7 Land Resources

7.1 Introduction

Land resources present at the McArthur River Mine Phase 3 Development Project (the Project) are described in this chapter. Geology, land systems, soils, geochemistry, land capability and visual amenity are included, together with potential impacts and mitigation measures on land resources.

More detailed information on the potential impacts and mitigation measures of land resources is provided in Appendix E1 – Tailings Storage Facility Management Plan, Appendix E2 – Overburden Emplacement Facility Management Plan, Appendix E4 – Mine Closure Plan and Chapter 5 – Rehabilitation and Decommissioning.

7.2 Existing Environment

7.2.1 Topography and Landscape Character

The topography and landscape character of the Project area is predominantly flat slopes to undulating, low hilly land. Most of the site has been cleared for the improvement of pastures for grazing leaving small patches of remnant vegetation. In general, the terrain units (topography and geology) across the Mineral Leases are consistent with, and typical of the Gulf Region.

Immediately east of the existing McArthur River Mine (MRM) mine site, the Bukalara Plateau, which is the major feature of the region, stands approximately 30 to 100 m above the surrounding countryside.

7.2.2 Land Use

Land within the Project area has historically been used for beef cattle grazing, although the last 15 years has also seen significant mining and exploration works undertaken (both underground and open pit). The majority of the area surrounding the Project site has been cleared for improved pasture, with pasture grasses well established in most soil units. There is no evidence of any cropping in the area.

A number of Mineral Leases for mining covered by the Project are shown and listed in Chapter 1 – Introduction.

7.2.3 Geology

7.2.3.1 Regional Geology

The Project area is located in the McArthur River alluvium and fractured rocks of the Proterozoic McArthur Group, in the McArthur Basin south of the Gulf of Carpentaria in the Northern Territory. The McArthur Group is an interbedded sequence of dolostones, sandstones, shales and siltstones comprising two sub-groups - the Batten and the underlying Umbolooga. It is up to 4,000 m thick in the McArthur River district where it is best exposed. The McArthur Group is part of the McArthur Basin along with the Roper, Nathan and Tawallah groups.

The Bukalara Plateau, the main local geographic feature is composed of the Early Cambrian Bukalara Sandstone overlying folded Proterozoic material. The Plateau lays unconformably over dolomitic sediments in the McArthur Group. Bukalara Sandstone is jointed, slightly feldspathic and has distinctive cross-bedding.

The McArthur River flows to a coastal plain and into the Gulf of Carpentaria. The coastal plain is comprised of laterite, sandy soils and McArthur River alluvium with some residual Mesozoic and Proterozoic rocks of the Roper Group scattered throughout, particularly in the vicinity of Borroloola where they rise approximately 30 m above the plain.

The McArthur River Basin contains faulting, gentle folding and is non-metamorphic. The Batten Fault Zone (Batten Trough) occurs in the south of the basin and trends north. It is an extensively faulted zone approximately 70 km wide. The Emu Fault Zone to the east of the Batten Fault Zone is a major structural lineament in the Project area.

7.2.3.2 Local Geology

Northern Territory Geological Survey (1991) mapping of the geological formations present in the Project area is shown in Figure 7-1.

The Umbolooga subgroup of the McArthur River Group is comprised of interbedded cycle dolostones, dolomitic siltstone, sandstone and shale. The Batten subgroup overlies the Umbolooga and is comprised of a succession of shallow marine deposits, chiefly dolomitic siltstone, cherty dolostone, pyritic shale, quartz sandstone and evaporites. The Middle Proterozoic McArthur River Group contains the oldest rocks in the McArthur Basin.

The youngest rocks in the McArthur Basin are found in the Roper Group and occur to the east of the Emu Fault Zone in the north-eastern sector of the Project area. They are comprised of a Proterozoic succession of quartz arenite, quartz sandstone, siltstone and shale.

The east of the Project area contains the Early Cambrian Bukulara Sandstone formation, a fine to very coarse grained, cross-bedded friable quartz to lithic sandstone with minor shale beds and basal pebbly conglomerate unconformable to the McArthur River Basin sequence.

Within the Project area, Quaternary sediments overlie the bedrock and consist of colluvial, alluvial, lacustrine sediment including clay, sand and silt, and gravelly residual soils. These strata are overlain by more recent alluvial silt, sand and clay deposited on the floodplains, flood terraces, levees and channel floors of the McArthur River and the Glyde River.

7.2.3.3 Mineralisation

The MRM deposit was discovered in the 1950s and originally named 'Here's Your Chance' (HYC). The mineralisation covers an area of 2 km^2 to a thickness of 55 m. The HYC deposit is comprised of eight discrete zinc and lead sulphide-rich siltstone horizons, seven of which are identified mineral resources.

The horizons are separated by cyclic barren sedimentary rock. Most of the ore dips 15-20 degrees to the east. Major sulphides present are pyrite (FeS_2), sphalerite (ZnS) and galena (PbS). Minor chalcopyrite ($CuFeS_2$), arsenopyrite (FeAsS) and marcasite (FeS_2) are also present.

7.2.4 Land Systems and Land Units

7.2.4.1 Geomorphology

Six geomorphic provinces have been defined in the Southern Gulf Region of the Northern Territory (Aldrick and Wilson, 1990). Each geomorphic province constitutes a landscape process zone, the major variances in each zone related to differences in rates and types of landscape denudation and transport of sediment to the coast. Occurrence of those geomorphic provinces is shown in Figure 7-2 and the main characteristics of each province summarised in Table 7-1.

Two of the six Southern Gulf Region geomorphological provinces are present in the Project area:

- high rocky sandstone plateaux and ridges mainly associated with the lower Cambrian Bukalara Sandstone (G3 in Aldrick and Wilson, 1990)
- high level valleys and depositional plains with a series of linear ridges of erosion resistant sedimentary rocks trending normal to the direction drainage, inhibiting down cutting of streams, resulting in water impoundment upstream of these transverse linear ridge features (G4 in Aldrick and Wilson, 1990).

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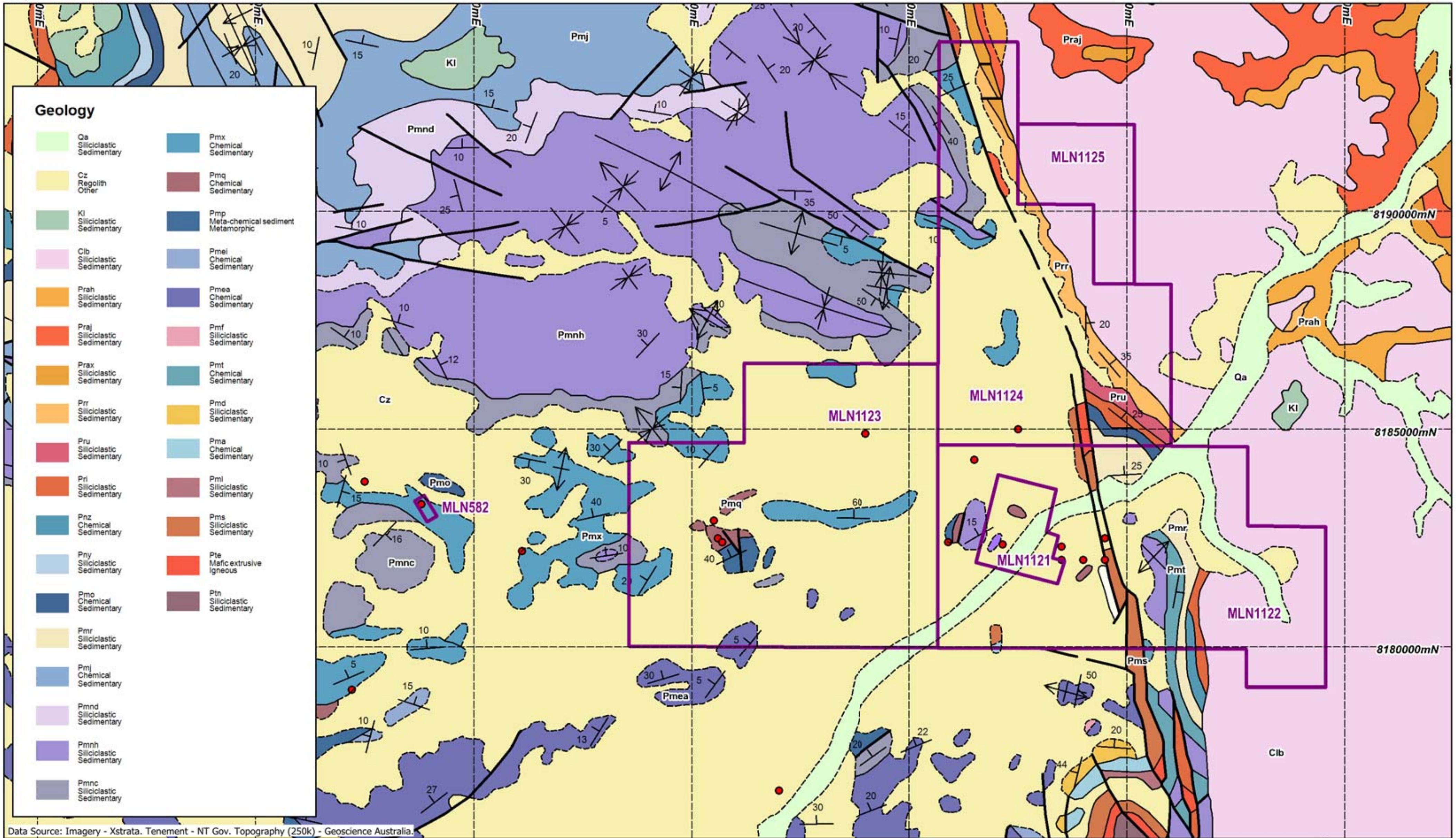


METSERVE
Mining & Energy Technical Services Pty Ltd

xstrata zinc

0 2.5

Kilometres

Scale: 1:120,000 (A4)

LEGEND

- Project tenement
- Fault
- Fold showing direction
- Structure showing orientation
- Mineral occurence

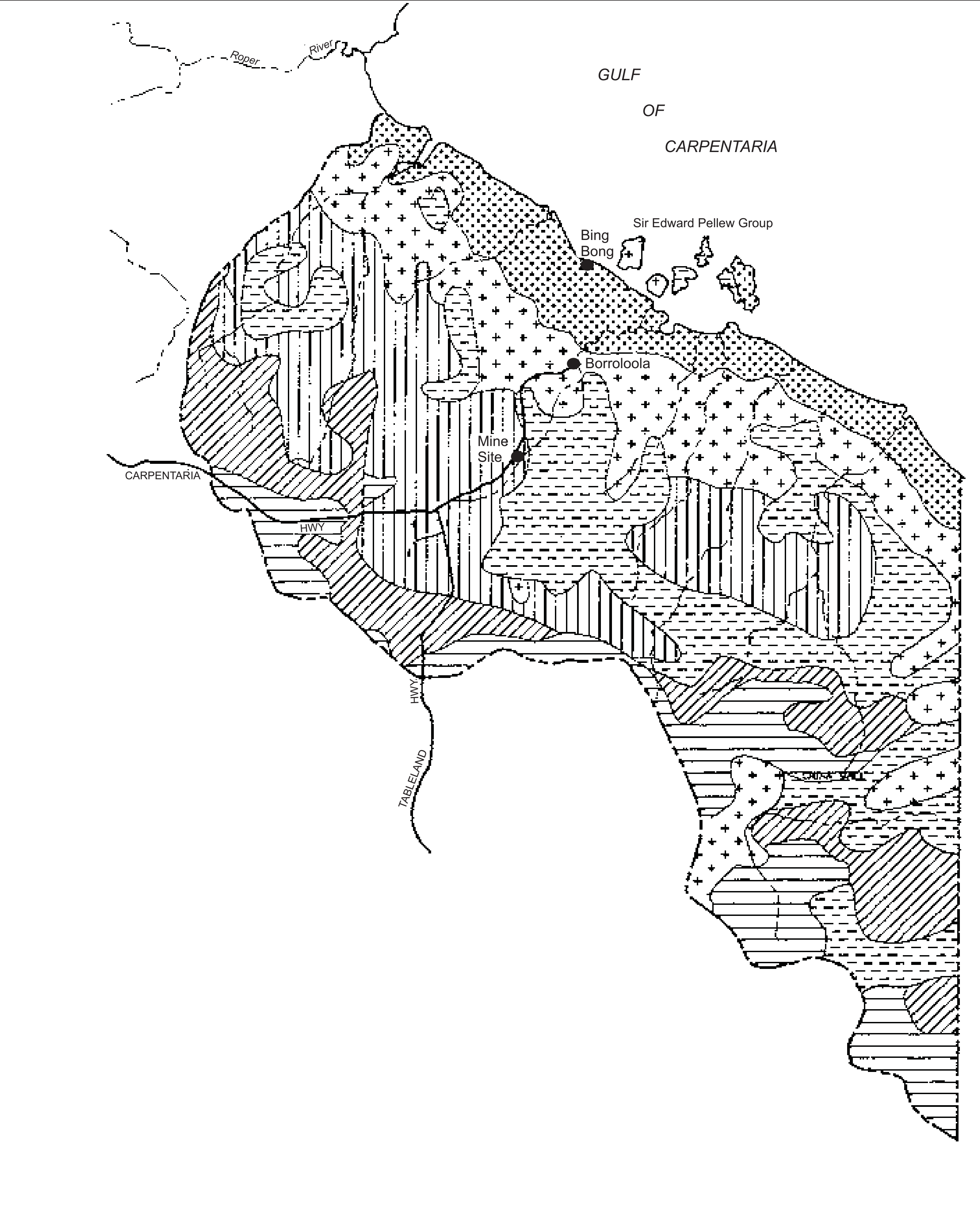
McArthur River Mine
Phase 3 Development Project

Geological Formations - McArthur River

19/10/2011

Datum: GDA94
Projection: MGA53

FIGURE 7 - 1



LEGEND

G1
G2
G3
G3
G5
G6
— Refer to Table 7.1

Major Road
River
Survey Boundary

Data Source: McArthur River Mining, Aldrick & Wilson (1990)

McArthur River Mine Phase 3 Development Project

Geomorphic Provinces

25 0 25 50 75
Kilometres
Scale: 1:2,500,000 (approx)

10/01/2012

Datum: GDA94
Projection: MGA53

FIGURE 7-2

METSERVE Mining & Energy Technical Services Pty Ltd

xstrata zinc

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Table 7-1 Factors Defining and Characterising the Geomorphic Provinces (Aldrick and Wilson, 1990)

Geomorphic Province	Definitive Factors that Differentiate Between the Geomorphic Provinces			Main Characteristics of the Geomorphic Provinces
	Rate of Natural Erosion	Rate of Sediment Removal	Influence of Base Level	
G1(a)	Very slow (very old, stable drainage network, very low relief, and permeable soils)	Very slow (little sediment produced due to very low relief, streams have low competence)	-	Intact areas of mature laterite on old, stable erosion surfaces
G1(b)	Slow (very old, stable drainage network, low relief, relatively dry climate)	Slow (due to low relief and low stream competence).	-	Extensive areas of old mature clay plains
G2	Rapid (soft rocks with high relief)	Rapid (high relief, with competent streams)	-	Escarpments, low hills, foot slopes and gentle plains where laterite, clay or sandstone cap rock has been incised exposing softer underlying materials
G3*	Slow (erosion resistant rocks)	Rapid (high relief and stream competence, however little sediment is available for transport)	-	High level, rocky plateaus and ridges of resistant sandstone and igneous rock

Table 7-1 Factors Defining and Characterising the Geomorphic Provinces (Aldrick and Wilson, 1990) (cont)

Geomorphic Province	**Definitive Factors that Differentiate Between the Geomorphic Provinces**			**Main Characteristics of the Geomorphic Provinces**
	Rate of Natural Erosion	**Rate of Sediment Removal**	**Influence of Base Level**	
G4*	Slow to moderate (local base levels and sediment accumulation lead to broad, shallow valleys. Only upper parts of relief are subject to strong erosion, but these are mostly resistant rocks)	Slow to moderate (local base levels slow stream incision and inhibit sediment removal. Sediment accumulates)	Local base level imposed by sandstone ridges across the direction of drainage impedes sediment transport	Areas where a series of linear sandstone ridges across the direction of drainage impose strong structural control and cause local accumulation of sediment
G5	Slow to moderate (low relief)	Moderate (low relief, low stream competence)	-	Gentle erosional slopes on the coastward side of the sandstone ridges that influence G4
G6	Very slow (very low relief, with a very young, immature weakly developed drainage pattern, and permeable soils)	Very slow (very low relief and incompetent, disintegrated stream patterns)	Ultimate base level (the sea) occurs immediately downstream. Concept of further sediment removal not relevant. Sediment accumulates	Almost flat coastal terraces

* Geomorphic provinces located within Project Area

7.2.4.2 Land Systems

Based on the land system types described by Aldrick and Wilson (1990), six land systems are present in the Project area. These land systems were identified as part of a previous environmental impact assessment (EIA) process undertaken for the underground to open pit mining conversion in 2005 (URS. 2005).

A map of the land systems present at the Project has been included as Figure 7-4. The six land systems are the following:

- **McArthur:** Broad or narrow fluvial corridors conducting regional drainage across various land systems towards the coast. Grey and brown clays and siliceous sands. Mid-high open woodland of *Eucalyptus terminalis* and *E. microtheca* which some *E. papuana* and *E. polycarpa.* Tall fringing riparian vegetation often includes *Melaleuca* spp
- **Bukalara:** Rugged rocky plateau and steep, linear ridges on massive sandstones such as the Bukalara Sandstone. Lithosols and shallow siliceous sands. Mid-high open woodland of *Eucalyptus dichromophloia* with *E. miniata, E. tetrodonta* and *E. leucophloia*
- **Unnamed:** Major river depositional flood plains. Grey cracking clays. Woodland of *Eucalyptus microtheca,* and *E. papuana*
- **Surprise:** Level to gently undulating plains of mainly unconsolidated, transported materials. Yellow and brown earths and cracking clays. Mid-high open woodland of *Eucalyptus tectifica, E. terminalis* and *Erythropheleum cholorostachys*
- **Emmerugga:** Undulating to rolling low hills on mainly argillaceous sediments. Lithosols and shallow yellow earths. Mid-high open woodland of *Eucalyptus leucophloia* with some *E. tectifica, E. terminalis* and *Erythropheleum cholorostachys*
- **Favenc:** Steep hills on mainly argillaceous sediments. Lithosols and brown earths. Mid-high open woodland of *Eucalyptus dichromorphloia, E. miniata* and *E. tetrodonta.*

7.2.4.3 Land Units

Previous investigations of Project area land resources were conducted in 2005 prior to the conversion to open pit mining from underground operations. The Project remains within the same geographical location. The previously identified land units remain unchanged with the exception of new disturbance areas caused by the current operation, such as the open pit and the North Overburden Emplacement Facility (OEF).

The geology, landform attributes and soil types of the Project area were previously assessed with the use of fieldwork, aerial photography interpretation and a review of existing land resource information. As a result of these investigations, a land unit map of the Project area was developed as part of the 2005 EIA process for the existing MRM operation. The methodology for this process has been included as Appendix D1 – Land Resources.

Land units are comprised of discrete recurring areas with specific attributes including bedrock, surface slope, land form, soil type and substrate conditions, which allow the extrapolation of environmental or engineering characteristics across areas of the same land unit. Distribution of land units across the Project area is presented in Figure 7-4 with an explanatory key in Table 7-2. Detailed descriptions of the land units can be found in Appendix D1 – Land Resources.

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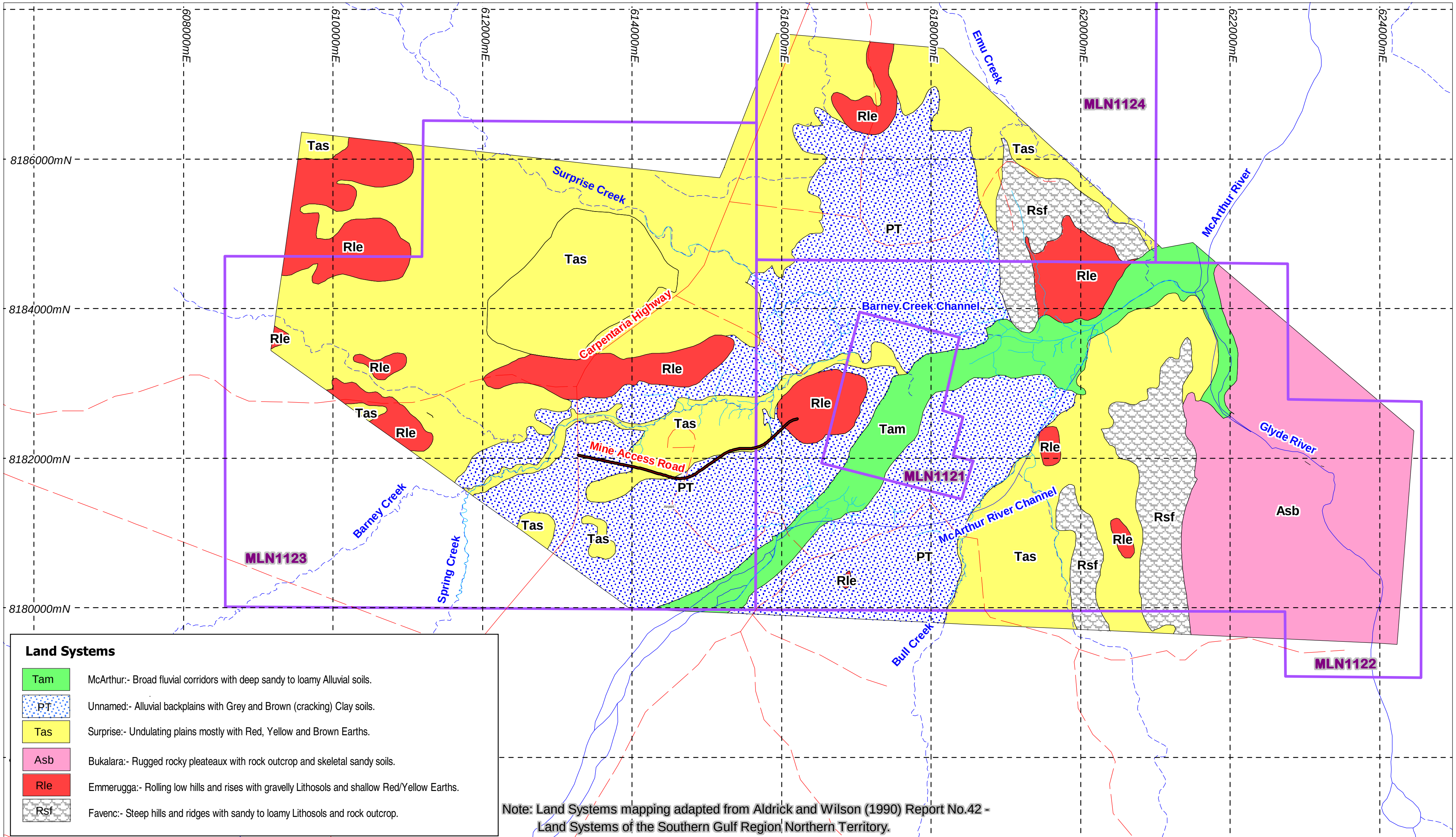

Land Systems

Tam	McArthur:- Broad fluvial corridors with deep sandy to loamy Alluvial soils.
PT	Unnamed:- Alluvial backplains with Grey and Brown (cracking) Clay soils.
Tas	Surprise:- Undulating plains mostly with Red, Yellow and Brown Earths.
Asb	Bukalara:- Rugged rocky pleateaux with rock outcrop and skeletal sandy soils.
Rle	Emmerugga:- Rolling low hills and rises with gravelly Lithosols and shallow Red/Yellow Earths.
Rsf	Favenc:- Steep hills and ridges with sandy to loamy Lithosols and rock outcrop.

Note: Land Systems mapping adapted from Aldrick and Wilson (1990) Report No.42 - Land Systems of the Southern Gulf Region Northern Territory.

METSERVE

xstrata zinc

0 1 2
Kilometres
Scale: 1:70,000 (A4)

LEGEND

- Project tenement
- Mine access road
- Road(sealed)
- Road(unsealed)
- Rivers
- Watercourse(major)

Data Source: Land systems-URS. Imagery - Xstrata. Tenement - NT Gov. Topography (250k) - Geoscience Australia.

McArthur River Mine
Phase 3 Development Project

Land Systems

13/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 3

7.2.5 Soils

A detailed soil survey conducted over the entire Mineral Lease area prior to the commencement of open pit operations at MRM was included in the 2005 EIA process (URS, 2005). This soil survey is applicable for the Project and the results are presented in Appendix D1 – Land Resources**.**

7.2.5.1 Physical Characteristics

Soils in the Project area vary according to terrain, ranging from lithosols on hill and ridge tops, to grey and brown cracking clays in gullies and depressions. A brief description of the soil types present is provided below:

- **Skeletal Soils** – Rocky outcrop with skeletal to shallow stony soils chiefly on arenaceous rock types
- **Lithosols** – Shallow, coarse to medium textured soils with reddish to yellowish brown colours neutral pH, typically with 50-60% stone or ironstone gravelly inclusions
- **Siliceous Sands** – Deep sandy alluvial soils, brownish yellow fine sands with slightly acidic pH and diffuse mottling in the deep subsoil
- **Siliceous Sands** – Shallow gravelly brown sands with neutral to slightly acidic pH over weathered sandstone/arenite
- **Earthy Sands** – Moderate to deep silty and clayey sands, locally gravelly with yellowish brown colour and neutral pH, over weathered rock or transported alluvial or colluvial materials
- **Alluvial Soils** – Deep uniform or weakly gradational fine sandy loam and clay loam alluvial soils.
- **Gravelly Loams/Lithosols** – Shallow to moderately deep gravelly red uniform or weakly gradational loams to clay loams underlain by weathered rock or gravelly colluvium
- **Silty to Loamy surface duplex soils** – Mostly deep yellowish brown, some yellowish red silty to loamy surface duplex or gradational soils with slightly acidic pH and mottled poorly drained clayey subsoils
- **Yellow Massive Earths** – Medium to deep gradational loamy massive yellow earths with neutral to slightly acidic pH and mottled clay loam to silty medium clay subsoils with some fine ferromanganiferous concretions throughout the profile
- **Red Massive or Structured Earths** – Medium to deep hard-setting loamy surface gradational massive red earths or thin loamy surface red duplex soils, with neutral to slightly acidic medium to heavy clay subsoils with some fine ferromanganiferous concretions throughout the profile
- **Grey and Brown (Cracking/Clays) –** Deep dark grey, dark brown or brown cracking clay soils with strongly structured A/B horizons and alkaline (carbonate and gypseous) heavy clay deeper subsoil horizons; locally with melon-hole gilgai formation and thin self-mulching surface soils.

Table 7-2 Identification Key of Land System Terrain Mapping Units at MRM

Geological Regime		Landform		Soil Type	
Symbol	**Formation/Lithology**	**Class**	**Description of Surface Form and Slope Range**	**Class**	**Material Type**
Qa	Quaternary Recent Alluvial Deposits – clay, silt, sand and gravel	0	Channel floor and banks, intra-channel stream terraces and broadly rounded levees, billabongs and waterways	0	Rock outcrop/exposed rock; some stony skeletal soils
Cz	Cainozoic Tertiary to Quaternary Undifferentiated – residual soils, colluvial and outwash fan deposits and older alluvium	1	Low-lying drainage flats, intermediate and upper stream terraces and broadly depressional drainage ways, generally poorly-drained flood prone areas	1	Predominantly gravelly residual, colluvial or alluvial soils, shallow gravelly lithoslols (K-Uc to K-Um)
Clb	Early Cambrian, Bukalara Sandstone – coarse-grained feldspathic and quartz sandstone	2	Near level to gently inclined plains, slopes <2%, mostly <1%, infrequently flood prone or inundated	2	Coarse-textured sandy soils, including deep alluvial sands, and shallow residual siliceous sands -2(g); (Uc1 - Uc2)
Pm	Middle Proterozoic McArthur Group – dolomitic, carbonaceous and pyritic shale and siltstone dololutite, dolomitic breccia and quartz arenite	3	Gently undulating plain pediplain and gently inclined dissection slope interfluves, slopes mostly <3%	3	Shallow to deep often gravelly earthy sands to sandy earth soils (Uc4-Uc6, Uml)

Table 7-2 Identification Key of Land System Terrain Mapping Units at MRM (cont)

Geological Regime		Landform		Soil Type	
Symbol	Formation/Lithology	Class	Description of Surface Form and Slope Range	Class	Material Type
		4	Undulating plains and rises, irregular to strongly undulating dissected rugged and eroded plateau surface, overall slopes up to 15 %, local subvertical rocky gorges	4	Shallow usually gravelly residual uniform to gradational loams to clay loams -4(g), and deep loamy alluvial soils (Uml-5, Gnl-2)
		5	Gently to moderately inclined, foot slopes, marginal slopes and slopes to drainage, locally intensively dissected and eroded slopes up to 15%	5	Sandy to loamy surface often bleached yellow and brown mottled duplex (podzolic–solodic) soils (Gn2-Dy3)
		6	Rounded low hills, rises and dissection slope interfluves; moderately steep slopes up to 20%	6	Gradational yellow massive earths usually medium to deep with varying amounts of ferruginous nodules included (Gn2-Um5)
		7	Rolling to hilly and steep dissected hilly lands with rounded hill crests and steep hill and ridges slopes typically in the range 20-30 %	7	Gradational shallow to moderately deep loamy red earths with massive or structured slightly acidic to neutral clayey subsoils (Gn2-Gn4, Dr2)
		8	Steep to very steep strike ridges, steep high hilly lands, escapement slopes and deep gorges; slopes 30-50%	8	Deep brown and grey (cracking) clays or black earths locally with thin self-mulching surface soils and strongly structured alkaline heavy clay subsoils
				D	Areas modified by cutting or filling or other mining related activities

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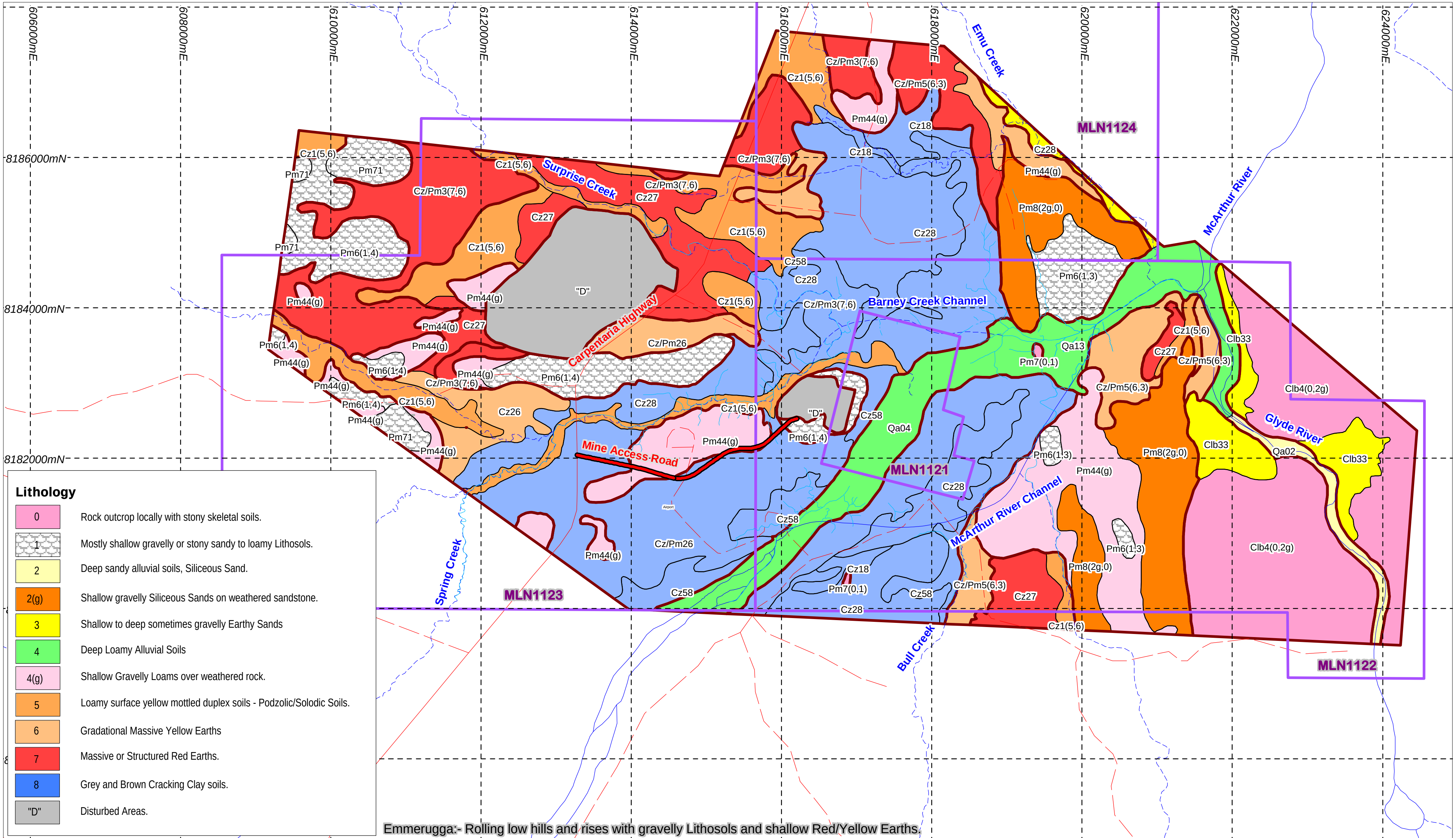

METSERVE

xstrata zinc

0 1 2

Kilometres

Scale: 1:70,000 (A4)

LEGEND

- Project tenement
- Mine access road
- Road(sealed)
- Road(unsealed)
- Rivers
- Watercourse(major)
- Geological Regime
- Terrain Unit Boundary

Data Source: Land systems-URS. Imagery - Xstrata. Tenement - NT Gov. Topography (250k) - Geoscience Australia.

McArthur River Mine Phase 3 Development Project

Soils

13/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 4

7.2.5.2 Chemical Characteristics

Chemical analysis of the Project area soil types conducted for the 2005 EIS have been included in Appendix D1 – Land Resources. Soil chemical characteristics can be summarised as follows:

- **Soil pH** – pH levels in general ranged from slightly acidic to neutral with strongly alkaline subsoils occurring in the grey and brown cracking clay soils
- **Salinity** - Electrical Conductivity (EC) levels were nil to slight (EC <280 µS/cm) in all soils tested except for the deeper subsoils of the brown cracking clay soils which were highly to severely saline (EC 1100 - >2300 µS/cm)
- **Dispersion** - With the exception of three of the 26 soil profiles tested which contained carbonate and/or gypsum in the subsoils, slightly dispersive soil layers were present in all the other soil profiles.

MRM's 2010-2011 Sustainable Development Mining Management Plan indicates that dust mitigation measures have limited the deposition of dust containing zinc and lead. Dust management measures will continue for the Project and are discussed in Chapter 11 – Air Quality and Greenhouse Gases.

7.2.6 Land Capability

A land capability assessment conducted for the 2005 EIA process is still applicable for the Project. The assessment of pre-mining land capability serves to indicate the target level for land use and rehabilitation requirements post-mining. In order to determine land capability classes at the Project, the approach used by Aldrick and Wilson (1990) was adopted.

The process includes an assessment of the severity of limiting factors to agriculture/pastoral land uses which, if not sustainable, may lead to long-term land degradation.

Limiting factors considered include:

- soil and site drainage conditions
- soil moisture holding capacity
- soil physical and chemical conditions
- soil erosion potential
- adverse site factors: rockiness, slopes, intensity and degree of dissection, flooding etc.

The land capability of the Project area for agricultural and pastoral use as shown in Table 7-3 is based on the occurrence of land systems described by Aldrick and Wilson (1990).

Table 7-3 Land Capability for Crop and Pasture Production

Land System	Land Capability Class (1 = best, 5 = worst)		
	Crop Use	Pastoral Use	Limitations/Comments
McArthur	3	2	Flooding, wet season access.
Unnamed (River Backplains)	2(4)	1(3)	Wet season access (intensively dissected margins), coarse soil structure/cracking.
Surprise	2	1	Impeded drainage, soil dispersion and erosion.
Bukalara	5	5	Rock outcrop/skeletal soils.
Emmerugga	5	3	Steep slopes, shallow gravelly soils.
Favenc	5	5	Steep slopes, rock outcrop and shallow soils.

Notes: Class 1 – No significant limitations to crop or pasture production
Class 2 – Up to three types of moderately severe limitations present
Class 3 – More than three types of moderately severe limitations present
Class 4 – One type of limitation present with a high degree of severity
Class 5 – Two or more types of limitations present with a high degree of severity.

7.2.7 Geochemistry

7.2.7.1 Overview

As a result of the Project an additional 530 million tonnes of overburden is expected to be removed from the open pit, to be stored in the OEFs North, South and East of the open pit as shown in Figure 4-1 in Chapter 4 – Project Description.

The North OEF, which will store the majority of waste rock, was primarily selected for this purpose after consideration of culturally significant sites, floodwater levels, the local topography, watercourse crossings, existing infrastructure and geotechnical stability.

The Projects footprint of the North OEF will cover approximately 485 ha and the maximum height will reach 80 m to accommodate the additional overburden material. The South and East OEFs will cover approximately 150 ha with a maximum height of 80 m.

The overburden has been divided into the following categories to define its potential environment impact:

- Potentially Acid Forming (PAF)
- Non-Acid Forming (NAF) – which also includes Acid Consuming (AC) or neutralising material.

The primary cause of acid generation is the oxidation of pyrite (FeS_2) which can be generally described by the following chemical equation:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \rightarrow Fe(OH)_3 + 2H_2SO_4$$

PAF overburden has the potential, in the presence of air and water, to generate acid water, soluble metals and salts that could impact the environment. NAF overburden is chemically stable with low potential for acid generation or high metals leachate. Some NAF overburden has the capacity to neutralise runoff and seepage from PAF material.

7.2.7.2 Previous geochemistry assessments

An investigation into the geochemical characteristics of the overburden has been reported previously in 'Geochemical Assessment of Overburden and Tailing Materials Including Conceptual Design of Overburden Emplacement Area' (URS, 2005a). This involved geochemical testing to a depth of approximately 420 m and this data has been used for the existing operations at MRM. This program covered the extent of the Project pit.

This study indicated that overburden contained reactive pyrite. Also contained in the overburden was a significant amount of AC material, as well as non-reactive sulphides such as galena (PbS) and sphalerite (ZnS) that do not generate acid. Results indicated that PAF material was restricted to zones within the upper and lower pyritic shale rock types, which had the capacity to generate a significant quantity of acid drainage. However, there was likely to be a period of time before acid conditions may become apparent in these materials (lag-period) due to high AC content.

The W-Fold Shale and Teena Dolomite rock types have a very low sulphur content and high Acid Neutralising Capacity (ANC). These rock types are NAF and are also a potential source of highly AC material. Lower dolomitic shales occasionally have relatively high sulphur content. However all samples have a moderate to high AC and a low (strongly negative) Net Acid Producing Potential (NAPP) value. Geochemical data suggests that most of the dolomitic shale materials also have significant acid consuming characteristics.

Multi-element tests indicated that arsenic (As), cadmium (Cd), copper (Cu), manganese (Mn), lead (Pb), and zinc (Zn) are commonly present in most overburden rock types at elevated concentrations. Enrichment of these elements with respect to normal background concentrations is to be expected and simply reflects the natural geochemical enrichment that defines a mineral deposit.

7.2.7.3 Project geochemistry assessment

A new drilling program has been designed to undertake a detailed geochemical analysis of the Project overburden material to increase confidence in predicting the occurrence of PAF during mining and to improve the efficiency with which the material can be separated from NAF/AC material. Sulphur content and speciation will be included in the investigation to distinguish acid-forming sulphides from other material containing sulphur. Other tests include ANC, Net Acid Generation (NAG), paste pH and EC, Acid Buffering Characteristic Curves (ABCC), Kinetic Net Acid Generation (KNAG), carbon speciation, and elemental analysis of solid material and water extracts.

Geochemical data will be used to determine the acid forming nature of overburden materials prior to Project mining using exploration drill core and/or active bench face samples. Acquired data will be used to block model overburden materials in advance of Project mining and to facilitate the implementation of proactive waste management strategies and procedures (i.e. selective handling, placement and clay encapsulation of PAF materials).

7.2.8 Seismicity

7.2.8.1 Earthquake risk

The McArthur River area is not considered to be a seismically active zone. Records of seismic events in the Northern Territory and Gulf Region obtained from Geoscience Australia are shown in Figure 7-5. No evidence of past earthquake activity has been recorded in the immediate area of the Project, which is located in an area of lowest earthquake hazard potential. There is only a remote possibility of re-activation of geologically ancient faults, causing earthquakes that could potentially affect the Project.

7.2.8.2 Liquefaction

Previous soil test pits (Appendix D1 – Land Resources) have demonstrated that the Project area soils are predominantly very stiff to hard clay and clay loam with small amounts of sand. Liquefaction potential of these soils is regarded as low due to the particle size distribution and the strength of these materials.

7.2.9 Visual Amenity

Most of the existing MRM facilities are set back from the Carpentaria Highway, with the primary mining and processing operations situated over 2 km away. The one exception to this is the existing TSF which is located 200 m to the west of the highway, and the North OEF, located approximately 1.5 km to the east of the highway. The raised perimeter of this facility is visible from the roadside.

The Bukalara Plateau, to the east of the Project site, stands approximately 30-100 m above the surrounding countryside and provides a natural backdrop to the mining operations.

The Project is situated in a sparsely populated area of the Gulf Region, well removed from the nearest residential area at Borroloola to the north-east. Other than the Carpentaria Highway, there are no significant public viewpoints from which the mine can be seen.

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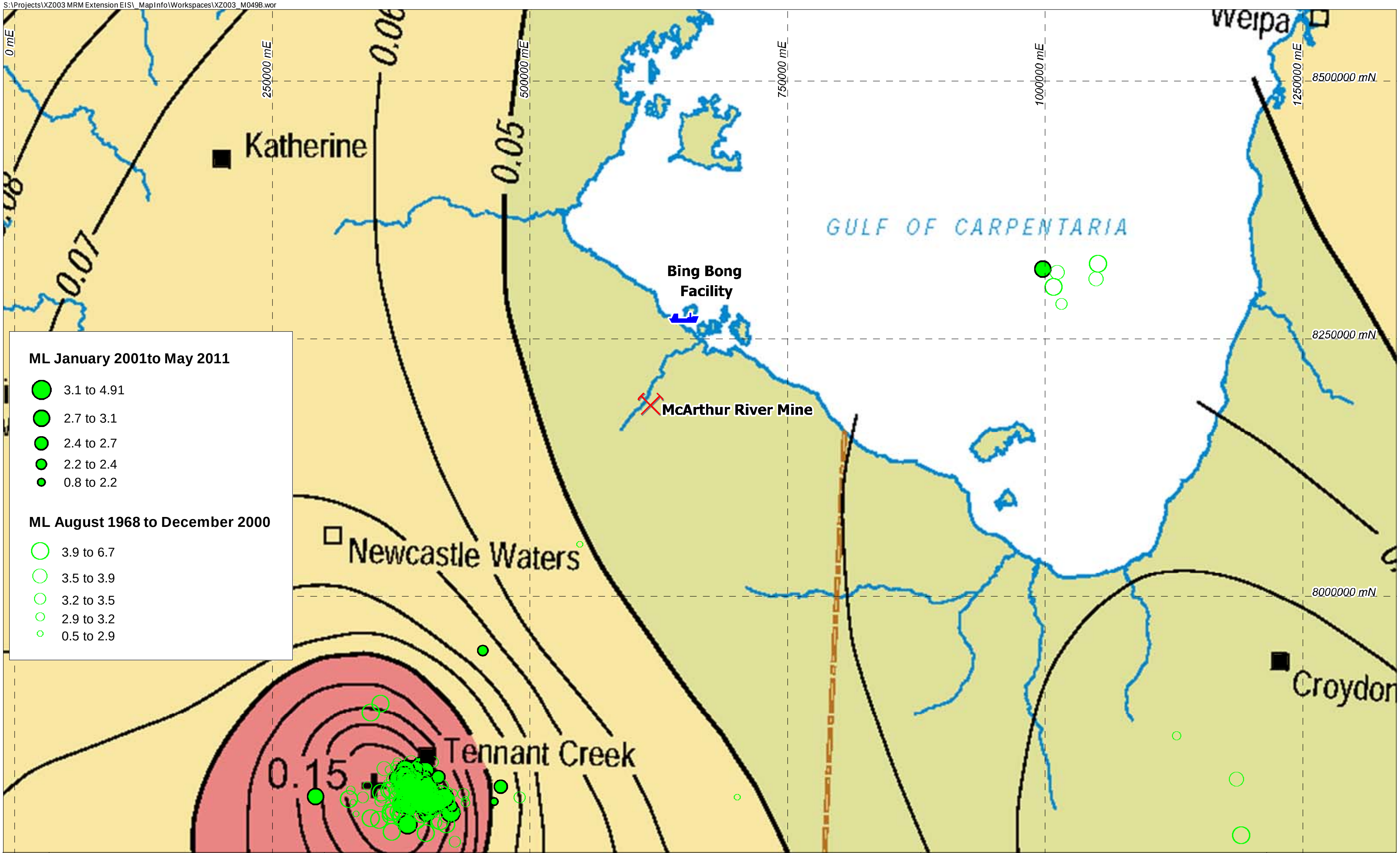

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Kilometres

Scale: 1: 5,000,000(A4)

LEGEND

McArthur River Mine

Station

Town

Bing Bong Concentrate Storage and Ship Loading Facility

Acceleration coefficient (a)
10% chance of being exceeded in 50 years

≥0.10

0.05 - 0.10

≤0.05

Data Source: Seismic Activities - NT GeoSurvey. Imagery - Xstrata. Tenement - NT Gov. Topography (250k) - Geoscience Australia.

McArthur River Mine
Phase 3 Development Project

Regional Seismic Activity

10/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 5

7.3 Potential Impacts and Mitigation Measures

7.3.1 Soils and Land Capability

Factors influencing changes in land capability include changed physical, chemical and biological properties of the soil, changes in slope, slope length and soil depth. The suitability of the OEFs for cropping and grazing is constrained by slope angle, the nature of soil cover, and altered soil moisture profile. These constraints will increase the risk of erosion significantly if cropping or grazing were undertaken.

Final land use criteria for the existing mine includes a mix of cattle grazing (non-disturbed areas) and native vegetation. The erosional stability of the OEFs may be compromised by grazing, and as such, grazing of any portion of the OEFs is not considered appropriate in the short term. Long term, the post mine land use will be generally returned to grazing.

The plateau-like upper surface of the OEFs is not considered suitable for rain-fed cropping, as most pre-mine soil types are unsuitable for such use. No areas considered suitable for cropping were identified in the Project area. Previous knowledge and experience within the industry indicates cropping is not an alternative post-mining land use.

7.3.1.1 Grazing

Limitations to cattle grazing of the post-mining OEF landforms within the Project area are based on slope, with erosion susceptibility being the major limiting factor governing the class. Grazed slopes would be highly prone to degradation from erosion if not managed appropriately. Steep sloping areas such as the slopes of the OEFs, TSF, and the final void are unlikely to sustain grazing. Considering this, no part of these final landforms is proposed for grazing. Landforms will be rehabilitated to areas of native bushland for pastoral use.

7.3.2 Overburden emplacement facilities

Three OEFs are currently used for the long-term and intermediate storage of rock material excavated from the existing open pit operations: the North OEF, West OEF and the Bund OEF.

The Project will expand the North OEF from 375 ha to 860 ha and the Bund OEF from 120 ha to 270 ha (with the addition of the South and East OEFs). Figure 7-4 shows the soil types that underlie the proposed new OEF footprints.

Chapter 4 – Project Description also shows five yearly snapshots of the Project demonstrating the increasing OEF footprint area over the Project's life.

The existing North OEF covers a near-level to gently inclined alluvial plain with deep grey and brown cracking clay soils. An extended North OEF footprint will cover more of this soils unit, as well as some yellow mottled loamy duplex soils and gradation massive yellow earth soils to the north and the west, red earth soils to the north-east and shallow gravelly loams to the north.

The South and East OEFs will overlie deep loamy alluvial soils of the former McArthur River Channel, as well as grey and brown cracking clay soils.

To reduce the risk of Acid Mine Drainage (AMD) enriched metal concentration and potential release to vegetation (plant uptake), atmosphere (dusting) or water resources (leaching), the following OEF management measures will be continued:

- dust suppression (watering) during OEF construction if required

- PAF material will be encapsulated by clay and NAF material in cells to take advantage of the acid buffering nature of the material in the North OEF (the South and East OEFs will contain only NAF material). The PAF cells will be completely surrounded by layers of clay that minimise the amount of air and water contacting the PAF rock. A layer of NAF material then further protects the cell from oxidation and erosion. The PAF cells are located above the 1-in-100 year flood level to avoid inundation from floodwaters
- exposure time of PAF and dispersive material to the surface will be kept to a minimum to reduce the potential formation of acid leachate and soil dispersion
- surface of the OEFs will be contoured so that run-off is shed from the landform
- final landform will incorporate soil covers, designed to protect the OEFs adequately from potential wind and surface water erosion and moisture infiltration. Drainage works will be designed to maintain long-term stability of the soil cover.

MRM's environmental monitoring program has demonstrated the existing operation has had no adverse impact on the McArthur River or Gulf environments. All current environmental monitoring used to assess impacts from the North OEF will continue with the new OEFs.

The environmental performance of OEFs will be monitored to check:

- water quality and sediments in the OEFs run-off ponds to make sure overburden is being categorised correctly and the management strategies are working
- groundwater quality through monitoring bores installed around the mine site
- physical stability against wind and water erosion.

More details of OEF management are listed in Chapter 5 – Rehabilitation and Decommissioning and Appendix E2 – Overburden Emplacement Facility Management Plan.

7.3.3 Tailing Storage Facility

The Project will require a fourth tailings storage cell; Cell 4.

Cell 4 will be a converted water evaporation/holding dam. Cell 4, to be located on the western side of the existing TSF facility, adjoining Cells 2 and 3, is currently being considered under the annual Sustainable Development Mining Management Plan process pursuant to Section 40 of the *Mining Management Act 2001*. Cell 4 is being designed and constructed to facilitate future use as a tailings storage facility in 2032, to store Project tailings as current approved TSF capacity is gradually utilised.

Cell 4 will increase the footprint area of the TSF by 73 ha. Figure 7-4 shows the soil types present in the vicinity of the TSF expansion.

The terrain underlying the TSF area is a gently inclined, broadly undulating plain. Soil types present are mostly deep red and yellow with medium to heavy clay subsoils grading through clayey gravels to weathered rock with dolomite or dolomitic siltstone at depths from 0.5-1.5 m. Deeper structured red earths with medium to heavy clay subsoils also occur. Moderately shallow gravelly red loams underlain by weathered dolomitic shale/siltstone occur locally on low rises. More detail on TSF management are provided in Chapter 5 – Rehabilitation and Decommissioning and Appendix E1 – Tailings Storage Facility Management Plan.

7.3.4 Open Pit Area

The Project will expand the open pit area from 145 ha to 210 ha. Soils disturbed in the expanded open pit area are near-level alluvial backplains comprising mostly of deep brown and grey cracking clay soils and deep loamy alluvial soils of the former McArthur River Channel.

At the end of mine life, a final void of 210 ha in area with a depth of 420 m will remain. The void will be bunded and fenced to prevent access and limit surface water drainage. More details of open pit and final void management are provided in Appendix E4 – Mine Closure Plan.

7.3.5 Erosion Control and Management

7.3.5.1 Erosion Controls

Land units in the Project area are susceptible to erosion due to the physical and chemical characteristics of the soils, the intensity of seasonal monsoonal rainfall and seasonal inundation from the McArthur River. Within the Project area, the majority of soils are of low to moderate dispersivity, though areas of highly dispersive soils do occur. Chemical analysis of soil samples has been included in Appendix D1 – Land Resources.

Impacts are typical of open pit mining methods currently used in Australia. Significant mitigation and management measures will be implemented progressively throughout the life of the Project to minimise both the degree and the extent of these impacts.

Potential impacts of erosion and landform instability include:

- impacts on water quality (suspended solids)
- impacts on surface water channels (sedimentation)
- rehabilitation failure
- loss of structural stability
- compromise of waste material capping
- increased infiltration and potential leaching.

In accordance with accepted practices, progressive revegetation will be undertaken at the Project as soon as viable areas become available, stabilising disturbed areas as quickly as practicable to limit erosion.

Erosion and sediment control measures will be employed which are consistent with the practices described in the Northern Territory Erosion and Sediment Control Guidelines. The existing erosion and sediment control practices will be upgraded and implemented throughout construction and operation phases of the Project. Areas where the final land form will result in changed slopes include the OEFs, TSF and the internal slopes of the final void.

Chapter 5 - Rehabilitation and Decommissioning, Appendix E1 – Tailings Storage Facility Management Plan, Appendix E2 – Overburden Emplacement Facility Management Plan and Appendix E4 – Mine Closure Plan details rehabilitation plans and ultimate rehabilitation success criteria for the Project. As a minimum, all areas significantly disturbed by mining activities will be rehabilitated to a stable landform with a self-sustaining vegetation cover.

Land will be regarded as successfully rehabilitated when nominated targets for land capability, land use, landform stability, and land contamination have been met.

The disturbance and handling of soils, landform creation and stabilisation will be guided by the following principles:

- all topsoil and soil-forming materials will be stockpiled in a manner which retains soil qualities
- re-use of all soil-forming materials will occur progressively
- limit soil stripping to the minimum area required for operational purposes at any one time;
- achieve physically and chemically stable landforms

- achieve appropriate landform profiles
- implement surface water management measures to minimise erosion and sedimentation
- revegetate new landforms with selected plant species, appropriate for achieving a physically stable landform.

Specific measures to minimise erosion for the Project disturbance areas are outlined in Table 7-4.

Design parameters for the construction of erosion control works such as rock armoured or grass lined waterways will be in accordance with sound engineering and soil conservation earthworks principles. Drainage will be designed to best practice and constructed to the accepted engineering standard.

Sediment control dams will be constructed as required to minimise the amount of soil lost to erosion during rainfall events. Details of the sediment control dams, clean water diversions and channels are presented in Chapter 10 - Water Resources.

These measures will also be employed should erosion requiring remediation be identified during monitoring.

7.3.5.2 Erosion Monitoring

An indicator of landform stability is the extent of soil loss from rehabilitation sites relative to background rates of soil loss. Selected final slopes on rehabilitation sites will be monitored to identify any excess background soil loss rates.

Table 7-4 Erosion Control Measures at MRM

Disturbance Area	Control Measure
Cleared Land	• restrict clearing to areas essential for the ongoing operational works • windrow vegetation debris along the contour • minimise length of time soil is exposed • divert run-off from undisturbed areas away from the works • direct run-off from exposed areas to sediment dams.
Exposed Sub-soils	• minimise length of time subsoil is exposed • direct run-off from exposed areas to sediment traps.
OEF	• direct all run-off from OEFs to sediment traps • avoid placement of sodic waste material on final external batters • control surface drainage to minimise the formation of active gullies • use soil and rock mulching to armour long and/or steep slopes.
Residual Voids	• re-grade slopes and/or provide suitable erosion treatments on geotechnically unstable voids • use of rock mulch to control erosion • apply seed or tube stock as necessary to facilitate rapid re-establishment of suitable ground cover.
Dams	• retain useful water storages to support post mine use • rehabilitate any dam not required post mining by regrading embankments or removing walls as required, capping any residual saline material, replacing topsoil, ripping on the contour and seeding.
Drainage Channels	• provide protection in drainage lines (e.g. grass) where water velocity may cause scouring • drainage channels are sized to suit the catchment and climatic conditions.
On-site Haul Roads	• confine traffic to maintained tracks and roads • install sediment traps and silt fences where necessary to control sediment.

For the Project, MRM will continue the existing erosion monitoring program, which will be revised and implemented to include the following:

- monitoring of rainfall and climatic conditions
- assessment of vegetation cover at permanent, representative monitoring locations
- documenting evidence of failure or instability on rehabilitated slopes at permanent, representative monitoring sites
- reporting as part of annual environmental reporting requirements.

If necessary, sediment traps may be utilised as an indicator of soil loss. Where monitoring identifies the need for corrective actions to be implemented, alternative strategies will be investigated with reference to best practice guidelines and appropriate industry standards.

7.3.6 Topsoil Management

Topsoil is an important resource which is stripped from new disturbance areas before mining activities commence. Topsoil stripping typically involves the removal of 100 mm to 150 mm of material. Topsoil is stored on-site in stockpiles less than 5 m high for future use in rehabilitation and decommissioning.

Resources of topsoil directly impacted as a result of mining activities will be stripped ahead of mining for reuse in the Project's rehabilitation program. In order to maintain the integrity of vegetation in areas adjacent to disturbed areas, appropriate erosion, sediment and dust controls will be established prior to and during soil disturbance.

Prior to stripping the soil, vegetation on areas to be disturbed will be cleared and windrowed. The windrowed material may be retained for fauna habitat or burnt on site. Designated topsoil stockpiling areas will be prepared to minimise topsoil losses. Topsoil stockpiling heights and storage time will be minimised as deterioration of soil chemical, physical and biological properties can occur during storage.

Where practicable, soil degradation will be minimised by aiming to conduct topsoil stripping during dry periods rather than during, or immediately after prolonged wet periods to avoid soil compaction and excess erosion. Coordinating topsoil stripping programs with rehabilitation works to use freshly stripped soil in rehabilitation areas will maximise soil viability and the health of soil microfauna

In order to retain seed viability and keep the soil micro-fauna active, freshly stripped topsoil will be respread over areas to be rehabilitated, where practicable.

Stockpiles which need to be retained for extended periods and which have not revegetated naturally, will be seeded with plant species planned for the revegetation component in the rehabilitation program. This practice will also reduce the potential for weed infestation and resultant weed seed store accumulation in the stockpiled soils.

Expansion of the open pit will yield additional topsoil stockpiles that will be used for rehabilitation works within the Project area. Due to progressive rehabilitation efforts, topsoil usage will largely depend on the topsoil requirements within the Project area at the time of stripping to minimise double-handling of material wherever possible.

Topsoil stripped from the footprint of the North OEF will continue to be stored in multiple topsoil stockpiles immediately adjacent to the North OEF for use in its rehabilitation. Topsoil stripping will also occur at the footprints of the new South and East OEFs.

As of the third quarter of 2011, topsoil stockpiles stand at approximately 430,000 bcm distributed among the OEFs. The estimated Life of Mine (LOM) maximum topsoil stockpile is approximately 2,330,000 bcm.

Distribution of the current and LOM stockpiles is shown in Table 7-5.

Table 7-5 Existing and Project Topsoil Stockpile estimations

OEF	Existing Topsoil Stockpile (3rd Quarter, 2011) (bcm)	Maximum Topsoil Stockpile (LOM) (bcm)
North OEF	370,000	1,592,000
South OEF	0	678,000
West OEF	20,000	20,000
Other	40,000	40,000
TOTAL	430,000	2,330,000

7.3.7 Land Contamination

Considering the site has been an existing operation for some time, current potential contamination sources have been identified and appropriate mitigation has occurred. The area within and surrounding the Mineral Leases has historically been used for cattle grazing.

Activities proposed at the Project pose a limited risk of contamination for the following reasons:

- all chemicals and fuels will be appropriately stored in accordance with relevant Australian Standards
- existing facilities and procedures for the prevention of land contamination and management of wastes will be utilised or expanded for the Project.

Waste management strategies that will be implemented to minimise the risk of land contamination at the site and will promote sustainable waste management practices.

Further strategies for the prevention of land contamination due to the storage, spillage or disposal of hazardous materials will include:

- constructing appropriate spill containment facilities for all areas where bulk process reagents and petroleum products are stored and used
- maintaining a register of location and quantities of hazardous substances including their storage, use and disposal, which will be updated regularly
- training operators on the implementation of safe work practices to minimise the risk of spillage
- inducting contractors to be aware of environmental protection responsibilities
- developing remediation plans for any contaminated sites. Plans will be dependent upon the contaminant type and contaminant levels. The remediation plan will include the details of the contaminated land investigation that forms the basis of the remediation plan
- maintaining emergency plans to be used in the event of a spill.

The key planning document to prevent or minimise land contamination will be the Waste Management Plan. More information is available in Chapter 9 – Waste and Chapter 18 – Hazard and Risk.

7.3.8 Water Quality Management

Field observations and pit water quality monitoring will be continued at the Project in order to identify the potential development of low pH conditions or AMD within the Project area.

Although the identified AMD risk associated with mine operations and overburden placement is low, the site water quality monitoring program will include as a minimum pH, electrical conductivity, alkalinity, acidity, water hardness as $CaCO_3$ and sulphate speciation in terms of $CaSO_4$ and $MgSO_4$ in order to detect processes of sulphide oxidation and acid generation within mine landforms. A full suite of metals analysis will be completed where acidic pH and/or elevated SO_4 values are identified, as well as regular monitoring of run-off and leachate from the OEFs.

As mentioned in Chapter 2 – Regulatory Environment, Independent Monitor audit reports have verified that MRM has consistently demonstrated a high level of conformance with respect to procedures and systems. Reviews of monitoring data by the auditors have shown that MRM is not impacting significantly on the surrounding environment.

7.3.9 Visual Amenity

The Carpentaria Highway will be the main public viewing point of the Project operations. From this location the North OEF and the TSF will be visible. Other mine facilities will be less visible. A series of maps depicting line-of-site (at 2 m viewing height) from four positions on the highway have been generated to illustrate the visual impact caused by the Project (Figure 7-6 to Figure 7-10). The distance between the first and last of these viewing points is approximately 8 km. The speed limit on the Carpentaria highway is 110 kmph. Persons in vehicles travelling at this speed would experience the visual impact depicted in these simulations for less than 5 minutes.

7.3.9.1 Overburden Emplacement Facilities

The North OEF is currently 1.5 km to the east of the Carpentaria Highway. At its maximum extent during the Project, the western side will be approximately 3 km long and will face the highway. During the Project, the North OEF is planned be extended to approximately 500 m from the Carpentaria Highway. The top of the North OEF will be increased from 50 m to 80 m above the original ground surface, which is the height of the adjacent Mount Stubbs. The South and East OEFs will be located to the east of the pit and will not be visible from the Carpentaria Highway.

The OEFs will be built up gradually in stages over the life of the Project, during which time they will resemble an active large scale earthmoving operation. As the lower berms and batters are completed, the outer batters will be re-contoured as necessary and the berms will be rehabilitated using a process of topsoil addition, contour ripping, seeding and fertilising. In this way the visual appearance of the OEF from the highway will gradually change over the life of the mine from an active earthworks operation to an embankment with vegetation growing along the berms.

7.3.9.2 Tailings Storage Facility

Decommissioning and rehabilitation of Cell 1 at the TSF is currently in progress and will result in its appearance changing from an active tailings disposal area to one which will be covered with soil and revegetated. The surface peak height of Cell 1 is approximately 20 m above ground level. The rehabilitation process will ultimately extend to the other TSF cells upon their decommissioning. Cell 2 of the TSF is currently used for tailings deposition. The ultimate height of the spillway of Cell 2 will be approximately 35 m above ground level. Cell 3 is currently a water storage facility, which will eventually be used for tailings deposition. These TSF cells are currently approved under the 2005 EIA process.

The Project will include the addition of Cell 4 on the western side of the current TSF configuration. Stage 1 of Cell 4 has an initial embankment height of 22 m in 2012 for use as a water storage dam with a future increase of 6 m to RL61 m planned for 2034 when tailings deposition continues. Cell 4 is on the opposite side to the Carpentaria Highway not visible to traffic.

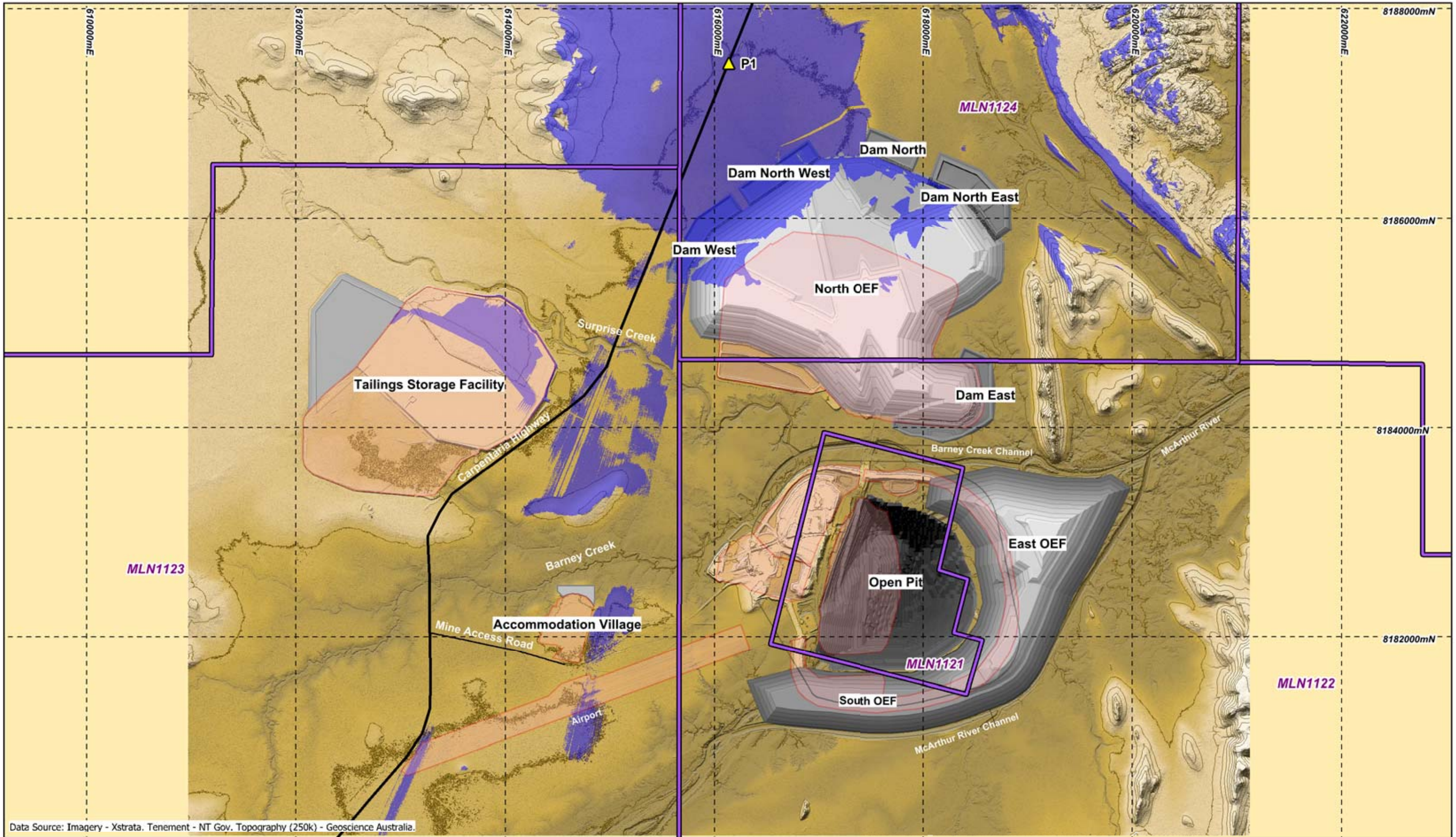
7.3.9.3 Processing Plant

There will be no significant visual changes to the processing plant within the Project facilities. New facilities will be located over 2 km to the east of the Carpentaria Highway, visually blending with the existing operations. Appearance will be similar to the existing plant and the visible components will have the visual effect of increasing the extent of the industrial facilities in an existing industrial landscape. However, most of the new facilities will be behind the existing flood protection bund screened from highway views.

7.3.9.4 Open Pit

The Project's open pit will not be visible from the Carpentaria Highway as it is below ground level, over 3 km away, surrounded by the existing flood protection bund. If any glimpses are seen, the view will be of the flood protection bund and the East and South OEFs.

S:\Projects\XZ003 MRM Extension EIS_MapInfo\Workspaces\XZ003_M013B.wor



METSERVE

xstrata zinc

0 1
Kilometres
Scale: 1:50,000 (A4)

LEGEND

- Project tenement
- Principal road
- Proposed Infrastructure Expansion
- Existing / Approved Footprint

Point of View

- Visible
- View point

McArthur River Mine
Phase 3 Development Project

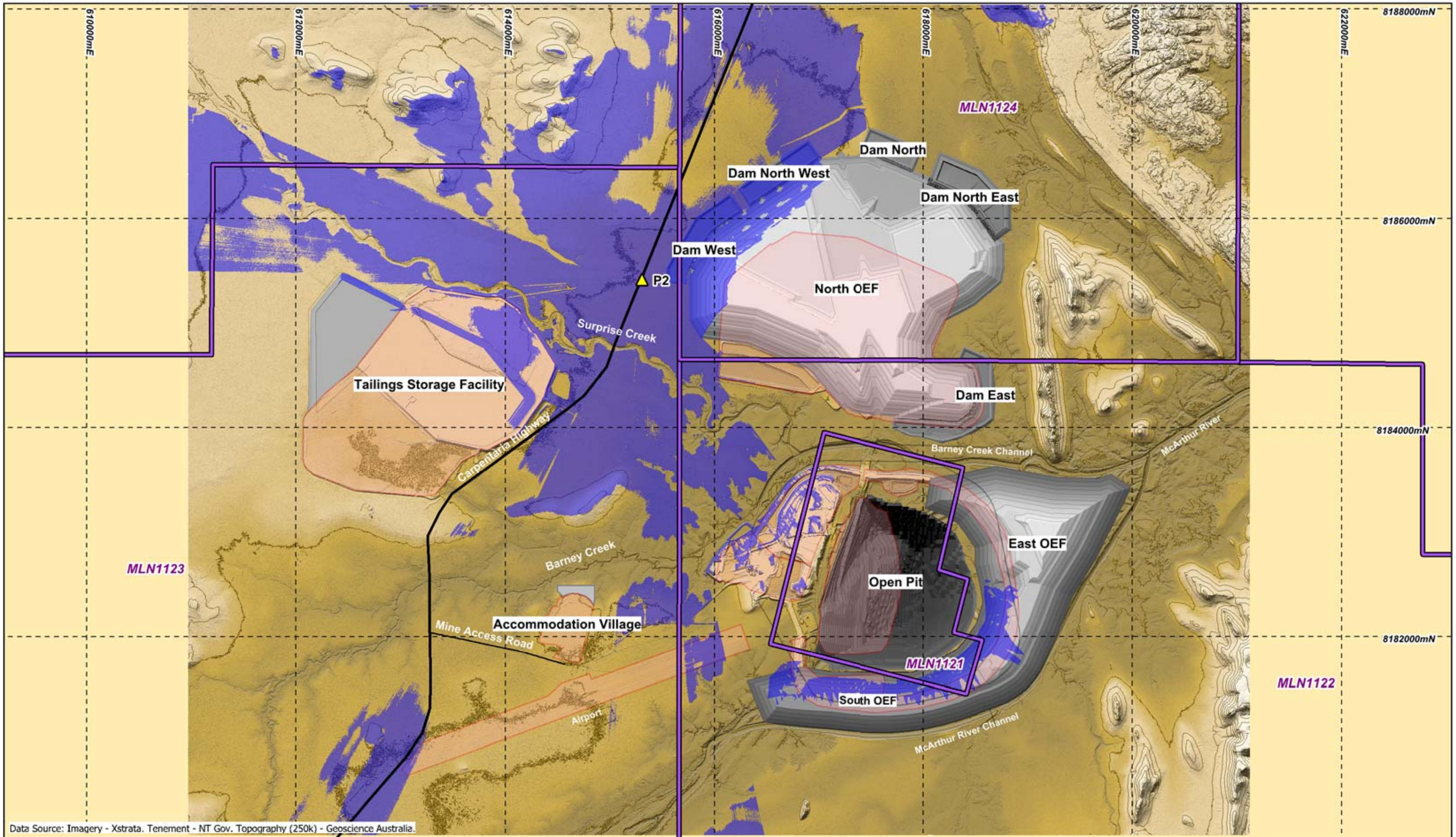
Visual Amenity View Point 1

13/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 6

S:\Projects\XZ003 MRM Extension EIS_MapInfo\Workspaces\XZ003_M014B.wor



Data Source: Imagery - Xstrata. Tenement - NT Gov. Topography (250k) - Geoscience Australia.

METSERVE

xstrata zinc

0 1 Kilometres

Scale: 1:50,000 (A4)

LEGEND

- Project tenement
- Principal road
- Proposed Infrastructure Expansion
- Existing / Approved Footprint

Point of View

- Visible
- View point

McArthur River Mine Phase 3 Development Project

Visual Amenity View Point 2

13/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 7

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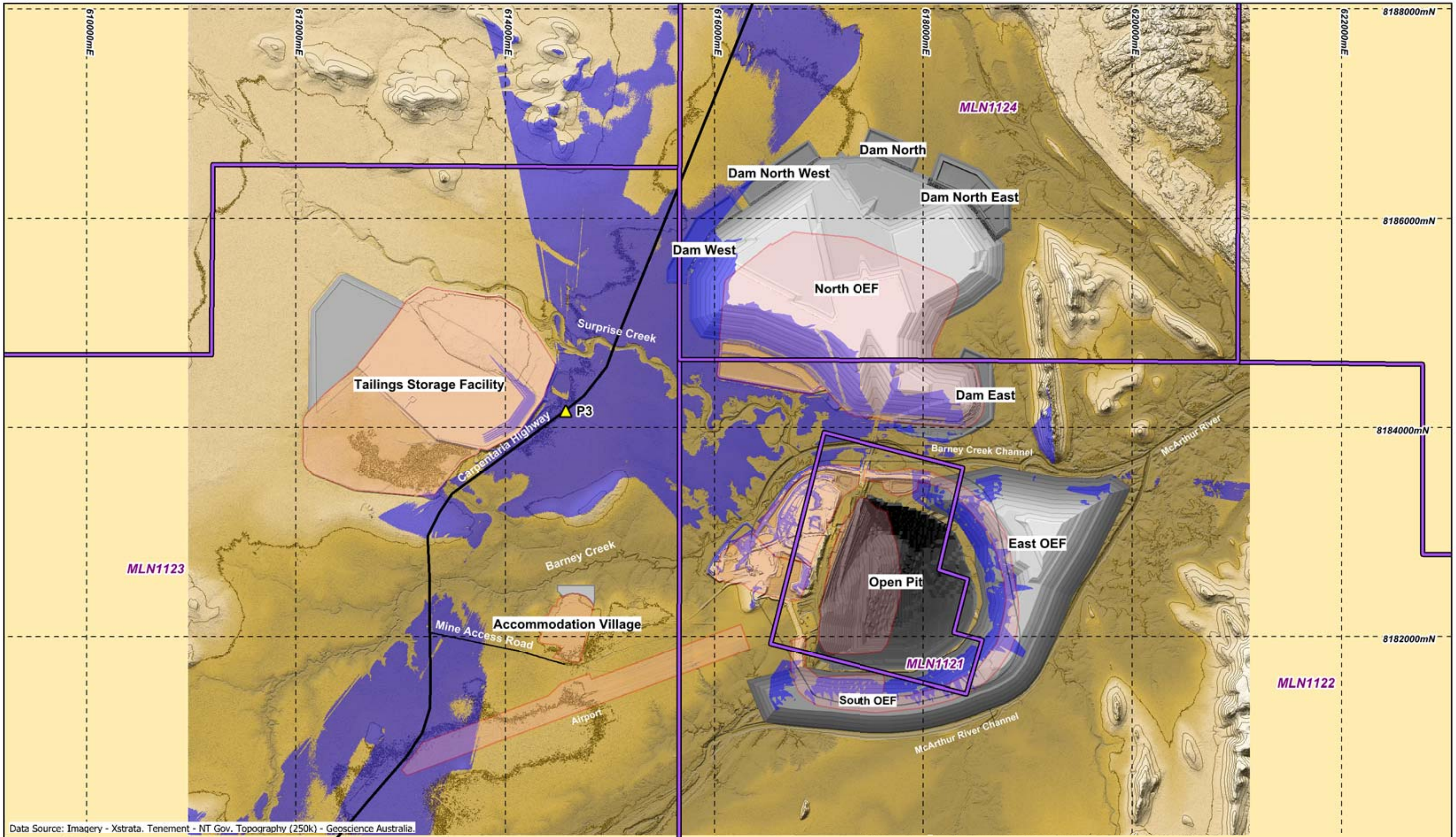


Data Source: Imagery - Xstrata. Tenement - NT Gov. Topography (250k) - Geoscience Australia.

METSERVE

xstrata zinc

0 1 Kilometres

Scale: 1:50,000 (A4)

LEGEND

- Project tenement
- Principal road
- Proposed Infrastructure Expansion
- Existing / Approved Footprint

Point of View

- Visible
- View point

McArthur River Mine Phase 3 Development Project

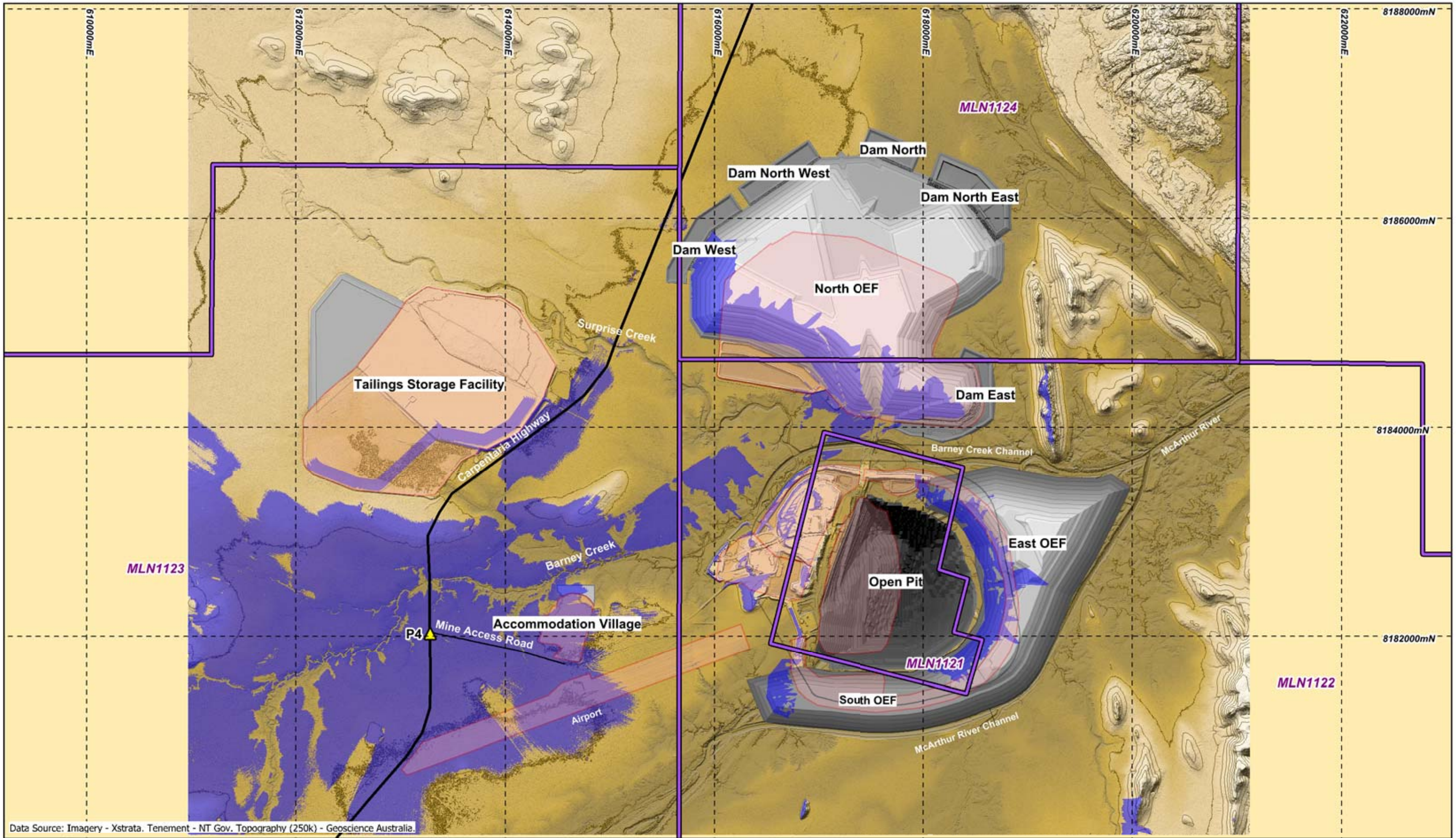
Visual Amenity View Point 3

13/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 8

S:\Projects\XZ003 MRM Extension EIS_MapInfo\Workspaces\XZ003_M016B.wor



METSERVE

xstrata zinc

0 1
Kilometres
Scale: 1:50,000 (A4)

LEGEND
- Project tenement
- Principal road
- Proposed Infrastructure Expansion
- Existing / Approved Footprint

Point of View
- Visible
- View point

McArthur River Mine Phase 3 Development Project

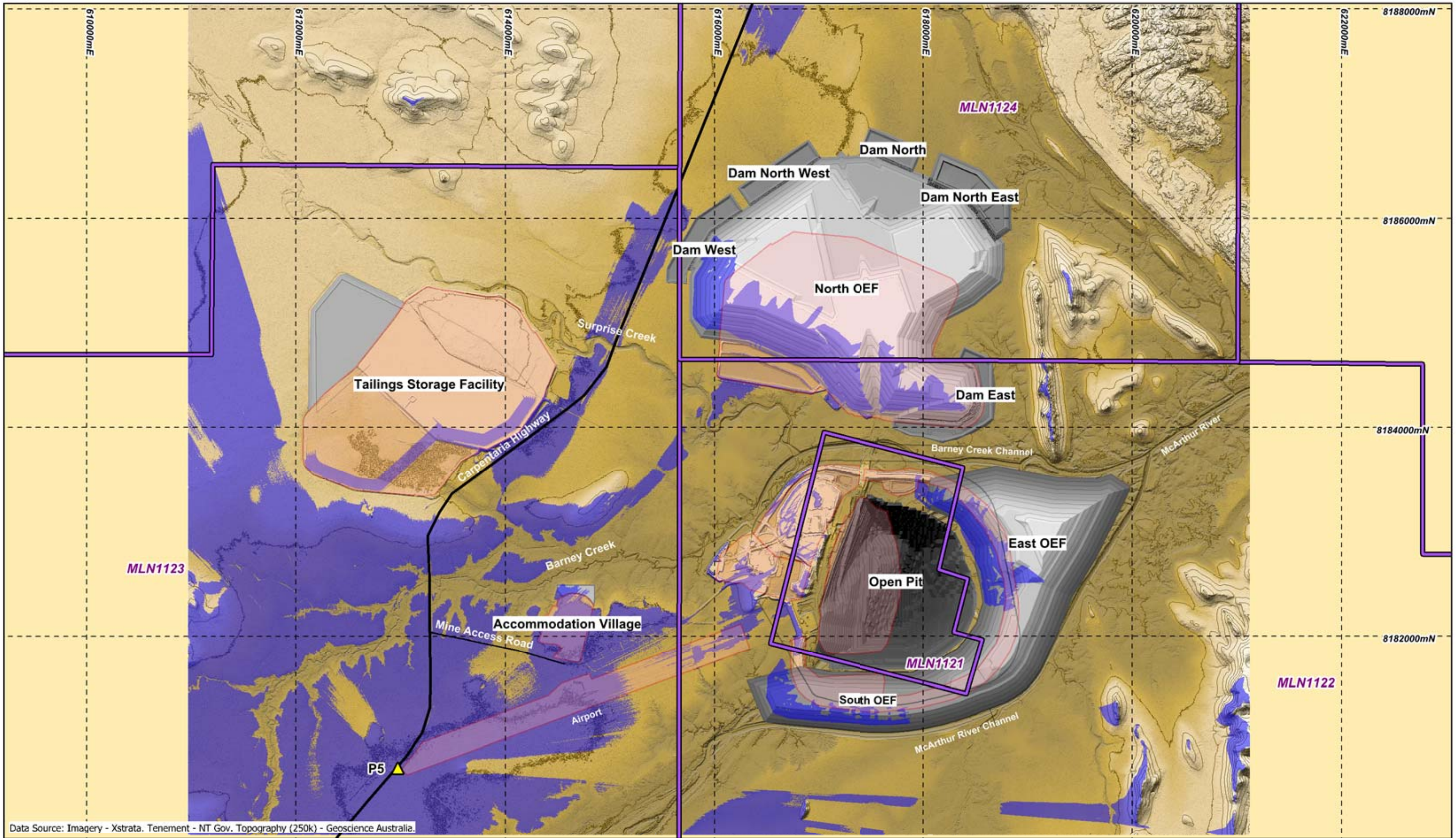
Visual Amenity View Point 4

13/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 9

S:\Projects\XZ003 MRM Extension EIS_MapInfo\Workspaces\XZ003_M017B.wor



METSERVE

xstrata zinc

0 1
Kilometres
Scale: 1:50,000 (A4)

LEGEND
- Project tenement
- Principal road
- Proposed Infrastructure Expansion
- Existing / Approved Footprint

Point of View
- Visible
- View point

McArthur River Mine Phase 3 Development Project

Visual Amenity View Point 5

11/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 7 - 10