4.1 Regional Conditions

The Princess Louise and North Point Project Area is situated within the Pine Creek Geosyncline, which is an early Proterozoic intracratonic sedimentary basin forming part of the North Australian Orogenic Province (Ahmad *et al* 1993).

Ahmad *et al* (1993) classifies the lithography in the project area as Gerowie Tuff, containing siltstone, phyllite, argillite and tuffaceous chert. Towards North Point deposit, the lithography also includes Mount Bonnie Formation, which contains shale, mudstone, siltstone and feldspathic greywacke (Ahmad *et al* 1993).

Storey (1969) also describes the local geomorphology as belonging to the Bend Land System, with erosion remnants of siltstone, sandstone and quartz on slightly weathered metasediments. In between the hills lie a network of alluvial flats and channels incised into deep alluvial sands and loams, and in places, clays exist. The remainder consists of colluvial wash slopes with veneer of siltstone flakes and sub-angular stony quartz over stony quartz in a loamy mix (Storey 1969).

The project area is in the upper region of the Adelaide River catchment (Ahmad *et al* 1993). The terrain in the area is strongly undulating with steep hilly ranges and strike ridges (AGSO 1998). Landforms in the project area are described by Ahmad *et a*l (1993) as “Uplands”, with low steep-sided hills separated by narrow valleys.

According to the existing Mine Management Plan (BOPL 2006), the three main geomorphic elements in the project area are hill slopes and summits, colluvial wash slopes, and alluvial flats and channels. Colluvial wash slopes are the dominant land unit within the project area and comprise of gentle slopes, which fringe the hill slopes and summits. Soils are predominantly loamy lithosols derived from metamorphosed slates and shales with some earthy sands and red/yellow earths. Soils are skeletal and generally acidic (BOPL 2006).

Princess Louise deposit is located on a small hill, with steep valleys on the north-east and southern sides. The North Point mine site is flatter, with a shallow gradient to the north-west; there is a ridge line to the east of the pit, however little mining will be undertaken on the eastern side.

Previous mining and exploration activity has occurred over most of the mining area on both sites, and this has removed most of the topsoil and associated organic matter. The remaining land surface is gravely and rocky.

The land system covering Princess Louise and North Point is characterised by Williams *et al* 1969 as Rumwaggon Land system. This consists of hills or raised gravel patches and intervening alluvial flats in south-west; skeletal soils and gradational yellow loamy soils on hill slopes, texture-contrast alkaline soils on flats, woodland (semi-deciduous eucalypt) or stunted woodland (mixed) on hill slopes, savannah woodland on flats. Further information is described in Table 4.1.

Table 4.1 Description and percentage distribution of geomorphology, soils and vegetation.

Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	45%	Low erosional rises or convex knolls: up to 18 m high; slopes to 25%; varied lithology (weathered sandstone, siltstone, chert, grey-wacke, and deeply weathered shales and sandstone); frequent rock out-crop on slopes above 8%; discontinuous stony regolith on steeper slopes, even layer of siltstone flakes and gravels on gentle slopes, buried pisolitic laterite cropping out locally, sheet wash and elevation.	Skeletal soils and Elliott (gradational yellow loam to clay); rare Angelara (clays derived from weathered alkaline shales)	Woodland or stunted woodland height 9 m and less, visibility 180 m, eucalypt and non-eucalypt over scanty tall, mid-height, or short grass (*E.clavigera*, *C.ferruginea*, *E.alba*, *C. foelscheana*, *E.tectifica*, *Erythrophleum*, *Xanthostemon*, *Cochlospermum, Grevillea heliosperma, Petalostigma, Gardenia, Themeda, Chrysopogon, Eriachne triseta*, annual *Sarga, Heteropogon tritceus, Schlzachyrium, Thaumastochloa; Cycas* west of Adelaide River)
2	25%	Alluvial flats: up to 270 m wide: slopes less than 2 %; channels up to 6 m wide, 0.6-4.5 m deep, incised locally into bed-rock; sheet floods and scalding, with termitaria locally undercut up to 0.3 m above ground level; in places incipient lateralization of alluvial clays and loams; elevation of sands and sandy loams.	Dominantly Margaret soils (texture-contrast loam over alkaline columnar-structured clay); Moline (gradational as above) on flats, McKinlay (gradational yellow loam to alkaline clay), and Stapleton (gradational yellow loam to clay with A2 horizons) on marginal areas.	Grassland, same as unit 1 of Fabian land system, or savannah, same as unit 1 of Flatwood land system
3	20%	Wash slopes; to 2 %; up to 135 m wide; gravely colluviums in sandy loam matrix; shallow streams dry for 6 months or more; locally incised into bed-rock; some termitaria (3 m); sheet wash and scalding.	Batten soils (gradational yellow loam to clay with shallow A2) dominant with Stapleton and Elliott soils	Woodland or stunted woodland as for unit 2 of Bend land system
4	10%	Slightly raised patches of residual gravels: up to 180 m wide; slopes generally less than 2%, locally to 5; relief to 4.5 m;	Elliott soils dominant, with skeletal soils, minor Batten	As for unit 1, but with occasional *Melaleuca argentea, M. nervosa, E. ferruginea*, perennial *Sarga, Ischaenum*, and *Pseudopogonatherum*

Source: Adapted from William *et al* (1969).

Both Princess Louise and North Point mine sites have been partly cleared through previous exploration and mining activities. Eucalyptus open forest remains around the edges of the disturbed areas (refer to Section 7). The condition of vegetation at the mine sites is described in more detail in Section 7, which includes photographs of the mine sites (Plates 7-1 and 7-2).

4.2 Impacts of Mining on Soils and Landforms

The topography of Princess Louise and North Point Mine sites strongly influenced the design of the mining infrastructure, particularly with regard to the placement of waste rock dumps and mine water dams.

Due to the small tenement size and the proximity to the western boundary, siting of the locations of the Princess Louise waste rock dump and sediment dam was constrained. The locations of the pit, waste rock dump, sediment dam and associated infrastructure are shown in Figure 2.2.

The landform in the region of North Point has less physical restraints to the placement of the, waste rock dump and sediment dam. The gentle slope of the land allows the waste rock dump and sediment dam to be placed in ideal locations. The locations of the pit and associated infrastructure are shown in Figure 2.3.

After mine closure, the open pits and mine water dams would remain open for potential future use, though the open pit voids will be bunded and fenced to ensure the pits are safe and stable. Following consultation with landowners, the fencing may be left open to allow stock access. The waste rock dumps will be shaped with any problematic material (Section 4.4) encapsulated inside the core of the dump, and the surfaces will be revegetated with native plant species.

Internal haul and access roads, ore stockpile areas, laydown areas and any other areas where transportable buildings were located will be re-contoured, ripped and seeded for revegetation.

For further information regarding rehabilitation refer to Section 4 – Rehabilitation. Owing to the short life of the mining operations (a few months), the final landform is shown only, in Figures 3.1 and 3.2.

4.3 Waste Rock Characterisation and Management

4.3.1 Waste rock characterisation

The open pit mining at Princess Louise is estimated to generate approximately 361,000 t of waste rock and the open pit mining at North Point is estimated to generate 1,030,000 t of waste rock.

Sampling of waste rock has been undertaken to characterise the waste rock and determine if any specific waste rock management requirements are necessary. The sampling program covered the range of rock types likely to be generated through open pit mining activities at both the proposed mine sites. Analysis included assessments of acid generation potential and metal concentration and mobility.

Representative samples of waste rock and ore materials were obtained by selecting discrete drill core samples from GBS' resource definition drilling program. Samples were selected to represent a drill core interval of less than 1 m, and discrete rock types. The depth of weathering at each site is approximately 20 m and hence the geochemical test program was skewed (in terms of material representation and number of samples) to focus on primary rock types below 20 m. However, the geochemical test program also includes weathered material to determine the presence and mobility of metals (particularly arsenic).

All waste rock and ore samples were geochemically tested at North Australian Laboratories Pty Ltd in Pine Creek.

4.3.2 Acid generating potential

A total of 202 (from 10 drill holes) and 151 (from 10 drill holes) representative samples of waste rock and ore were geochemically tested for Princess Louise and North Point open pit areas, respectively, using the criteria defined in Table 4.2.

Table 4-2 Waste Rock Classification Criteria

Type of Material	NAPP (kgH_2SO_4/t)	NAG_{pH}	$NAG_{Capacity}$ (kgH_2SO_4/t)	Material Classification
Type 1	Negative	>4.5	0	NAF
Type 2	Positive	<4.5	0 – 10	PAF-LC
Type 3	Positive	<4.5	>10	PAF-HC

Notes:
NAPP = Net Acid Producing Potential; and NAG = Net Acid Generation
NAF = Non-Acid Forming; PAF = Potentially Acid Forming; LC = Low Capacity; and HC = High Capacity

The results are summarised in Table 4.3 which indicates that only a very small proportion of samples tested are Potentially Acid Forming (PAF) and the overwhelming majority are Non-Acid Forming (NAF)[1].

When integrated with mine planning information (i.e. total waste rock volume to be produced and relative proportions of significant waste rock types), the results of the geochemical test program indicate that approximately 2-3 % of waste rock will be PAF, and that this small amount of PAF material is restricted to material at depth. All weathered waste rock material, i.e. at a depth of less than 20 m is likely to be NAF as indicated by the geochemical test results.

[1] The criteria used for initial screening of the acid forming nature of waste rock materials is adapted from that used at URGM during mining operations.

Table 4-3 Waste Rock Classification Criteria

Type of Material	NAGpH	NAGCapacity (kgH2SO4/t)	Material Classification	Princess Louise (%)	North Point (%)
Type 1	>4.5	0	NAF	98.0	96.7
Type 2	<4.5	0 - 10	PAF-LC	1.5	2.6
Type 3	<4.5	>10	PAF-HC	0.5	0.7

Notes:
NAG = Net Acid Generation; NAF = Non-Acid Forming; PAF = Potentially Acid Forming; LC = Low Capacity; and HC = High Capacity

4.3.3 Metal concentration and mobility

Metal Concentration in Solids

The waste rock (and ore) samples tested in Section 4.3.2 were also tested for metal content to determine whether metal concentration or mobility may be an issue.

Table 4-4 Summary of Enriched Metals in Waste Rock

Pit Name	Concentration greater than ANZECC2 environmental investigation guideline for soils	Concentration greater than NEPC3 health-based investigation guideline for soils
Princess Louise	As, Cu, Mn, Ni, Zn	As
North Point	As, Cu, Mn, Ni, Zn	As

The results presented in Table 4.4 indicate that some metals (As, Cu, Mn, Ni and Zn) can be present in waste rock (and ore) at a concentration greater than the recommended ANZECC (1992) Environmental Investigation Level (EIL) for these elements. However, only arsenic is present in some waste rock at concentrations greater than NEPC (1999) Health-Based Investigation Levels (HIL(F)) for “commercial and industrial sites”[2].

The enrichment of metals with respect to normal background concentrations is to be expected and simply reflects the natural geochemical enrichment, which defines a mineral deposit. Notwithstanding, waste rock with an arsenic concentration greater than 500mg/kg will be managed to ensure that relevant materials do not report to the final surface of the waste rock dump[2].

[2] Elevated As concentrations are more prevalent in waste rock from North Point compared to waste rock from Princess Louise.

4.4 Management

4.4.1 Waste rock dump design

The waste rock dumps at the proposed Princess Louise and North Point mines will be constructed, operated and rehabilitated to ensure that the environmental impact of any PAF or arsenic enriched material is minimised during and after mining operations cease. Waste rock will be geochemically characterised prior to excavation and potentially “problematic” material will be selectively handled and deposited in the core of the waste rock dump as illustrated in Figure 4.1.

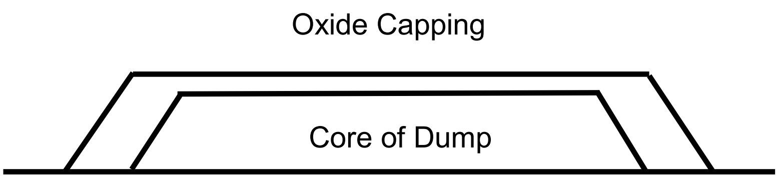

Figure 4-1 Schematic cross section of waste rock dump

The NAG test will be used to determine the acid forming nature of the waste rock material and total arsenic concentration will be determined through routine assay. The identification of potentially “problematic” waste rock material within transitional/primary pit zones will be the responsibility of BOPL’s mining/geology personnel, and acquired geochemical information will be used for mine scheduling and planning of waste rock dump construction. Confirmation sampling and analysis of placed material at the waste rock dump will also occur to confirm the integrity of the waste rock management strategy.

4.5 Commitments

After completion of mining, BOPL commits to re-contouring, ripping and seeding internal haul and access roads, ore stockpile areas, laydown areas and other areas where transportable buildings were located, following closure.

During and after mining, BOPL commits to minimising the impact of potentially acid forming (PAF) soils and arsenic (As) generating material.

During mining, BOPL commits to geochemically characterising any potentially problematic waste material prior to excavation, and encapsulating any such material within the core of the waste rock dump.

BOPL commits to encapsulating any waste rock material with an arsenic concentration greater than 500mg/kg, during mining.