10.0 Terrain and Soils

10.1 Geology

10.1.1 Regional Geology

The McArthur River district lies on the eastern margin of a north-west trending belt of Middle Proterozoic sediments that extend from the Gulf of Carpentaria in the north to Mt Isa in the south.

Much of the existing mine site and the proposed open cut area is underlain by alluvium associated with the McArthur River, and fractured rocks of the McArthur Group. This group is one of four groups in the McArthur Basin succession (the others being the Roper, Nathan and Tawallah) and is a thick sequence of Proterozoic rocks extending from the Queensland border to Arnhem Land. The McArthur Group occurs throughout the McArthur Basin but is thickest and best exposed near the mine site and immediately to the west. The McArthur Group, comprising an interbedded sequence of dolostones, sandstones, siltstone and shales, has a composite thickness of more than 4,000 m in the McArthur River Region. The group has been subdivided into two subgroups: the Umbolooga Subgroup, and the overlying Batten Subgroup.

The Bukalara Plateau, immediately east of the mine site, is a major feature of the region and is composed of flat-lying Bukalara Sandstone standing approximately 30 to 100 m above the surrounding countryside. The Bukalara Sandstone is of Early Cambrian age and occurs widely through the Gulf region. It forms a plateau over folded Proterozoic rocks and, in the area of the mine site, lies unconformably above the dolomite sediments of the McArthur Group. The sandstone is characterised by its joint pattern, distinctive cross-bedding and slight feldspathic nature.

Downstream from the mine site, the McArthur River descends to a coastal plain before reaching the Gulf of Carpentaria. The coastal plain is composed mainly of laterite, sandy soils and alluvium, but scattered residual Mesozoic and Proterozoic rocks (Roper Group) rise approximately 30 m above the plain, particularly in the vicinity of Borroloola.

The rocks of the McArthur River Basin are faulted, gently folded and non-metamorphic. The southern McArthur Basin is dominated by the Batten Fault Zone (also termed the Batten Trough) which is a north-trending extensively faulted zone approximately 70 km wide, the eastern edge of which is the Emu Fault Zone which comprises a major structural lineament in the project area.

10.1.2 Local Geology

Based on mapping by the Northern Territory Geological Survey (1991), the geological formations that occur within the general vicinity of the proposed mine open cut area are shown in Figure 10.1.

The oldest rock types within the project area are those of the Middle Proterozoic McArthur Group - Umbolooga Subgroup which comprise a sequence of interbedded cyclic dolostones, dolomitic siltstone,

Qa	Alluvium
Cz	Undifferentiated Residual Soils and Alluvial Deposits
Clb	Bukalara Sandstone

ROPER GROUP – Lower Roper Group

Prr	Crawford Formation
Pru	Mainoru Formation
Pri	Limmen Formation

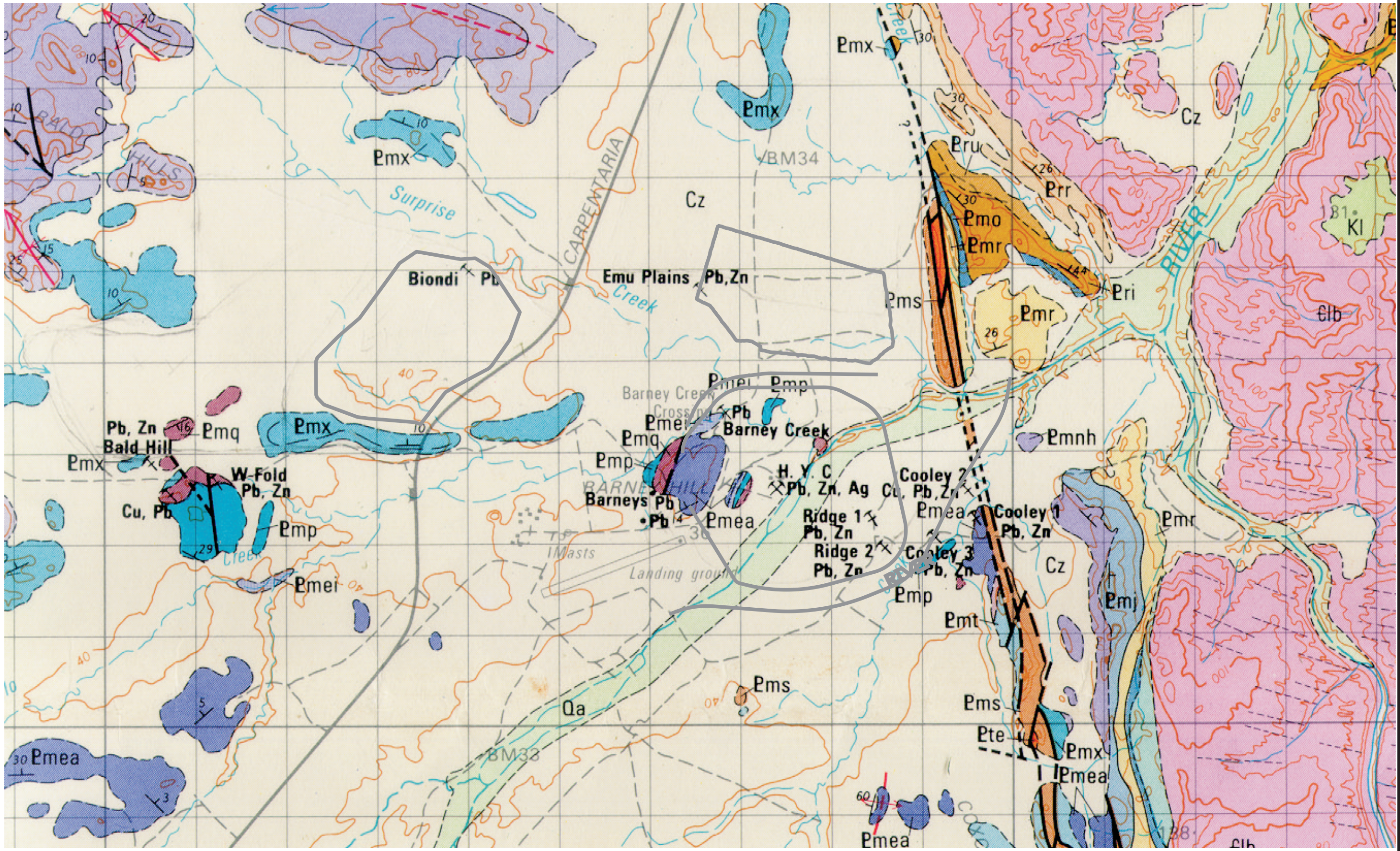
McARTHUR GROUP

Batten Subgroup

Pmo	Looking Glass Formation
Pmr	Stretton Sandstone
Pmj	Yalco Formation
	Hot Spring Member
Pmnc	Caranbirini Member

Umbolooga Subgroup

Pmx	Reward Dolomite
Pmq	Barney Creek Formation
Pmp	Teena Dolomite
Pmei	Mitchell Yard Dolomite Member
Pmea	Mara Dolomite Member
Pmt	Tooganinie Formation
Pms	Masterton Sandstone



0 0.5 1.0 2.0 3.0Km

SCALE - 1 : 80 000

SOURCE: 1:100000 GEOLOGICAL SPECIAL McARTHUR RIVER REGION, NORTHERN TERRITORY GEOLOGICAL SURVEY

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McARTHUR RIVER MINE
OPEN CUT PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Drawn: VH | Approved: CMP | Date: 18-07-2005

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GEOLOGICAL FORMATIONS

Figure: 10.1

Rev. B

A4

sandstone and shale. The sequence is overlain by the Batten Subgroup which consists of a succession of shallow marine deposits, chiefly dolomitic siltstone, cherty dolostone, pyritic shale, quartz sandstone and evaporites.

Local outcrops of quartz arenite, quartz sandstone, siltstone and shale of the Roper Group occur to the east of Emu Fault Zone in the north-eastern sector of the project area. These comprise the youngest succession of the Proterozoic McArthur basin sequence.

The Early Cambrian Bukalara Sandstone formation occurs to the east of the mine site, east of the Emu Fault Zone. The formation is unconformable on the McArthur Basin sequence and comprises fine to coarse-grained, sometimes pebbly feldspathic quartz sandstone.

Cainozoic Tertiary to Quaternary sediments occur extensively within the area. As mapped, they include gravelly residual soils underlain by bedrock, colluvial and outwash fan deposits, older alluvial and lacustrine deposits of clay, silt and sand.

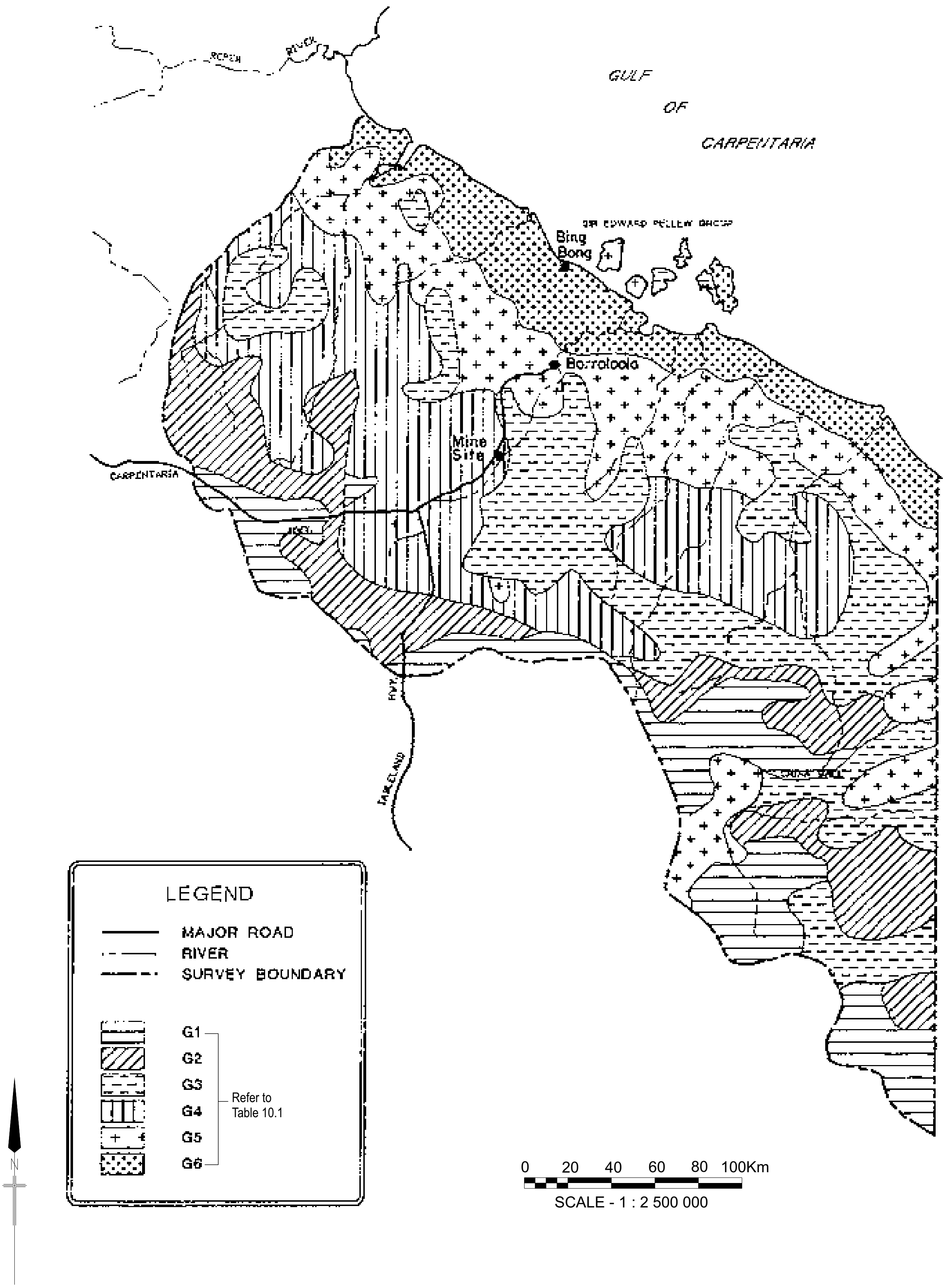
Quaternary Recent Alluvium consisting of silt, sand and gravel, occurs on the flood plains, levees, flood terraces and channel floors of the McArthur River and the Glyde River.

10.2 Land Systems and Land Units

10.2.1 Geomorphology

Aldrick and Wilson (1990) identified and described six geomorphic provinces in the Southern Gulf Region. Essentially each geomorphic province constitutes a landscape process zone, the major differences being related to differences in rates and types of landscape denudation and transport of sediment to the coast. The occurrence of those geomorphic provinces is shown in Figure 10.2 and the main characteristics of each province is summarised in Table 10.1.

Two geomorphological provinces occur in the vicinity of the mine area. The first includes the high rocky sandstone plateaux and ridges mainly associated with the Lower Cambrian Bukalara Sandstone (G3). The second comprises areas of high level valleys and depositional plains with a series of linear ridges of erosion resistant sedimentary rocks, which trend normal to the direction of drainage and inhibit the normal downcutting of the streams, resulting in a tendency for water impoundment upstream of these transverse linear ridge features (G4).



SOURCE: ALDRICK & WILSON (1990)

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McARTHUR RIVER MINE
OPEN CUT PROJECT
ENVIRONMENTAL IMPACT STATEMENT

GEOMORPHIC PROVINCES

Drawn: VH	Approved: CMP	Date: 12-11-2004	Figure: **10.2**	Rev. A
Job No.: **42625552**	File No. 42625552-g-011.cdr			A4

Table 10.1

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, footslopes 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 plateaux and ridges of resistant sandstone and igneous rock
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

10.2.2 Land Systems

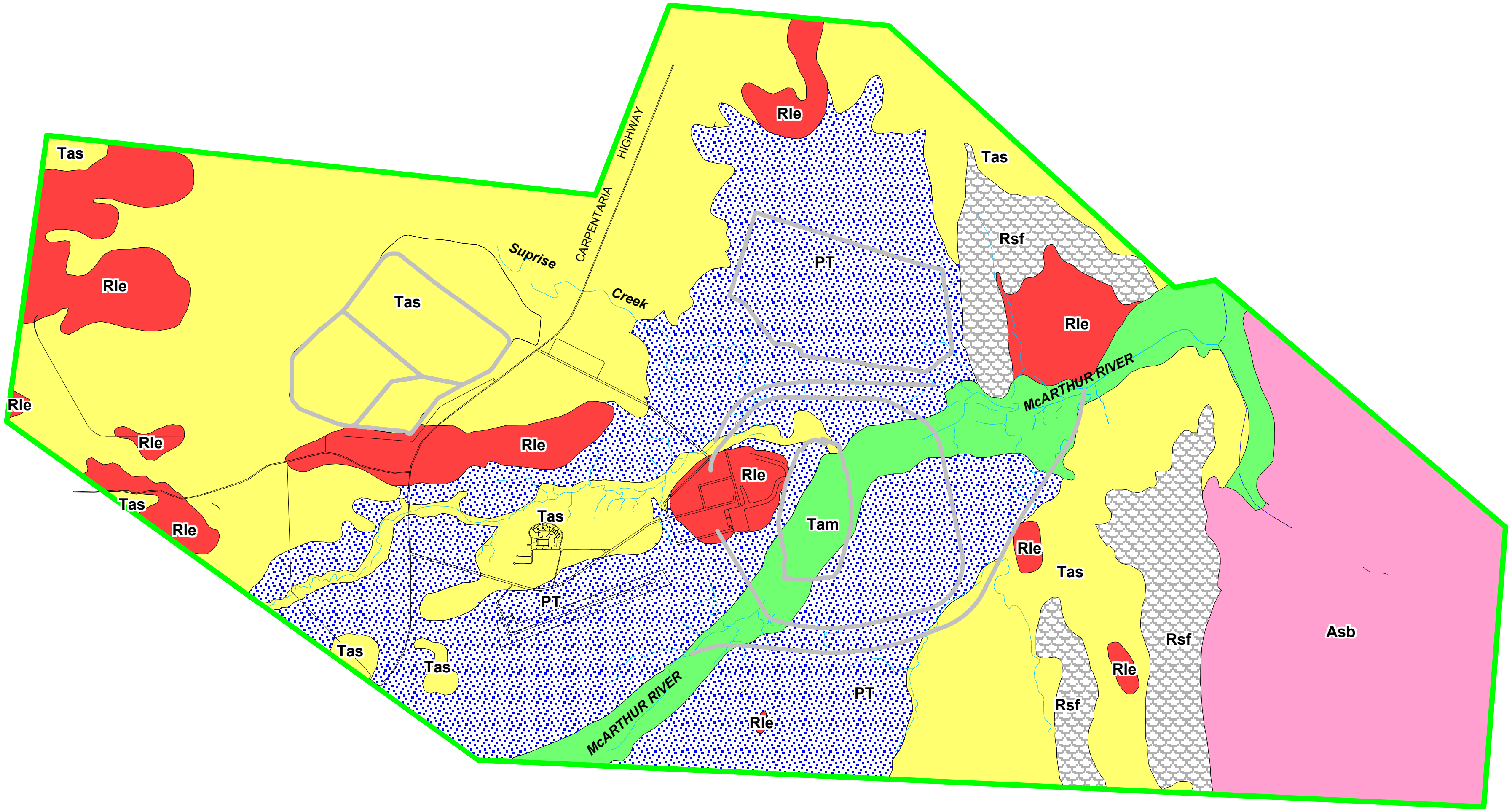
Six land systems have been identified within the project area (Figure 10.3). As described by Aldrick and Wilson (1990), these are:

- **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 argeillaceous 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 on *Eucalyptus dichromorphloia, E. miniata* and *E. tetrodonta.*

10.2.3 Land Units

The terrain of the project area has been assessed in terms of its geology, landform attributes and soil types. The terrain mapping has been carried out primarily from interpretation of aerial photographs together with field inspections and sampling, with reference to existing geological, topographical and land system information as a basis for identifying "terrain units" (land units). Methodology and sampling locations are presented in Appendix F.

As mapped, a terrain unit comprises a discrete recurring area of land that is considered have a particular combination of physical attributes in terms of bedrock, surface slope and form, and soil/substrate conditions. Accordingly, engineering and environmental characteristics determined at one location may be extrapolated to other occurrences of the same terrain unit. A key to the identification of terrain units in terms of their geological, landform and soil characteristics is shown in Table 10.2. Descriptions of the terrain units identified are given in Appendix F.1. The occurrence and distribution of terrain units within the mine site are shown in Figure 10.4



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

LEGEND

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.

N

0 1 2km

Scale: 1:65 000 (A4)

Horizontal Datum: AGD84, Zone 53

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McARTHUR RIVER MINE
OPEN CUT PROJECT
ENVIRONMENTAL IMPACT STATEMENT

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LAND SYSTEMS

Figure: 10.3

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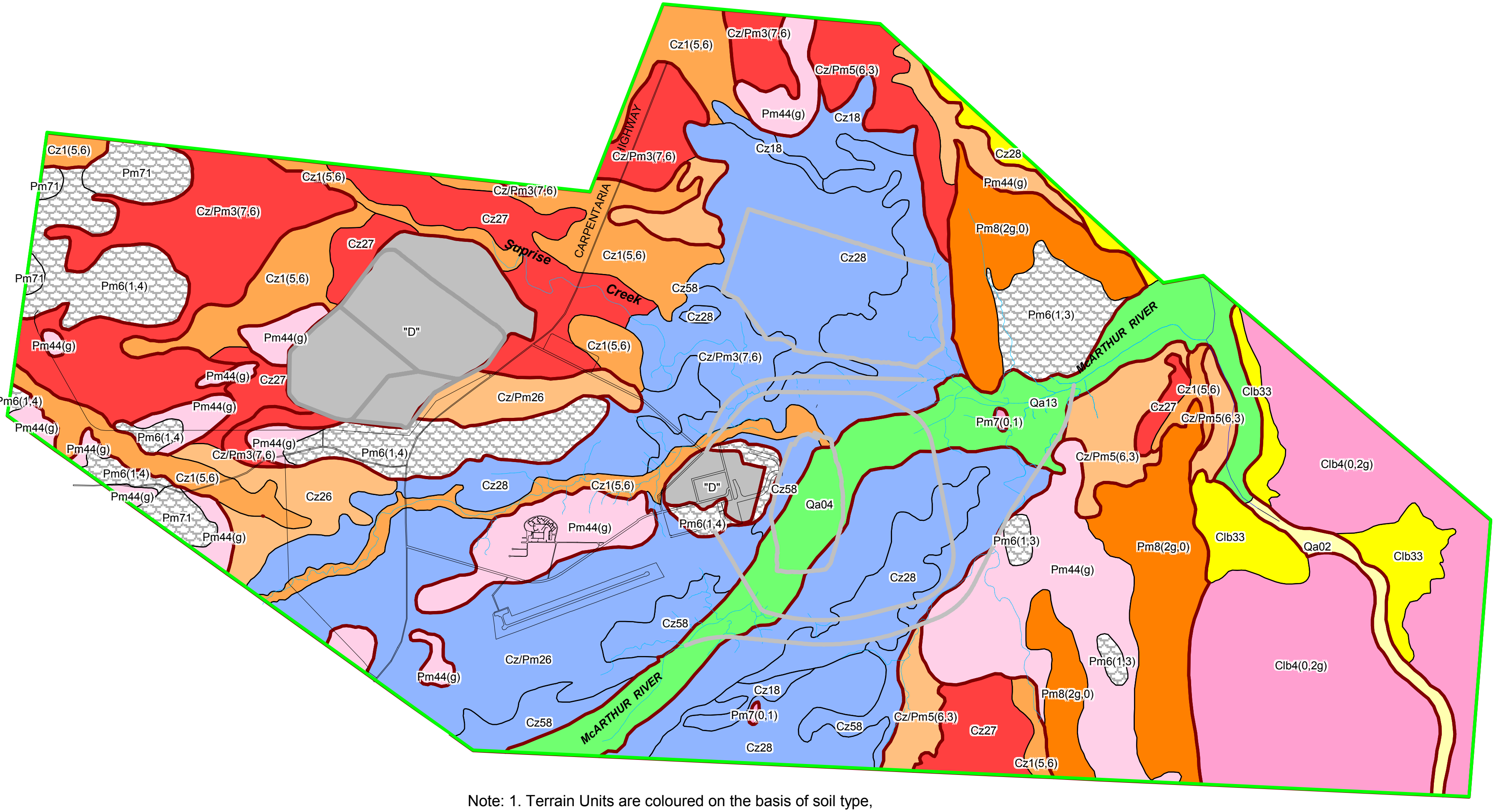

Note: 1. Terrain Units are coloured on the basis of soil type,
2. Refer to Table 10.2 for details of the Terrain Unit nomenclature

LEGEND

0	Rock outcrop locally with stony skeletal soils.
1	Mostly shallow gravelly or stony sandy to loamy Lithosols.
2	Deep sandy alluvial soils, Siliceous Sand.
2(g)	Shallow gravelly Siliceous Sands on weathered sandstone.
3	Shallow to deep sometimes gravelly Earthy Sands
4	Deep Loamy Alluvial Soils
4(g)	Shallow Gravelly Loams over weathered rock.
5	Loamy surface yellow mottled duplex soils - Podzolic/Solodic Soils.
6	Gradational Massive Yellow Earths
7	Massive or Structured Red Earths.
8	Grey and Brown Cracking Clay soils.
"D"	Disturbed Areas.
	Geological Regime
	Terrain Unit Boundary

N

0 1 2km

Scale: 1:65 000 (A4)

Horizontal Datum: AGD84, Zone 53

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McARTHUR RIVER MINE
OPEN CUT PROJECT
ENVIRONMENTAL IMPACT STATEMENT

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SOILS

Figure: 10.4

Rev: C

A4

Table 10.2

Key to the Identification of Terrain Mapping Units

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 drainageways, generally poorly-drained floodprone 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 floodprone 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 sitstone 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).
		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, footslopes, 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.

10.3 Soils

10.3.1 Physical Characteristics

The soils in the mine 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 soils is provided below.

- **Skeletal Soils –** Rock 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 acid pH and diffuse mottling in the deep subsoil.
- **Siliceous Sands** – Shallow gravelly brown sands with neutral to slightly acid 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.

Overburden Emplacement Facility

The terrain within the overburden emplacement facility (OEF) primarily comprises a near level to gently inclined alluvial backplain of the McArthur River with deep grey and brown cracking clay soils. That unit is bordered along the southern and eastern boundaries of the OEF by locally intensively dissected and eroded marginal slopes to drainage which also comprise deep mostly brown cracking clay soils.

The cracking clay soils are generally deep (>2.0 m) with strongly structured surficial soil horizons which have cracking extending to a depth of about 0.8 m during the dry season. The deeper subsoils (>1.2 m) are calcareous and locally gypseous with massive soil structure and very low permeability/hydraulic conductivity.

To the north and west of the OEF, the terrain comprises gently undulating plain with shallow to medium deep red and yellow earth soils underlain by weathered dolomite or dolomitic siltstone and local low gravelly rises. Intervening broad near level to broadly depressional drainage flats also occur, which have moderate to deep silty to loamy surface duplex soils and mottled yellow earths with medium to heavy clay subsoils.

Tailing Storage Facility

The terrain in the proposed tailings storage facility area comprises a gently inclined and broadly undulating plain. The soils are mostly medium to deep red and yellow with medium to heavy clay subsoils which grade through clayey gravels to weathered rock with dolomite or dolomitic siltstone at depths varying between about 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.

Open Cut Area

The terrain in the proposed open cut area includes areas of near-level alluvial backplains and dissected marginal slopes where adjacent to the McArthur River. The soils comprise mostly deep brown and grey cracking clay soil on the floodplains and marginal slopes to drainage with deep loamy alluvial soils which occur within the fluvial corridor.

New River Channel Alignment

From the departure point on the McArthur River, the realigned channel initially traverses a short section of the fluvial corridor, crosses the marginal slopes and river backplain, then follows a small tributary stream line which separates the alluvial backplain from the undulating pediplain to the west. The eastern sector of the new channel crosses dissected marginal slopes adjacent to the McArthur River fluvial corridor before rejoining the original course of the river. The surficial soils intersected along the alignment are diverse and range from fine sandy clay loams within the river corridor, to cracking grey and brown clays on the backplain and marginal slopes, to shallow gravelly sandy to loamy soils, yellow earths and earthy sands.

Barney Creek Realignment

The proposed realignment of Barney Creek crosses moderately intensively dissected and eroded marginal slopes of the alluvial backplain mostly in deep cracking and highly erodible clay soils.

10.3.2 Chemical Characteristics

Details of the pH, salinity and dispersion characteristics of the soils for the area are given in Appendix F.2. These characteristics can be summarised as follows:

- **Soil 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) in the deeper subsoils.
- **Dispersion -** With the exception of 3 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 soils profiles.

The chemistry of some soils adjacent to existing operational areas has been affected by lead and zinc contained in dust from materials handling activities. The significance of these effects is discussed in Section 8.4.1.

10.3.3 Topsoil Management

Existing Resources

Topsoil resources contain seedstock, micro-organisms and nutrients necessary for plant growth. Approximately 32,500 m^3 of topsoil has been stockpiled along the western wall of the tailings storage facility. This topsoil was stockpiled in 1999 and 2001 during the earthworks associated with the facility's development. A further 10,400 m^3 is stored along the eastern side of the tailings storage facility. This topsoil is planned to be utilised for rehabilitation of the currently active tailings storage cell.

Topsoil stockpiles have been revegetated where required in order to minimise erosion and have been constructed in such a manner to maintain the viability of the topsoil. Topsoil stockpiles are less than 2 m in height.

Additional Resources

As part of the open cut project, additional quantities of topsoil will become available. These will be predominantly from the area of the open pit, overburden emplacement facility, and the areas proposed for new river and creek channels. These areas contain reserves of topsoil and useable subsoil resources that will be suitable for rehabilitation purposes.

The soil sampling and testing undertaken for the soil survey and land capability assessment has also provided the basis for assessing the quality and indicative soil stripping depths of the topsoil resources present within the areas to be disturbed by the open cut operation. Indicative topsoil/subsoil stripping depths and volumes have been determined for the terrain units that occur within each of the main infrastructure development areas. The subsoil resources identified represent occurrences of lesser quality but useable soil resources that could be used to supplement topsoil resources should there be a shortfall of good quality topsoil.

Table 10.3 summarises the topsoil resources available in the operation areas and further details are provided in Appendix F.5.

Table 10.3

Additional Topsoil Resources

Area	Topsoil		Subsoil	
	Depth Range (mm)	Volume (m^3x 1,000)	Depth Range (mm)	Volume (m^3x 1,000)
Overburden Emplacement Facility	0-200	490	200-500	730
Open Pit	0-700	600	300-1,200	520
New River Channel	0-700	110	200-1,200	110
New Creek Channel	0-200	25	200-500	40
Total		1,225		1,400

Topsoil will be used to improve the chances of successful revegetation of areas disturbed during construction. Topsoil that has been stripped and is excess to these requirements will be stockpiled for subsequent use in the mine's rehabilitation program.

Stripping of the topsoil and any subsoil layers will be planned, where practicable, to be undertaken during the dry season and not following any prolonged wet periods. This will reduce the potential for soil compaction and for degradation of the soil structure due to mechanical handling of soils when in a wet condition.

In all cases, care will be exercised during the removal and replacement of the topsoil material to ensure that physical deterioration of the soil is avoided and that excessive soil compaction does not occur during the stockpiling or replacement processes. Where practicable, freshly stripped topsoil will be respread over areas to be rehabilitated in order to retain seed viability and to keep the soil micro-fauna active.

Stockpiles which are 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.

Control of erosion will be a high priority both during the site clearing and topsoil stripping stage and in relation to the long-term stability of topsoil stockpiles to be preserved for rehabilitation purposes. Site clearing and soil stripping operations will be carried out progressively, where practicable, and immediately prior to the commencement of construction activities in the particular area.

Clearing of vegetation will be limited to that considered necessary for the efficient performance of construction activities. Where the construction activities are likely to extend over a lengthy period of one to two months or more, temporary erosion control measures will be installed to limit surface runoff and restrict sediment loss from any de-vegetated surfaces.

Where topsoil is required to be stockpiled for extended periods, the material will be placed a pre-determined area free from regular activities and not within a waterway or drainage path. The material will be placed in low mounds constructed to a maximum height of 2 m as is the case for the existing stockpiles.

When the topsoil is eventually removed from the stockpile, an end-loader/dump truck operation will be used. This material handling method will reduce structural degradation often associated with scraper operations. It will also facilitate mixing of the upper and lower levels of the stockpile and the more even spread of mico-organisms and seed stock.

10.4 Land Capability

Land capability ratings indicate the capacity of land to sustain the impact of agricultural (cropping) and/or pastoral use. The assessment of pre-mining land capability serves to indicate the target level for land use and rehabilitation requirements post-mining.

Agricultural use implies broadacre rainfed cropping and infrastructure including land clearing and cultivation. Pastoral use implies the upgrading of land with limited clearing and occasional cultivation for the introduction of improved or native pasture species. The requirements for fertiliser use and the provision of watering points, access tracks and fencing is also implied.

In order to determine land capability classes at the mine site, the approach used by Aldrick and Wilson (1990) has been 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.

The limiting factors considered include:

- Soil and site drainage conditions.
- Soil moisture holding capacity.
- Soil physical and chemical conditions.
- Soil erosion potential.
- Adverse site factors including rockiness, slopes, intensity and degree of dissection, flooding etc.

Table 10.4 summarises the land capability ratings for both cropping and pastoral use, based on the occurrence of land systems which occur within the mine site (Figure 10.3).

Table 10.4

Land Capability for Crop and Pasture Production

Land System	Land Capability Class (1 = best, 5 = worst)		
	Agricultural (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.

10.5 Soil Erosion

10.5.1 Erosion Potential

The lands of the region are prone to erosion due to the high intensity rainfall events during the summer period, and the inherent erodibility of the soils and landscapes.

The majority of the soil types that occur within the mine site contain some slightly to moderately dispersive soil layers and in places strongly dispersive soils may occur. Within the project area, parts are relatively stable and other parts are prone to active erosion.

In the areas of higher relief, the dominant soil types are lithosols together with abundant rock outcrop. Although surface runoff from those areas may be very rapid, the very gravelly nature of the soils and the erosion resistant rock types, limit the potentially high impact of surface sheet erosion and gullying.

Some areas have a moderate incidence of and potential for erosion, particularly if overgrazed or subject to intensified use. In the soils on the older alluvial outwash plains and terraces of the Surprise land system and the lower slopes of the Emmerugga land system, surface scalds are evident on the flatter red earth occurrences and they are potentially prone to sheet erosion due to wind and surface runoff. These soils may also have a moderate to high potential for soil dispersion and erosion, particularly where drainage becomes concentrated along tracks and on slopes towards drainage lines. In these locations some local gully erosion is currently occurring.

The river backplains of the Unnamed land system, includes extensive areas of brown and grey cracking clay soils which tend to have dispersive soil layers, particularly in the subsoil. Exposure of those soil layers either in cuttings or in existing natural gully systems can lead to rapid regressive gully development, with associated local land degradation. Terrain Unit Cz58 is one such area where active gully erosion is occurring on both sides of the McArthur River (Figure 10.4).

The alluvial floodplains, levees, and terraces of the McArthur River are generally seasonally inundated. Soil slippage in the high alluvial banks of the river is common, resulting from rapid rise and fall in river levels and local scour and undercutting.

10.5.2 Erosion Management

An Erosion and Sediment Control Management Plan will be developed and implemented throughout construction and operation phases of the project. It will contain control measures based on the Engineering Guidelines for Queensland for Soil Erosion and Sediment Control (Institute of Engineers Australia *et. al.,* 1996), The Department of Conservation and Land Management (1992), and also from Applegate (1983). Typical control measures are discussed below.

All significant runoff with potential to cause erosion and sedimentation from the mine area will be contained within the flood protection bund. The bund wall will be uniformly graded to drain into the bunded area. In addition, the bund wall will prevent wet season surface water inflows (including flooding) into the area. Within the bunded area, surface water drainage will be directed to a number of settlement ponds and away from the open pit.

As discussed in Section 12, runoff from the operational areas of the OEF will flow to either the PAF (potentially acid forming) containment pond or the NAF (non acid forming) sediment pond. The PAF containment pond will be designed with a 1 in 100 year overflow risk while the NAF pond will be designed to contain 50 mm of erosion from its catchment. This water management system will ensure that erosion from the OEF will be managed with minimal impact on downstream water quality.

Erosion on construction areas cannot be eliminated completely, but measures will be taken to minimise the impact by:

- Limiting the area disturbed, and clearing progressively, immediately prior to construction activities commencing.
- Safeguarding the surface layer by stripping and stockpiling topsoil prior to construction.
- Using temporary soil diversion mounds to control runoff within, and divert water away from, the construction site where practicable.
- Minimising the period that bare soil is left exposed to erosion.
- Using sediment traps/silt fences etc. to minimise off-site effects of erosion.

- Where access is required for temporary use only, lightly ripping disturbed areas, restoring those areas to a stable condition and revegetating as soon as practicable following the completion of construction.
- Where significant disturbance of the ground surface is necessary, removing topsoil from the area to be disturbed and stockpiling it as work commences. Upon completion of work, the topsoil will be respread over any exposed subsoil areas, and the areas of disturbance stabilised by establishing suitable species of vegetation.
- In areas where stormwater diversion channels and culverts are proposed to divert flow and control runoff, providing outlets with scour protection as necessary.
- Grading service tracks to a crown and providing efficient surface drainage to prevent runoff eroding either the road surface or the adjacent land. Where necessary, low mounds angled across the track will be construction to divert runoff (at non-erosive velocity) into adjacent areas.
- Ripping, seeding and fertilising all temporary construction tracks and associated disturbed areas when construction is completed. Stockpiled topsoil will be respread before sowing. On steeper slopes the seeded areas will be protected if necessary.

Where practicable, procedures for the construction and maintenance of the sediment traps will include the following:

- Sediment traps will be preferably excavated below the natural ground surface. Where it is necessary to construct embankments to form a sediment trap, embankments will to be adequately compacted with batter slopes commensurate with the available materials.
- Sediment traps will include a high flow 'spillway' outlet to safely pass floods without breaching the basin. Spillways will be sized for 10 year Average Recurrence Interval events.
- Sediment traps will include adequate provisions for access for regular monitoring and maintenance to clean out captured sediments.
- Subject to constraints of available space and topography, sediment traps will be constructed with a plan shape aspect ratio of at least 3 to 1 (length measured from inlet to outlet in relation to width).
- Sediment traps will be sized with sufficient sediment storage capacity to match the combination of the rate of sediment 'supply' and planned frequency of sediment removal from the basin.
- Clean water diversion drains will be installed to divert clean stormwater flow from undisturbed areas away from the sediment traps. Diversion drains will also be installed as necessary to direct sediment-laden stormwater flow to the sediment traps. Diversion drains will to be sized for 5 year Average Recurrence Interval storm events with flow velocities limited to 1 m/s.

10.6 Seismicity

10.6.1 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 have been obtained from the Bureau of Mineral Resources (BMR) in Canberra, and the available data are summarised below.

The BMR earthquake data file contains all recorded events of all magnitudes since 1921. Figure 10.5 shows the location of the larger events recorded within a 500 km radius of the site. There is no recorded evidence of past earthquake activity in the immediate area of the mine. Furthermore the mine site is located in the area of lowest earthquake hazard potential.

The possibility of re-activation of geologically ancient faults is considered remote. Seismic design for the open cut will be based on the level of ground vibration associated with a design earthquake event appropriate to the region.

10.6.2 Liquefaction

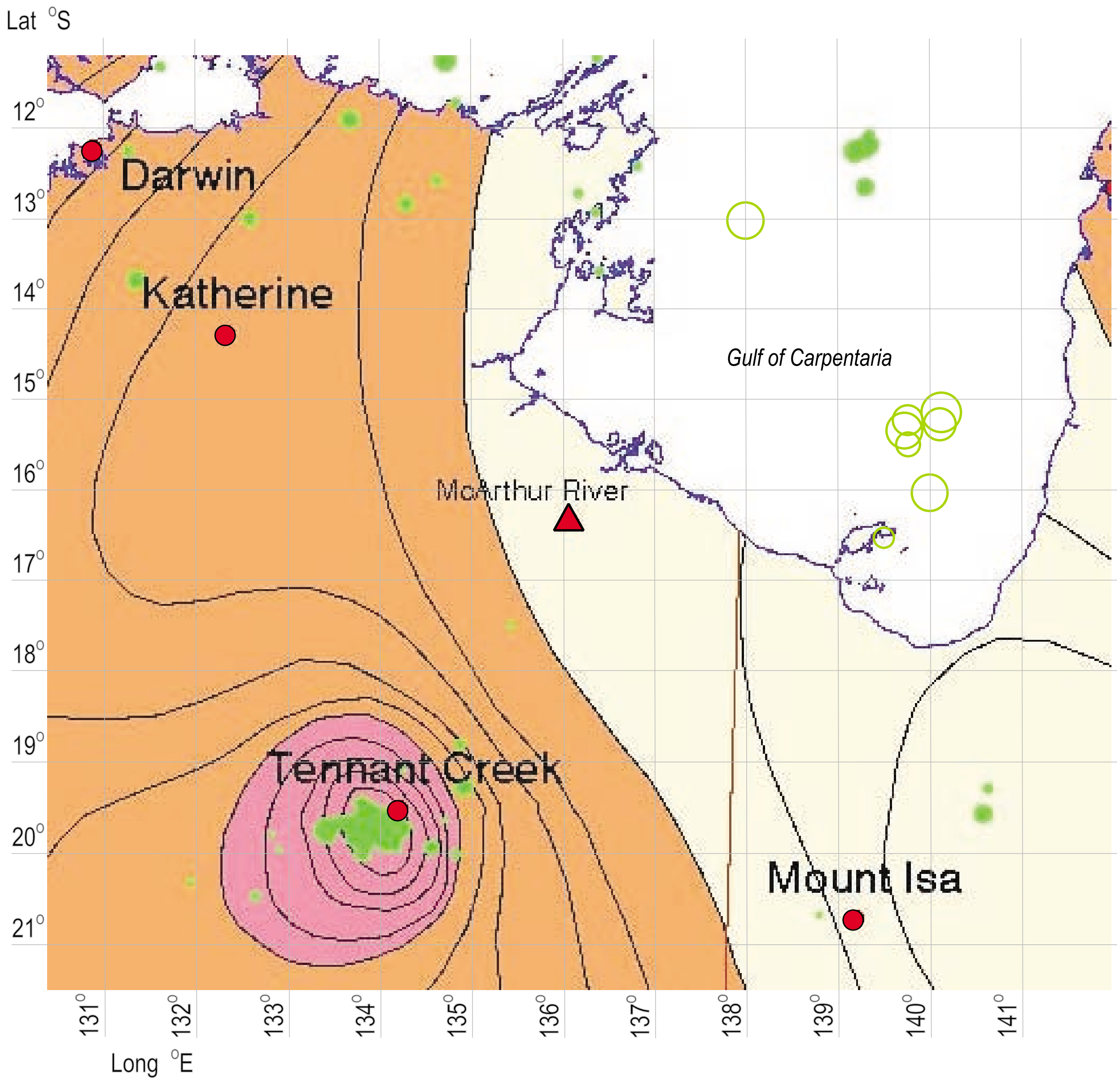
Seismic liquefaction may occur in saturated loose sandy and silty deposits as a result of pore water pressure increases following undrained loading during and after earthquake activity. The development of soil liquefaction in a given soil deposit is closely linked to the intensity and duration of seismic shaking, the relative density of the soil, the soil particle size distribution, and the location of the water table.

The test pits across the site (Appendix F.3.) show that the *in situ* soils on the site are predominantly very stiff to hard clay and clay loam. Consequently their liquefaction potential will be low due to the strength of these materials and small amount of sand present.

Tailings stored in the tailings disposal facility are extremely fine with more than 80% of the particles less than 7 μm. Because the vast majority of the stored tailings has a fine particle size in the clay/silt range rather than the more coarse sand range, the potential for liquefaction of the stored tailings is considered to be low. However as the concept design for the TSF incorporates the construction of portions of the perimeter bund across Cell 1 of the existing TSF, a liquefaction assessment of the tailings will be undertaken as part of the detailed design of the TSF. The liquefaction assessment will be undertaken in general accordance with the ANCOLD 1999 Guidelines for Tailings Dam Design.

10.6.3 Design Standard

The seismic design standard for the project is Australian Standard AS 1170.4-1993 ‘Minimum Design Loads on Structures – Part 4: Earthquake Loads’. This Standard requires that the earthquake design for structures incorporates an assessment of all relevant factors including ground acceleration coefficients of the area, site factors, the importance or consequence of failure of the structure, and the structure type. The proposed project will comply with this standard.



PLOT OF ASSESSED EPICENTRES AND MAGNITUDES OF SEISMIC EVENTS (>ML 2.5) WITHIN 500km RADIUS OF SITE UP TO 27/05/2003

ML Mar 1921 to Feb 1992
- Magnitude 3.0
- Magnitude 4.0

ML Feb 1992 to May 2003
- 2.5 - 2.8
- 2.8 - 3.3
- 3.3 - 3.8
- 3.8 - 4.4
- 4.4 - 5.2

EARTHQUAKE HAZARD POTENTAL
(10% chance of being exceeded in 50 years)

- GREATER THAN 0.10
- BETWEEN 0.05 AND 0.10
- LESS THAN 0.05

N

0 100 200 300 400Km

SCALE - 1 : 8 000 000

SOURCE:

xstrata / URS	McARTHUR RIVER MINE OPEN CUT PROJECT ENVIRONMENTAL IMPACT STATEMENT		**REGIONAL SEISMIC EVENTS**
Drawn: VH	Approved: CMP	Date: 12-11-2004	Figure: **10.5** — Rev. A
Job No.: **42625552**	File No. 42625552-g-014.cdr		A4

The seismic acceleration coefficient map of the Northern Territory is used to obtain the ground acceleration factors. Site factors are based on data obtained from on-site geotechnical investigations. The importance of the structure is assessed on the basis of:

- how essential it is to post-earthquake recovery;
- how many people would be at risk if it failed; and
- the environmental consequences of structural failure.