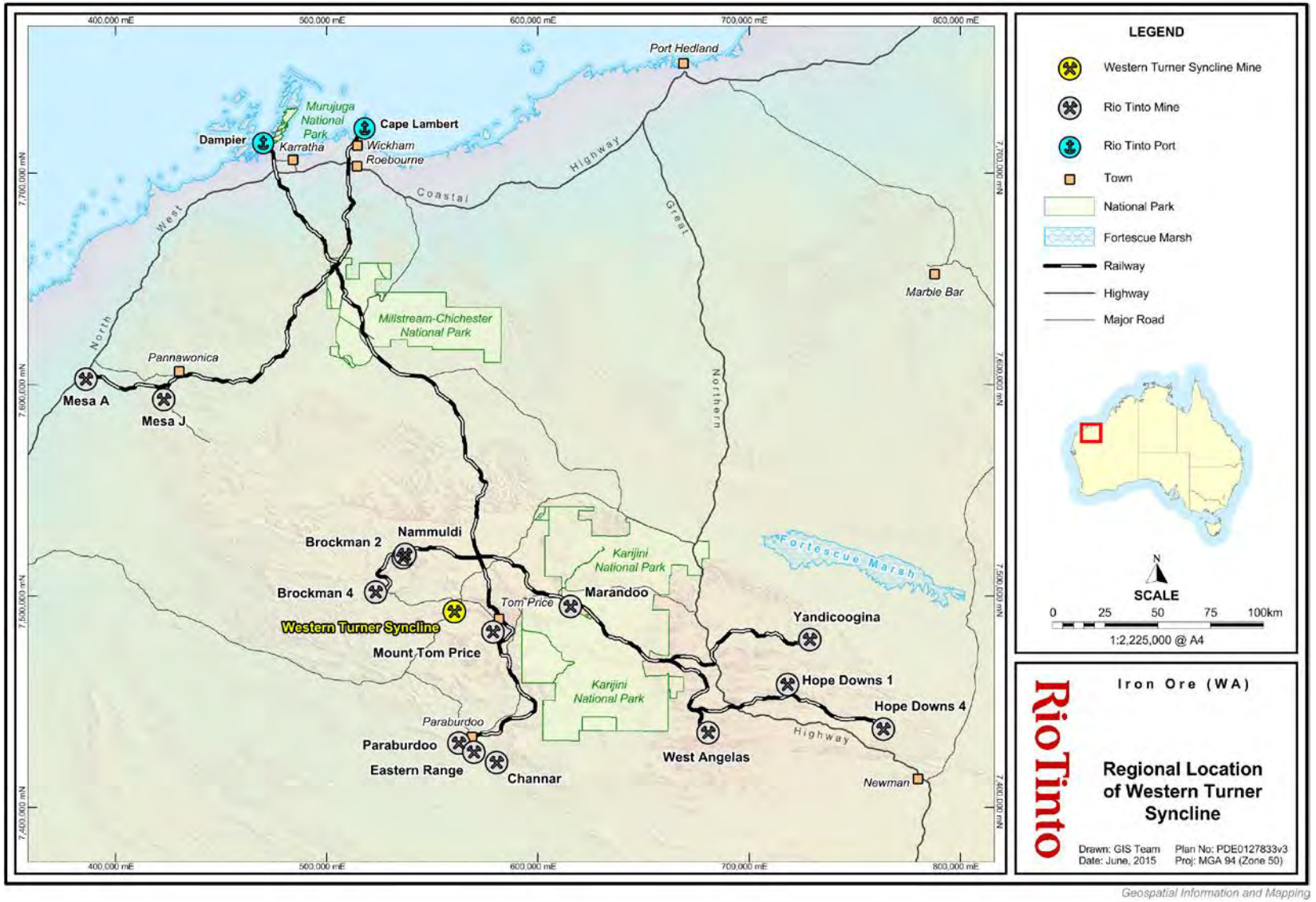


Figure 2-1 Regional Location Map

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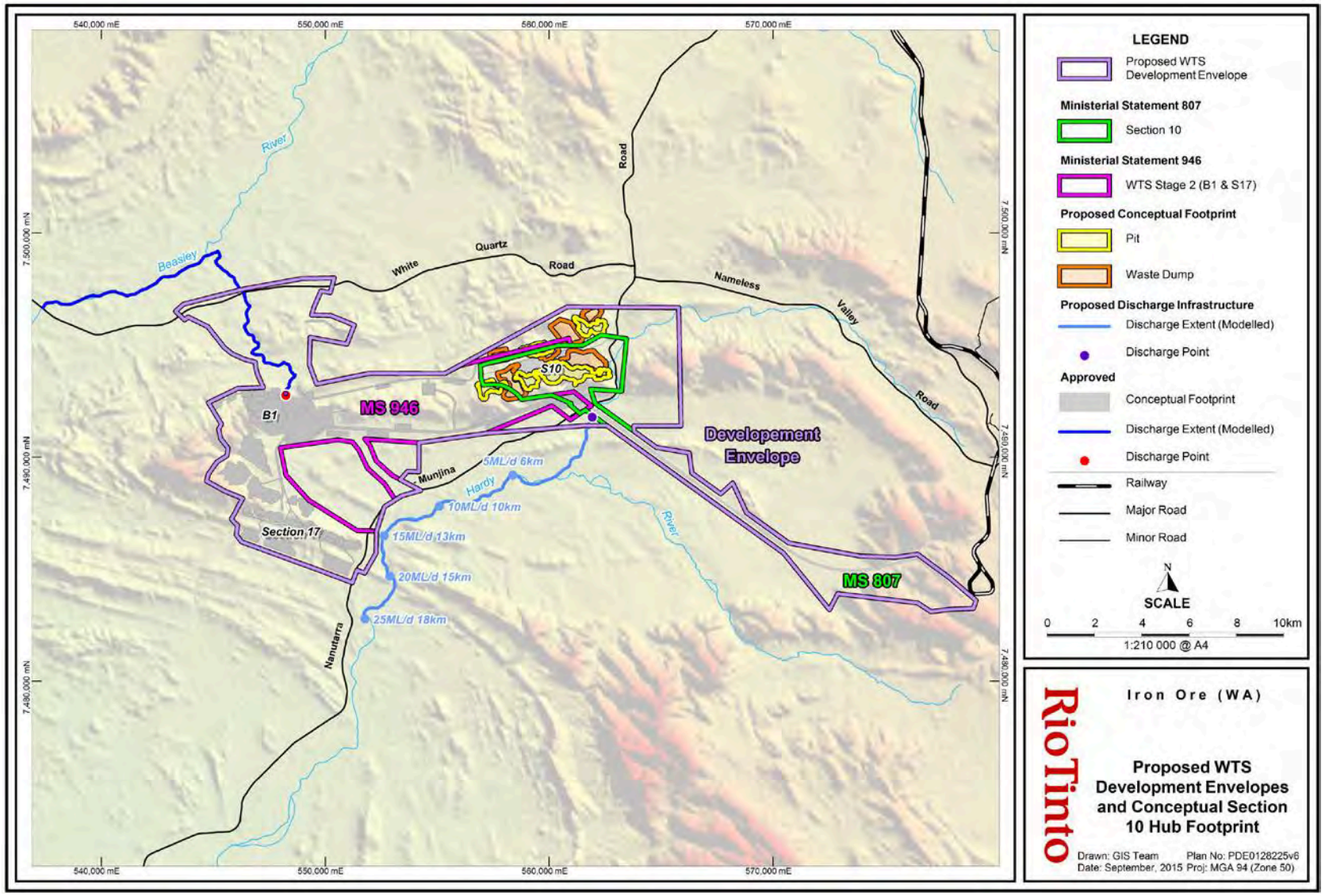


Figure 2-2 WTS Development envelope

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2.4 RATIONALE AND APPROACH

Results of baseline surveys and a number of assumptions and uncertainties informed the management approach for meeting the environmental outcome stated in section 2.2. The identified early response criteria, trigger criteria, threshold criteria, early response-, trigger level actions and threshold contingency actions are aligned with the overall management approach.

2.4.1 Results of baseline surveys conducted

Extensive vegetation mapping and baseline surveys (since 2011) have been undertaken of the Beasley River and Hardey River, including upstream and downstream of the discharge impact areas, and of several tributaries, including the discharge watercourses. The vegetation mapping informed the selection of monitoring sites and the selection of early response-, trigger and threshold criteria.

2.4.2 Key assumptions and uncertainties

Prolonged saturated soil conditions may occur in proximity to the watercourse channels affected by dewatering discharge, potentially causing declines in health and abundance of flora species not adapted to waterlogged/saturated soil conditions. Therefore, potential impacts on vegetation communities in proximity to watercourses affected by dewatering may include the decline in health and/ or death of less waterlogging tolerant species and increase in abundance of more waterlogging tolerant species. After cessation of dewatering discharge, riparian vegetation is expected to gradually revert to a pre-impact condition.

2.4.3 Management approach

This WTS MMP addresses the key environmental factor (and relevant EPA environmental objective) determined by the EPA as being relevant to the management of WTS riparian vegetation. Overall, the WTS MMP has been developed to address condition-based environmental outcome.

The WTS MMP also details the management of dewatering discharge to minimise long term impacts to the environmental and conservation values of the Beasley River and Hardey River systems. It further details the environmental criteria that the Proponent will use to measure performance of the contingency measures relative to the environmental objective.

The management approach also includes the internal use of early response indicators and criteria of multiple performance indictors to track impacts.

Further this WTS MMP includes the trigger criteria management actions and threshold criteria contingency actions that the Proponent will undertake if the environmental outcome is exceeded.

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2.4.4 Rationale for choice of environmental criteria

The riparian vegetation community (understorey and overstorey) on Beasley River and Hardey River are the monitored parameters upon which early response, trigger and threshold criteria are set. This is supported by an extensive monitoring program to assist in the early detection or detecting risks associated with dewatering discharge on riparian systems and management action ensuring these are minimal.

The criteria have been developed from the perspective of three monitoring and management zones (Table 2-1) located on the Beasley River (including the discharge creek flowing into Beasley River) and Hardey River respectively (Figure 2-3 and Figure 2-4).

Table 2-1 Monitoring and management zones in the Beasley River and Hardey River systems.

River System	Management zone	Management zone monitoring
B1 discharge creek (~9.5 km) flowing into Beasley River	Zone 1	Comprise the discharge watercourse from the discharge point to the junction with Beasley River, where weed management will be the primary focus.
Beasley River	Zone 2	Comprise the riparian woodland on the Beasley River within the maximum approved extent of discharge, where intensive monitoring and management will be applied.
	Zone 3	Comprise a reference area on the Beasley River upstream of the discharge impact area, for comparison to monitoring results from Zone 2.
Hardey River	Zone 1	Comprise upstream potential impact zone (within cone of depression) where Digital Canopy Photography (**DCP**) monitoring will be the primary focus.
	Zone 2	Comprise the Hardey River discharge watercourse, within the maximum approved extent of discharge, where intensive monitoring and management will be applied, including weeds.
	Zone 3	Comprise two reference areas upstream of S10 mine. One is located on the Hardey River and one is located on a tributary to the east of Hardey River, for comparison to monitoring results from Zone 2.

The potential for the early response- and trigger criteria to be detected due to natural variability in vegetation communities must be accounted for in the management response. Therefore, the response to a detection of the early response and trigger criteria requires identification of potential impacts during dewatering discharge.

The early response- and trigger criteria will not be treated as a non-compliance of the Project to the environmental objective.

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The potential for the threshold criterion to be detected due to natural variability in vegetation communities must also be accounted for in the management response. After cessation of dewatering discharge, the majority of riparian vegetation is expected to gradually revert to a pre-impact condition (e.g. structural composition, functional behaviour, habitat elements and recruitment dynamics).

The threshold criterion will be treated as a non-compliance of the Project to the environmental objective if the exceedance is attributable to the Project.

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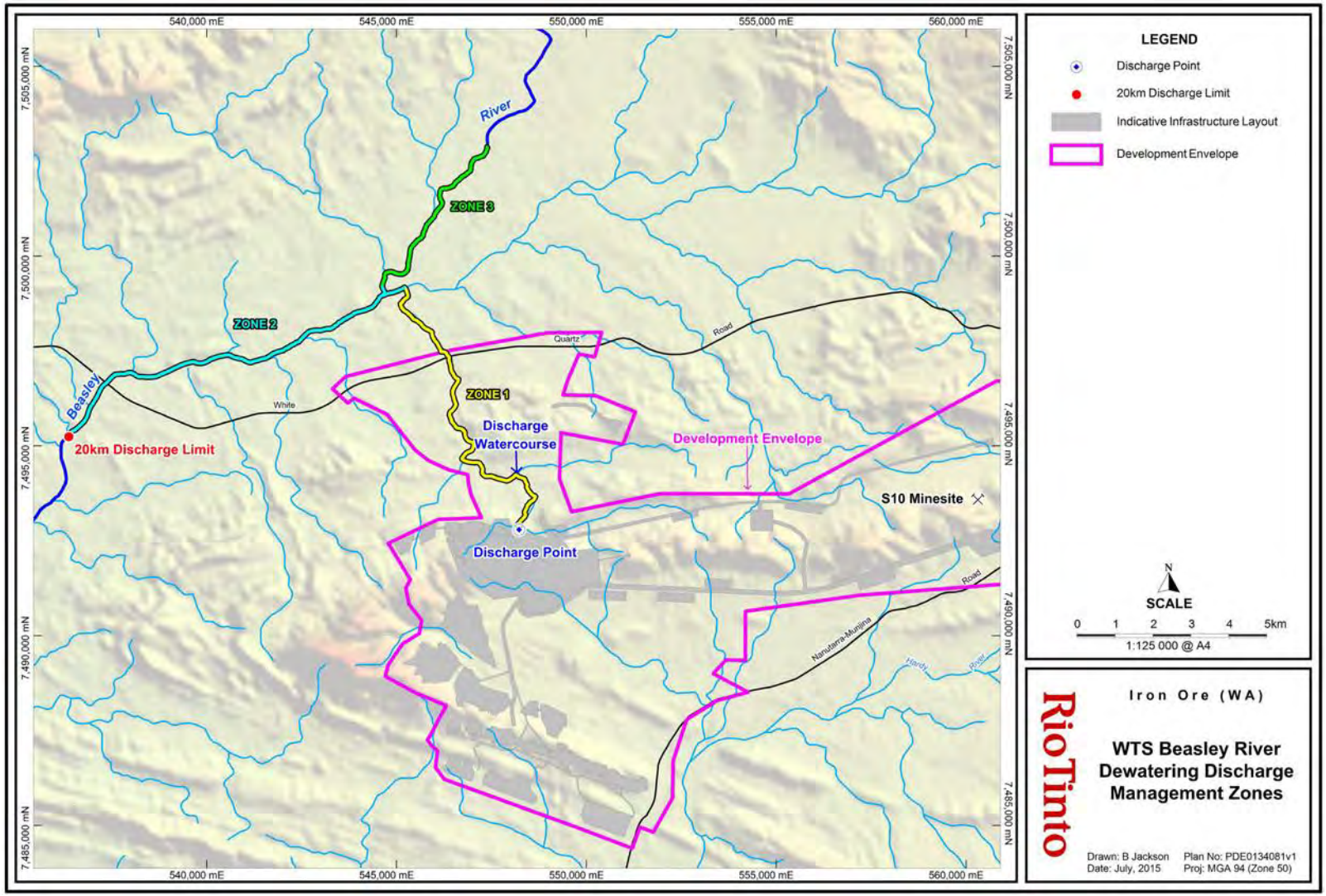


Figure 2-3 WTS Beasley River dewatering discharge management zones

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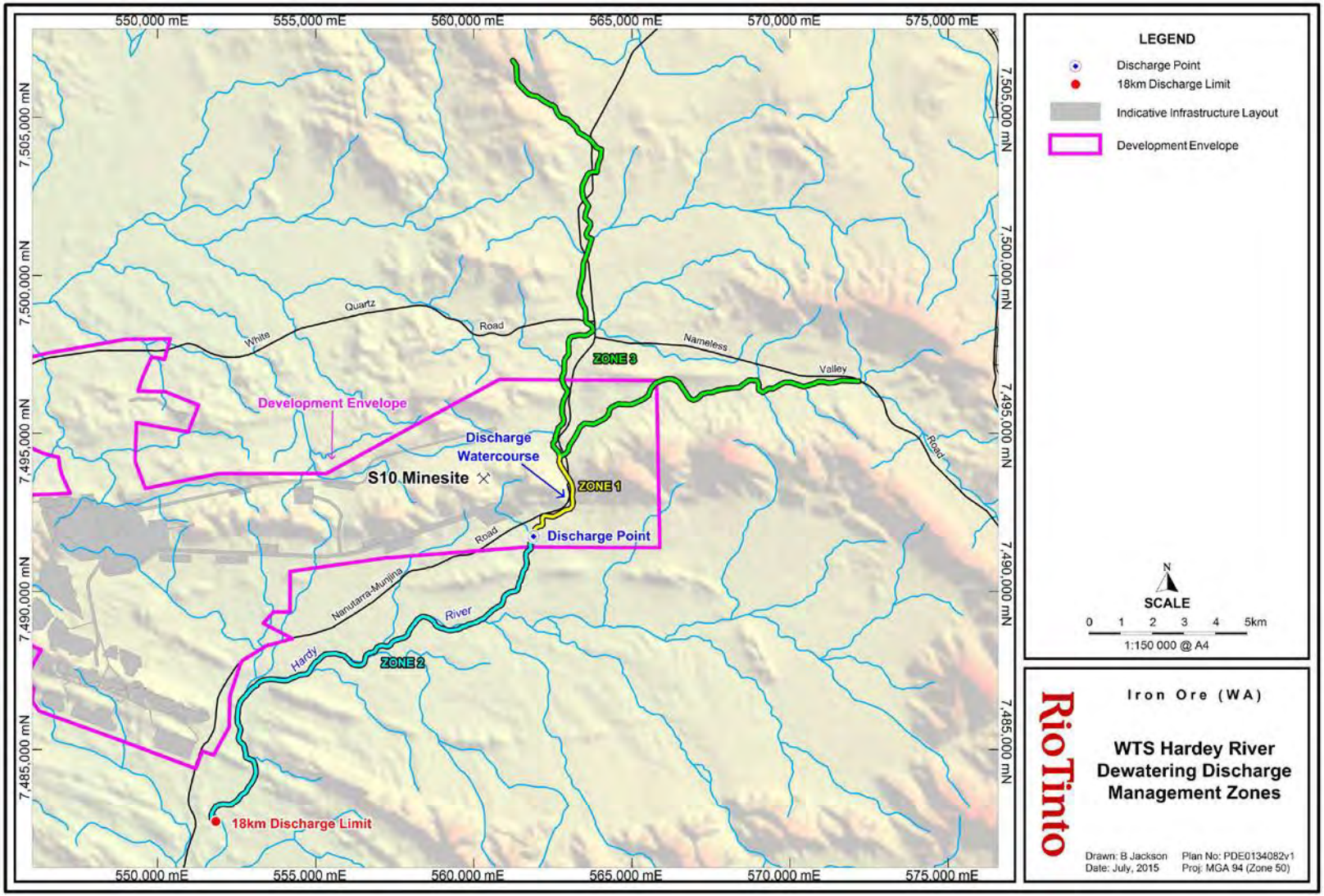


Figure 2-4 WTS Hardey River dewatering discharge management zones

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3 MANAGEMENT PLAN PROVISIONS

This section of the WTS EMP identifies the legal provisions that the Proponent proposes to implement to ensure that dewatering required for the WTS Project does not adversely impact the riparian vegetation associated with the Beasley and Hardey River systems. It identifies the environmental criteria that the Proponent will use to measure performance and monitoring that will be undertaken in relation to these environmental criteria. Finally, it defines the trigger level actions and threshold contingency actions that the Proponent will undertake if the environmental criteria area exceeded.

3.1 ENVIRONMENTAL CRITERIA

Three levels of criteria, which vary in function, have been developed for the WTS MMP:

1. **Early response criterion**: measure set at a more conservative level than trigger criteria to provide early internal feedback on increasing or expanding impacts.

2. **Trigger criterion**: measure set at a conservative level to ensure management actions are implemented well in advance of the environmental objective being compromised. Thus, trigger criterion are set at a level below the threshold criterion to signal the need to focus and investigate and where applicable, mitigate the impact further or increase the level of production or rehabilitation.

3. **Threshold criterion**: framed to measure achievement of the environmental objective. A failure to meet the threshold criterion, if attributable to the implementation of the WTS Project, signals the environmental objective is not being met.

The early response, trigger, and threshold criteria to be applied to the riparian vegetation environmental objective for the Beasley River and Hardey River vegetation communities are divided into overstorey vegetation, understorey vegetation and introduced (exotic) species.

Overstorey vegetation (*Eucalyptus victrix* and *Eucalyptus camaldulensis* var. *refulgens*)

1. **Early response criterion**: ±15 percent change in mean foliage cover relative to baseline, in excess of change in reference sites.

2. **Trigger criterion**: ±25 percent change in mean foliage cover relative to baseline, in excess of change in reference sites.

3. **Threshold criterion**: ±40 percent change in mean foliage cover relative to baseline, in excess of change in reference sites.

Understorey vegetation

1. **Early response criterion**: 15 percent decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference sites.

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2. **Trigger criterion**: 20 percent decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference sites.

3. **Threshold criterion**: 30 percent decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference sites.

Introduced (exotic) species

1. **Trigger criterion:** Introduced (exotic) species recorded at an impact site, which has not previously been recorded within the project area and/ or significantly increased since baseline or significantly different from reference sites.

2. **Threshold criterion**: Introduced (exotic) species not previously recorded within the project area, and classified by the department of Parks and Wildlife as having High Ecological Impact and Low Feasibility of control and exceeds 60 percent of total understorey cover at impact sites.

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3.2 MONITORING

The purpose of the monitoring is to inform, through the environmental criteria, if the condition environmental outcome is being achieved and when management actions will be implemented.

Refer to Table 3-1 for monitoring provisions, and how these will determine performance against the environmental criteria.

3.3 IMPLEMENTATION OF THE TRIGGER LEVEL ACTIONS

The Proponent has developed trigger level actions that would be implemented if the associated trigger criterion signals the need for increased mitigation or protection (Table 3-1). These trigger level actions will be implemented by the proponent to mitigate and manage impacts so they once again will meet trigger criteria and safeguard threshold criteria.

3.4 IMPLEMENTATION OF THE THRESHOLD CONTINGENCY ACTIONS

The Proponent has developed a number of threshold contingency actions that would be implemented if the associated threshold criterion signals that the environmental outcome is exceeded (Table 3-1). The threshold contingency actions will be implemented to manage aspects of the proposal and achieve the condition environmental outcome and manage the impact to below threshold and trigger criteria again and hence bring the Proponent back into compliance.

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Table 3-1 Monitoring to measure the environmental outcome against early response, trigger and threshold criteria with corresponding management actions against that criteria for the Riparian vegetation at the Beasley and Hardey River systems.

Environmental objectives for the WTS Project	Monitoring Aspect	Monitoring Location	Frequency	Early response criteria	Early response criteria management actions	Trigger criteria	Trigger criteria management actions	Threshold criteria	Threshold criteria contingency actions
Minimise impacts to the riparian vegetation along the Beasley River and Hardey River from discharge of surplus mine dewater as a result of the WTS Project.	Riparian overstorey vegetation (*E. victrix* and *E. camaldulensis* var. *refulgens*) monitoring at established transects (Figure 3-1 and Figure 3-2) Digital Cover Photography (**DCP**) at established sites (Figure 3-3 and Figure 3-4).	Potential impact sites: • Zone 2 (Beasley River) • Zone 1 & Zone 2 (Hardey River) Reference sites: • Zone 3 (Beasley and Hardey Rivers).	Annually (post- wet season, Q1/Q2)	±15% change in site mean foliage cover relative to baseline[1], in excess of change in reference sites.	1. Review degree of exposure of impacted trees to dewatering discharge, via review of site specific observations, discharge volumes and extent, and hydrological model. 2. Review reference site data to ascertain if change has also occurred at reference site. 3. Review site and tree condition information from impact and reference sites to determine if other environmental factors may have caused change (fire, storm damage, insect activity etc).	±25% change in site mean foliage cover relative to baseline, in excess of change in reference sites	As for early response criteria, with addition of the following: 1. If causal environmental factors for foliage cover decline other than dewatering discharge cannot be identified; undertake expanded on-ground assessment of tree condition within the impact and reference sites. 2. If preliminary assessment indicates it is warranted, undertake investigations of water levels/ waterlogging in the rooting zone of impacted trees. 3. If investigations indicate it is appropriate, expand the extent and frequency of tree condition monitoring within the impact and reference sites. 4. Review potential remediation actions/ strategy, including modification to discharge regime. 5. Consultation with the OEPA may be considered, particularly if investigations indicate “threshold criteria” likely to be exceeded.	±40% change in mean foliage cover relative to baseline, in excess of change in reference sites.	As for early response and trigger criteria with addition of the following: 1. Within 21 days of confirmation of this threshold criteria being exceeded, provide a report to the OEPA in accordance with Ministerial Condition. 2. If threshold criteria exceedance is considered likely to be due to dewatering discharge, report to include proposed remedial action/s identified through consultation process (as per trigger criteria #5), including revision to discharge regime.
	Riparian understorey vegetation i. Species present ii. # individuals and/ or percentage foliage cover iii. Vegetation condition	Potential impact sites: • Zone 2 (Beasley River and Hardey River) Reference sites: • Zone 3 (Beasley River and Hardey River)	Annually (post- wet season, Q1/Q2)	15% decline in number[2] of common[3] native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference areas.	1. Review degree of exposure to dewatering discharge of transects quadrats where declines have occurred, via review of site specific information, discharge volumes and extent, and hydrological model. 2. Review reference monitoring sites data to ascertain if declines have also occurred at control sites. 3. Review potential impact and reference site data to ascertain if existing weed populations, or populations of other native species, are expanding at the same transect quadrats where declines in native species have occurred. 4. Review site and vegetation condition information from potential impact and reference site to determine if other environmental factors may have caused declines (fire, storm, insect activity etc).	20% decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference areas.	As for early response criteria, with addition of the following: 1. If investigations indicate it is appropriate, expand the extent and frequency of understorey monitoring within the impact and reference areas. 2. Review potential remediation actions/strategy, including modification to discharge regime, control of existing weed population, and control of other native species (such as thinning of riparian tree seedlings). 3. Consultation with the OEPA may be considered appropriate, particularly if investigations indicate “threshold criteria” likely to be exceeded.	25% decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in reference areas.	

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Environmental objectives for the WTS Project	Monitoring Aspect	Monitoring Location	Frequency	Early response criteria	Early response criteria management actions	Trigger criteria	Trigger criteria management actions	Threshold criteria	Threshold criteria contingency actions
	Establishment of new Introduced (exotic) species in riparian vegetation established transect sites (Figure 3-1 and Figure 3-2). i. Introduced (exotic) species present ii. # individuals and/ or percentage foliage cover (exotic species) iii. Vegetation condition	Potential impact sites: Zone 1 and Zone 2 (Beasley River) Zone 2 (Hardey River) Reference sites: Zone 3 (Beasley River and Hardey River).	Annually (post- wet season, Q1/Q2)	n/a	n/a	Introduced (exotic) species recorded at an impact site, which has not previously been recorded within the project area[4] and/ or significantly increased since baseline and/ or significantly different from reference sites.	1. Review reference site data to ascertain if species has also established at reference sites. 2. If causal environmental factors for establishment of new introduced (exotic) species other than dewatering discharge cannot be identified: i. Undertake expanded on-ground assessment within the dewatering impact area for other occurrences of the species. ii. Implement control measures for these species within the dewatering impact area.	Introduced (exotic) species not previously recorded within the project area, and classified by Parks and Wildlife as having High Ecological Impact and Low Feasibility of control, exceeds 60% of total understorey cover at impact sites compared to baseline and reference sites.	

1. Baseline values are the mean % canopy foliage cover of all measurements prior to discharge
2. Number of species relative to baseline
3. Species present at ≥50% of impact monitoring sites (transects) on the Beasley River.
4. Including upstream reference areas.

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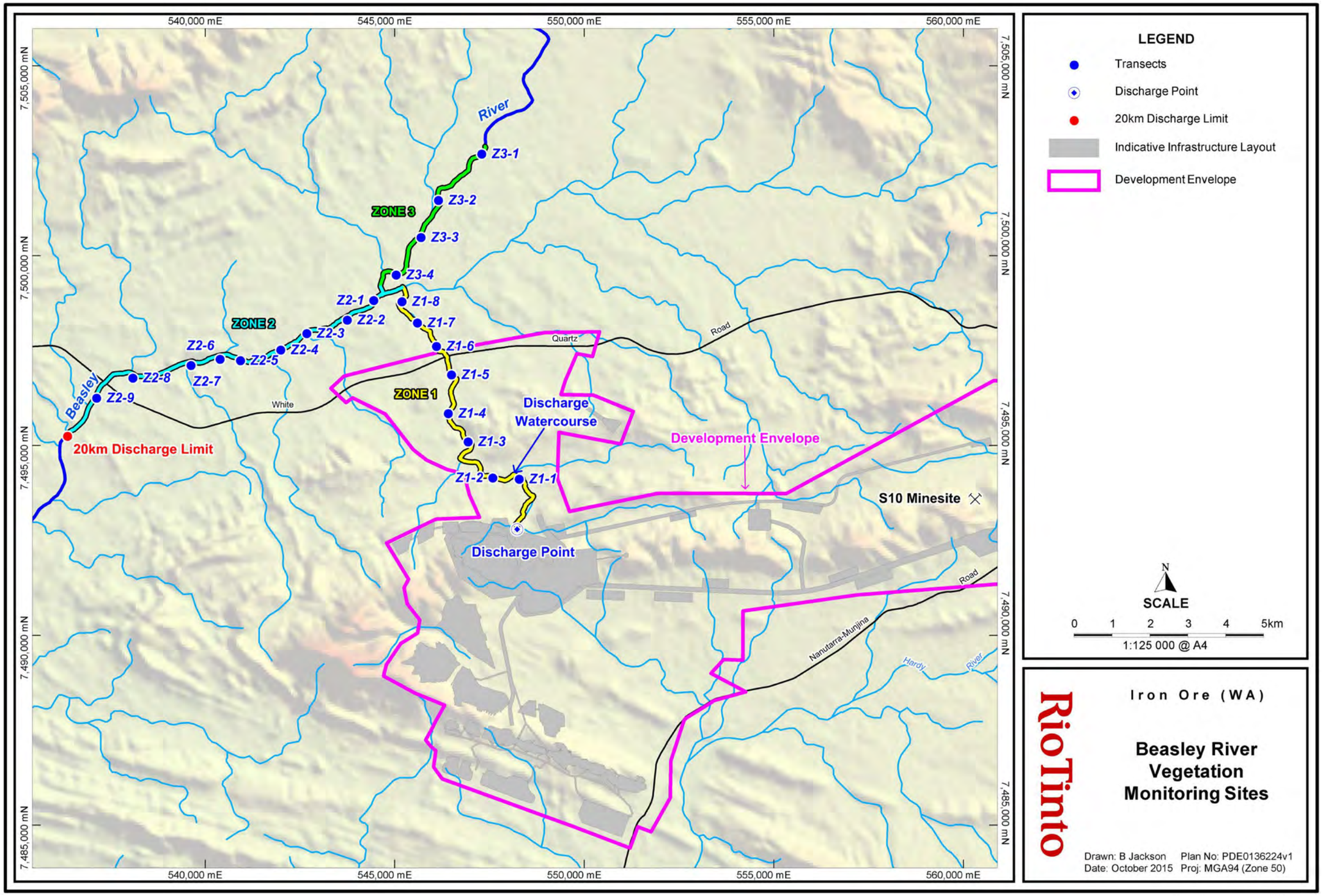


Figure 3-1 Beasley River vegetation monitoring sites

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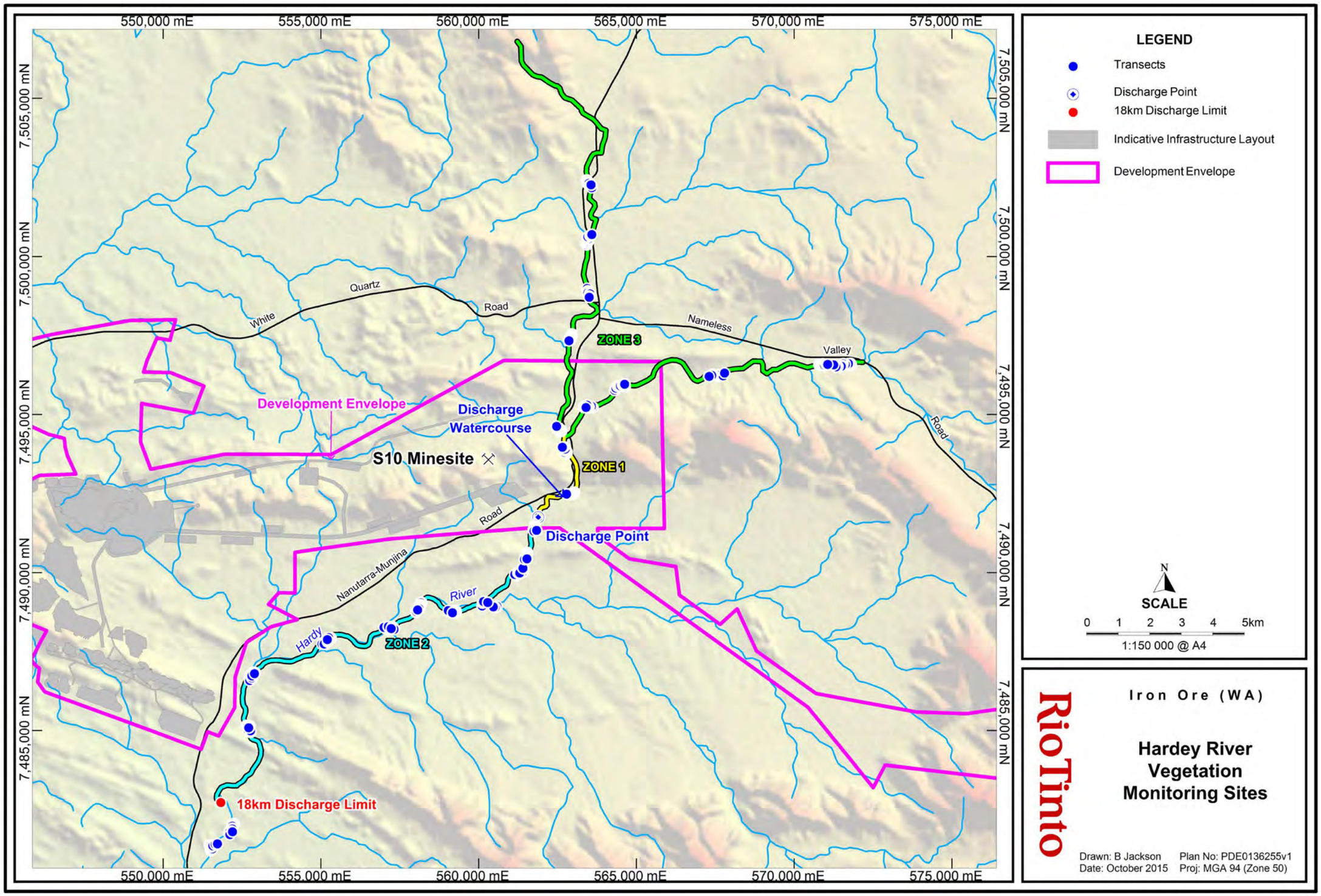


Figure 3-2 Hardey River vegetation monitoring sites

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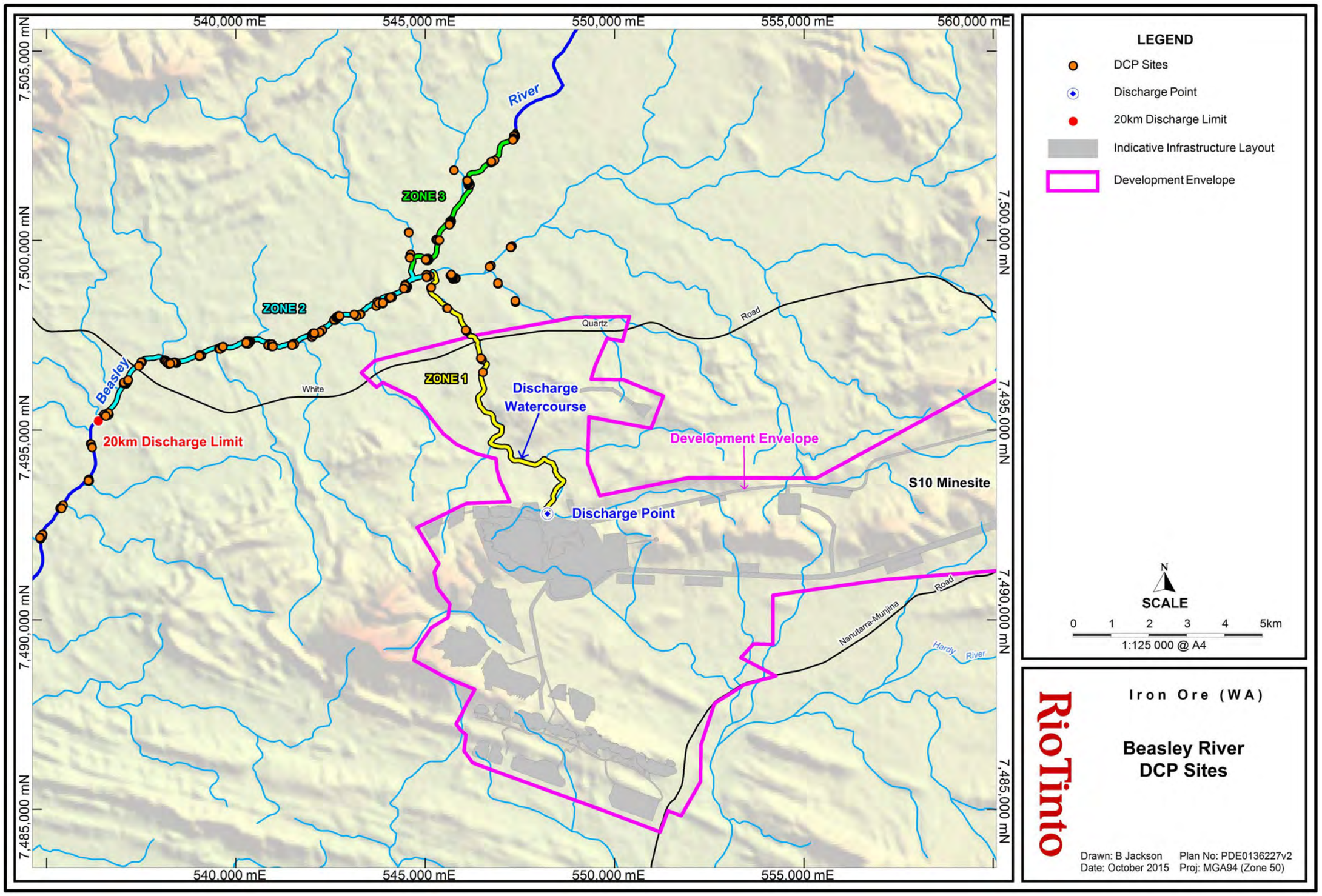


Figure 3-3 Beasley River Digital Canopy Photography sites

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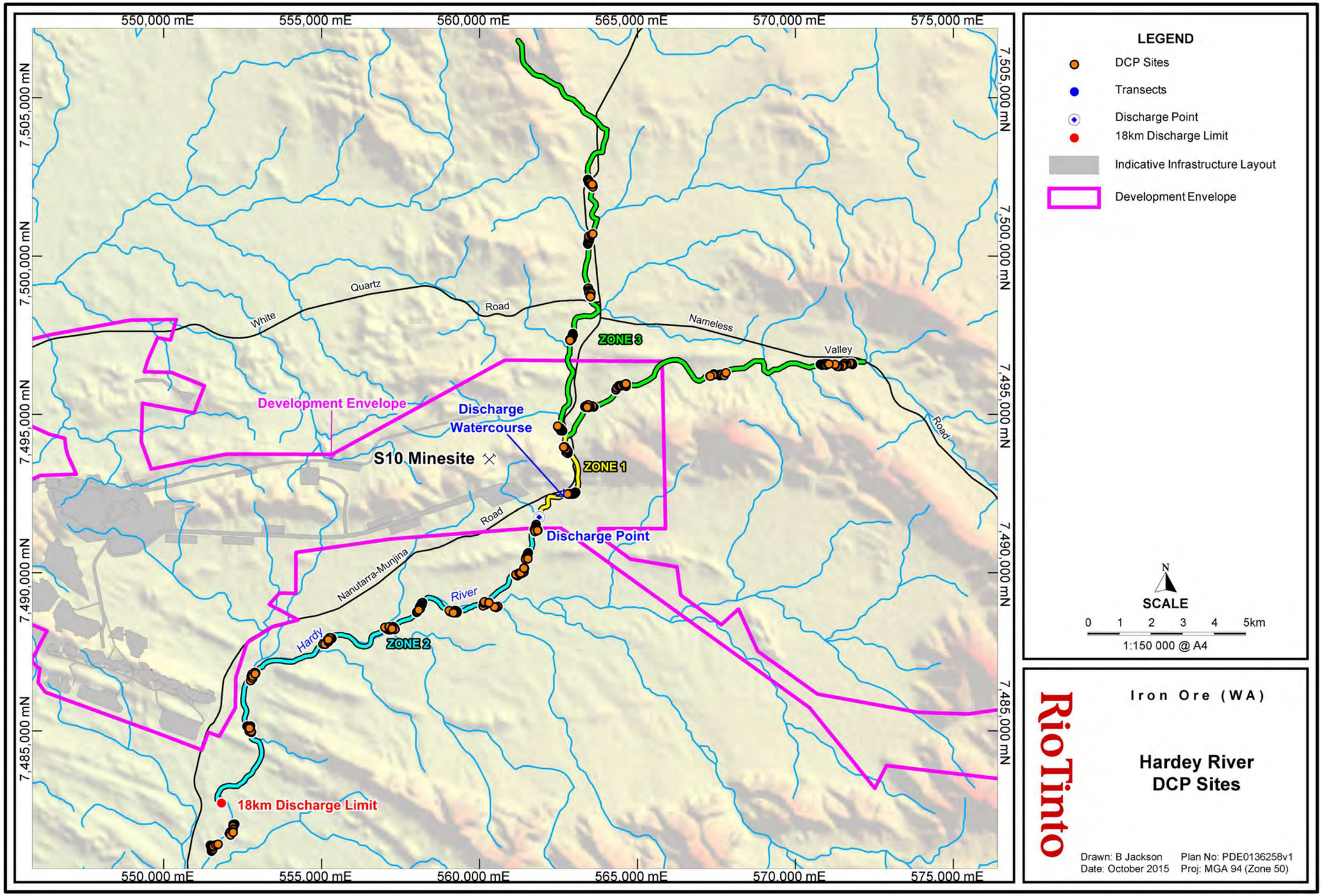


Figure 3-4 Hardey River Digital Canopy Photography sites

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3.5 REPORTING PROVISIONS

The environmental outcome will be reported against trigger and threshold criteria (Table 3-2) for the calendar year in the annual compliance report for its Ministerial Statement.

In the event of exceedance of any threshold criteria, the proponent will notify the OEPA in writing as stated in Table 3-1.

The annual report will also include a description of the effectiveness of management actions that have been implemented to manage impact in the event that the trigger or threshold criteria were exceeded during that reporting period.

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Table 3-2 Western Turner Syncline Riparian Vegetation Monitoring and Management Plan Reporting Table

Key environmental factor: Riparian Vegetation of the Beasley and Hardey Rivers		
Conditioned environmental outcome, threshold and trigger criteria	**Reporting on threshold and trigger criteria**	**Status[1]**
The discharge of surplus mine dewater is managed in a manner that minimises impacts to the riparian vegetation. <u>Trigger criteria riparian overstorey:</u> • ±25% change in mean foliage cover relative to baseline, in excess of change in references sites, and as a result of the proposal. <u>Trigger criteria riparian understorey:</u> • 20% decline in number of common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in references areas, and as a result of the proposal. <u>Trigger criteria introduced (exotic) species:</u> • Introduced (exotic) species recorded at an impact site, which has not previously been recorded within the project area, and/or significantly different from reference sites, and as a result of the proposal. <u>Threshold criteria riparian overstorey:</u> • ±40% change in mean foliage cover relative to baseline, in excess of change in references sites, and as a result of the proposal. <u>Threshold criteria riparian understorey:</u> • 30% decline in common native perennial riparian understorey and groundcover species at impact sites, in excess of declines in references areas, and as a result of the proposal. <u>Threshold criteria introduced (exotic) species:</u> • Introduced (exotic) species not previously recorded within the project area, and classified by Parks and Wildlife as having High Ecological Impact and Low Feasibility of control, exceeds 60% of total understorey cover at impact sites compared to baseline and reference sites, and as a result of the proposal.	The discharge of surplus mine dewater was managed / not managed such that the impacts to the riparian vegetation was minimised. Trigger criteria riparian overstorey --- Trigger criteria riparian understorey --- Trigger criteria introduced (exotic) species --- Threshold criteria riparian overstorey --- Threshold criteria riparian understorey --- Threshold criteria introduced (exotic) species. --- Notes: The status of achievement of environmental objectives is indicated by the following symbols: ■ Environmental outcome achieved ● Environmental outcome not achieved	■ or ● or

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4 ADAPTIVE MANAGEMENT AND REVIEW OF THE WTS EMP

Adaptive management involves implementing mitigation measures, monitoring, and evaluation relative to formulated early response, trigger and threshold criteria, and systematically adapting management and monitoring based on learning and experience from past actions to better meet the environmental objectives. Thus, implementation of the WTS MMP considers uncertainties in the ecosystem. Assumptions and model-predicted ecosystem responses will be evaluated against collected monitoring data on a recurrent basis in a process of continual improvement. Monitoring data will be analysed to evaluate environmental performance relative to early response, trigger and threshold criteria and management adapted to meet environmental objectives more effectively

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5 REFERENCES

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Ministerial Statement 946 RTIO-HSE-0195573

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Trudgen M. E. 1988, *A Report on the Flora and Vegetation of the Port Kennedy Area*. Unpublished report prepared for Bowman Bishaw and Associates, West Perth, M.E. Trudgen and Associates, Western Australia.

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WESTERN TURNER SYNCLINE IRON ORE PROJECT

Proposal:	Proposal to amend the Western Turner Syncline Project, the subject of Statement No. 807 dated 17 September 2009 and Statement No. 946 dated 22 August 2013.
Proponent:	Hamersley Iron Pty Limited Australian Company Number 004 558 276
Proponent Address:	Level 22 152-158 St Georges Terrace PERTH WA 6000

Assessment Number: XXXX

Report of the Environmental Protection Authority Number: XXX

Previous Assessment Number: 1786, 1925

Previous Report of the Environmental Protection Authority: 1325, 1477

Previous Statement Numbers: 807: 17 September 2009; 946: 22 August 2013

The implementation conditions of this Statement supersede the implementation conditions of Statements 807 and 946 in accordance with section 45B of the *Environmental Protection Act 1986*. Pursuant to section 45, read with section 45B of the *Environmental Protection Act 1986*, it has been agreed that:

1. the Proposal described and documented in Table 2 of Schedule 1 may be implemented; and
2. the implementation of the Proposal, being the Western Turner Syncline Iron Ore Project as defined by this Proposal, is subject to the following revised implementation conditions:

1 Proposal Implementation

1-1 When implementing the proposal, the proponent shall not exceed the authorised extent of the proposal as defined in Column 3 of Table 2 in Schedule 1, unless amendments to the proposal and the authorised extent of the proposal have been approved under the EP Act.

2 Contact Details

2-1 The proponent shall notify the Chief Executive Officer (CEO) of any change of its name, physical address or postal address for the serving of notices or other correspondence within twenty eight (28) days of such change. Where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State.

3 Compliance Reporting

3-1 The proponent shall prepare and maintain a Compliance Assessment Plan to the satisfaction of the CEO.

3-2 The proponent shall submit to the CEO the Compliance Assessment Plan required by condition 3-1 at least six (6) months prior to the first compliance assessment report required by condition 3-6, or prior to implementation, whichever is sooner.

The Compliance Assessment Plan shall indicate:

(1) the frequency of compliance reporting;

(2) the approach and timing of compliance assessments;

(3) the retention of compliance assessments;

(4) the method of reporting of potential non-compliance and corrective actions to take;

(5) the table of contents of Compliance Assessment Reports; and

(6) public availability of Compliance Assessment Reports.

3-3 The proponent shall assess compliance with the conditions in accordance with the Compliance Assessment Plan required by condition 3-1.

3-4 The proponent shall retain reports of all compliance assessments described in the Compliance Assessment Plan required by condition 3-1 and shall make these reports available to the CEO upon request.

3-5 The proponent shall advice the CEO of any potential non-compliance within seven (7) days of that non-compliance being known.

3-6 The proponent shall submit to the CEO a compliance assessment report by 30 April each year addressing compliance in the previous calendar year. The first compliance assessment report shall be submitted by 30 April 2017 addressing compliance for the period from the date of issue of this statement, notwithstanding that the first reporting period may be less than / more than 12 months. The Compliance Assessment Report shall:

(1) be endorsed by the proponent's Chief Executive Officer or a person delegated to sign on the Chief Executive Officer's behalf;

(2) include a statement as to whether the proponent has complied with the conditions;

(3) identify all potential non-compliances and describe corrective and preventative actions taken;

(4) be made publicly available in accordance with the approved Compliance Assessment Plan; and

(5) indicate any proposed changes to the Compliance Assessment Plan required by condition 3-1.

4 Public Availability of Data

4-1 Subject to condition 4-2, within a reasonable time period approved by the CEO of the issue of this statement and for the remainder of the life of the proposal the proponent shall make publicly available, in a manner approved by the CEO, all validated environmental data (including sampling design, sampling methodologies, empirical data and derived information products (e.g. maps)) relevant to the assessment of this proposal and implementation of this Statement.

4-2 If any data referred to in condition 4-1 contains particulars of:

1. a secret formula or process; or

2. confidential commercially sensitive information;

the proponent may submit a request for approval from the CEO to not make this data publicly available. In making such a request the proponent shall provide the CEO with an explanation and reasons why the data should not be made publicly available.

5 Riparian Vegetation of Beasley and Hardey River

5-1 The proponent shall manage the discharge of surplus mine dewater from the Western Turner Syncline Iron Ore Project in a manner that minimises impacts to the riparian vegetation along the Beasley River and Hardey River.

5-2 The proponent shall implement the Western Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xx), or subsequent revisions approved by the CEO, from the commencement of discharge of surplus mine dewater from the Western Turner Syncline Iron Ore Project until advised otherwise by the CEO.

5-3 The proponent may review and revise the Western Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xx), or any subsequently approved revisions, to the requirements of the CEO.

5-4 The proponent shall review and revise the Western Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xx), or any subsequently approved revisions, as and when directed by the CEO.

6 Rehabilitation and Decommissioning

6-1 The proponent shall ensure that the project is decommissioned and rehabilitated in an ecologically sustainable manner, consistent with agreed outcomes and land uses, and without unacceptable liability to the State of Western Australia, through the implementation of the Mine Closure Plan required by condition 6-2.

6-2 The proponent shall prepare the Western Turner Syncline Mine Closure Plan in accordance with the *Guidelines for Preparing Mine Closure Plans*, June 2011 and any updates, to the requirements of the CEO on advice of the Department of Mines and Petroleum.

6-3 The proponent shall review and revise the Western Turner Syncline Mine Closure Plan required by Condition 6-2 at intervals not exceeding three years, or as otherwise specified by the CEO.

6-4 The proponent shall implement the latest revision of the Western Turner Syncline Mine Closure Plan, which the CEO has confirmed by notice in writing, satisfies the requirements of condition 6-2.

7 Residual Impacts and Risk Management Measures

7-1 In view of the significant residual impacts and risks as a result of implementation of the proposal, the proponent shall contribute funds for the clearing of 'good to excellent' condition native vegetation calculated pursuant to condition 7-2. This funding shall be provided to a government-established conservation offset fund or an alternative offset arrangement providing an equivalent outcome as determined by the Minister.

7-2 The proponent's contribution identified in condition 7-1 shall be paid biennially, the first payment due two years after ground disturbance. The amount of funding will be made on the following basis and in accordance with the approved Impact Reconciliation Procedure:

1. $750 AUD (excluding GST) per hectare of 'good-to-excellent' condition native vegetation cleared within the area delineated in Figure 1; and
2. $1,500 AUD (excluding GST) per hectare of vegetation of conservation significance cleared within the area delineated in Figure 3.

7-3 The clearing of 750 ha and 150 ha approved under MS 807 and CPS 4851 respectively is exempt from this requirement for offsets.

7-4 The proponent shall prepare and submit an Impact Reconciliation Procedure and submit it for approval of the CEO prior to ground disturbance.

7-5 The Impact Reconciliation Procedure required pursuant to condition 7-3 shall:

1. include details of a methodology to identify clearing of 'good to excellent' condition native vegetation;
2. require the proponent to submit spatial data identifying areas of 'good to excellent' condition native vegetation that has been cleared;
3. include a methodology for calculating the amount of clearing undertaken during each biennial time period; and
4. state dates for the commencement of the biennial time period and for the submission of results of the Impact Reconciliation Procedure, to the satisfaction of the CEO.

7-6 The real value of contributions described in condition 7-2 will be maintained through indexation to the Perth Consumer Price Index (CPI), with the first adjustment to be applied to the first contribution.

Schedule 1

The Proposal (Assessment No. xxx)

General Description

The Proposal is to sustain operations at Western Turner Syncline by increasing the clearing limit to support ongoing operations (including prospective areas) and mining below water table. The Proposal includes rationalisation of existing Statements for Western Turner Syncline.

The Proposal is described in the Western Turner Syncline Section 10 Iron Ore Project EPS (Strategen 2009) and Western Turner Syncline Stage 2 Deposits API (Strategen 2012) and Western Turner Syncline Proposal API (Rio Tinto 2015).

Table 1: Summary of the Proposal

Proposal Title	Western Turner Syncline Iron Ore Project
Proponent Name	Hamersley Iron Pty Limited
Short Description	Development of above and below water table iron ore deposits and associated infrastructure at Western Turner Syncline, approximately 30 km north-east of Tom Price in the Pilbara region. Surplus water management options for mining below water table include use on site and discharge to the environment.

Table 2: Location and Authorised Extent of Physical and Operational Elements

Column 1	Column 2	Column 3
Element	**Location**	**Authorised Extent**
Development Envelope	Figure X and Schedule 2	Clearing of no more than 4,350 ha (which includes the additional ground disturbance of 750 ha) within the Development Envelope of 15,836 ha.
Dewatering	Figure x and Schedule 2	Up to 18.3 GL/annum.
Surplus Dewater Management	Figure X and Schedule 2	Surplus water management options include use on site and discharge to the environment. Controlled dewater discharge to extend along: • Beasley River, no further than 20 km downstream of the discharge point under natural no-flow conditions. • Hardey River, no further than 15 km downstream of the discharge point under natural no-flow conditions.
Backfilling of mine pits		Mining at WTS will leave mine voids on closure, of which the following extend into the groundwater table: • The S10 BRK Main and B1 Main pits; which will not be backfilled, resulting in formation of pit lakes. • Section 17 (pits 3 and 8) and Section 10 MME and MMW Pits; which will be backfilled to prevent the formation of permanent pit lakes.

Appendix 17 Justification for Rationalisation of Conditions MS 946 and 807

	Condition		Compliant	Justification	#	Proposed Condition
1.	**Proposal Implementation**				**1.**	**Proposal Implementation**
807	The proponent shall implement the proposal as assessed by the Environmental Protection Authority and described in schedule I of this statement subject to the conditions and procedures of this statement.		Compliant	This condition is still relevant and has been retained.		When implementing the proposal, the proponent shall not exceed the authorised extent of the proposal as defined in Column 3 of Table 2 in Schedule 1, unless amendments to the proposal and the authorised extent of the proposal has been approved under the EP Act.
946	When implementing the proposal, the proponent shall not exceed the authorised extent of the proposal as defined in Column 3 of Table 2 in Schedule 1, unless amendments to the proposal and the authorised extent of the proposal has been approved under the EP Act.					
2.	**Contact Details**				**2.**	**Contact Details**
807	2-1	The proponent for the time being nominated by the Minister for Environment under sections 38(6) or 38(7) of the Environmental Protection Act 1986 is responsible for the implementation of the proposal.	Compliant	This condition is still relevant and has been retained.	2-1	The proponent shall notify the CEO of any change of its name, physical address or postal address for the serving of notices or other correspondence within twenty eight (28) days of such change. Where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State
	2-2	The proponent shall notify the Chief Executive Officer (CEO) of the Department of Environment and Conservation of any change of the name and address of the proponent for the serving of notices or other correspondence within 30 days of such change.				
946	2-1	The proponent shall notify the CEO of any change of its name, physical address or postal address for the serving of notices or other correspondence within 28 days of such change. Where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State.				
3.	**Time Limit for Proposal Implementation**					
807	3-1	The authorisation to implement the proposal provided for in this statement shall lapse and be void within five years after the date of this statement if the proposal to which this statement relates is not substantially commenced.	Compliant	Both of the WTS Projects (Section 10 BRK and Stage 2) have substantially commenced. As this is a Revised Proposal this condition is no longer required and has therefore been removed.		
	3-2	The proponent shall provide the CEO of the Department of Environment and Conservation with written evidence which demonstrates that the proposal has substantially commenced on or before the expiration of five years from the date of this statement.				

	Condition		Compliant	Justification	#	Proposed Condition
946	3-1	The proponent shall not commence implementation of the proposal after the expiration of 5 years from the date of this statement, and any commencement, within this 5 year period, must be substantial.				
	3-2	Any commencement of implementation of the proposal, within 5 years from the date of this statement, must be demonstrated as substantial by providing the CEO with written evidence, on or before the expiration of 5 years from the date of this statement.				
4.	**Compliance Reporting**				**3.**	**Compliance Reporting**
807	4-1	The proponent shall prepare and maintain a compliance assessment plan to the satisfaction of the CEO of the Department of Environment and Conservation	Compliant	This condition is still relevant and shall be retained as a contemporised version.	3-1	The proponent shall prepare and maintain a compliance assessment plan to the satisfaction of the CEO.
	4-2	The proponent shall submit to the CEO of the Department of Environment and Conservation, the compliance assessment plan required by condition 4-1 at least six months prior to the first compliance assessment report required by condition 4-6. The compliance assessment plan shall indicate: 1. the frequency of compliance reporting; 2. the approach and timing of compliance assessments; 3. the retention of compliance assessments; 4. reporting of potential non-compliances and corrective actions taken; 5. the table of contents of compliance assessment reports; and 6. public availability of compliance assessment reports.			3-2	The proponent shall submit to the CEO the compliance assessment plan required by condition 3-1 at least six (6) months prior to the first compliance assessment report required by condition 3-6, or prior to implementation, whichever is sooner. The compliance assessment plan shall indicate: 1. the frequency of compliance reporting; 2. the approach and timing of compliance assessments; 3. the retention of compliance assessments; 4. the method of reporting of potential non-compliances and corrective actions taken; 5. the table of contents of compliance assessment reports; and 6. public availability of compliance assessment reports.
	4-3	The proponent shall assess compliance with conditions m accordance with the compliance assessment plan required by condition 4-1.			3-3	The proponent shall assess compliance with conditions in accordance with the compliance assessment plan required by condition 3-1
	4-4	The proponent shall retain reports of all compliance assessments described in the compliance assessment plan required by condition 4-1 and shall make those reports available when requested by the CEO of the Department of Environment and Conservation.			3-4	The proponent shall retain reports of all compliance assessments described in the compliance assessment plan required by condition 3-1 and shall make those reports available when requested by the CEO.

	Condition		Compliant	Justification	#	Proposed Condition
807	4-5	The proponent shall advise the CEO of the Department of Environment and Conservation of any potential non-compliance as soon as practicable.			3-5	The proponent shall advise the CEO of any potential non-compliance within seven days of that potential non-compliance being known.
	4-6	The proponent shall submit a compliance assessment report annually from the date of issue of this Implementation Statement addressing the previous twelve-month period or other period as agreed by the CEO of the Department of Environment and Conservation. The compliance assessment report shall: 1. be endorsed by the proponent's Vice-President or a person, approved in writing by the CEO of the Department of Environment and Conservation, delegated to sign on the Vice-President's behalf; 2. include a statement as to whether the proponent has complied with the conditions; 3. identify all potential non-compliances and describe corrective and preventative actions taken; 4. be made publicly available in accordance with the approved compliance assessment plan; and 5. indicate any proposed changes to the compliance assessment plan required by condition 4-1.			3-6	The proponent shall submit to the CEO a compliance assessment report by 30 April each year addressing compliance in the previous calendar year. The first compliance assessment report shall be submitted by 30 April 2016 addressing compliance for the period from the date of issue of this statement, notwithstanding that the first reporting period may be less than / more than 12 months. The compliance assessment report shall: 1. be endorsed by the proponent's Chief Executive Officer or a person delegated to sign on the Chief Executive Officer's behalf; 2. include a statement as to whether the proponent has complied with the conditions; 3. identify all potential non-compliances and describe corrective and preventative action taken; 4. be made publicly available in accordance with the approved compliance assessment plan; and 5. indicate any proposed changes to the compliance assessment plan required by condition 3-1.
946	4-1	The proponent shall prepare and maintain a compliance assessment plan to the satisfaction of the CEO.				
	4-2	The proponent shall submit to the CEO the compliance assessment plan required by condition 4-1 at least six months prior to the first compliance assessment report required by condition 4-6, or prior to implementation, whichever is sooner. The compliance assessment plan shall indicate: 1. the frequency of compliance reporting; 2. the approach and timing of compliance assessments; 3. the retention of compliance assessments; 4. the method of reporting of potential non-compliances and corrective actions taken; 5. the table of contents of compliance assessment reports; and 6. public availability of compliance assessment reports.				

	Condition		Compliant	Justification	#	Proposed Condition
946	4-3	The proponent shall assess compliance with conditions in accordance with the compliance assessment plan required by condition 4-1.				
	4-4	The proponent shall retain reports of all compliance assessments described in the compliance assessment plan required by condition 4-1 and shall make those reports available when requested by the CEO.				
	4-5	The proponent shall advise the CEO of any potential non-compliance within seven days of that potential non-compliance being known.				
	4-6	The proponent shall submit to the CEO a compliance assessment report by 30 April each year addressing compliance in the previous calendar year. The first compliance assessment report shall be submitted by 30 April 2014 addressing compliance for the period from the date of issue of this statement, notwithstanding that the first reporting period may be less than / more than 12 months. The compliance assessment report shall: 1. Be endorsed by the proponent's Managing Director / General Manager / Chief Executive Officer or a person delegated to sign on the Managing Director's / General Manager's / Chief Executive Officer's behalf. 2. Include a statement as to whether the proponent has complied with the conditions. 3. Identify all potential non-compliances and describe corrective and preventative action taken. 4. Be made publicly available in accordance with the approved compliance assessment plan. 5. Indicate any proposed changes to the compliance assessment plan required by condition 4-1.				
5	**Public Availability of Data**				**4**	**Public Availability of Data**
807	5-1	The proponent shall submit to the CEO of the Department of Environment and Conservation Performance Review Reports at the conclusion of the first year after commencement of operation, and thereafter in the proponent's triennial reports. The Performance Review Reports shall address: 1. the major environmental risks and impacts; the	Compliant	This condition is still relevant and shall be retained; however it has been updated	4-1	Subject to condition 4-2, within a reasonable time period approved by the CEO of the issue of this statement and for the remainder of the life of the proposal the proponent shall make publicly available, in a manner approved by the CEO, all validated environmental data (including sampling design,

	Condition		Compliant	Justification	#	Proposed Condition
		performance objectives, standards and criteria related to these; the success of risk reduction/impact mitigation measures and results of monitoring related to the management of the major risks and impacts; 2. the level of progress in the achievement of sound environmental performance, including industry benchmarking, and the use of best available technology where practicable; and 3. significant improvements gained in environmental management which could be applied to this and other similar projects.		to reflect contemporary presentation.		sampling methodologies, empirical data and derived information products (e.g. maps)) relevant to the assessment of this proposal and implementation of this statement.
946	5-1	Subject to condition 5-2, within a reasonable time period approved by the CEO of the issue of this statement and for the remainder of the life of the proposal the proponent shall make publicly available, in a manner approved by the CEO, all validated environmental data (including sampling design, sampling methodologies, empirical data and derived information products (e.g. maps)) relevant to the assessment of this proposal and implementation of this statement.			4-2	If any data referred to in condition 4-1 contains particulars of: 1. a secret formula or process; or 2. confidential commercially sensitive information; the proponent may submit a request for approval from the CEO to not make this data publicly available. In making such a request the proponent shall provide the CEO with an explanation and reasons why the data should not be made publicly available.
	5-2	If any data referred to in condition 5-1 contains particulars of: 1. a secret formula or process; or 2. confidential commercially sensitive information; the proponent may submit a request for approval from the CEO to not make this data publicly available. In making such a request the proponent shall provide the CEO with an explanation and reasons why the data should not be made publicly available.				
6.	**Flora and Vegetation**					
807	6-1	The proponent shall monitor the health and abundance of native flora including *Goodenia* sp. Pilbara calcrete, the listed Priority 1 flora species adjacent to areas to be cleared, to ensure that there is no decline in their health or abundance through the implementation of the proposal, in particular from the effects of dust and water application for dust control. This monitoring is to be carried out to the satisfaction of the CEO of the Department of Environment and Conservation.	Compliant	The *Goodenia* sp. Pilbara calcrete (P1) has been re-classified as *Goodenia* sp. East Pilbara (P3) since MS 807 was issued; however this is currently under taxonomic review as this may potentially represent *Goodenia pedicellata.* Regardless, this condition is no longer required as: • Clearing of the species will be avoided / minimised where possible. • *Goodenia pedicellata* has a total population count of over 1419 individuals from 124 records within the Rio Tinto database and has been previously recorded from Ophthalmia in the east to Western Turner Syncline in the west (range of 220 kms).		
	6-2	The proponent shall submit annually the results of monitoring required by condition 6-1 to the CEO of the Department of				

	Condition		Compliant	Justification	#	Proposed Condition
		Environment and Conservation.		• Survey work was conducted by a qualified Botanist during the March 2012-July 2012 monitoring period to assess the distribution of *Goodenia* sp. East Pilbara in the WTS local area. Significant populations of *Goodenia* were recorded in suitable habitat within 1.5 km of the southern edge of the Section 10 site and haul road. A transect was taken along the Nanutarra-Munjina Road and additional populations of *Goodenia* were recorded between approximately up to 14 km from the haul road. • Monitoring of control and impact *Goodenia* populations has shown no significant trends in the impact population in terms of numbers of individuals or the health of individuals compared with the control population. • In October 2010, 13 km of the haul road was sealed including 500 m either side of the intersection with the Nanutarra-Munjina road. During 2013 a 1.7 km section of the Nanutarra-Munjina road (in proximity of Goodenia populations) was sealed adjacent to the operations area and infrastructure corridor further reducing dust generation. • The use of the haul has been reduced as the covered conveyor from Section 10 to Tom Price is now functional.		
	6-3	In the event that monitoring required by condition 6-1 indicates a decline in the health or abundance of native flora outside the areas to be cleared and which is attributable to the development proposal, the proponent shall report such findings to the CEO within 21 days of the decline being identified, and shall state the actions the proponent shall take to remediate the decline.				
	6-4	The proponent shall not take any Declared Rare Flora or Priority Flora species when clearing vegetation for borrow pits, and avoid Declared Rare Flora and Priority flora outside the areas to be cleared.				
	6-5	The proponent shall make the monitoring repm1s required by condition 6-2 publicly available in a manner approved by the CEO of the Department of Environment and Conservation.				
6.	**Discharge of Water to Local Watercourses and Beasley River**					
946	6-1	The proponent shall ensure that the discharge of surplus water from the Western Turner Syncline Stage 2 site as a result of mining does not cause long term impacts to environmental and conservation values of the Beasley River System.	Compliant	This condition is still relevant; however it is proposed to merge this condition with condition 7 of MS 946. Refer below.		
	6-2	To verify that condition 6-1 is being met, the proponent shall develop an Environmental Values Statement for the Beasley River System that defines the environmental values of the Beasley River System to the satisfaction of the CEO.				
	6-3	The proponent shall ensure that dewatering discharge from the Western Turner Syncline Stage 2 site does not cause water flow or pooling further than the extent identified in Schedule 1, Table 2				

	Condition		Compliant	Justification	#	Proposed Condition
	6-4	Prior to discharging water from the Western Turner Syncline Stage 2 site, the proponent shall develop a Water Discharge Monitoring and Management Plan in consultation with the DoW, to the satisfaction of the CEO, to ensure that the environmental and conservation values associated with the Beasley River and any downstream ecosystems are maintained. This plan shall: 1. Describe the water discharge program. 2. when implemented, demonstrate, by monitoring, whether conditions 6-1 and 6-3 are being met. 3. When implemented, require the proponent to manage the implementation of the proposal to meet the requirements of conditions 6-1 and 6-3. 4. Detail management actions and strategies to be implemented should the monitoring required by condition 6-4 (2) indicate that condition 6-1 may not be met.				
	6-5	The proponent shall implement the Water Discharge Monitoring and Management Plan and any subsequent approved revisions from the commencement of discharge of excess water from the Western Turner Syncline Stage 2 site until advised otherwise by the CEO.				
7	**Terrestrial Fauna**					
807	7-1	The proponent shall implement measures, to be agreed in consultation with the Department of Environment and Conservation that may be required to facilitate protection of the conservation status of any short range endemics, including the Trapdoor Spider (*Nemesiidae* sp.) located in the proposal area.	Compliant	Request removal of this condition as further survey work with a specialist determined that the *Nemesiidae* specimen was not restricted to the Project area and was recorded up to 18 km away. Parks and Wildlife responded on 23 June 2011 supporting the Proponents proposal that the restriction around the trapdoor spider was no longer required (correspondence included in Appendix 11e). The OEPA also confirmed on 29 July 2011 (via a letter; Appendix 11f) that based on the Proponent's Report on the specimen and DEC advice, the special measure of restricting clearing of C1 vegetation required by Condition 6-1 [of MS 807] is no longer required. This condition is no relevant as terrestrial fauna is not a key environmental factor for the WTS Project. Therefore it is proposed that this condition be removed.		
	7-2	The proponent shall submit annually the outcomes from any measures required by condition 7 -1 to the CEO of the Department of Environment and Conservation.				

	Condition		Compliant	Justification	#	Proposed Condition
7.	**Riparian Vegetation**				**5.**	**Riparian vegetation of Beasley and Hardey Rivers**
946	7-1	The proponent shall ensure that the discharge of surplus dewater does not cause long term impacts on the health and abundance of riparian vegetation associated with the Beasley River System.	Compliant	In line with more recent Ministerial Statement (i.e. Brockman Syncline 4 MS 1000, condition 6) it is proposed to merge Condition 6 and Condition 7 of MS 946 into one Condition for the protection of environmental values of the two discharge creek systems.	5-1	The Proponent shall manage the discharge of surplus mine dewater from the WTS Proposal in a manner that minimises impacts to the riparian vegetation along Beasley and Hardey Rivers.
946	7-2	To verify that condition 7-1 is being met, prior to discharging water from the Western Turner Syncline Stage 2 site the proponent shall develop a Riparian Vegetation Monitoring and Management Plan to the satisfaction of the CEO. The Riparian Vegetation Monitoring and Management Plan shall include: 1. identification of monitoring and control sites; 2. the design of a survey to acquire baseline data, including health and abundance parameters; 3. definition of health and abundance parameters; 4. definition of environmental parameters to be monitored, including discharge rates and extent; 5. definition of monitoring frequency and timing; 6. identification of criteria to measure decline in health; 7. definition of trigger levels for 'no irreversible impact'; and 8. details of management actions and strategies to be implemented should the 'no irreversible impact' trigger levels be exceeded.			5-2	The proponent shall implement the Western Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xxx), or subsequent revisions approved by the CEO, from the commencement of discharge of surplus mine dewater from the WTS Revised Proposal until advised otherwise by the CEO.
	7-3	The proponent shall implement the Riparian Vegetation Monitoring and Management Plan required by condition 7-2 and any subsequent approved revisions from the commencement of discharge of surplus water until advised otherwise by the CEO			5-3	The proponent may review and revises the Western Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xxx), or any subsequently approved revisions, to the requirements of the CEO.
	7-4	Prior to the commencement of discharge of surplus water, the proponent shall implement the baseline monitoring survey required by condition 7-2 (2) for all sites identified in condition 7-2 (1) and submit the results to the CEO.			5-4	The proponent shall review and revised the Western Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xx), or any subsequently approved revisions, as and when directed by the CEO.
	7-5	In the event that monitoring required by condition 7-2 indicates that a trigger level required by condition 7-2 (7) has			5-5	The proponent shall continue to implement the management actions in accordance with the Western

	Condition		Compliant	Justification	#	Proposed Condition
		been exceeded, the proponent shall provide a report to the CEO within 21 days of the decline being identified which: 1. describes the decline or change; 2. provides information which allows determination of the likely root cause of the decline or change; and 3. if considered likely to be the result of activities undertaken in implementing the proposal, proposes the actions and associated timelines to remediate the decline or change.				Turner Syncline Riparian Vegetation Monitoring and Management Plan (dated xx) until the CEO has confirmed by notice in writing that it has been demonstrated that the objective in condition 5-1 is being and will continue to be met and therefore the implementation of the management actions are no longer required.
	7-6	The proponent shall implement the actions identified in condition 7-5 (3) until the CEO determines that the remedial actions may cease.				
8.	**Surface Water Flows**					
807	8-1	The proponent shall ensure that the run-off or seepage from mine components does not cause the quality of water in or leaving the proposal area to exceed ANZECC* requirements, taking into consideration natural background water quality, so that existing and potential uses, including ecosystem maintenance, are protected. * - *Australian Water Quality Guidelines for Fresh and Marine Waters*, ANZECC (November 1992, and its updates).	**Non-compliant** (one occasion of elevated aluminium and total dissolved solids)	Request removal of this condition as the water quality aspects are adequately managed under Part V of the EP Act and the RiWI Act. The riparian vegetation aspects of the discharge will be managed via the condition on Riparian Vegetation. Please note that Rio Tinto prepares a Spontaneous Combustion and ARD (SCARD) Management Plan for Operations with ARD/AMD risk. A SCARD Management Plan for WTS has been included in Appendix 12.		
	8-2	The proponent shall monitor the quality of any run-off or seepage from mine components on and in proximity to the project area shown in Figure 1 of Schedule 1 to the Minister's Statement with particular regard to acid mine drainage. This monitoring is to be done to the satisfaction of the CEO of the Department of Environment and Conservation.	Compliant			
	8-3	The proponent shall submit the results of the monitoring to the CEO of the Department of Environment and Conservation.				
	8-4	In the event that monitoring shows that the quality of water in or leaving the proposal area exceeds ANZECC requirements the proponent shall, in consultation with the Department of Environment and Conservation, undertake measures to improve the water quality to conform with ANZECC requirements.	**Potentially non-compliant** (taking into account notification condition above)			

	Condition		Compliant	Justification	#	Proposed Condition
8/9	**Closure and Rehabilitation**				**6.**	**Rehabilitation and Decommissioning**
807	9-1	Prior to commencement of mining the proponent shall have conducted surveys of the proposal area to collect baseline information on the following: 1. soil profiles; 2. groundwater levels; 3. surface water flows; 4. plant communities and flora; and 5. landscape and landforms.	Compliant	This condition is still relevant, so it has been retained. However it has been updated to reflect contemporary Rehabilitation and Closure conditions.	6-1	The Proponent shall ensure that the proposal is decommissioned and rehabilitated in an ecologically sustainable manner, consistent with agreed outcomes and land uses, and without unacceptable liability to the State of Western Australia, through the implementation of the Mine Closure Plan required by condition 6-2.
	9-2	Waste dumps and other artificial landforms shall be constructed so that their shape, size, stability, soil profiles, ability to support native vegetation and response to surface water flows are comparable to natural landforms in the area.			6-2	The proponent shall prepare the Western Turner Syncline Mine Closure Plan in accordance with the Guidelines for Preparing Mine Closure Plans, June 2011 and any updates, to the requirements of the CEO on advice of the Department of Mines and Petroleum.
	9-3	Waste dumps, artificial landforms and other disturbed areas outside the pit, shall be progressively rehabilitated with native plant species of local provenance.			6-3	The Proponent shall review and revise the Western Turner Syncline Closure Plan required by Condition 6-2 at intervals not exceeding three years, or as otherwise specified by the CEO.
	9-4	Within five years of mine closure, the percentage cover of native vegetation shall be comparable with that of natural landforms in the area.	Not yet required		6-4	The proponent shall implement the latest revision of the Western Turner Syncline Mine Closure Plan, which the CEO has confirmed by notice in writing, satisfies the requirements of condition 6-2.
	9-5	No new noxious or environmental weed species shall be introduced into the area as a result of the implementation of the proposal.	Compliant			
	9-6	Within five years of mine closure the distribution and abundance of weeds shall be no greater than the distribution and abundance of weeds prior to the implementation of the proposal.	Not yet required			
	9-7	Within five years of mine closure the proponent shall submit a report of rehabilitation performance monitoring to the CEO of the Department of Environment and Conservation and the Director General of the Department of State Development and shall address in the report the following: 1. progress towards meeting the criteria required by conditions 9-2 to 9-6 inclusive; and				

	Condition		Compliant	Justification	#	Proposed Condition
		2. contingency management measures in the event that criteria are unlikely to be met.				
946	8-1	Within 6 months following commissioning of the first Western Turner Syncline Stage 2 pit, or as otherwise agreed by the CEO, the proponent shall prepare a Western Turner Syncline Stage 2 – B1 and Section 17 Deposits Mine Closure Plan in accordance with the *Guidelines for Preparing Mine Closure Plans, June 2011*, in consultation with the DMP, and undertake any updates of the Mine Closure Plan to the requirements of the CEO on advice of the DMP.	Not yet required	This condition is still relevant, so it has been retained. However it has been updated to reflect contemporary Rehabilitation and Closure conditions. Refer to above proposed condition.		
	8-2	The Mine Closure Plan required by condition 8-1 shall ensure that closure planning and rehabilitation are carried out in a coordinated, progressive manner and are integrated with development planning, consistent with current best practice, and the agreed land uses.	Compliant			
	8-3	Within 12 months following commissioning of the first Western Turner Syncline Stage 2 pit, or as otherwise agreed by the CEO, the proponent shall implement the Western Turner Syncline Stage 2 – B1 and Section 17 Deposits Mine Closure Plan required by condition 8-1 and any subsequent approved revisions and continue implementation until otherwise agreed by the CEO.				
9.	**Residual Impacts and Risk Management Measures**				**7.**	**Residual Impacts and Risk Management Measures**
946	9-1	In view of the significant residual impacts and risks as a result of implementation of the proposal, the proponent shall contribute funds for the clearing of 'good to excellent' condition native vegetation calculated pursuant to condition 9-2. This funding shall be provided to a government-established conservation offset fund or an alternative offset arrangement providing an equivalent outcome as determined by the Minister.	Compliant	This condition is still relevant and shall be retained to reflect the Revised Proposal.	7-1	In view of the significant residual impacts and risks as a result of implementation of the proposal, the proponent shall contribute funds for the clearing of 'good to excellent' condition native vegetation calculated pursuant to condition 7-2. This funding shall be provided to a government-established conservation offset fund or an alternative offset arrangement providing an equivalent outcome as determined by the Minister.

	Condition		Compliant	Justification	#	Proposed Condition
	9-2	The proponent's contribution identified in condition 9-1 shall be paid biennially, the first payment due two years after ground disturbance. The amount of funding will be made on the following basis and in accordance with the approved Impact Reconciliation Procedure: 1. $750 AUD (excluding GST) per hectare of 'good-to-excellent' condition native vegetation cleared within the area delineated in Figure 1; and 2. $1,500 AUD (excluding GST) per hectare of vegetation of conservation significance cleared within the area delineated in Figure 3.	Not yet required		7-2	The proponent's contribution identified in condition 7-1 shall be paid biennially, the first payment due two years after ground disturbance. The amount of funding will be made on the following basis and in accordance with the approved Impact Reconciliation Procedure: 1. $750 AUD (excluding GST) per hectare of 'good-to-excellent' condition native vegetation cleared within the area delineated in Figure 1; and 2. $1,500 AUD (excluding GST) per hectare of vegetation of conservation significance cleared within the area delineated in Figure 3. The clearing approved under MS 807 and CPS 4581 is exempt from the requirements for an offset.
	9-3	The proponent shall prepare an Impact Reconciliation Procedure and submit it for approval of the CEO prior to ground disturbance.	Compliant		7-3	The proponent shall prepare an Impact Reconciliation Procedure and submit it for approval of the CEO prior to ground disturbance.
	9-4	The Impact Reconciliation Procedure required pursuant to condition 9-3 shall: 1. include details of a methodology to identify clearing; 2. include a methodology for calculating the amount of clearing undertaken during each biennial time period; 3. state dates for the commencement of the biennial time period and for the submission of results of the Impact Reconciliation Procedure, to the satisfaction of the CEO.	Not yet required	This condition is still relevant and shall be retained to reflect the Revised Proposal.	7-4	The Impact Reconciliation Procedure required pursuant to condition 7-3 shall: 1. include details of a methodology to identify clearing of 'good to excellent' condition native vegetation; 2. require the proponent to submit spatial data identifying areas of 'good to excellent' condition native vegetation that has been cleared; 3. include a methodology for calculating the amount of clearing undertaken during each biennial time period; 4. state dates for the commencement of the biennial time period and for the submission of results of the Impact Reconciliation Procedure, to the satisfaction of the CEO.
	9-5	The real value of contributions described in condition 9-2 will be maintained through indexation to the Perth Consumer Price Index (CPI), with the first adjustment to be applied to the first contribution.	Not yet required		7-5	The real value of contributions described in condition 7-2 will be maintained through indexation to the Perth Consumer Price Index (CPI), with the first adjustment to be applied to the first contribution.