9 Environmental Effects of Residue Storage Facility

9.1 Terrain and Soils

The terrain of the residue storage facility (RSF) site has been assessed in terms of its geology, landform and soil types.

Terrain mapping has been carried out primarily from interpretation of aerial photographs with reference to existing geological, topographical, and soils information and background data sources. This was followed by a site reconnaissance survey and soil sampling to provide the basis for identifying 'terrain units' which occur within the proposed project area.

As mapped, a terrain unit comprises a single or recurring area of land that is considered to have a unique 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.

The methodology employed for the description and assessment of terrain (landform) types, geology and soil types within the RSF site is discussed in Appendix E.

9.1.1 Existing Environment

9.1.1.1 Topography and Drainage

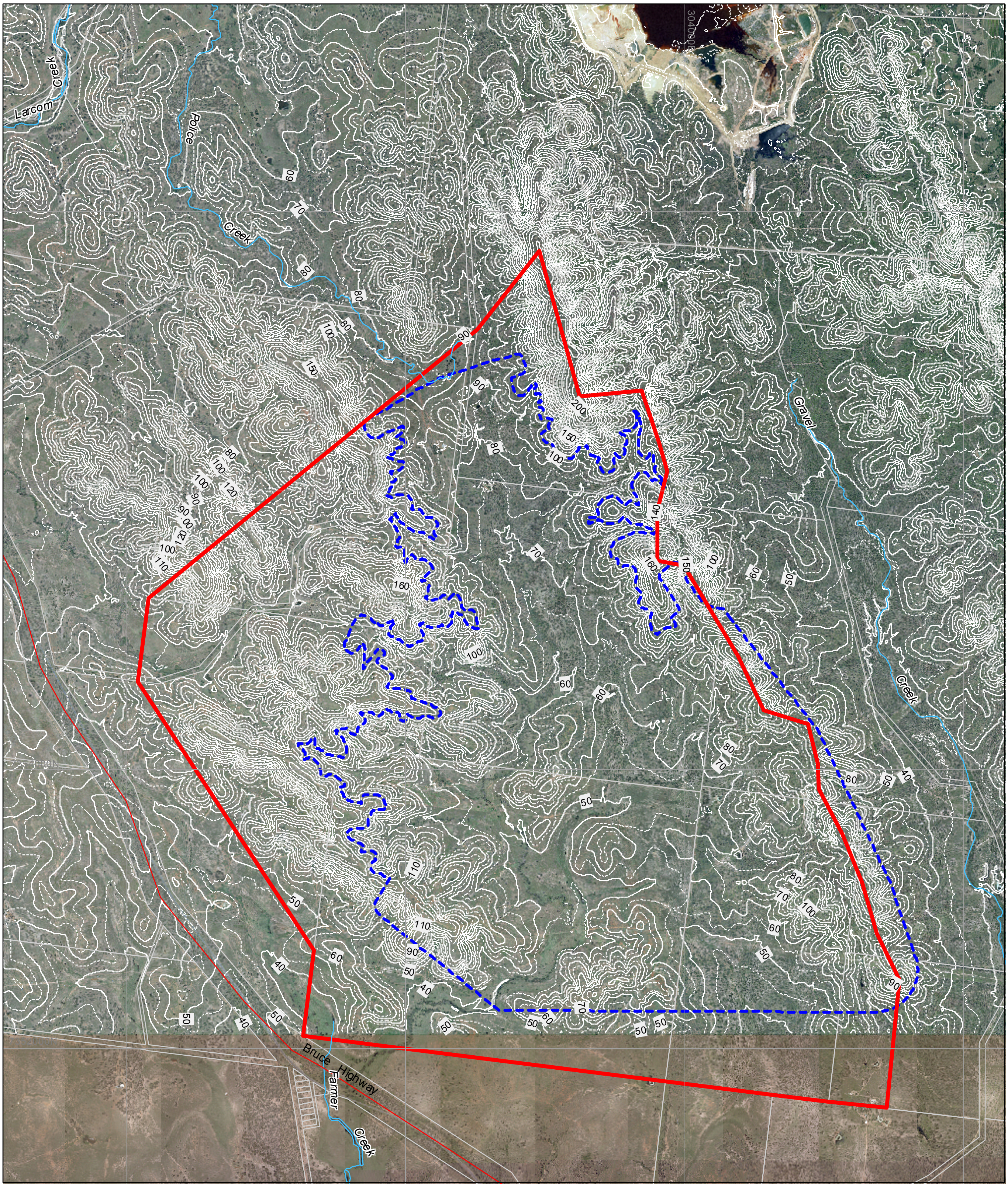
The terrain in the proposed RSF study area comprises steep, closely dissected north/south trending high hilly lands along the eastern and western perimeters of the site. The eastern and western perimeters consist of elongated, semi-continuous narrow sharply rounded ridges and spurs with steep irregular planar hill slopes and dissection slope interfluves, mostly in the range 25-40%. Surface elevations in these areas vary from approximately RL 150-200 m Australian Height Datum (AHD) in the northern sector of the site to about RL 80-100 m AHD towards the south. A lowland valley system, with a general surface elevation of about RL 50-60 m AHD, trends in a NNE-SSE direction diagonally through the central sector of the site. The terrain in the area comprises undulating to low rounded hilly lands and rises, and gently inclined dissection slope interfluves with overall surface slopes varying between about 3-10% in the flatter and undulating lowland areas. The topography of the RSF site is shown in Figure 9.1.1 (refer to Section 10.10.2 for the land tenure and land access description, including Gladstone Pacific Nickel Limited's (GPNL's) licence to operate in development areas outside of the site boundary).

Surface drainage and runoff within the RSF study area is controlled by a watershed divide crossing the central northern sector which directs the local surface water flow into Larcom Creek via Police Creek. Runoff from the southern sector is via headwater tributaries of the Calliope River located approximately 7 km to the south of the site.

Terrain units which reflect the topographic (landform), geological and soil characteristics of the study area are shown in Figure 9.1.2.

9.1.1.2 Site Geology

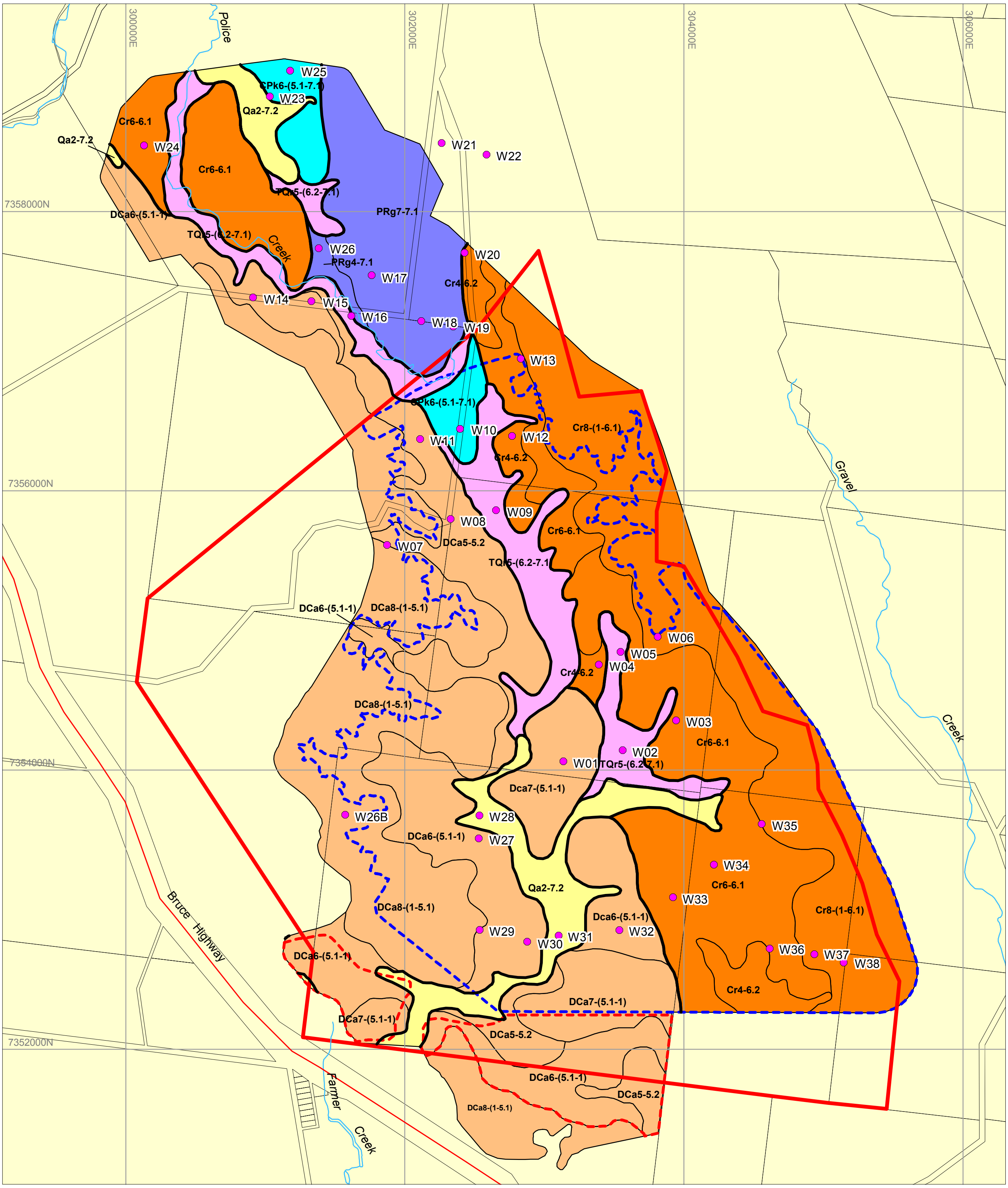
The RSF study area is underlain mainly by sedimentary bedrock units. The Late Devonian to Early Carboniferous Mount Alma Formation (DCa), which consists of thinly interbedded fine-grained siltstone, sandstone and mudstone, occurs along the western side of the site. The Early Carboniferous Rockhampton Group (Cr) comprises mudstone, siltstone, felsic volcaniclastic sandstone, polymictic conglomerate, oolitic and pisolitic limestone and minor skeletal limestone and occurs mainly in the eastern half of the site. Minor occurrences of Permo-Carboniferous Berserker Group (CPk) with similar lithology to the Rockhampton Group occur in the central and northern sectors of the area.



0 500 1000m
Scale 1:20,000 (A4)
MGA Z56, GDA94

RSF site boundary
RSF footprint
100 (white) Contour (mAHD)

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	**TOPOGRAPHY - RESIDUE STORAGE FACILITY**
URS	Drawn: VH / Approved: CMP / Date: 23-10-06	Figure: **9.1.1** / Rev: A
	Job No: **4262 5791** / File No: 42625791-g-057.wor	**A4**



NOTE:
This Figure 9.1.2 must be viewed with Figure 8.1.2b (Terrain Units Identification Key)

N

0 500 1000m

Scale 1:20,000 (A4)

MGA Z56, GDA94

W29	Soil sampling location		RSF site boundary
	Geological Regime Boundary		RSF footprint
Cr4-6.2	Terrain Unit and Terrain Unit Boundary		Topsoil stockpile

Client: Gladstone Pacific Nickel Ltd

URS

Project: GLADSTONE NICKEL PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title: **TERRAIN UNITS AND GEOLOGICAL REGIMES - RESIDUE STORAGE FACILITY**

Drawn: VH	Approved: CMP	Date: 26-10-06
Job No: **4262 5791**	File No: 42625791-g-058.wor	

Figure: **9.1.2**

Rev: A

A4

The contact between the sedimentary bedrock units trends north-west/south-east, approximately through the centre of the site. The contact forms part of a regional fault system and is represented by moderately steeply inclined and dissected footslopes which form a central system of structurally controlled narrow valleys. A Late Permian-Early Triassic gabbro intrusion (PRg) in the northern sector of the site is associated with and/or most likely the cause of the local structural deformation events. This gabbro intrusion lies between the two sedimentary bedrock units and has an associated layer of greenstone on its adjacent contact boundaries.

A thin surficial layer of Tertiary-Quaternary unconsolidated alluvium/colluvium (TQr) occurs on the lower slopes and within the topographically low drainage lines which drain to the north and south. Limited occurrences of Quaternary alluvium (Qa), comprising predominantly clayey alluvial deposits, have been mapped in the northern and southern sectors of the area.

9.1.1.3 Soils

The soils in the study area are shown in Figure 9.1.3 and largely reflect the geological regimes in which these have been mapped. The main soils comprise soil classes 1, 5, 6 and 7 as described in Table 9.1.1. Details of the soil classification methods and extent of profiles examined are provided in Appendix E. The soils types associated with individual terrain units are also described in Appendix E.

9.1.1.4 Soils Associated with the Quaternary Alluvial Deposits (Qa)

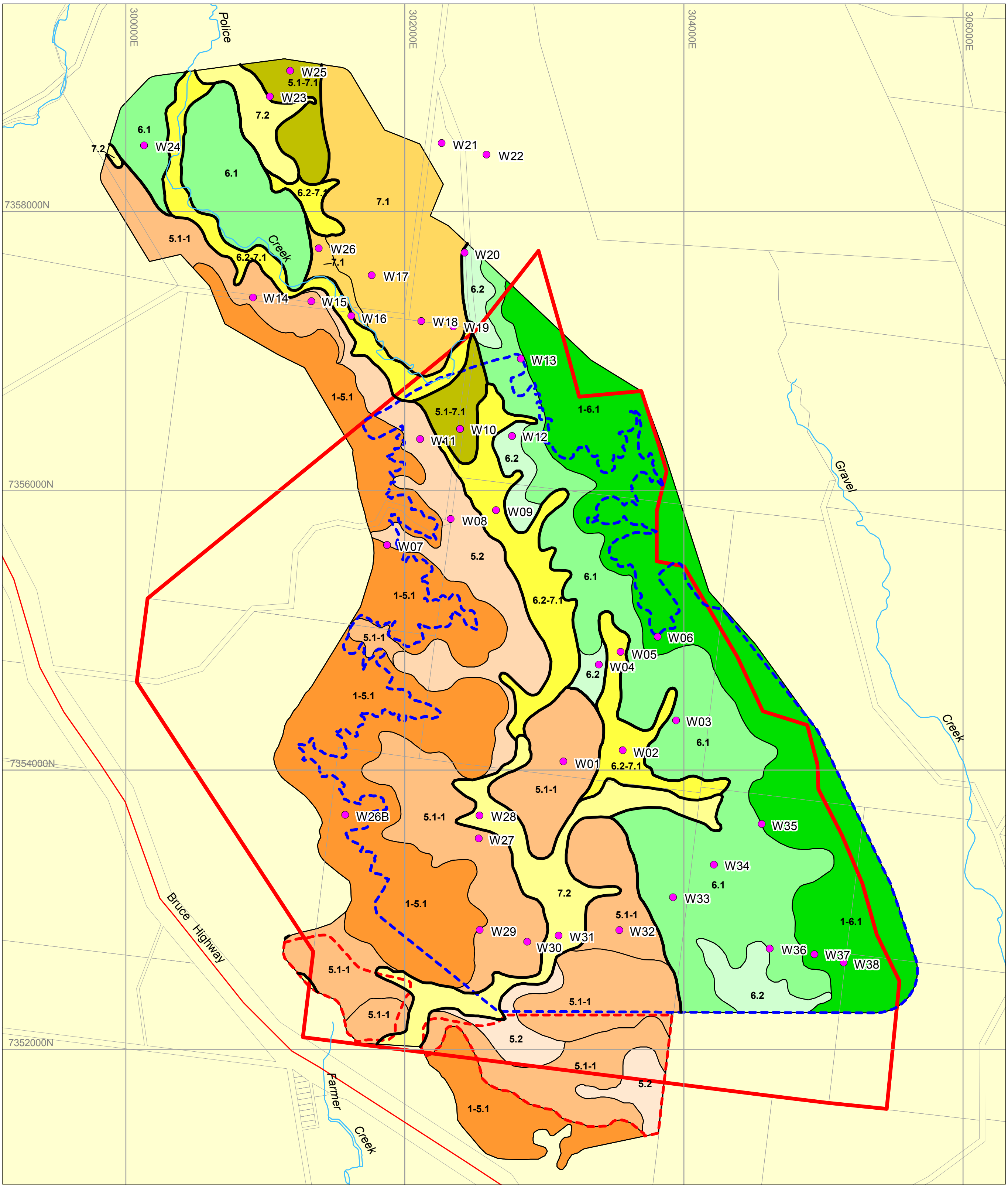
The soils developed on the Quaternary alluvial deposits are of limited extent within the far northern and southern sectors of the RSF study area. These have been classified as soil type 7.2 in terrain unit Qa2-7.2 and comprise medium to deep uniform clay soils with thin dark grey-brown to brownish black friable loamy medium to heavy clay surface soils with weak self-mulching to fine blocky structure. These overly medium to coarse blocky tending to massive, diffusely mottled heavy clay or gravelly clay sub-soils that tend to be slightly to moderately saline, sodic and dispersive in the deeper subsoil layers.

9.1.1.5 Soils Associated with the Tertiary-Quaternary Alluvio-Colluvial Deposits and Residual Soils (TQr)

Only terrain unit TQr5-(6.2-7.1) has been mapped within the TQr geological regime, within which the soils comprise a complex association of residual and gravelly colluvial soils on the lower slopes and narrow valley floors, and layered clayey and gravelly alluvial soils on local drainage flats and terraces adjacent to drainage lines. Gravelly and loamy surface duplex soils (Type 6.2) are more common. These comprise medium deep hardset sandy to silt loamy, locally gravelly surface duplex soils with a pale or bleached (A2) horizon over brown or yellow-brown diffusely mottled, in places moderately saline, sodic and dispersive heavy clay subsoils underlain by clayey gravel-gravelly clay weathered rock or colluvium. Layered alluvial-colluvial soils (Type 7.1) with shallow to medium deep nutty to fine-structured medium clay surficial soils with clayey coarse gravel and medium to heavy clay lenses of varying thickness occur in the deeper subsoil layers. These soils may be classified either as Melanic-Vertic Black Dermosols or in places as Gravelly Fluvic-Colluvic Clastic Rudosols (Isbell, 1996).

9.1.1.6 Soils Associated with the Late Permian-Early Triassic Intrusives (PRg)

The dominant soils (Type 7.1) found in this geological regime occur in Terrain Units PRg4-7.1 and PRg7-7.1. These comprise mainly shallow uniform clay soils with dark-coloured organic rich, friable well-structured tending to self-mulching medium clay surface soils over fine to medium and locally coarser structured heavy clay subsoils underlain by highly weathered intrusive rock, predominantly gabbro. Although relatively shallow, these soils provide the most productive topsoil resource within the study area.



NOTE:
This Figure 9.1.3a must be viewed with Figure 9.1.3b (Legend -Soil Mapping Units - RSF)

N

0 500 1000m

Scale 1:20,000 (A4)
MGA Z56, GDA94

W29	Soil sampling location		RSF site boundary
	Geological Regime Boundary		RSF footprint
Cr4-6.2	Terrain Unit and Terrain Unit Boundary		Topsoil stockpile

Client: Gladstone Pacific Nickel Ltd	Project: GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	Title: SOIL TYPES RESIDUE STORAGE FACILITY
URS	Drawn: VH / Approved: CMP / Date: 26-10-06	Figure: 9.1.3a / Rev: A
	Job No: 4262 5791 / File No: 42625791-g-059.wor	A4

LEGEND: SOIL MAPPING UNITS - RSF

Map Unit	Description
1-5.1	Shallow rocky/gravelly soils – Very Gravelly Lithic Rudosols; some shallow gravelly duplex`soils – Gravelly Red-Brown Chromosols
1-6-1	Shallow rocky/gravelly soils – Very Gravelly Lithic Rudosols; some shallow gravelly duplex soils – Gravelly Yellow-Brown Kurosols and Sodosols
5.1-1	Shallow Gravelly duplex`soils – Gravelly Yellow-Brown Chromosols; some shallow rocky/gravelly soils - Very Gravelly Lithic Rudosols
5.1-7.1	Shallow Gravelly duplex`soils – Gravelly Yellow-Brown Chromosols; some shallow uniform structured clay soils – Melanic Black-Brown Dermosols
5.2	Medium deep gravelly duplex soils –Gravelly Red-Brown Chromosols
6.1	Shallow gravelly duplex soils – Bleached Sodic Yellow-Brown Kurosols and Sodosols
6.2	Medium deep loamy surface mottled duplex soils – Mottled Yellow-Brown Sodosols
6.2-7.1	Medium deep loamy surface duplex soils – Yellow-Brown Sodosols; some shallow uniform clay soils – Melanic Brown Dermosols
7.1	Shallow uniform structured clay soils – Melanic Brown-Black Dermosols
7.2	Medium to deep uniform clay soils with sodic locally moderately saline subsoils – Vertic Sodic Brown-Black Dermosols.

Client	Project	Title
Gladstone Pacific Nickel Ltd / URS	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	LEGEND - SOIL MAPPING UNITS - RESIDUE STORAGE FACILITY
	Drawn: VH · Approved: CMP · Date: 26-10-06	Figure: **9.1.3b** · Rev: A
	Job No: **4262 5791** · File No: 42625791-g-059.wor	A4

Table 9.1.1 Soil Types within the RSF Site

Soil Class	Soil Type	Soil Classification			
		Aust. Soil[1] Group	P.P.F.[2]	U.S.C.[3]	A.S.S[4]
1. Predominantly rocky or coarse gravelly residual, colluvial, alluvial soils (>60% rock cobbles and gravel)	Shallow coarse gravelly/ rocky loams to loamy gravels over HW rock	Skeletal Soils/ Lithosols	K-Um1.23	GW-GM-GC	Very Gravelly Lithic Leptic Rudosols
5. Sandy to silt loamy surface duplex soils with acidic to alkaline non sodic, non-saline clay or sandy clay subsoils	5.1. Shallow to medium deep, gravelly loam or hardset loamy surface weak duplex soils with brown or reddish brown medium to heavy clay or gravelly clay subsoils over HW rock	Yellow-Brown, Red Podzolic Soils	Dy4.11 Dr4.21 Db3.51	CL/CL-CH GC/GC-CL CL/GC-CL/CL-CH	Bleached Eutrophic Red-Brown Chromosols; Melanic Brown Chromosols
	5.2. Medium deep gravelly loam and clay loamy surface duplex soils with weak to mod. strongly structured brown and reddish brown medium to heavy acidic clay and locally gravelly clay subsoils over Hw rock between 0.8-1.4 m.	Yellow-Brown, Red Podzolic Soils	Dy2.31 Dr4.11	CL/CH GC/CL-CH	Haplic Eutrophic Red-Brown Chromosols
6. Silty or clay loamy surface duplex soils with strongly acidic or strongly alkaline, sodic often saline clay subsoils	6.1 Shallow clay loam to gravelly loamy surface duplex soils with a pale or bleached sub-surface (A2) horizon over red-brown or brown, structured, acidic, locally strongly acidic dispersive. medium to heavy clay or gravelly clay subsoils	Soloths, Solodic Soils	Db1.11 Dr4.21 Dy5.31 K-Db1.51	GC/GC-CL/CH	Bleached-Mottled Sodic Yellow-Brown Kurosols; Sub-natric Bleached Red Sodosols; Vertic Brown Sodosols
	6.2. Medium deep hardset sandy to silt loamy, locally gravelly surface duplex soils with a pale or bleached (A2) horizon over brown or yellow-brown diffusely mottled mod. saline, sodic and dispersive heavy clay subsoils	Solodic Soils, Soloths	Db2.81 Db3.31-Dy2.43 Dy3.41-Dy3.11	CL-ML/CH CL-ML/GM-GC/CH	Mottled Mesonatric Yellow-Brown Sodosols; Bleached Mottled Sodic Grey Kurosols
7. Uniform or weakly gradational (non-cracking) clay or silty clay soils (incipient cracking clays)	7.1. Shallow uniform clay soils with dark-coloured organic rich friable well-structured medium clay surface soils over strong fine to medium structured heavy clay subsoils over HW rock	Dark Brown (Non-Cracking) Friable Clay Soils	Uf6.11, Uf6.31, Uf6.12	CL/CL-CH or CH CL-CH/CH	Melanic Black-Brown Dermosols Gravelly Red-Brown Dermosols
	7.2. Medium to deep uniform clay soils, locally gravelly clays of high plasticity, often slightly to mod. saline, sodic and dispersive in the deeper subsoil layers	Alluvial Soils Dense Hard Pedal Sodic-Saline Clays	Uf6.32 Uf6.22 Uf6.31	CH/CH CL-CH/CH GC-CH/CH	Melanic Vertic Sodic Brownish-Black Dermosols

Notes: (1) - *Common Soil Group Name* Stace et al. (1968); (2) - *Principal Profile Form* Northcote (1971); (3) - *Engineering Soil Class* (AS 1764-1990); (4) - *Australian Soil Classification* Isbell (1996

9.1.1.7 Soils Associated with the Early Carboniferous Rockhampton Group (Cr)

The soils that occur in this geological regime represent a catena determined by topographic position in the landscape. In the steep higher hilly lands mapped as Terrain Unit Cr8-(1-6.), the dominant soils are gravelly lithic leptic rudosols- soil class 1, which comprise shallow gravelly/rocky loams to loamy gravels with (<50%) fines of low plasticity underlain by highly weathered sedimentary rock. These occur locally in association with some shallow gravelly duplex soils (Type 6.1) with coarse gravelly/rocky sandy to silt loamy surface soils over gravelly medium clay-clayey gravel sub-soils, transition to the underlying weathered rock.

Trending downslope through terrain unit Cr6-6.1, the dominant soils (type 6.1) comprise shallow (<0.6 m) loamy or gravelly loam to clay loamy surface duplex soils with a pale or bleached sub-surface (A2) horizon over red-brown or brown, structured, acidic, locally strongly acidic dispersive medium to heavy clay sub-soils underlain by weathered rock.

On the gently to moderately inclined footslopes and erosional valley floors represented by terrain unit Cr4-6.2, the dominant soils (type 6.2) comprise medium deep (0.6-1.2 m) hardset fine sandy to silt loamy, locally gravelly surface duplex soils with a pale or bleached sub-surface (A2) horizon over brown or yellow-brown diffusely mottled moderately saline sodic and dispersive heavy clay subsoils underlain by highly weathered sedimentary rock.

9.1.1.8 Soils Associated with the Devonian-Carboniferous Mt. Alma Formation (DCa)

As with the soils associated with the Rockhampton Group sedimentary sequences, the soils that occur in this geological regime also reflect a catena determined by topographic position in the landscape. In the steep higher hilly lands mapped as terrain unit DCa8-(1-5.1), the dominant soils are gravelly lithic leptic rudosols- soil class 1, comprising mostly shallow (<0.6 m) coarse gravelly/rocky loams to loamy gravel soils over highly weathered (HW) rock. These soils occur locally in association with some shallow gravelly loamy or loamy surface duplex soils (type 5.1) which have acidic yellowish brown or reddish brown gravelly clay or clayey gravel subsoils, classified as (gravelly) red-brown chromosols (Isbell, 1996).

Trending downslope through dissected hilly and low hilly lands to undulating to rolling low rises and mapped as terrain units DCa7-(5.1-1) and DCa6-(5.1-1), is the dominant soils type 5.1. Soil type 5.1 comprises mainly shallow gravelly loamy or loamy surface duplex soils in places with a weak pale (A2) sub-surface horizon over acidic yellowish brown or reddish brown gravelly clay or clayey gravelly sub-soils underlain by highly weathered rock, classified as humose melanic (gravelly) red-brown chromosols (Isbell, 1996). Some occurrences of shallow coarse gravelly/rocky loams to loamy gravel soils (Class 1) – gravelly lithic leptic rudosols, occur locally.

On the gently to moderately inclined footslopes and lower dissection slope interfluves mapped as terrain unit DCa5-5.2, the dominant soils (type 5.2) comprise medium deep (0.8-1.2 m) gravelly loam and clay loamy surface duplex soils with weak to moderately strongly structured brown and reddish brown medium to heavy acidic clay and locally gravelly clay sub-soils over highly weathered rock, classified as gravelly haplic eutrophic red-brown chromosols (Isbell, 1996).

9.1.1.9 Soils Associated with the Permian-Carboniferous Berserker Group (CPk)

The soils associated with this geological regime have been mapped in terrain unit CPk6-(5.1-7.1) and are of limited extent within the study area. As mapped these include soil type 5.1, comprising shallow (<0.6 m) loamy surface duplex soils with a bleached sub-surface (A2) horizon with moderately strongly structured yellowish red non-sodic medium to heavy clay subsoils, bleached haplic red chromosols, and soil type 7.1 comprising shallow (<0.6 m) gravelly uniform red-brown medium clay soils with strong nutty to medium blocky structure underlain by highly weathered rock - gravelly red dermosols.

9.1.2 Topsoil Resources

The occurrence of useable topsoil resources within the RSF study area has been assessed based on the methodology described in Appendix E. With the exception of terrain units Qa2-7.2, PRg7-7.1 and PRg4-7.1, the occurrence of good quality topsoil within the area is poor due mainly to the shallow gravelly nature of the soils that occupy the bulk of the area. A summary of the available resources within the study area is provided in Table 9.1.2.

Table 9.1.2 Topsoil Material Resources

Terrain Units	Study Area (ha)	Topsoil Resources		Subsoil Supplement Resources		Soil Erosion Potential
		Indicative Depth (m)	Volume ($m^3 \times 10^6$)	Indicative Depth (m)	Volume ($m^3 \times 10^6$)	
Qa2	110.6	0.3	3.318	0.3	3.318	L-M
TQr5	160.1	0.15	2.402	0.15	2.402	M
PRg4	8.8	0.35	0.308	0.2	0.176	L
PRg7-7.1	140.9	0.35	4.932	0.2	2.818	L-M
CPk6-(5.1-7.1)	49.4	0.3	1.482	0.2	0.988	L-M
Cr4-6.2	56.0	0.15	0.840	0.15	0.840	M
Cr6-6.1	376.3	0.15	5.645	0.15	5.645	M
Cr8-(1-6.1)	312.6	0	0	0.1	12.504	M
DCa5-5.2	142.8	0.4	5.712	0.3	4.284	L-M
DCa6-(5.1-1)	276.1	0.15	4.142	0.35	9.664	M
DCa7-(5.1-1)	118.0	0.15	1.770	0.35	4.130	M
DCa8-(1-5.1)	381.3	0	0	0.4	15.252	M
Total	**2,132.9**	**-**	**30.551**	**-**	**62.021**	-

The proposed development footprint of the RSF will disturb an area of approximately 1,185 ha (excluding the topsoil stockpile areas). This land encompasses terrain units with potential topsoil resources of approximately 15.9 million m^3 and subsoil supplement resources of 29.5 million m^3.

Assuming the rehabilitation of the RSF will require at least 0.3 m of topsoil replacement to provide a suitable planting medium over the surface of the proposed engineered low-permeability capping layer a total of approximately 35.5 million m^3 of topsoil will be required. On this basis there will be a shortfall of topsoil material of 19.6 million m^3. Accordingly, it will be necessary to supplement the available topsoil resources with the sub-soil supplement resources identified within the proposed development footprint.

Two areas have been identified as potential areas to stockpile topsoil in the south-west corner of the RSF (refer Figure 9.1.3). These areas include a total land area of 140 ha. These areas will be utilised for stockpiling good quality topsoil that can be recovered to rehabilitate the RSF.

Each area was identified as containing favourable terrain conditions (low to moderate grade) and is not within drainage paths on site. In addition the proposed stockpile areas are within modified pastoral grasslands with scattered emergent *Eucalypt* spp. Therefore, disturbance to vegetation as a result of stockpiling materials is limited.

Prior to the commencement of the stripping of topsoil, areas will be cleared of vegetation. Trees will be felled and together with shrubby vegetation, pushed into windrows. Consideration will be given to salvaging any marketable timber prior to chipping/mulching and composting of the smaller branches, shrubs and foliage. This material would be available to provide a thin surface mulch to improve the topsoil productivity.

The topsoil and subsoil supplement materials will be stripped and placed in separate stockpiles, or selectively placed in pre-determined rehabilitation areas. Earthmoving plant operators will be trained and/or supervised to ensure that stripping operations are conducted in accordance with stripping plans and *in-situ* soil conditions. This will ensure that all suitable topsoil material resources are salvaged and that the quality of the stripped topsoil is not reduced through contamination with unsuitable soils. Other general procedures relating to topsoil stripping and management, along with details of the rehabilitation strategy are provided in Section 9.8.3.

9.1.3 Implications for Rehabilitation

9.1.3.1 Soil Properties

The soil attributes that may have deleterious effects in the rehabilitation process include soil acidity/alkalinity, salinity, sodicity and dispersion characteristics. Analysis of the results of the indicative and laboratory testing carried out are included in Appendix E and discussed below.

9.1.3.2 Soil pH

The preferred pH range for most plants varies between 6.0 to 8.0, depending on the plant species. With the exception of the terrain units with associated soil types 1, 5.1 and 6.1, the majority of which have moderately strong to very strongly acidic surface and immediate subsoil horizons, all other soil types tested had pH levels in the surficial (A1 and B1) soil horizons mainly within the moderately acidic to moderately alkaline range (pH 5.8-8.2).

The pH levels in the subsoil layers, below about 0.5 m deep, generally ranged from moderately acidic through to moderately alkaline (pH 5.8-8.2). Some exceptions are in the deeper subsoil (B-C) horizons of some soils type 6.1, 6.2 and 7.2, which locally exhibit more acidic (pH <5.5) or alkaline conditions (pH 8.5-9.0).

For soils that have been rated as marginal for use as topsoil due to low or high pH levels, pH correction can be achieved by the application of lime to increase pH levels or sulphur to reduce alkalinity as appropriate.

9.1.3.3 Salinity

The results of soil testing for electrical conductivity (EC) levels in Appendix E, indicates that the subsoil (B2 and B-C) horizons in terrain units with soil types 6.2 and 7.2, have low to moderate salinity levels. All other soil types within the area are non-saline or exhibit low salinity levels. In general, soils with elevated levels of salinity are not considered to be suitable for rehabilitation purposes and will not be incorporated within the root zone of the proposed re-vegetation plant species.

9.1.3.4 Sodicity

The laboratory testing included in Appendix E indicates that the subsoil B1 and deeper subsoil B2 and B-C horizons in soil types 6.2 and 7.2 are sodic or strongly sodic. In general, sodic soils will not be used as topsoil resources. Should materials placed at or near the finished surface level of the soil capping layer be found to be sodic, then gypsum may be incorporated into the surface of the capping material, to help restore the ionic balance and reduce the sodicity levels of those materials prior to the placement of topsoil material.

9.1.3.5 Dispersion Characteristics

The results of the soil dispersion testing shown in Appendix E, indicate that the surficial and immediate subsoil horizons of most soil types are either non-dispersive (class 6-8) or comprise gravelly loams or clayey gravel soils which contain soil fines that are slightly dispersive (dispersion class 5 or 3(1)). The deeper subsoil horizons and in places the highly weathered rock substrate material in soil types 1, 5.2, 6.1, 6.2 and 7.2 exhibit moderate or strong dispersion characteristics (class 3(2) to 2(1) or 2(2) to1). This is consistent with the levels of sodicity recorded in the various soil horizons where in general, the more dispersive soil materials correspond with the more sodic soil layers. Wherever possible, dispersive materials will not be recovered for topsoil replacement purposes.

9.1.4 Soil Erosion

Based on interpretation of aerial photography, together with general observations made during the field survey, accelerated soil erosion does not appear to be a significant problem within the study area, due largely to the well-established woodland vegetation and the gravelly/rocky nature of the soils. However, some occurrences of gully erosion are evident locally within the site in particular on some slopes adjacent to drainage lines and on the mid to lower parts of dissection slope interfluves and in intervening erosion gullies in terrain units Cr8-(1-6.1), Cr4-6.2 and Qa2-7.2.

9.1.4.1 Soil Erosion Potential

The majority of the soil types that occur within the project area contain soil horizons or soil layers that exhibit slight to moderate and some strongly dispersive characteristics. Approximately one in three of the samples submitted for laboratory testing, (refer Appendix E) were either sodic or strongly sodic in the B1, B2, or B-C horizons particularly in terrain units with associated soil types 6.1, 6.2, 7.2. A medium or high level of sodicity tends to predispose soils to dispersion and subsequent erosion if exposed and unprotected from uncontrolled surface water runoff. Over time this will lead to exposure of the more strongly dispersive subsoil layers that will exacerbate the effects and severity of the gully erosion.

The erosion potential of the soils in the study area that have been identified as potential topsoil or subsoil supplement resources, has been assessed and rated in Table 9.1.1 and on a terrain unit basis in Appendix E. The assessments have been based on the criteria for soil erodibility classes included in Appendix E.

9.1.4.2 Erosion Control Measures

Erosion and sediment controls, which will be implemented during construction of the RSF, are as follows:

- Vegetation clearing will be conducted progressively so that the minimum area necessary for efficient operations is cleared at any time.
- Earthworks batters that will remain will be constructed to stable slopes and re-vegetated soon after construction.
- Runoff from areas subject to earthworks will be collected in drains and directed through sediment traps and settling ponds to remove suspended sediment prior to discharge from the site.
- Long-term topsoil stockpiles will be seeded and will have drainage and sediment controls for runoff water.
- Slopes will have contour drains to minimise slope lengths and runoff velocities.
- Runoff from rehabilitated areas will be collected in contour drains and collection drains and directed to sediment dams and settling ponds to remove suspended sediment prior to draining from the site.
- A maintenance program will be implemented to ensure the proper functioning of drainage and sediment control structures.

Soil erosion measures to be employed throughout construction are also discussed in Section 9.1.4.

9.1.5 Agricultural Land Capability

An assessment of the agricultural land capability of the study area has been carried out in accordance with State Planning Policy 1/92: *Development and the Conservation of Agricultural Land*. The assessment requires the evaluation of the potential for the land to sustain a specific land use. The assessment has been based on the four class system for defining good quality agricultural land (DPI and DHLGP, 1993). The land classes are summarised as follows:

- Class A: Crop Land; land suitable for current and potential crops with limitations to production which range from nil to moderate levels.
- Class B: Limited Crop Land; land that is marginal for current and potential crops due to severe limitations, but is suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for sustainable cropping/cultivation.
- Class C: Pasture land; land suitable for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment.
- Class D: Non-agricultural Land; land not suitable for agricultural uses due to extreme limitations. This may comprise undisturbed land with significant habitat, conservation and/or catchment values, or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage.

The current and recent history of land use in the general vicinity of the study area is primarily cattle grazing on partially cleared land with improved or native pastures. No dry-land (rain-fed) cropping has been undertaken within this area due to topographic constraints and shallow rocky/gravelly soils.

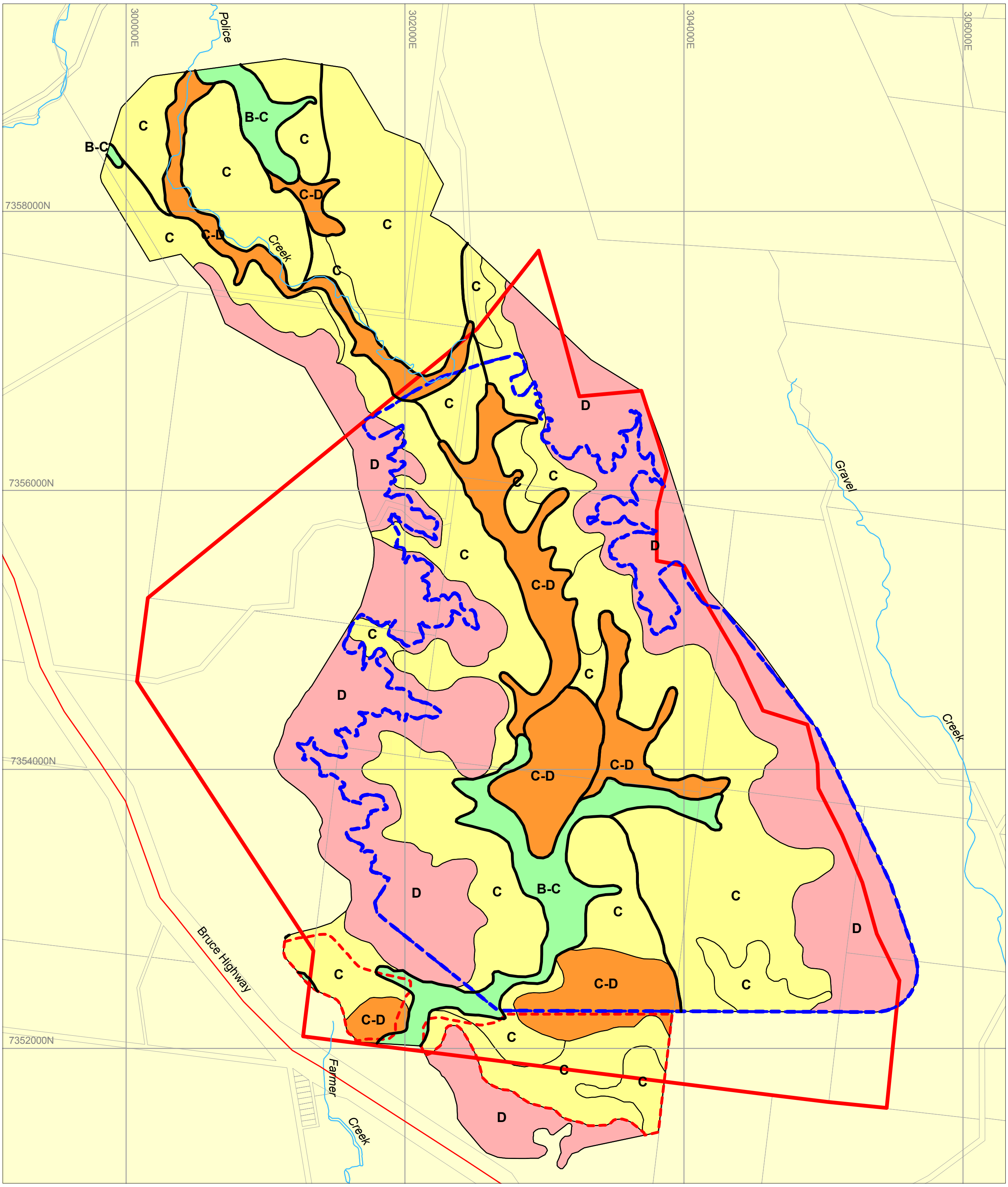
In order to determine the appropriate agricultural land class, terrain units identified within the project area have been assessed for land suitability for cattle grazing. The soil and landform limitations criteria on which the land suitability classifications have been determined are included in Appendix E and are based on the guidelines for agricultural land evaluation published by the Queensland Department of Primary Industries (DPI, 1990), modified by inclusion of criteria proposed by Shields and Williams (1991). The system of classification is based on the identification of physical and chemical limiting factors or constraints with respect to a specific land use, adopting the following protocols:

- Class 1: High quality land with few or very minor limitations for the intended land use.
- Class 2: Land with minor limitations for the intended land use.
- Class 3: Land with moderate limitations to sustaining the intended land use.
- Class 4: Marginal land requiring major inputs to sustain the intended land use.
- Class 5: Unsuitable land due to extreme limitations for the intended land use.

The pre-construction land suitability assessment for cattle grazing, from which the agricultural land capability classes have been evaluated, are included in Table 9.1.3 below and shown in Figure 9.1.4.

Table 9.1.3 RSF Site Agricultural Land Capability Assessment

Terrain Unit	Landform and Soils	Area (ha)	Ag. Land Class	Grazing Suitability
Qa2-7.2	Alluvial plains with medium to deep clay soils with sodic, dispersive subsoils	110.58	B-C	2-3
TQr5-(6.2-7.1)	Lower slopes and narrow valley floors with gravelly sodic duplex soils and layered clayey and gravelly alluvial soils	160.09	C-D	4
PRg4-7.1	Lower slopes and broadly rounded saddle with shallow clay soils over HW rock	8.82	C	2-3
PRg7-7.1	Low rounded hilly and hilly lands with shallow uniform clay soils over HW rock	140.89	C	4



NOTE:
This Figure 9.1.4 must be viewed with Figure 8.1.4b (Agricultural Land Classes)

N

0 500 1000m

Scale 1:20,000 (A4)

MGA Z56, GDA94

W29	Soil sampling location		RSF site boundary
	Geological Regime Boundary		RSF footprint
Cr4-6.2	Terrain Unit and Terrain Unit Boundary		Topsoil stockpile

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	**AGRICULTURAL LAND CLASSES - RESIDUE STORAGE FACILITY**
URS	Drawn: VH / Approved: CMP / Date: 26-10-06	Figure: **9.1.4** / Rev: A
	Job No: **4262 5791** / File No: 42625791-g-060.wor	A4

Table 9.1.3 RSF Site Agricultural Land Capability Assessment

Terrain Unit	Landform and Soils	Area (ha)	Ag. Land Class	Grazing Suitability
CPk6-(5.1-7.1)	Low hilly lands and rises with shallow gravelly acidic loamy surface duplex soils and shallow uniform clays over HW rock	49.42	C	4
Cr4-6.2	Gently inclined footslope plains with medium deep hardset loamy duplex soils with sodic, dispersive clay subsoils	56.0	C	3
Cr6-6.1	Undulating to rolling rises and rounded hills with shallow gravelly acidic loamy duplex soils locally with strongly acidic, dispersive, sodic subsoils over HW rock	376.27	C	4
Cr8-(1-6.1)	Dissected steep hilly lands with narrow ridge and spur crests, with shallow rocky - gravelly loams to light clays ; some shallow gravelly duplex soils Type 6.1	312.58	D	5
DCa5-5.2	Gently to mod. inclined footslopes, with medium deep gravelly and loamy surface acidic duplex soils over HW rock	142.80	C	2-3
DCa6-(5.1-1)	Low hilly lands and rounded rises with shallow gravelly loamy duplex soils Type 5.1; some gravelly lithosols, soil Type 1	276.12	C	4
DCa7-(5.1-1)	Dissected hilly to low hilly lands with shallow gravelly loamy duplex soils Type 5.1; some gravelly lithosols, soil Type 1	118.0	C-D	4-5
DCa 8-(1-5.1)	Dissected higher hilly lands with narrow ridge crests with shallow gravelly/rocky loams and clay soils over HW rock; some gravelly loamy duplex soils Type 5.1	381.27	D	5

The study area includes a total area of approximately 2,133 ha. Based on the cumulative areas of the terrain units described in Table 9.1.3, a summary of the results of the land capability assessment is as follows:

- There is no Class A or purely Class B land within the project area as mapped.
- Class B-C land comprises approximately 110.6 ha (5.2%) of the project area.
- Class C land comprises approximately 1,050.3 ha (49.2%) of the project area.
- Class C-D land comprises approximately 278.1 ha (13%).
- Class D land comprises approximately 693.9 ha (32.5%) of the project area.

Based on the above results, while grazing activities will be displaced by the construction and operation of the RSF, this is not anticipated to be a significant issue as there is extensive suitable grazing land available in the region.

9.2 Residue Characterisation

9.2.1 Introduction

The residue to be stored in RSF has the potential to impact upon surface water and groundwater. To assess this potential impact, geochemical characterisation and assessment of the residue has been completed to:

- Determine the physical and chemical characteristics of the residue solids and supernatant liquid.
- Determine the potential for residue solids and supernatant liquid to generate acidic, saline and/or sodic conditions.
- Determine the multi-element composition of residue solids and supernatant liquid.
- Outline a water quality monitoring program for the RSF and determine any constraints related to final rehabilitation based on observed residue characteristics.

Residue to be placed within the RSF will undergo initial treatment in the final neutralisation circuit at the refinery. In this process, the pH is raised to 7.0 allowing most of the heavy metals to be precipitated. Limestone will be added as a reactant to the first stage, raising the pH of the slurry to approximately 5.5. Lime slurry will be added as reactant to the second stage, raising the pH of the final slurry to approximately 7.0. The neutralised slurry containing residues from ore and other process inputs, in addition to gypsum generated during neutralisation, will be pumped to the RSF thickeners located at the RSF.

A bulk residue sample was geochemically tested in April 2006 by Australian Laboratory Services Pty Ltd and SGS Lakefield Oretest Pty Ltd. The residue sample analysed by these laboratories was neutralised to a pH of 7.0, in order to generally replicate the chemistry of residue material to be stored in the RSF. However, some aspects of residue treatment are still to be finalised and a more representative sample of residue material will be available for validation test work from combined Marlborough and overseas ore in 2007.

Details of the tests are provided in Appendix O.

9.2.2 Residue Characteristics

9.2.2.1 Acid-Base Characteristics

Acid-base test results for the neutralised residue solid sample are provided in Appendix O and summarised below.

- The neutralised residue sample has a neutral pH of 7.0 and net acidity of 1.2 kg sulphuric acid per tonne (H_2SO_4/t).
- The EC is high (83,600 µS/cm) and the sample is highly saline.
- Total sulphur concentration is relatively high (5.30%) and sulphate sulphur concentration is also high (5.26%), indicating that only a small amount of sulphur is present in the sulphidic (unoxidised) form. The relatively high sulphate sulphur concentration is due to the presence of gypsum, which is produced during neutralisation.
- The low oxidisable sulphur concentration (0.04%) and maximum potential acidity (1.2 kg H_2SO_4/t) of the sample is much less than the acid neutralising capacity (ANC) of 9.7 kg H_2SO_4/t.
- Net acid producing potential (NAPP) for the sample is negative (-8 kg H_2SO_4/t). This finding, together with the low oxidisable sulphur content of the sample, indicates that the residue is non-acid forming (NAF). The NAF sample classification is confirmed by the results of the net acid generation (NAG) test (NAGpH is 7.5).

9.2.2.2 Multi-Element Composition of Solids

Multi-element test results for neutralised residue solid are provided in Appendix O. The results indicate that process residue has metal concentrations in solids that are generally within relevant Environmental Protection Agency (EPA) (1998) and National Environmental Protection Council (NEPC) (1999 (a)) guideline criteria for soils. The main exceptions are manganese, chromium and nickel. Manganese concentrations slightly exceed the EPA environmental investigation levels (EIL) for this metal; however, these are well within relevant NEPC health-based investigation level (HIL) guidelines for soil. Chromium and nickel concentrations exceed the NEPC HIL guidelines for soil. The residue sample tested currently complies with the EPA's solids assessment criteria for classification of dams containing hazardous waste (EPA, 2006 (e)), although the current nickel concentration is close to the limit.

9.2.2.3 Multi-Element Composition of Liquor

Multi-element test results for neutralised residue liquor (supernatant) are provided in Appendix O. The results indicate that the sample contains relatively high concentrations of soluble salts, with sulphate concentrations almost two orders of magnitude greater than the selected guideline criteria (ANZECC, 2000).

The supernatant has soluble metal concentrations that are generally within Australian and New Zealand Environment and Conservation Council (ANZECC) guideline values for livestock drinking water and below groundwater investigation levels (NEPC, 1999 (a)). Exceptions are soluble nickel and manganese concentrations. The soluble nickel concentration (31.5 mg/L) is elevated compared to the ANZECC value for livestock drinking water (1 mg/L). No livestock drinking water quality guidelines exist for manganese, therefore the recommended NEPC irrigation water guideline criteria has been selected for reference. The soluble manganese concentration (407 mg/L) is elevated compared to the NEPC value for irrigation water (2 mg/L).

Comparison of the concentration of metals and salts in supernatant liquor against the EPA's liquids criteria for classification of dams containing hazardous waste (EPA, 2006 (e)) indicates that the soluble chloride, sulphate, and nickel concentrations currently exceed the EPA criteria, and the soluble fluoride concentration matches the EPA criteria (although it also matches the detection limit of the analytical test for this element).

9.2.2.4 Sodicity and Dispersion

Sodicity and dispersion analysis results for the neutralised residue sample are provided in Appendix O. The exchangeable sodium potential (ESP) is the proportion of sodium adsorbed onto a material surface as a proportion of the total cation exchange capacity. The residue sample has a high ESP (exchangeable sodium of 13.9%) indicating that the material is slightly sodic. However, the material has an Emerson Class Number of 4, which indicates that the material is generally cohesive and unlikely to disperse.

9.2.2.5 Organic Carbon and Nutrients

The total organic carbon (TOC) concentration in the residue sample is relatively low (0.19%) indicating that this material is unlikely to be suitable as a growth medium without addition of organic material.

The total nitrogen concentration in the residue sample is low (<50 mg/kg) as is the bicarbonate extractable phosphorus (extractable P) concentration (<2 mg/kg). These results indicate that the sample material is unlikely to be suitable as a growth medium without fertilizer addition.

9.2.2.6 Geochemical Summary

Geochemical test results for residue material likely to report to the RSF indicate that:

- The residue is likely to be NAF.

- The concentration of metals in the residue sample solids is generally within applied environmental and health based investigation guideline levels for soils. However, elevated concentrations of chromium, manganese and nickel in solids are indicated.
- The residue sample complies with EPA assessment criteria for solids for dams containing hazardous waste (EPA, 2006 (e)), although the current nickel concentration is close to the limit.
- The concentration of soluble metals in the supernatant solution is generally low and within applied guideline criteria. However, elevated concentrations of soluble manganese and nickel are indicated.
- The concentration of soluble salts in the supernatant solution is generally high. The soluble sulphate concentration exceeds applied guideline criteria.
- The supernatant liquor generally complies with EPA assessment criteria for liquids for dams containing hazardous waste (EPA, 2006 (e)). However, soluble chloride, sulphate, and nickel concentrations in the sample exceed EPA criteria, and the soluble fluoride concentration matches the EPA criteria.
- The residue sample has an elevated ESP indicating that the material is slightly sodic. However, the Emerson Class Test indicates that the material is generally cohesive and unlikely to disperse.
- The residue material contains low levels of TOC, total extractable phosphorous and total nitrogen.

The initial geochemical assessment results indicate that direct revegetation of the process residue material in the RSF (as part of final rehabilitation) is unlikely to be appropriate due to high salinity levels, elevated metal concentrations, sodicity, and low nutrient issues. Therefore, a cover system will be utilised as part of the final rehabilitation of the RSF (refer Section 9.5).

Investigations are continuing to reduce the concentration of specific solutes in residue liquor. A more representative sample of residue material is expected to be available for validation test work from combined Marlborough and overseas ore in early 2007.

A detailed mass balance indicates that the concentration of nickel in the RSF liquor, in practice, will be significantly lower than the sample on which the EIS geochemical results were based. GPNL expects that the concentrations of nickel and manganese in solution will be less than that in the single sample.

Testing of a more representative sample of residue material will commence, when this becomes available, to confirm expectations on seepage quality as discussed above. Any additional testing required to provide an indication of ongoing leachate quality and facilitate optimisation of a seepage monitoring program will then be determined.

In order to optimise residue consolidation and overall storage capacity, the RSF will not be lined. Seepage from the RSF will be collected and recycled (refer Section 9.3 for further details of the seepage collection system).

9.2.2.7 Geotechnical Characteristics

Geotechnical testing was undertaken on a residue sample which included sieve analysis, Atterberg limits, specific gravity determination, consolidation testing, slurry settling and sedimentation, drying, and rheology testing for pipeline pumping (URS, 2006).

The results from the sieve analyses and Atterberg limits indicate that the residue classifies as a silt material, with over 90% of the particles passing the 0.075 mm sieve. The specific gravity of the residue ranges from 2.94 to 3.01.

Slurry settling test results indicate that the residue has low to moderate settling characteristics. The test results showed that the residue will settle to an initial dry density of 0.66 t/m³. The results of the consolidation test indicates the dry density of the residue will increase with time as the material consolidates under self-weight (more residue accumulates in the facility). The consolidation tests indicate the final dry density will vary between 0.99 and 1.1 t/m³. The calculated hydraulic conductivity of the residue ranges from 6×10^{-12} to 5×10^{-9} m/s.

The slurry settling and consolidation test results indicate that while the residue requires a moderate amount of time to settle and consolidate, consolidation time to reach high residue density can be achieved by employing thin-bed sub-aerial deposition techniques. Thin-bed deposition will be achieved by frequently moving the residue deposition location so that only a thin layer of residue, typically 50 mm thick, is deposited before the deposition point is moved. This technique allows the residue to consolidate prior to additional residue deposition.

9.3 RSF Design

Details of the REF design are given in the concept design report (URS, 2006). This section summarises the content of that report.

9.3.1 Design Criteria

Table 9.3.1 presents the criteria used for the development of the concept-level design of the RSF. The design criteria were developed with input from GPNL personnel, from laboratory test data, and from information gathered during site characterisation studies.

Table 9.3.1 Design Criteria Summary

Item	Design Criteria
Geometry	
Design capacity requirement	25 years – initial embankment designed to provide storage for Stage 1 at full production (7 years, 47 million tonnes)
Residue production rate	See Figure 9.3.1
Average in-place density (after consolidation)	0.98 t/m³ based on laboratory testing of residue.
Residue beach slope	150H:1V (based on residue rheological test data)
Solution Balance	
Residue percent solids by weight during deposition	36%
Reclaim liquor percentage	100 % reclaim from RSF, when available
Minimum water level over residue surface	1.5 m in reclaim pool
Design storm event (full containment)	10-year, 3-month wet season
Containment Dam Stability	
Minimum acceptable operational static factor of safety	1.5
Minimum acceptable operational seismic factor of safety	1.1 or permanent displacements less than 0.5 m under Operational Basis Earthquake.
Surface Water	
Hazard Category of Dam	Significant
RSF operational spillway capacity	Spillway designed to safely pass 1 in 10,000 AEP – 96 hour flood plus wave run-up from worst wind speed on record (750 mm)
Seepage Water	
Water quality guidelines	Queensland Government. Department of Environment. Draft Guidelines for the Assessment & Management of Contaminated Land in Queensland. May 1998. National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM).

The design in based on the residue generation rate given in Figure 9.3.1.

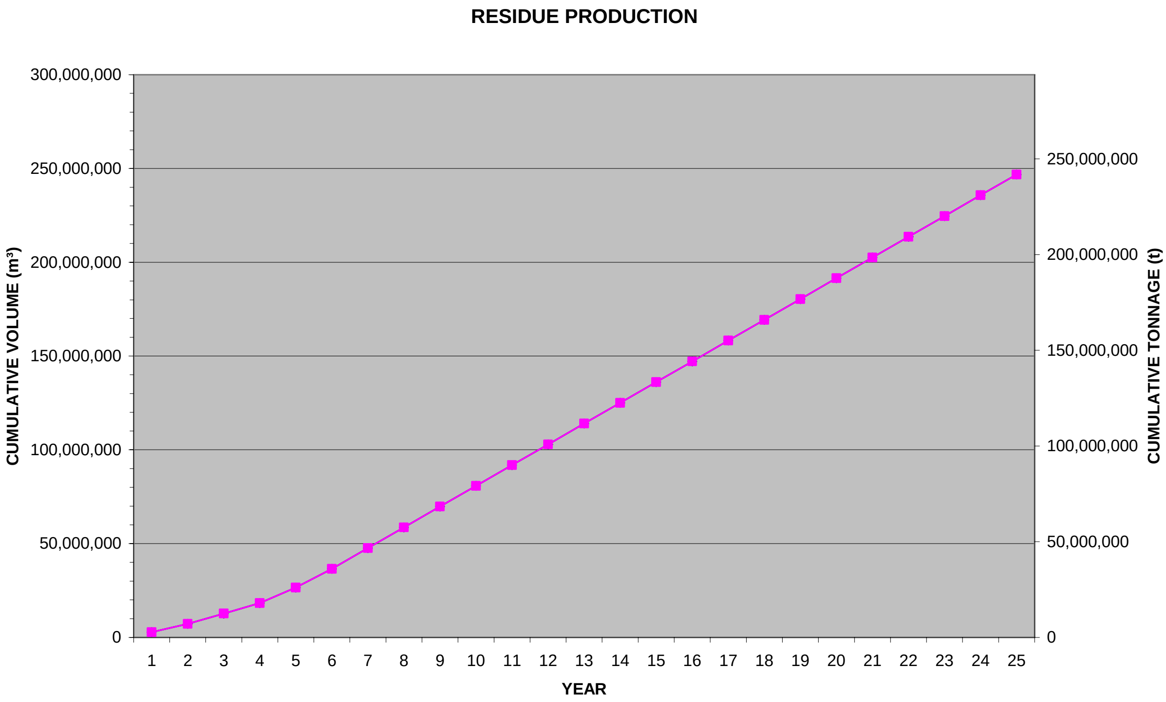


Figure 9.3.1 Residue Production Rate

9.3.2 Embankment Design

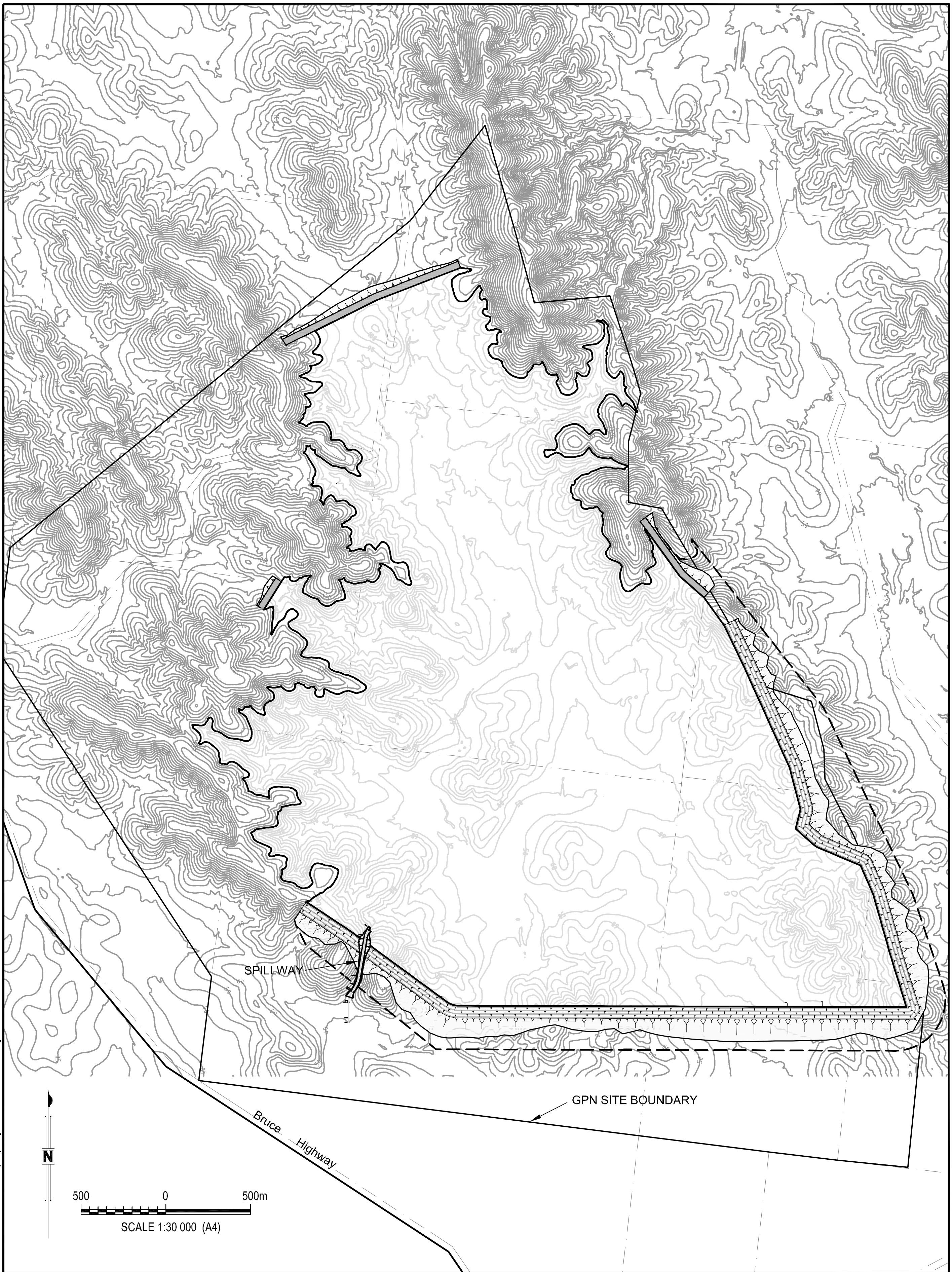
As shown on Figure 9.3.2, the residue at the RSF will be contained behind a series of embankments placed between areas of high ground forming the valley in which the RSF is located. The main embankment will be located at the southern and south-eastern ends of the RSF and will be built to a height of approximately 86 m AHD. Smaller embankments will be constructed along the sides of the RSF to prevent the residue from flowing into surrounding low-lying areas. At the northern end of the RSF another embankment will be constructed to prevent residue from entering the Police Creek catchment.

The RSF embankments will be constructed of earthen (soil and rock) fill and designed to provide stable containment of the residue under the anticipated static and seismic loads. The embankment cross-sections will include the following components:

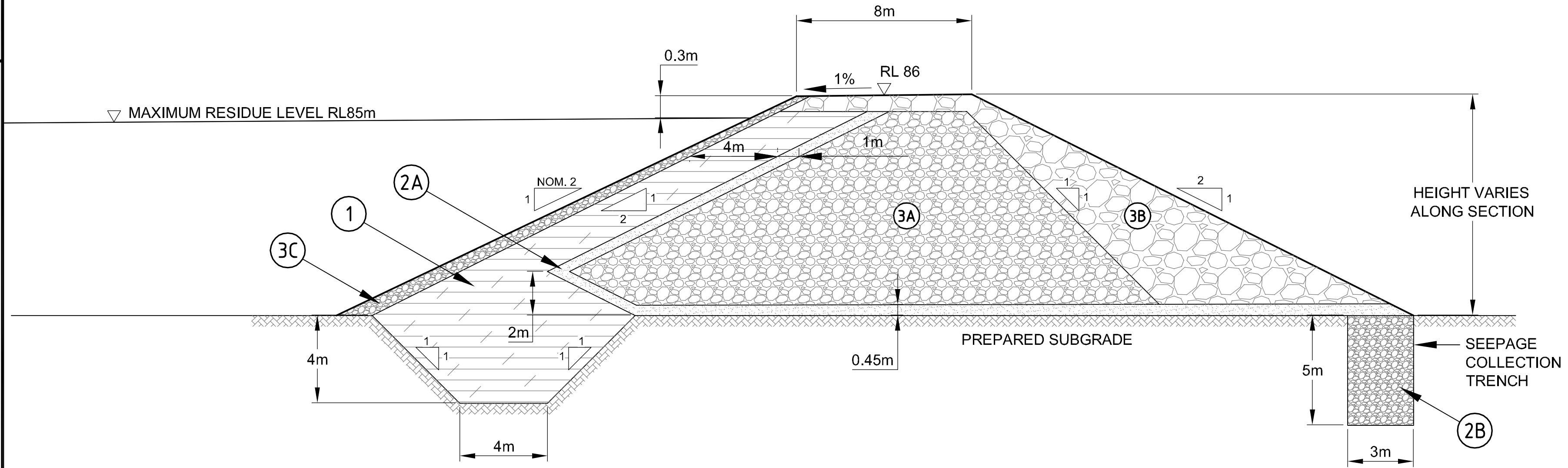
- Upstream erosion protection rockfill.
- An upstream compacted clay zone that is contiguous with the cut-off trench to control seepage.
- Internal chimney and blanket drains for control of pore pressures.
- Intermediate compacted rockfill zone to provide structural stability of the dam.
- Downstream rockfill shell to provide gravity fill for the dam.

A typical embankment cross-section is presented in Figure 9.3.3.

The embankments are designed to have an upstream slope of 2 horizontal (H): 1 vertical (V). A piping risk assessment of the design determined that the risk of piping failure was very low and within the risk criteria set forth in ANCOLD (2003). Filter drains will be included in the embankment to assist in control of pore and seepage pressures. The filter drains will help prevent loss of core material.



Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	RESIDUE STORAGE FACILITY GENERAL LAYOUT
URS	Drawn: VH · Approved: CMP · Date: 27/10/2006	Figure: 9.3.2 · Rev. A
	Job No.: 4262 5791 · File No.: 42625791-g-094.dwg	A4



TYPICAL SECTION

SCALE 1:300

NOTES:

(1) COMPACTED CLAY - NATIVE CLAYEY SOILS. MOISTURE CONDITIONED AT OR -4 BELOW OMC. COMPACTION BY 10t VIBRATORY SMOOTH DRUM ROLLER OR SHEEPSFOOT TO 95% PROCTOR MDD. MAX. LIFT THICKNESS: 300mm

(2A) FILTER SAND - NATIVE RIVER SAND. MOISTURE CONDITIONED AND COMPACTION BY 10t VIBRATORY SMOOTH DRUM ROLLER. MAX. LIFT THICKNESS: 300mm

(2B) DRAINAGE AGGREGATE - HARD, DURABLE DRAINAGE 20mm AGGREGATE

(3A) ROLLER COMPACTED ROCKFILL - NATIVE OR QUARRIED ROCK (D50 = 300mm), MOISTURE CONDITIONED. COMPACTION BY 10t VIBRATORY SMOOTH DRUM ROLLER. MAX. LIFT THICKNESS: 1m

(3B) TRUCK COMPACTED ROCKFILL - NATIVE OR QUARRIED ROCK (D50 = 550mm), MOISTURE CONDITIONED. COMPACTION BY HAUL TRUCK TRAFFICKING. MAX. LIFT THICKNESS: 2m

(3C) EROSION LAYER - QUARRIED ROCK (D50 = 600mm), MOISTURE CONDITIONED. COMPACTION BY HAUL TRUCK TRAFFICKING. MAX. LIFT THICKNESS: 2m

URS

Gladstone Pacific Nickel Ltd

Project: GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT

Drawn: SCB/VH | Approved: CMP | Date: 01/11/2006

Job No.: 42625791 | File No.: 42625791-g-084.dwg

Title: **RESIDUE STORAGE FACILITY - MAIN EMBANKMENT CROSS SECTION**

Figure: 9.3.3 | Rev. A | A4

Stability analyses were conducted to evaluate the performance of the embankments under static and earthquake loads. These assessed the maximum cross-section through the embankment, which was considered to be the most critical since it has the maximum load and is founded on the thickest section of foundation soils.

The stability analysis calculates the percentage by which the available shear strength exceeds, or falls short of, that required to maintain equilibrium. Therefore, safety factors in excess of 1.0 indicate stability and those less than 1.0 indicate instability, while the greater the mathematical difference between a safety factor and 1.0, the larger the "margin of safety" (for safety factors in excess of 1.0), or the larger the likelihood of failure (for safety factors less than 1.0).

The results of the stability analyses indicate that the factor of safety of the embankment under static loading was 1.9, while the results of the analyses under earthquake loading indicated that the containment dam will have a factor of safety of 1.8. Therefore the embankment stability meets the design criteria for the project.

9.3.3 Upstream Raises

The capacity of the RSF with a main embankment height of 86 m AHD is sufficient for the initial 7 years of residue production at the rates shown in Figure 9.3.1. Beyond Year 7 it is proposed to increase the capacity of the RSF through a series of upstream raises, as shown in Figure 9.3.4. It is likely that three raises will be necessary to increase the embankment height by approximately 15 m to 101 m AHD which will be necessary to contain 25 years of residue production.

The upstream raises will be founded on compacted residue, compacted rockfill, and/or another suitable material. Preliminary shear strength tests on compacted residue indicate the material will have sufficient strength to support the upstream raises. Further testing on the residue will be required during detailed design to define the compaction parameters and placement to achieve a suitable upstream raise foundation.

The upstream raises would consist of compacted rockfill over a prepared foundation, and include internal drainage (chimney and blanket drains). The foundation would likely be formed as part of the operation, prior to the upstream raise. This could be done by soil farming, displacement, and/or periodic compaction during thin-bed deposition. The raise would consist of excavating a key into the existing containment dam to expose the lower internal drain. The compacted rockfill and blanket drain from the raise would tie directly into the lower containment dam, providing a continuous structure.

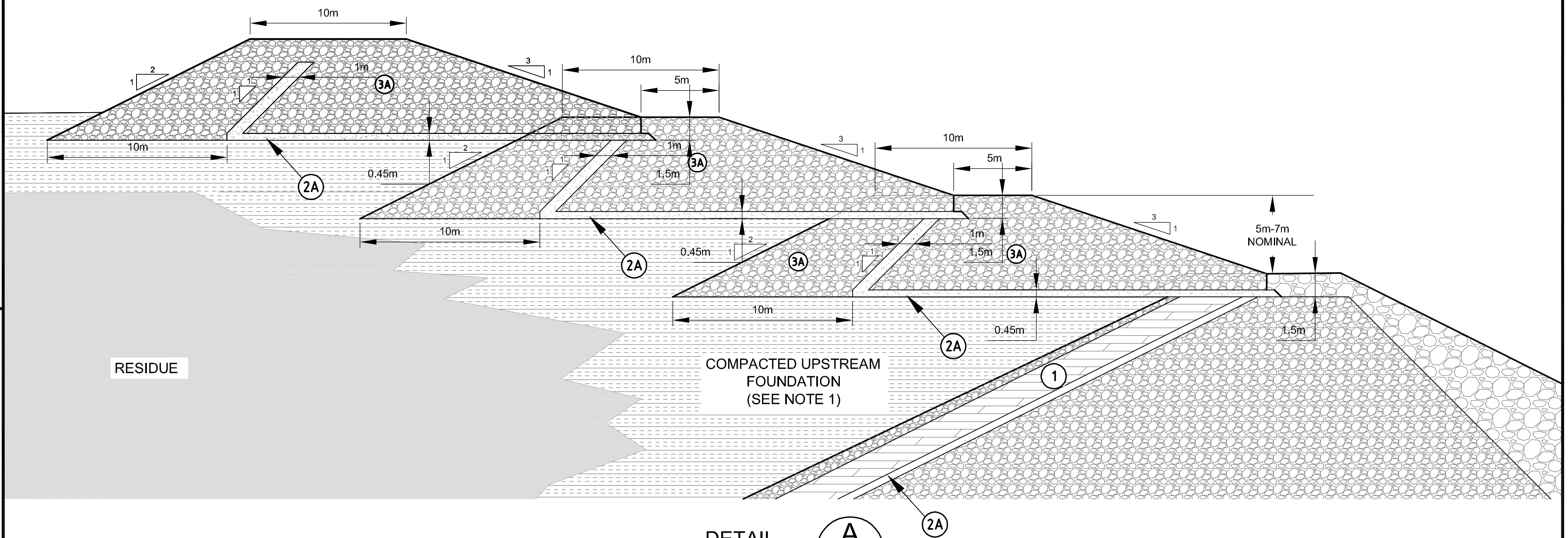
Stability analyses for the upstream raise sections indicate that the end-of-construction (short-term) factor of safety of under static loading is 1.4. The long-term factor of safety will be greater than end-of-construction factor of safety as the residue material consolidates and gains shear strength.

9.3.4 Seepage Collection System

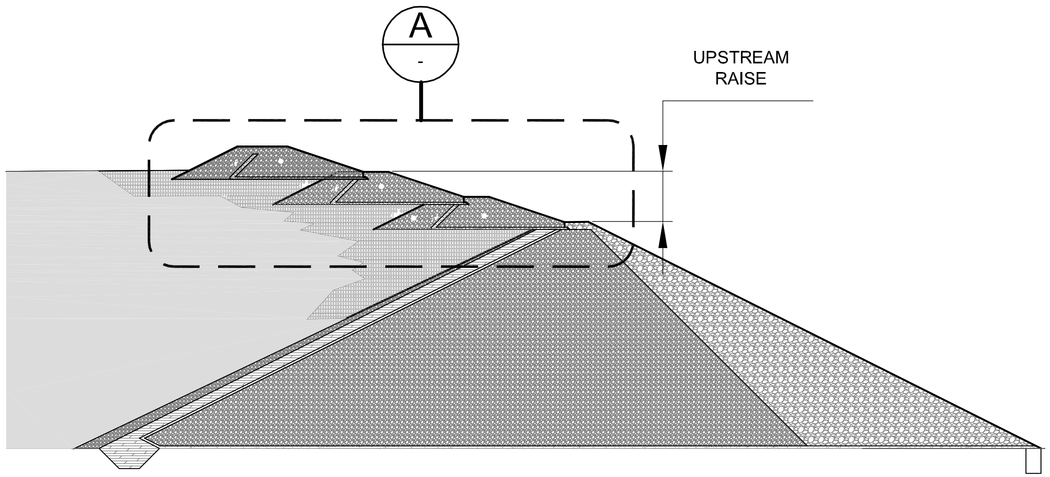
On the basis of ANCOLD (1999), the following design objectives have been adopted for seepage at the RSF:

- Surface expression of seepage discharge downstream of the RSF should not occur.
- No significant impact on the environmental quality of receiving waters should occur.
- The potential beneficial uses of surface and groundwater downstream of the RSF should not be compromised.

For the embankment design, a seepage analysis was conducted to quantify the amount of seepage reporting to the collection system. Seepage will be controlled through a combination of measures including a low-permeability clay core and cut-off key in the RSF embankment and a seepage collection system. The material properties used in the seepage analyses were based on either laboratory test data or typical values referenced in the open literature and are summarised in Table 9.3.2.



DETAIL A
SCALE 1:400



TYPICAL SECTION
RSF S EMBANKMENT
SCALE 1:1500

NOTES:

1. UPSTREAM FOUNDATION MAY CONSIST OF ROCKFILL, COMPACTED RESIDUE AND/OR AMENDED RESIDUE.

LEGEND:

1	COMPACTED CLAY - NATIVE CLAYEY SOILS. MOISTURE CONDITIONED AT OR -4 BELOW OMC. COMPACTION BY 10t VIBRATORY SMOOTH DRUM ROLLER OR SHEEPSFOOT TO 95% PROCTOR MDD. MAX. LIFT THICKNESS: 300mm
2A	FILTER SAND - NATIVE RIVER SAND. MOISTURE CONDITIONED AND COMPACTION BY 10t VIBRATORY SMOOTH DRUM ROLLER. MAX. LIFT THICKNESS: 300mm
2B	DRAINAGE AGGREGATE - HARD, DURABLE DRAINAGE 20mm AGGREGATE
3A	ROLLER COMPACTED ROCKFILL - NATIVE OR QUARRIED ROCK (D50 = 300mm), MOISTURE CONDITIONED. COMPACTION BY 10t VIBRATORY SMOOTH DRUM ROLLER. MAX. LIFT THICKNESS: 1m
3B	TRUCK COMPACTED ROCKFILL - NATIVE OR QUARRIED ROCK (D50 = 550mm), MOISTURE CONDITIONED. COMPACTION BY HAUL TRUCK TRAFFICKING. MAX. LIFT THICKNESS: 2m
3C	EROSION LAYER - QUARRIED ROCK (D50 = 600mm), MOISTURE CONDITIONED. COMPACTION BY HAUL TRUCK TRAFFICKING. MAX. LIFT THICKNESS: 2m

URS

Gladstone Pacific Nickel Ltd

Project
GLADSTONE NICKEL PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Drawn: SCB/VH | Approved: CMP | Date: 01/11/2006

Job No.: 42625791 | File No.: 42625791-g-085b.dwg

Title
RESIDUE STORAGE FACILITY - CONCEPTUAL UPSTREAM RAISE DETAIL

Figure: 9.3.4 | Rev. B | A4

Table 9.3.2 Hydraulic Conductivity of RSF Components

Component	Hydraulic Conductivity (m/s)
Containment Dam Clay Zone	$1x10^{-8}$
Chimney and Blanket Drain Fill	$1x10^{-4}$
Containment Dam Fill	$1x10^{-6}$
Subgrade Alluvial Soils	1.3×10^{-7}
Bedrock	1.0×10^{-7}
Residue	$1x10^{-8}$

Based on the average depth to groundwater from the field investigations, the seepage analysis has assumed that the groundwater level is approximately 40 m below the ground surface.

The seepage analysis was conducted using SEEP/W (Geoslope, 2006 (b)), a commercially available computer program that is designed to analyse steady-state and transient seepage under saturated and partially saturated conditions. The results from the seepage analysis indicate that the anticipated seepage through the containment dams is approximately 10 litres per day per linear metre length of dam.

The seepage collection system was designed to intercept seepage from the containment dams and return the seepage to the RSF impoundment. It consists of a collection trench with a pump-back riser. The collection trench is an excavated trench (5 m deep and 3 m wide) that is geotextile lined and backfilled with drainage fill (sand and/or gravel). At the bottom of the trench is a 300 mm diameter, slotted PVC pipe. The slotted pipe is connected to a riser pipe from which a submersible pipe will pump the seepage back to the RSF.

In some areas, it may not be practical to construct a seepage collection trench given the constraints. In these areas, the collection trench may be replaced with one or two 5 m deep extraction wells.

Seepage analyses indicate that seepage that is not directly intercepted by the collection system is not anticipated to migrate more than approximately 65 m downgradient of the RSF over a period of 50 years. Post-closure after the RSF is covered, constituents within the groundwater will be continually diluted as the source (e.g. the RSF) is no longer contributing seepage into the groundwater.

9.3.5 Spillway

The RSF design will include a spillway to allow controlled discharge of excess water, should it be needed under extreme climatic conditions. No discharge from the RSF is anticipated under normal operating conditions. The RSF was assessed as a significant hazard dam according to the Department of Minerals and Energy (DME) guidelines (1995(a)) because of the potential for “significant” economic loss and environmental impact from a failure of the dam embankment. As such, the spillway is sized to safely pass the runoff from an annual exceedance probability (AEP) of 1 in 10,000, 96-hour storm event, the conservative (upper bound) of the guidelines. ANCOLD (2000) recommends an additional freeboard of 0.3 m for “significant” hazard category dams or the worst wet season on record plus wave run-up.

9.4 RSF Operations

9.4.1 Residue Disposal

After thickening, slurry residue from the refinery will be discharged via spigot disposal along the RSF perimeter. The residue will form a beach as it flows away from the spigots and settle. The liquor entrained in the slurried residue will flow to a low point at the end of the residue beach and collect in a reclaim pond. Residue discharge will be managed so that the reclaim pond is located away from the embankment towards the centre of the RSF. In addition, alternating spigotting points will be employed to promote thin-layer deposition, thereby enhancing consolidation and increasing the residue dry density. Liquor will be pumped from the reclaim pond, combined with liquor separated in the RSF thickener, and pumped back to the refinery (return liquor).

Slurry settling test results indicate that the residue has low to moderate settling characteristics. The test results showed that the residue will settle to an initial dry density of 0.66 t/m³. The results of the consolidation test indicate the dry density of the residue will increase with time as the material consolidates under self-weight as more residue accumulates on top of the previously-deposited residue. The consolidation tests indicate the dry density will vary between 0.99 to 1.1 t/m³.

The slurry settling and consolidation test results indicate that consolidation time to reach high residue density can be obtained by employing thin-bed sub-aerial deposition techniques. Thin-bed deposition will be achieved by frequently moving the residue deposition location so that only a thin layer of residue, typically 50 mm thick, is deposited before the deposition point is moved. This technique allows the residue to consolidate prior to additional residue deposition. This technique does not require any additional equipment other than multiple spigots around the RSF perimeter.

9.4.2 Mud Farming

GPNL will adopt the advanced residue management practice of “mud farming” where specialised earthmoving equipment (twin-archimedes screw tractor) is used to control and accelerate the residue dewatering process. Supporting equipment may also include low ground-pressure bulldozers and excavators as required.

Mud farming was developed to assist in the management of alumina refining residues and is currently practiced at six alumina refineries around Australia. Mud farming accelerates the residue dewatering process by creating preferential surface drainage and opening up the residue to evaporation. By accelerating the dewatering process, the area required for residue operations is reduced, final residue densities are often higher, and the total volume required for residue storage is reduced.

A key feature of mud farming is the ability to permit direct access to the residue surface during the dewatering period with no additional engineering controls for safe access. Maintaining safe access to the residue surface at all stages of the dewatering cycle allows routine minor adjustments to the residue deposition plan to occur as required.

Residue will be placed in discrete areas in shallow layers and permitted to flow to the lowest point of elevation. Periodically, the screw tractors will plough the residue surface liberating entrained water that will be directed to surface drainage systems and captured. As increased amounts of entrained water are removed, the density of the residue slurry will increase such that it will begin to behave more like a solid than a slurry. As the residue layer opens up to the ploughing process, the residue surface area increases further enhancing water loss through evaporation. When the target final densities are reached, the process will be repeated. The dewatering cycle times will vary throughout the year in response to potential evaporation rates and hence the area required for mud farming operations will also change in response to the seasons.

As the residue has been dewatered to a high density and high strength it is planned to re-use the residue as a construction material for internal RSF wall construction for upstream raising, negating the need to clear additional areas for the importation of additional materials.

By using mud farming to control the dewatering process, the potential for uneven drying and dust generation across large areas will be reduced. This is achieved by maintaining the minimum operational residue areas, high moisture loss across the full profile of the residue layer, and the high surface roughness and hence lower wind speeds at the evaporating surface.

9.4.3 Water Balance

An aggregated and simplified water balance has been produced for the RSF concept design study (URS, 2006). The basic model (Figure 9.4.1) was developed from the following governing inflow equals outflow equation using GoldSim modelling software (GoldSim, 2006):

Inflows + Previous Storage – Outflows = New Storage

Water is added to the system from:

- Rainfall across the catchment area within the watershed upstream of the embankment (directly onto the residue area and reclaim pond and indirectly via run-on from the surrounding area).
- Liquor deposited as part of the residue.

Outflows from the RSF include:

- Evaporation from the reclaim pond, residue area and surrounding catchment.
- Reclaim liquor from the RSF pond back to the refinery.

Seepage through the RSF foundation is not considered significant enough to the overall water balance to be modelled and, as discussed below, no losses associated with overflows were predicted to occur during operation.

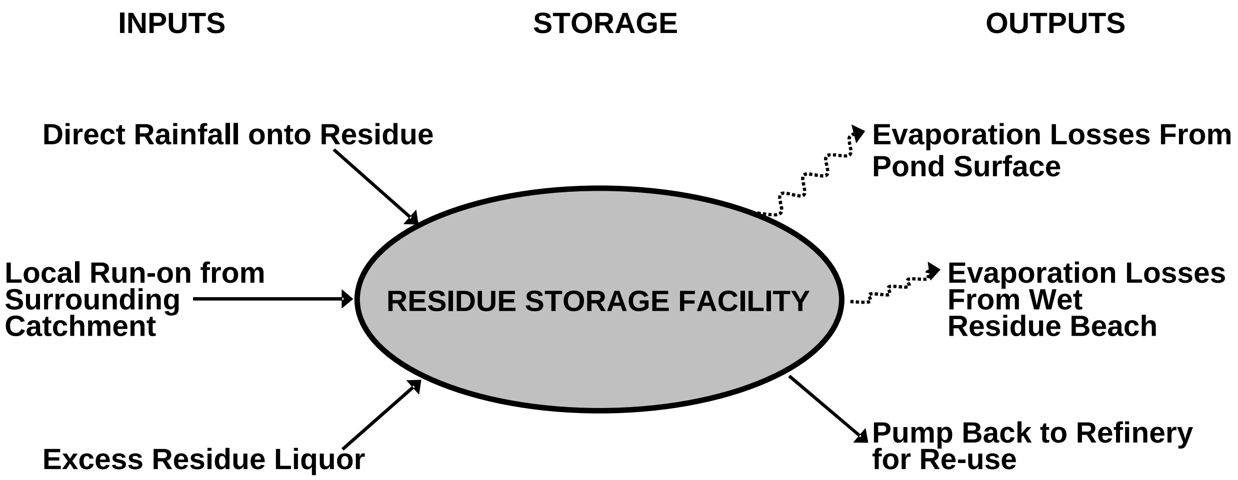


Figure 9.4.1 Conceptual Water Balance Model

In order to accurately represent the site-specific interaction between inflows and outflows, 100 years of rainfall and evaporation data from 1906-2006 were acquired. By using such a long record, it was possible to account for variability in the amount of precipitation and evaporation and model real sequences of events. This is particularly important for the consideration of long-term 'wet' or 'dry' periods.

The beach surface for the maximum deposition of residue was used to calculate the geometric relationship between depth of liquor, surface area and volume of liquor storage. This was considered the critical geometry for testing the RSF design and infrastructure (e.g. pump capacities) as it represented the minimum volume storage capacity for liquor. This scenario was furthermore critical to the management of the reclaim pond because, with residue deposition at a maximum, the maximum depth of liquor in the pond had to be kept below 10 m to prevent interference with residue consolidation. The model assumed that pumps will be turned on to return liquor to the refinery when the pond depth reached 1.5 m.

The water balance showed that the volume of liquor in the reclaim pond generally fluctuates between a minimum of approximately 3 ML and a maximum of approximately 13,800 ML. The liquor level fluctuates frequently after rainfall events as does the depth of liquor in the pond. This can generally be managed to between 1.5 m and 10m deep. The liquor level was modelled to be above 10 m for 933 days over the 100-year simulation period (approximately 3% of the simulation time). The longest time required to reduce the liquor level to below 10 m deep after it had risen above this level was approximately 6 months. On this occasion, emergency pumps had to be employed to reduce the liquor level though these were not utilised at any other time during the 100 year simulation. For all other events where the liquor level had risen above 10 m deep, the permanent pump capacity was adequate to reduce the depth below this threshold within a shorter period than 6 months.

Table 9.4.1 provides a summary of annual inflows and outflows for the RSF.

Table 9.4.1 Summary of Annual Average Inflows and Outflows for the RSF

Inflow	Average Volume (ML/y)	Outflow	Average Volume (ML/y)
Direct Rainfall	6,900	Evaporation from Pond	1,500
Run-on	2,000	Evaporation from Beach	3,500
Liquor in Residue	15,000	Reclaim Liquor	18,800
Total	23,900	Total	23,800

The small discrepancy between inflows and outflows can be attributed to the fact that the model was begun with the RSF empty. The pumps returning liquor to the refinery are operational, on average, approximately 98% of the time. This means that, although climatic data may vary, the rate of return liquor will be relatively consistent throughout the year.

9.4.4 Monitoring

Monitoring the performance of the RSF is a key component of demonstrating that the design assumptions and mitigation measures are effective in controlling potential environmental impacts.

9.4.4.1 RSF Embankment

Monitoring bores will be used to measure the phreatic surface through the embankment during the operating life of the RSF, and additional monitoring bores will be progressively installed in each embankment lift. The monitoring bores will comprise slotted unplasticised polyvinyl chloride (uPVC) standpipes along the base of the RSF embankment. Monitoring of piezometric levels in all bores will be conducted whilst the RSF is being operated.

The condition of the RSF embankments will be inspected on a regular basis, with a particular focus on evidence of surface expression of seepage around the embankment perimeter and surrounding areas.

9.4.4.2 Groundwater

Groundwater levels will be recorded at observation bores constructed downstream of RSF to assess the impact to the local groundwater system from residue deposition. It is anticipated that a groundwater mound will develop beneath the RSF.

Samples will be collected from the seepage collection system and monitoring wells located downgradient of the RSF. These data will be used to assess seepage transport through the foundation and seepage velocities.

9.4.4.3 Reclaim Pond Water

The reclaim liquor pond level will be observed regularly during inspections of the RSF. The pond level data will be linked to the groundwater mound data to assess the hydraulic interaction between the RSF and the local groundwater regime.

Reclaim pond water quality testing will be undertaken in conjunction with the surface water and seepage monitoring described above.

9.4.5 Risk Management

A low risk rating will be achieved for the RSF because of the "multiple lines of defence" approach that has been taken in its design. Risk minimisation aspects that have been incorporated in the design include:

- Several features for seepage control and collection in the embankment design including:
  - A cut-off key comprising compacted low-permeability clay, which will be included below the embankment to provide a barrier to seepage flows through upper zones of potentially higher permeability material.
  - A compacted low-permeability clay core, supported by rock-fill. The clay core will be integral with the underlying clay cut-off to provide a continuous barrier to seepage.
  - A foundation seepage collection system downstream of the embankment. The seepage collection system will consist of a series of collection drains that will be used to intercept seepage and pump it back into the impoundment.
- Reclaim liquor stored away from the embankments, thereby reducing the potential for piping failure through the embankments.
- Residue deposited sub-aerially in thin layers, which maximises the density of the residue beach against the embankments, providing a low permeability layer between the reclaim pond and the RSF floor.
- Direct access to the residue surface for mud farming, which improves residue consolidation.
- Monitoring wells will be located downstream of the RSF to monitor groundwater quality. If the results of the water quality monitoring indicate that downgradient groundwater quality has been degraded, water recovery bores will be installed to recover impacted groundwater to the RSF.

The predicted operational seepage volumes are generally low and are of the order of 310 $L/y/m^2$. The post- closure seepage volumes are estimated to be a maximum of 44 $L/y/m^2$, reducing to zero after 25 years of cover placement.

A key component to reducing potential risks to the environment is monitoring. A comprehensive monitoring program will be maintained over the life of the RSF. Details of the monitoring program are provided below and within the environmental management plan in Section 14.

9.5 RSF Closure

9.5.1 Overview

The proposed closure strategy for the RSF consists of the following:

- Cessation of residue deposition into the RSF.
- Re-profiling the RSF surface to provide a well graded surface that promotes surface runoff and prevents ponding.
- Construction of a low-permeability cap across the final landform surface. This cap will limit the infiltration of water and provide a suitable medium for establishing vegetation.
- Construction of a surface water management system across the RSF to collect rainfall and discharge this clean water to the surrounding environment in a controlled manner. The surface water management system would include graded drains and rock-lined chutes, with flows routed through sediment ponds during the establishment

phase. Water would be discharged to the surrounding environment only after water quality monitoring had confirmed that discharge standards had been reached.

- Maintaining the seepage collection system until the hydraulic head within the RSF has been lowered to the design level.
- Monitoring the groundwater levels around the perimeter of the RSF to ensure that the ongoing seepage performance meets the design expectations.

It is important to note that the RSF cover will not be designed in detail until prior to site closure, not until at least 20 years time. By that time considerable operational experience and monitoring data will be available to guide the design. This section outlines the design concepts as currently proposed. However, the design concepts could change as more monitoring and operational information becomes available.

9.5.2 Cover Design

9.5.2.1 Approach

The design of a RSF cover can include a range of materials and different layers, depending upon the local site conditions and the potential environmental risks that are considered acceptable after rehabilitation. In general, the number of layers within a cover may vary from one to five, depending on the characteristics of the local soils. The thickness of the cover layers may also vary depending on the soil properties and climatic conditions for the site.

The conceptual design for the RSF cover includes a four-layered system based on the concepts presented in the US EPA guidance document entitled Evaluation of Subsurface Engineered Barrier at Waste Sites (US EPA 1998). The cap design considered was developed to provide long-term stability in a tropical monsoonal climate with wet and dry seasons. These layers are described below:

- The first layer placed over the residue is a capillary break to limit the potential for salts to rise from the residue surface into the cover. This material will consist of coarse sand or gravel with low fines content.
- The second layer placed is a barrier layer comprising a low permeability, fine-grained clayey material that will be compacted in place to increase its efficiency to act as a barrier to moisture inflow.
- The third layer is a drainage/protection layer for the barrier layer and consists of sand and fine gravel material. This material will have low fines content, and will be used to route seepage off the top of the barrier layer, thereby reducing the driving hydraulic head.
- The final layer will be topsoil to provide a growth layer for vegetation.

Additional layers may be added to the cover design depending on the desired performance. The final cover design will be advanced during operations once RSF performance has been assessed.

9.5.2.2 Capillary Break Layer

A capillary break layer is required to limit the potential for salts to rise from the residue surface into the cover and evapo-concentrate at the surface. Should this occur, the salts could have a detrimental impact on the sustainability of vegetation and may also be leached from the cover into surface runoff.

The thickness of the capillary break layer will be dependent upon the nature of the surface of the residue material at the time of construction of the rehabilitation works. Typically a thickness of 600 mm of material is required; however, a minimum thickness of 300 mm may be achievable.

9.5.2.3 Barrier Layer

The barrier layer will comprise a fine-grained material with high clay content. This material will be compacted in place to obtain a low permeability layer to act as a barrier to water infiltration.

Based on the results of laboratory testing in previous studies, the available clayey materials that could be sourced from suitable borrow area near the RSF have a hydraulic conductivity of approximately $1x10^{-10}$ m/s, if compacted to achieve a density ratio of 100% of the standard maximum dry density. However, it is likely the clayey barrier soils will be placed at a lower compaction effort. In-place soil tests indicate that the native soils (with no compaction) have a hydraulic conductivity with a geometric mean of approximately $1x10^{-7}$ m/s. To be conservative, this was the hydraulic conductivity considered for design.

The thickness of the barrier layer will be dependent upon the nature of the clayey native soil. Typically a thickness of 600 mm of material is required; however, a minimum thickness of 300 mm may be achievable.

9.5.2.4 Drainage/Protection Layer

The protection layer will comprise sand and fine gravel to provide for the drainage of any water accumulating on the top of the barrier layer. The drainage layer will also provide protection of the barrier layer from invasive roots.

The thickness of the drainage/protection layer is typically 600 mm; however, a minimum thickness of 300 mm may be achievable.

9.5.2.5 Topsoil Layer

Topsoil will be stripped and stockpiled during the construction phase. Upon closure, the topsoil will be recovered from the stockpiles and spread over the drainage/protection layer. A minimum thickness of 300 mm is envisaged for this layer. A crop of sterile exotic and native grasses and shallow-rooted shrubs will be sown in the topsoil cover to stabilise the surface against erosion.

9.5.3 Seepage Modelling

9.5.3.1 Cover

The cover performance was evaluated using the computer program HYDRUS-1D version 3.0 (Simunek et al., 2005). HYDRUS-1D is a one-dimensional finite element software package used to simulate the movement of water, heat, and multiple solutes in variably saturated media. It takes into account the possibility of surface runoff when the precipitation rate is higher than the soil cover storage capacity.

The analysis was carried out using local precipitation and evaporation data from the area. The thickness and the hydraulic properties of the residue cover used in the HYDRUS analysis are given in Table 9.5.1.

Table 9.5.1 Hydraulic Properties RSF Cover Design

Material	Thickness (m)	θr	θs	α	n	k_s (m/s)
Top soil	0.3	0.065	0.41	0.0075	1.89	$1.2x10^{-5}$
Drainage sand	0.3	0.045	0.43	0.0145	2.86	$8.2x10^{-5}$
Low permeability soil	0.6	0.068	0.38	0.0008	1.09	$5.5x10^{-7}$

Note: θr = residual water content; θs = saturated water content; α and n = constants used in the van Genuchten-Mualem equation; k_s = saturated conductivity.

Note that the cover performance did not include the capillary break layer, since this layer does not influence the net infiltration rate through the cover. Also note that the layer thicknesses in the cover would be subject to change during the detailed design.

The analysis was conducted using the van-Genuchten-Mualem hydraulic model (van Genuchten, 1980) with time dependent boundary conditions obtained directly from the precipitation and evaporation data. The analysis was run for 360 days to simulate the average annual infiltration through the cover. The results from the HYDRUS-1D model indicate that the net infiltration through the cap is approximately 44 mm/y which represents approximately 5% of the annual precipitation (873 mm) for the area.

During the post-closure period, the maximum volumetric seepage through the base of the cover layer is estimated to be 0.04 $m^3/y/m^2$.

9.5.3.2 RSF Floor

Seepage that passes through the floor of the RSF will flow into the underlying groundwater system. Some of that seepage will be collected by the seepage collection system located at the downstream toe of the containment dam. However, the seepage collection system may not intercept all of the seepage from the RSF. Seepage entering the groundwater table will be transported at the velocity of the groundwater.

A groundwater seepage model, SEEP/W version 5.20 (Geo-slope, 2004), was used to simulate seepage from the RSF. SEEP/W is a two-dimensional finite element software product that can be used to model seepage movement and pore-water pressure distribution within porous materials such as soil and rock. Its comprehensive formulation makes it possible to analyse both simple and highly complex seepage problems.

The model has predicted that groundwater velocities will be in the range 0.013 to 1.3 m/year. Therefore, over the 25 year life of the RSF, seepage would travel approximately 0.3 to 30 m from the RSF if it was not intercepted by the seepage collection system. The volumetric seepage through the floor of the RSF is estimated to be 0.31 $m^3/y/m^2$ of floor area.

Figure 9.5.1 presents the predicted seepage velocities from the RSF at maximum capacity (highest hydraulic gradient). This figure demonstrates that, even under the highest hydraulic gradient, the seepage velocities are low due to the low hydraulic conductivity of the foundation materials. The results show that after 25 years of operations there is a saturated zone within the residue with vertical seepage through the residue into the underlying groundwater. There is no surface expression of this groundwater downstream of the RSF.

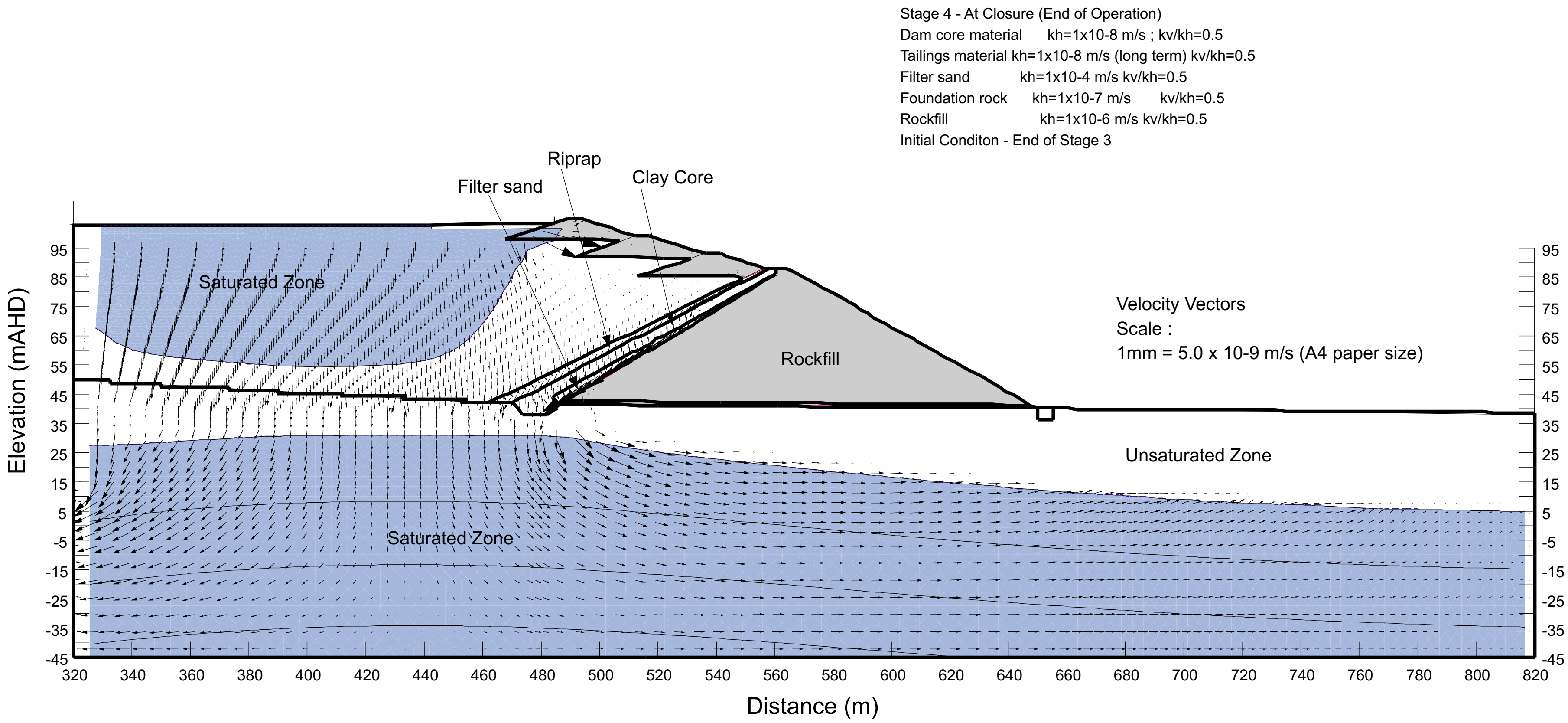
The situation 25 years after closure (Figure 9.5.2) shows that the residue is unsaturated. This is because no additional residue (and its associated process and slurry water) has been added to the RSF and the infiltration of direct rainfall has significantly reduced due to the presence of the RSF cover. The residue has effectively drained and minimal seepage is reporting to the underlying groundwater. By this time, the seepage velocities are predicted to be of the order of $1x10^{-10}$ to $1x10^{-12}$ m/s.

Over the 50 year period (25 years of operation and 25 years of post-closure), seepage exiting the RSF is anticipated to have travelled approximately 65 m (using the upper bound of groundwater velocity) if it had not been intercepted by the seepage collection system.

9.5.4 Stormwater Management

The overall design objective of surface water management strategies for the closed RSF is to limit erosion of the surface during high intensity rainfall events.

Drainage works will be designed to cater for peak flow conditions. In this respect, the design criterion for revegetated drains, rock lined drains, and rock chutes that form the permanent drainage system is for adequate erosion resistance for large storms with up to 1-in-100-year ARI rainfall intensity.



URS

Client: Gladstone Pacific Nickel Ltd

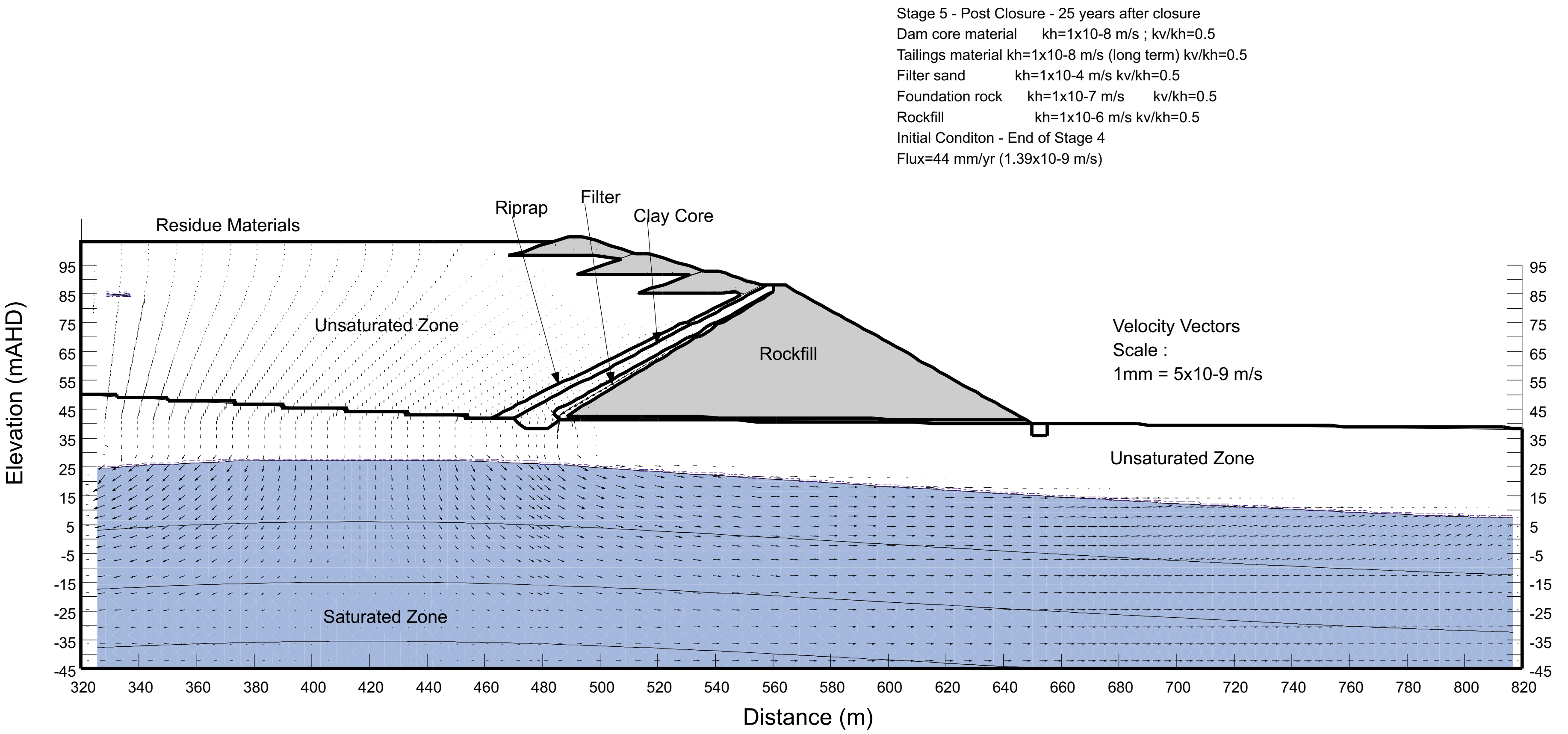
Project: GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **PREDICTED RSF SEEPAGE AT CLOSURE**

Drawn: VH | Approved: CMP | Date: 06/11/2006

Job No.: **4262 5791** | File No. 42625791-g-096.cdr

Figure: **9.5.1** | Rev. A | A4



Client: Gladstone Pacific Nickel Ltd

Project: GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **PREDICTED RSF SEEPAGE 25 YEARS AFTER CLOSURE**

Drawn: VH | Approved: CMP | Date: 06/11/2006

Job No.: **4262 5791** | File No. 42625791-g-097.cdr

Figure: **9.5.2** | Rev. A | A4

9.5.4.1 Contour Drains

Regularly spaced contour drains will be provided as the primary design mechanism against sheet flow causing rilling and gully erosion of the crest and outer slopes of the RSF embankment.

Across the crest of the RSF embankment, the longitudinal gradient of contour drains will be no flatter than 1 in 200. As such, these contour drains may be susceptible to siltation; however, the general gradient of the crest of the RSF is expected to generate only minor quantities of sediment.

The contour drains will be formed by small embankments as opposed to drains cut into the slope as this ensures that adequate cap depth will remain beneath the drains. The drains will be V-shaped with relatively flat side slopes. Such drains have similar performance to wide drains in terms of limiting peak velocity, but are less prone to siltation when flow is less than the design capacity.

It can be expected that the base of the V-shaped contour drains will eventually silt up and form a parabolic shaped cross-section. Such sediment will not be removed unless an excessive depth of sediment substantially reduces the flow capacity of the contour drain.

It is desirable to retain minor silt deposits (say up to 150 mm thick) in the drains as this assists in maintaining moisture in the soil profile and maximising the success of vegetation growth along the contour drains.

In lesser storm events the deposition of silt promotes shallow flow hydraulics and assists in limiting flow energy. In more intense storm events, the silt deposits erode and consume flow energy.

The contour drains will be spaced to limit the velocity of sheet flow across the surface of the RSF. Under bare earth conditions, the surface of the RSF with an alluvial silt or silt loam cover will be able to resist sheet flow velocities up to 0.6 m/s (IEAust, 1996). Under revegetated conditions, the surface will be able to resist flow velocities up to 1.0 m/s depending on uniformity and condition of the vegetation.

The crest contour drains will discharge into rock-lined channels. Where the channel gradient needs to be steeper than 1 in 20 (5%) rock chute structures will be used.

9.5.4.2 Rock-Lined Channels and Chutes

Rock-lined channels and rock chute drop structures will be provided to convey flow from the contour drains safely to the toe of the RSF. Unlined drains are not suitable, because the flow discharging from the contour drains may result in flow velocities exceeding maximum permissible velocities during more intense rainfall events.

Rock-lined channels will be used for drains where the longitudinal gradient is at 1 in 20 (5%) or less.

For steeper drains, the combination of flow forces and gravity forces acting to destabilise the rock armouring are too high to utilise simple rock lined channels, and engineered rock chute drop structures will be used.

The rock-lined channels will be sized as wide shallow V-shaped drains with 1 in 10 side slopes and armoured with rock. The relatively shallow side slopes of the drain will ensure that flow velocities are adequately limited for the specified rock size, and will allow passage of off-road maintenance vehicles across the drains and hence eliminate the need to construct formal access road crossings.

The dimensions of the rock chute drop structures depend on peak flows, slope of the chute, height of the chute, and grading (size) of the rock. The rock chute drop structures are likely to use a rock grading D_{50} of 300 mm. The flow down the rock chute drop structures will have high velocity and energy, and outlet aprons will be provided to dissipate flow energy at the toe of the chute. The rock chute drop structures will be constructed of durable rock, as these structures are required for the long-term stability of the RSF.

9.6 Surface Water

9.6.1 Catchment Context

The RSF area is located within a natural valley and is bounded to the east and west by low-lying hills with a maximum elevation of between approximately 120-200 m AHD. The lowest point of the valley floor is approximately 45 m AHD. Natural drainage paths are to the south-east, leading into Farmer Creek to the south and then to the Calliope River. Farmer Creek has a total catchment area of approximately 23 km^2 at the junction with the Calliope River. The topography and surface water flows on the RSF site are shown on Figure 9.6.1.

9.6.2 Rainfall and Evaporation

As described in Section 8.7.2, the regional climate is subtropical with distinct wet summers and dry winters. Rainfall and evaporation statistics for the Gladstone area are further described in Section 8.7.2. Site-specific rainfall and evaporation data over the past 100 years from 1906-2006 were synthesized by Department of Natural Resources and Water (DNRW) and are summarised in Table 9.6.1.

Table 9.6.1 Summary of Annual Rainfall and Evaporation Statistics

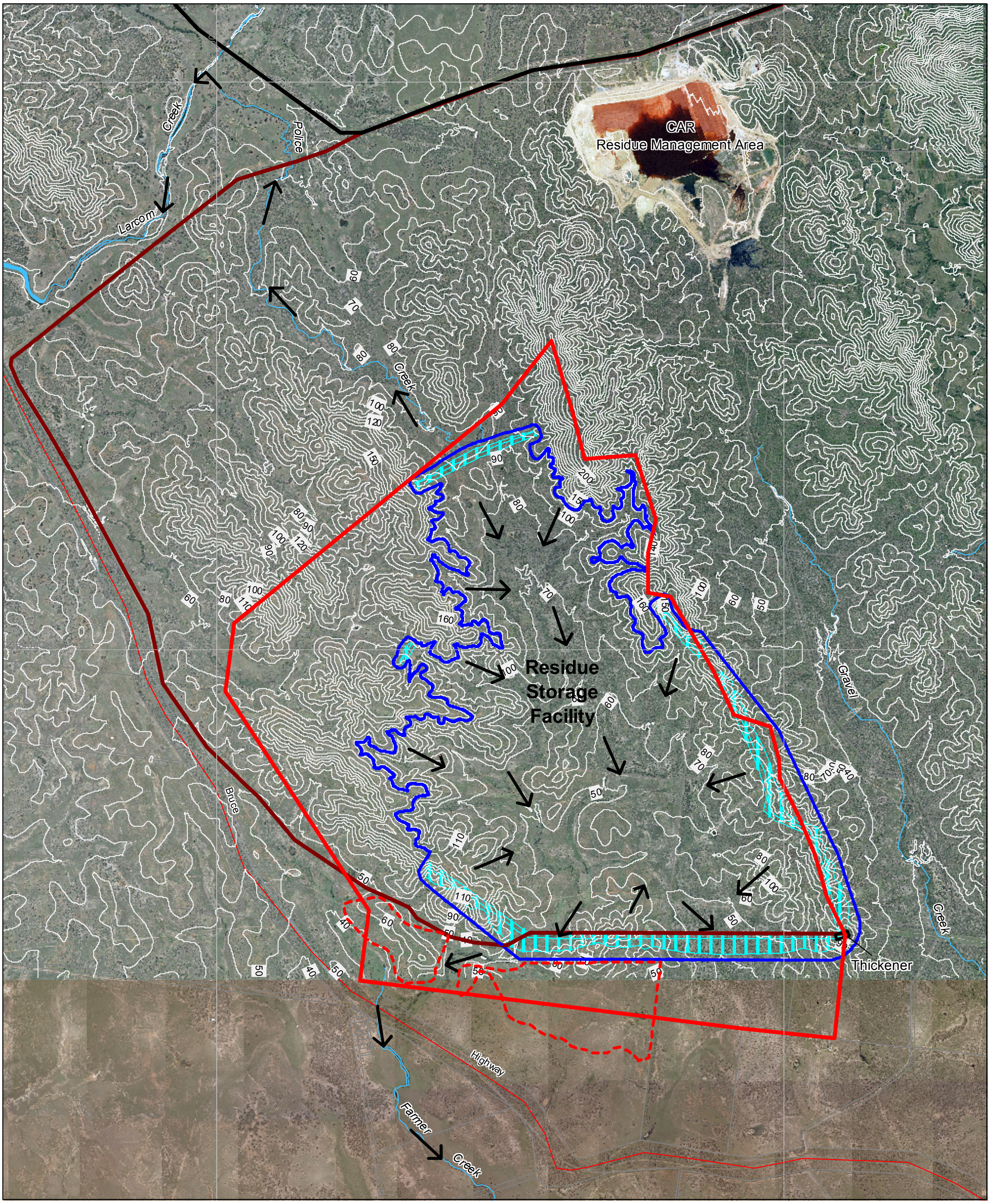
	Annual Rainfall (mm/y)	Annual Evaporation (mm/y)
Average	873	1,853
10th Percentile	539	1,765
90th Percentile	1,295	1,953

The variability of rainfall and evaporation throughout the year is very similar to that for Gladstone with some minor variance (Table 9.6.2).

Table 9.6.2 Summary of Monthly Rainfall and Evaporation Averages

Month	Monthly Rainfall (mm)	Monthly Evaporation (mm)
January	147	207
February	162	174
March	97	175
April	45	139
May	44	109
June	45	92
July	34	97
August	24	118
September	24	149
October	53	186
November	74	197
December	119	211

The highest rainfall occurs between December and March with the maximum rainfall occurring in February (162 mm). Evaporation has a similar seasonal trend although maximum evaporation occurs in December (211 mm).



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MGA Z56, GDA94

60	Contour (mAHD)		RSF site boundary
	Surface flow direction (pre RSF)		RSF footprint
	Slurry pipeline route		Topsoil stockpile
	Residue and return liquor pipeline route		

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	**SURFACE WATER FLOWS** **RESIDUE STORAGE FACILITY**
URS	Drawn: TN · Approved: CMP · Date: 06-09-06	Figure: **9.6.1** · Rev:B
	Job No: **4262 5791** · File No: 42625791-g-072b.wor	A4

9.6.3 Catchments, Drainage and Topography

The RSF site is bounded on the eastern and western sides by hills. The land forms a valley that drains into the main tributary (Farmer Creek) meandering to the south-east to the Calliope River. Surface water flow directions are presented in Figure 9.6.1.

During site inspections in May 2006, no natural permanent waterholes were present in the upper reaches of Farmer Creek. In the lower reaches (south of the Bruce Highway) several large pools were present. Flow is ephemeral and almost entirely dependent on rainfall. Although the area has been extensively cleared for grazing, relatively dense and predominantly native riparian vegetation exists along the creek.

The only freshwater features within the RSF study area were a number of small farm dams (less than 1 ha). Further information is provided in Section 9.11.

9.6.4 Streamflow and Flow Regime

No flow data are available for Farmer Creek tributary. A GoldSim water balance model was developed to carry out a series of analyses of surface flows and potential water management strategies for the RSF. Details of this model are provided in URS (2006). Table 9.6.3 presents statistics for derived estimates of runoff from the Farmer Creek catchment (approximately 25 km^2).

Table 9.6.3 Modelled Runoff Statistics for Farmer Creek Catchment

	Annual Runoff (ML/y)
Average year	4,900
10th Percentile (dry year)	3,100
90th Percentile (wet year)	7,400

Streamflow information for the Calliope River at Castlehope (approximately 4 km downstream of the intersection with Farmer Creek) is provided in Section 8.2.

There are no known records of flooding within the Farmer Creek catchment. However, the elevation of the RSF site (45 m AHD lowest level) indicates that the site is unlikely to be affected by backwater flooding from the Calliope River (highest flood level recorded in Calliope River at Castlehope GS132001A was approximately 19.6 m AHD corresponding to 4,038 m^3/s peak flow in February 1947).

9.6.5 Water Quality

The ephemeral nature of flows within Farmer Creek and the limited opportunity for water sampling constrained specific baseline monitoring to characterise the quality of runoff from the site. There are no known records of water quality in Farmer Creek.

Some water quality samples/measurements were collected from the farm dams located within this catchment in May 2006. The pH at these sites was near neutral (7.4) and EC was low (180 μS/cm).

Water quality data for Castlehope Gauging Station (132001A), approximately 4 km downstream of the intersection of Farmer Creek with the Calliope River, are presented in Table 9.6.4.

Table 9.6.4 DNRW Water Quality Monitoring Data for Calliope River at Castlehope Gauging Station

Indicator	Units	ANZECC/ARMCANZ (2000) trigger level	QLD Water Quality (2006) criteria	Castlehope
		Lowland River Aquatic Ecosystems	Lowland Streams	Median Value
pH	Unit	6.5 – 8.0	6.5 – 8.0	7.3
Conductivity	µS/cm	na	970	58
Turbidity	NTU	50	8	2.8
Total Nitrogen	mg/L	0.5	0.5	0.44
Total Phosphorus	mg/L	0.05	0.05	0.03

Notes: na – no data available

All water quality parameters measured at Castlehope Gauging Station are within screening criteria.

9.6.6 Water Use

There are 13 existing water allocations to extract water from a watercourse downstream of the RSF on either the Calliope River or Farmer Creek. Only one of these water allocations allows water to be taken from Farmer Creek. Details of these allocations were supplied by DNRW. The locations of these allocations are presented in Figure 9.6.2.

The main water use is irrigation (5 allocations). Other purposes include domestic supply, stock watering and/or irrigation (4 allocations); aquaculture (2 allocations); quarrying (1 allocation); and water harvesting (1 allocation). Volumetric data were not available for all of the allocations. However, allocations of 200 ML/y from the Calliope River for an aquaculture enterprise and 1 ML/y for one allocation for agricultural use were identified.

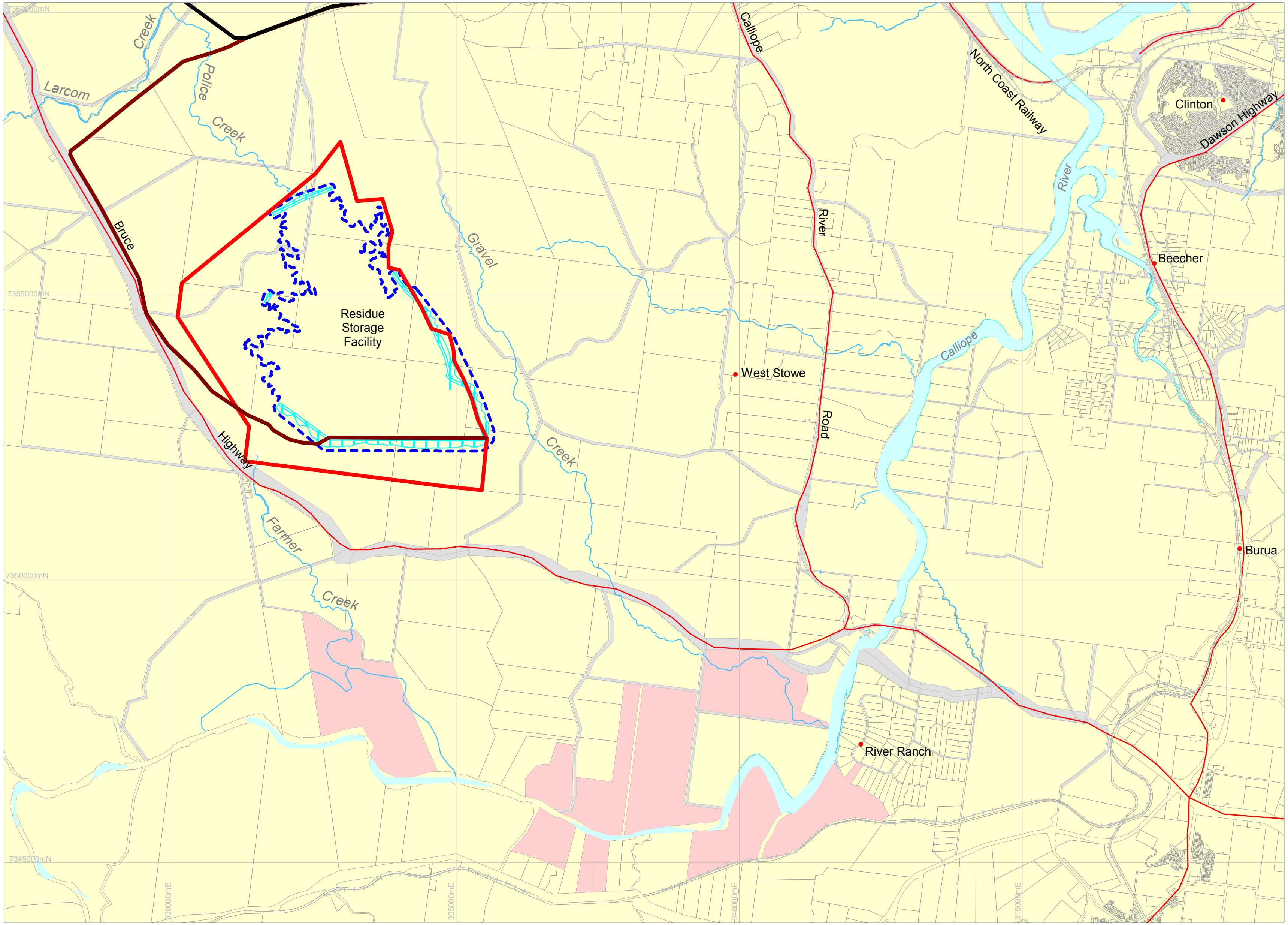
9.6.7 Summary of Environmental Values

Specific environmental values for Farmer Creek are not defined under the *Environmental Protection (Water) Policy 1997* (EPP Water). Further details on the environmental values of the Calliope River are presented in Section 8.2. Farmer Creek does not appear to have current recreational use and is almost entirely located within land holdings associated with one property.

9.6.8 Potential Impacts and Mitigation Measures – Construction Phase

9.6.8.1 RSF Catchment

The overall footprint of the RSF is approximately 11.9 km^2. The area of the Farmer Creek catchment, upstream of the RSF embankment, is approximately 12.2 km^2. As the RSF will occupy virtually all of the Farmer Creek catchment upstream of the embankment, there will be little run-on of clean water to the RSF and no need for diversion channels around the RSF.



N

0 1.25 2.5km

Scale 1:100,000 (A4)

MGA Z56, GDA94

Source: Environmental Protection Agency - Estate 23/03/2006.

Legend			
	Property with water extraction allocation		Residue and return liquor pipeline route
	RSF Site Boundary		Slurry pipeline route
	RSF Footprint		RSF Embankment

URS

Client: Gladstone Pacific Nickel Ltd

Project: GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT

Drawn: TN | Approved: CMP | Date: 26-10-06

Job No: 4262 5791 | File No: 42625791-g-041.wor

Title: **PROPERTIES WITH WATER USAGE LICENCES**

Figure: **9.6.2**

Rev: A

A4

9.6.8.2 Sediment/Contaminant Mobilisation

Sediment mobilised during construction activities may enter surface water runoff during rainfall events and be discharged to Farmer Creek and other downstream watercourses. A discussion of the erosion potential of soils at the RSF site and methods to mitigate the effects of erosion is presented in Section 9.1.4. Implementation of these control measures will minimise the risk of downstream impacts.

Upon completion of the construction phase, the majority of disturbed areas of the site will be upstream of the dam. All surface flow within the Farmer Creek catchment upstream of the RSF embankment, including mobilised sediment, will be retained within the RSF preventing downstream impacts.

Drainage arrangements for the topsoil stockpiles are outlined in Section 9.1.4. Measures will be implemented to prevent sedimentation of downstream waterways through the use of appropriate surface water management measures such as silt fences or sediment ponds. Topsoil will be revegetated and graded in order to limit erosion so that the overall impact of sedimentation from soil stockpiles will be low.

9.6.8.3 Contamination Effects

Potential sources of on-site contamination during the construction phase predominantly comprise diesel and other petroleum-based fuels and lubricants used by excavation and construction machinery. All fuel storage and equipment refueling operations will be undertaken within bunded areas to contain any spillage.

Temporary on-site sanitary arrangements including toilet facilities will be provided throughout the construction phase. All waste produced in temporary facilities will be removed off-site to a licensed disposal facility.

9.6.8.4 Works Adjacent to/within Drainage Lines

Infilling of on-site surface water flow paths and gullies will be unavoidable under proposals for the RSF deposition schedule. The only permanent water features located within the RSF area are small man-made farm dams. As all of the work will take place at the top of the Farmer Creek catchment, there will be no significant disturbance to the Farmer Creek system outside of the RSF footprint.

9.6.8.5 Mitigation Strategies

The potential impacts outlined above will be managed with the implementation of the surface water management plan for the construction phase. Key strategies will include:

- Preparation and implementation of a site-specific construction erosion and sediment control plan in accordance with Institution of Engineers Australia – Erosion and Sediment Control Guidelines (1996).
- Minimising the area of disturbance.
- Installation of temporary drainage works (channels and bunds) in areas required for sediment and erosion control and around storage areas for construction materials.
- Development of temporary sediment basins to capture sediment-laden runoff from the site.
- Reinstatement of vegetation with endemic species or provision of appropriate surface treatments as soon as practicable following earthworks.
- Provision of bunded storage areas for fuels and dangerous goods required for construction equipment in accordance with Australian Standards (AS 1940:2004 and AS 3780:1994).
- Control and management of all transfers of fuels and chemicals to prevent spillage outside bunded areas.
- Provision of spill clean-up kits and development of spill clean-up plan in the event that chemical spillage/leakage occurs.

The effective implementation of these mitigation measures will mitigate the potential for adverse impacts on receiving surface water environments. A monitoring program will be implemented involving the periodic inspection of drainage works, sediment basins and areas susceptible to erosion for signs of potential surface water impacts.

9.6.9 Potential Impacts and Mitigation Measures – Operational Phase

9.6.9.1 Changes to Flow Regime

Management of the RSF will involve pumping residue slurry into the storage area from which excess liquor contained within the residue slurry will flow to the reclaim pond. Some of this water will present as free liquor with the initial slurry deposition. Further liquor will be released over longer time periods as a result of the stabilisation and settlement of the residue. All liquor will drain to the reclaim pond from where it will be pumped back to the refinery.

The RSF liquor containment strategy is necessary to prevent downstream water quality impacts. As a result of this strategy, the total catchment area of Farmer Creek will be reduced. Water balance modelling of the RSF was carried out using GoldSim software described in Section 9.4.3. Table 9.6.5 presents comparisons of the annual runoff estimates (existing and with proposed RSF) and estimates for the overall reduction in mean annual flow in Farmer Creek at the junction with the Calliope River.

Table 9.6.5 Farmer Creek Catchment Modelled Annual Runoff Statistics Comparison of Existing and Post-RSF Catchment Conditions

	Existing Catchment Runoff (ML/y)	Catchment Runoff after RSF Construction (ML/y)	Change in Annual Runoff (ML/y)
Average year	4,900	2,600	-2,300
10^{th} Percentile (dry year)	3,100	1,600	-1,500
90^{th} Percentile (wet year)	7,400	3,900	-3,500

The runoff modelling results presented in Table 9.6.5 indicates an approximate 47% reduction in total flow from the Farmer Creek catchment. Although this is a significant reduction in the total flow within Farmer Creek, this represents approximately 0.5% of the total flow in the Calliope River. Downstream water users that take their water from the main Calliope River are unlikely to be significantly impacted by the reduction in post-development flows from the Farmer Creek catchment. However, an alternative source of supply may be required for the one allocation that takes water from Farmer Creek if this activity is to continue.

Modelling of the long-term water balance (using 100 years of historical rainfall and evaporation data) presented in the RSF concept design report (URS,2006) shows that the volume of water contained within the RSF would not rise above 20% of the total storage capacity of the RSF and overflows to downstream receiving water environments would not occur. Further information on the RSF water balance modelling is given in Section 9.4.3.

The model simulation indicates that the water level in the RSF will not rise above approximately 80 m AHD. The average water level will be at approximately 74 m AHD. The height of the spillway crest level is 83.8 m and the height of the RSF is 86 m. Thus there will be no expected overflow of water from the RSF into the downstream drainage system.

9.6.9.2 Water Quality Impact

As described above, the RSF will be operated to fully contain all RSF waters with negligible probability of overflow. Water balance modelling indicates that, even with total pump failure, it would take approximately 4 to 5 years for the RSF to fill with water to the point where it would overflow. There will therefore be no impacts from surface flows derived from the RSF on surface water quality downstream of the RSF.

9.6.9.3 Mitigation Measures

The main objective of the mitigation measures to minimise potential impacts to surface water is to ensure negligible probability of discharge of potentially contaminated water from the RSF to the receiving environment. As described above, infrastructure for the RSF including liquor reclaim pumps and storage with sufficient capacity (maximum of more than 50,000 ML) are the principal engineered measures for preventing overflows. The water level in the RSF will be maintained between 1.5 and 10 m deep to ensure that ponded water does not interfere with residue settling. Extensive modelling of the RSF water balance has demonstrated that the proposed management procedures and infrastructure are appropriate to meet this objective.

Regular monitoring of the level of water in the RSF will be undertaken to ensure that management options are adequately implemented.

9.7 Groundwater

9.7.1 Existing Groundwater Data

An assessment of existing groundwater conditions for the RSF site has been undertaken. This assessment is based on the following available data sources:

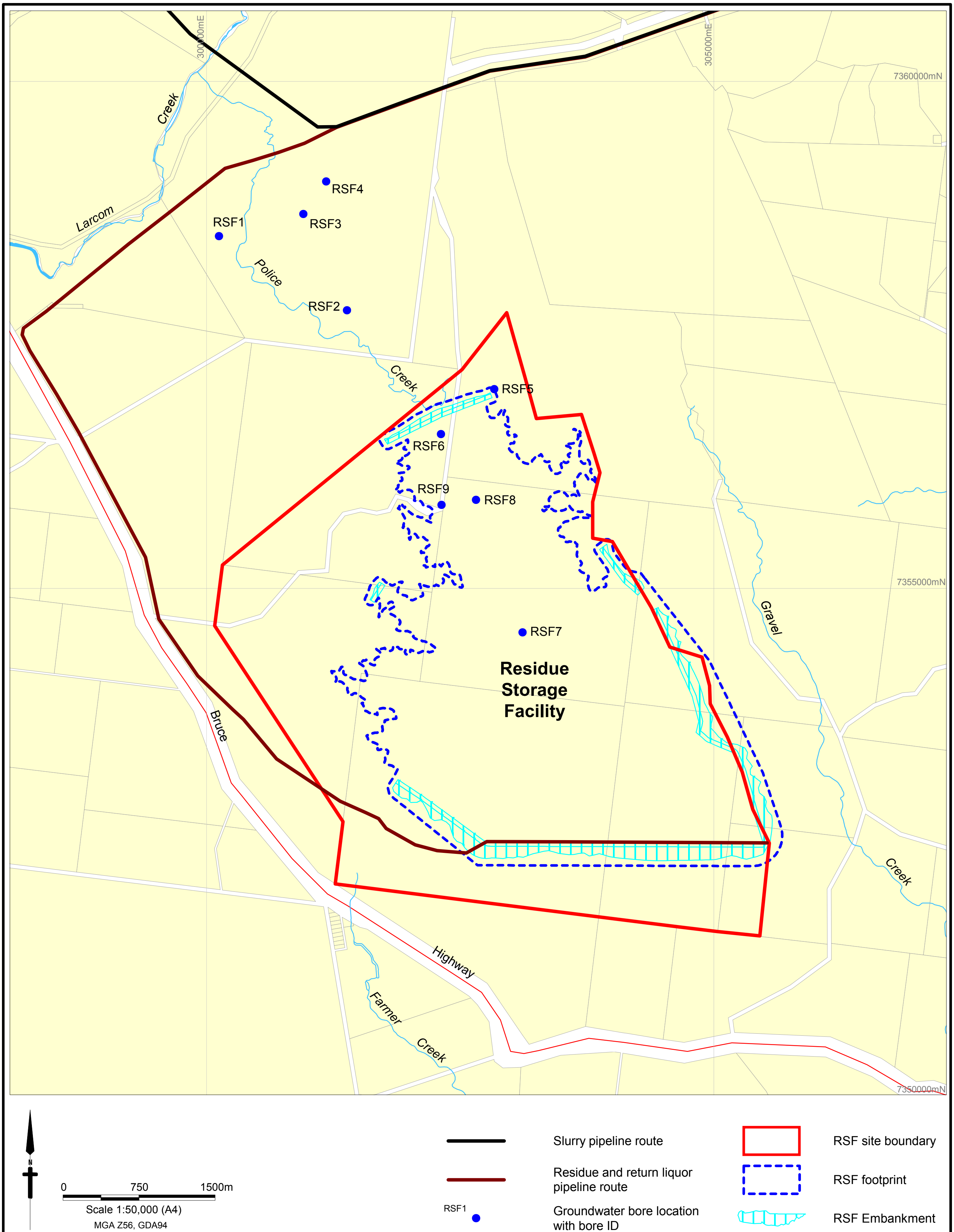
- DNRW groundwater database.
- Previous groundwater assessments undertaken within the vicinity of the project.
- Gladstone 1:100,000 Geology Map (Sheet 9150) – Queensland Department of Mines.
- Additional groundwater data collected on-site by URS between April and May 2006.

DNRW groundwater data were obtained for all bores within a 3 km radius of the RSF. The registered bores within the specified area are shown on Figure 9.7.1 and the bore data sheets are available in Appendix J.

9.7.2 Groundwater Geology and Aquifer Occurrence

Groundwater in the vicinity of the RSF site mainly occurs within bedding and fractures of the regional sedimentary bedrock units. The two relevant sedimentary bedrock aquifer units are the Late Devonian to Early Carboniferous Mount Alma Formation and the Rockhampton Group. The Mount Alma Formation consists of thinly interbedded fine-grained siltstone, mudstone, shale, and sandstone. The Rockhampton Group is comprised of mudstone, siltstone, felsic volcaniclastic sandstone, polymictic conglomerate, oolitic and pisolitic limestone and minor skeletal limestone. The contact between the two bedrock units trends northwest-southeast through the RSF site. The contact is also represented as a regional fault system, with a Late Permian gabbro intrusion to the north-west of the RSF, likely a by-product or cause of the structural deformation event. This gabbro intrusion lies between the two sedimentary bedrock units and has an associated layer of greenstone on its adjacent contact boundaries.

A thin layer of surficial unconsolidated alluvium/colluvium exists within the topographically low drainage lines which trend north to south within the RSF site.



Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	**LOCATION OF GROUNDWATER BORES RESIDUE STORAGE FACILITY**
URS	Drawn: TN · Approved: CMP · Date: 26-10-06	Figure: **9.7.1** · Rev: A
	Job No: **4262 5791** · File No: 42625791-g-035.wor	**A4**

9.7.3 Groundwater Levels and Flow Characteristics

Nine groundwater monitoring bores (RSF1 to RSF9) were installed between 28 April and 1 May 2006. The locations of these bores are shown on Figure 9.7.1 and the hydrogeological logs are presented in Appendix J. The hydrogeological conditions encountered at each monitoring bore site are summarised in Table 9.7.1.

Table 9.7.1 Summary of Hydrogeological Conditions Observed at Monitoring Bores

Monitoring Bore ID	Hole Depth (m)	Aquifer/ Aquitard Material	Aquifer Depth Interval (m)	Screen Interval (m)	Aquifer Type	SWL (mbgl)	SWL (mAHD)*
RSF1	39	siltstone	31 to 39	36 to 39	confined	36.72	35.28
RSF2	9	gabbro	NAP	6 to 9	NAP	Dry	Dry
RSF3	4	alluvium: sandy clay	NAP	2.5 to 4	NAP	Dry	Dry
RSF4	9	shale	NAP	6 to 9	NAP	Dry	Dry
RSF5	18	shale	NAP	15 to 18	NAP	Dry	Dry
RSF6	15	greenstone	NAP	12 to 15	NAP	Dry	Dry
RSF7	8	mudstone	NAP	2 to 8	NAP	Dry	Dry
RSF8	12	shale	NAP	3 to 6	NAP	Dry	Dry
RSF9	24	mudstone	16 to 24	21 to 24	confined	17.93	66.07

NAP = No aquifer present; *Based on elevation data provided by RLMS.

Groundwater levels in monitoring bores RSF1 and RSF9 were measured on 4 May and 5 May 2006, respectively. The remaining bores were observed to be dry. Groundwater within RSF1 is hosted within confined siltstone beds of the Rockhampton Group. There is a significant unsaturated zone at this location, with the potentiometric surface measured at 36.7 mbgl. Groundwater within RSF9 is hosted within confined mudstone beds of the Mount Alma Formation. The potentiometric surface at this location was measured at 17.9 mbgl. The direction of groundwater flow within the bedrock units is dependent upon the subsurface orientation and inclination of the aquifer bedding units.

The surficial alluvium situated in the low-lying drainage lines was shown to be very thin. The maximum thickness of alluvium encountered was 4 m at RSF3 and RSF7. The material was mainly comprised of low plasticity sandy clays and clayey sands. There was no evidence of groundwater, and the surface soils were heavily cracking to depths of up to 0.4 m.

Travel time velocity estimates were calculated using the analytical Darcy's Law equation. A hydraulic conductivity range of 1×10^{-2} to 1×10^{-4} m/day was assumed, which is consistent with the high end of a shale and the lower end of a sandstone aquifer (Freeze & Cherry, 1979). A drainable porosity range of 0.01 to 0.05 was assumed for the sake of conservatism (i.e. to project the maximum potential off-site velocity). The range of calculated groundwater flow velocities varied from 0.013 m/y to 1.3 m/y.

9.7.4 Hydraulic Parameters

Falling head tests were conducted for a majority of the monitoring bores on 4 May and 5 May 2006, to provide details on hydraulic conductivity of the various rock and soil materials. Analysis of the rising head datasets using a standard analytical method (Hvorslev, 1951) is provided in Appendix J. A summary of the rising head test data analysis results is provided in Table 9.7.2. The range of hydraulic conductivity (K) values from 1.26 x 10^{-1} to 1.43 x 10^{-4} m/day reflects the very low permeability of the bedrock material.

Table 9.7.2 Hydraulic Conductivity of Various Aquifer Materials

Monitoring Bore ID	Hole Depth (m)	Aquifer/ Aquitard Material	K mean (m/s)	K mean (m/day)
RSF1	39	siltstone	2.22 x10^{-9}	1.92 x10^{-4}
RSF2	9	Gabbro	9.64 x10^{-8}	8.33 x10^{-3}
RSF3	4	alluvium: sandy clay	5.80 x10^{-9}	5.01 x10^{-4}
RSF4	9	shale	1.65 x10^{-9}	1.43 x10^{-4}
RSF5	18	shale	6.21 x10^{-7}	5.37 x10^{-2}
RSF6	15	greenstone	1.46 x10^{-6}	1.26 x10^{-1}
RSF7	8	mudstone	1.99 x10^{-7}	1.72 x10^{-2}
RSF9	24	mudstone	1.18 x10^{-8}	1.02 x10^{-3}

9.7.5 Water Quality

A summary of measured water quality of groundwater samples taken from monitoring bores RSF1 and RSF9 between 4 May and 5 May 2006, is provided in Table 9.7.3.

Table 9.7.3 In situ Physico-chemical Parameters for RSF Monitoring Bores

Bore ID	Date of Testing	SWL (mbgl)	Dissolved Oxygen (ppm)	Electrical Conductivity (µS/cm)	TDS (mg/L)	pH	Eh (mV)	Temp. (˚C)
RSF1	05/05/2006	36.72	4.30	2,050	1,312	7.59	+84	25.9
RSF9	04/05/2006	17.93	2.62	1,496	957	7.16	+207	25.0

The physico-chemical parameters measured for both samples indicate that the groundwater is relatively fresh (<1,500 mg/L TDS), has a near-neutral pH and is oxidized. This type of oxidized, fresh water is more commonly associated with shallow alluvium and fractured rocks (recent recharge) rather than within confined, slow transmitting sedimentary bedrock.

Groundwater samples were analysed at a NATA certified laboratory for major ions and select heavy metals. A summary of the analytical results is provided in Table 9.7.4. The environmental values of the water have been assessed against the values identified in the EPP Water. The environmental values (ANZECC/ARMCANZ, 2000) of relevance to the groundwater at the RSF site are:

- Suitability for livestock drinking water use.
- Suitability for irrigation use.

According to the ANZECC (2000) guidelines, groundwater present within RSF1 and RSF9 is deemed to be suitable for both livestock drinking water and irrigation purposes.

Table 9.7.4 Summary of Groundwater Quality at the RSF Site

Analyte	Units	Monitoring Bores		Environmental Investigation Trigger Levels: ANZECC, 2000	
		RSF1	RSF9	Stock Water	Irrigation
TDS	mg/L	1,312	957	2,000- 4,000#	NR
Calcium	mg/L	32	79	1,000	NR
Magnesium	mg/L	51	47	NR	NR
Sodium	mg/L	394	165	NR	115-460*
Potassium	mg/L	10	4	NR	NR
Sulphate	mg/L	150	27	1,000	NR
Chloride	mg/L	226	171	NR	175-700*
Total Alkalinity	mg/L	787	543	NR	NR
Arsenic	mg/L	<0.001	0.002	NR	2.0^
Barium	mg/L	0.155	0.257	NR	NR
Cadmium	mg/L	0.0001	<0.0001	NR	0.05^
Chromium	mg/L	0.021	<0.001	NR	1.0^
Cobalt	mg/L	<0.001	<0.001	NR	0.1^
Copper	mg/L	0.002	0.002	NR	5^
Lead	mg/L	0.079	0.298	NR	5^
Manganese	mg/L	0.022	0.055	NR	10^
Nickel	mg/L	0.004	<0.001	NR	2^
Zinc	mg/L	0.047	0.234	NR	5^
Mercury	mg/L	0.0001	0.0002	NR	0.002^

Notes: *plant dependent; #animal dependent; ^short-term trigger value; NR= no values recommended

9.7.6 Groundwater Use in Neighbouring Areas

There is no significant groundwater usage registered on the DNRW groundwater database. There are only three registered groundwater bores within a 3 km radius of the RSF site. Detailed DNRW bore cards are provided in Appendix J. Two of these bores are situated within 2 km of the western boundary (RN111019 and RN91090).

RN111019 is a low-yield windmill bore (0.63 L/s air lift yield) established in September 1995, that intersects the Mount Alma Formation beds. An initial standing water level of 1.5 mbgl was recorded for this bore, but no recent data have been measured for comparison with present day water levels. An initial water quality of 1600 mg/L TDS was recorded for this bore. RN91090 has a better recorded air lift yield (4.5 L/s) with a water quality of 1050 mg/L TDS, and an initial standing water level of 3 mbgl, measured in April 1993. The third registered bore (RN111795) is situated approximately 2.5 km to the east of the proposed RSF. It intersects the Yarwun Beds, a separate geological unit to the Rockhampton Group and Mount Alma Formation.

A number of unregistered windmill bores are also situated within a 3 km radius of the proposed RSF. These bores are dedicated stock watering facilities, with low extraction yields.

The Comalco Alumina Refinery (CAR) residue management area (RMA) is situated within approximately 3 km of the north-eastern boundary of the RSF. The RMA does not use abstraction bores. Comalco has installed a monitoring bore network for the RMA to observe spatial and temporal variations in both water quality and physical aquifer parameters.

9.7.7 Potential Groundwater Impacts – Construction Phase

Groundwater removal to assist in foundation excavation is not anticipated during construction. Maximum construction depths are expected to be less than up to 5 mbgl. Groundwater monitoring of RSF1 to RSF9 has shown that the water table within the bedrock units is between 20 and 40 mbgl, and that the thin alluvial channels were dry. Should seasonal fluctuations cause a significant rise in groundwater levels then dewatering may be required for the sake of foundation excavation. If dewatering is required, it is not expected to be prolonged, owing to the low permeability (and therefore low groundwater recharge rates) of the various materials. Any water extracted during this time, will be utilised for dust suppression around the construction site.

Compression of the ground surface associated with the construction of the RSF is not expected to greatly alter the permeability of strata immediately beneath the site, and as such will not hinder the recharge of the underlying alluvium or bedrock strata.

Dissolved and free-phase hydrocarbon, as well as other stored chemicals, may impact on the underlying soils and aquifers down-gradient of areas of fuel and chemical storage and usage, if these areas are not managed appropriately. Workshop areas, vehicle and equipment wash-down areas and equipment and machinery repair areas all have the potential to spill fuels, lubricants, solvents or other products. Appropriate design of fuel and chemical storage areas, which includes spill containment bunding and sealing the surface area, will reduce the risk of groundwater contamination resulting from fuel and chemical spills. Bunded storage areas for fuels and dangerous goods will be provided with spill cleanup kits in accordance with Australian Standards (AS 1940:2004 and AS 3780:1994). All transfers of fuels and chemicals will be controlled and managed to prevent spillage outside bunded areas.

The low permeability of the soils and bedrock will enable isolation and remediation of potential spills.

9.7.8 Potential Groundwater Impacts – Operations Phase

There will be no extraction of groundwater during the operation phase; therefore, there will be no direct interference of the existing groundwater environment or direct influence on the local groundwater flow regime.

There is potential for seepage water to enter the deeper bedrock aquifers. Taking into account the maximum calculated travel time (for groundwater in the bedrock) of 1.3 m/y, a minimum distance of 5 km to the nearest branch of the Calliope River (assuming that the aquifer flows towards the creek, the aquifer is continuous, and that the Calliope River is a gaining river at this reach of its course), it would take 5000 years for seepage water to come into connection with the river. The role of groundwater base flow in sustaining recharge to the Calliope River is not well understood, and in particular the role that isolated fractured bedrock aquifers play in terms of overall river base flow is unknown (DNRM&W, 2005).

9.7.8.1 Seepage from RSF

The RSF design (refer Section 9.3) incorporates mitigation measures, to limit seepage through the dam to the underlying aquifers as well as a seepage collection system. As discussed in Section 9.3, seepage from the RSF will be controlled through a combination of measures including a low-permeability clay core and cut-off key in the RSF embankment and a seepage collection system. Modelling has shown that any seepage that is not directly intercepted by the trench collection system would move no more than 65 m downgradient of the RSF over a 50 year period. Any movement will be detected by the monitoring bores, and if necessary, recovery bores will be installed to recover impacted groundwater to the RSF.

9.7.8.2 Hydrocarbon and Chemical Contamination

Areas of hydrocarbon and chemical storage will have spill control measures and regular inspection regimes in order to prevent and monitor activities that could potentially lead to contamination of groundwater.

Accidental spills will be assessed on a case by case basis and remediated in accordance with the requirements of the EPA.

9.7.8.3 General Groundwater Monitoring Program

A network of monitoring bores will be installed in strategic locations to monitor any potential seepage from the RSF. This monitoring bore network will consist of:

- Shallow bores (up to 20 m in depth) situated within each alluvial aquifer which intersects the site.
- Monitoring bores in a cluster at the toe of the RSF.
- Intermediate bores (to intersect Mount Alma Formation and Rockhampton Group aquifers) spaced appropriately around the perimeter of the RSF at varying depths.
- Shallow bores (up to 20 m in depth) at all locations where surface drainage lines intersect the RSF boundary.
- A background bore to be situated 2 km down-gradient of the RSF (screened within the local bedrock aquifer) to enable differentiation between groundwater rises associated with natural recharge and rises associated with any mounding of the aquifer attributed to seepage from the RSF.

The monitoring program will be instigated prior to operation of the RSF and continued routinely for the life of the RSF. An annual review of the monitoring program will be conducted to evaluate the effectiveness of each monitoring location, and to assess where new locations and/or modifications to the existing program may be needed to evaluate what impacts may be occurring.

The monitoring program will include the parameters outlined in the environmental management plan in Section 14.

9.8 Land Management and Rehabilitation

9.8.1 Rehabilitation Goals

GPNL will rehabilitate areas disturbed during construction and operation of the project, including the RSF. GPNL will also decommission project infrastructure at the end of the project life and rehabilitate those areas where use of that infrastructure cannot continue (refer Section 2.9).

Rehabilitation aims to return disturbed areas to safe, non-polluting, stable landforms with a self-sustaining vegetation cover that meets an agreed land use. The specific goals for rehabilitating disturbed land that will result from the project are as follows:

- Achievement of acceptable land use suitability – Rehabilitation will aim to create a stable landform with a post-project land use capability and/or suitability similar to that prior to disturbance, unless other beneficial land uses are pre-determined and agreed.
- Creation of stable landform – The RSF and other disturbed land will be rehabilitated to a safe condition that is self-sustaining, or to a safe condition where maintenance requirements are consistent with an agreed post-project land use.
- Preservation of downstream water quality – Surface and ground waters that leave the project area will meet accepted closure criteria. Current and future water quality will be maintained at levels that are acceptable for users downstream of the site.

Objectives, indicators and closure criteria will be developed for each of these goals in a closure plan that will be prepared at least five years prior to the planned site closure date. This section of the EIS outlines the general rehabilitation and strategies and methods that will be incorporated into the closure plan.

9.8.2 Post-Project Land Use and Suitability

The overriding principle of rehabilitation is to create the most beneficial future use of rehabilitated land that can be sustained in view of the limiting factors that exist. In the absence of any agreed higher value land use (e.g. industry) currently the "base case" final land use proposed is native bushland (some fast growing sterile exotic groundcover species may also be included for initial stabilisation of landforms). Adequate consideration of management aspects to achieve this final land use will be given early in the rehabilitation planning process, particularly from the viewpoint of compatibility with adjoining grazing lands.

As the RSF is located in the Gladstone State Development Area (GSDA), beneficial industrial land use opportunities may evolve during the operating life of the facility. These will be considered prior to detailed design of the closure strategy.

Most of the RSF site has been cleared for grazing and is now dominated by grassland. The centre of the site supports open *Eucalyptus* woodlands which have been highly modified by grazing and selective clearing.

The surface of the rehabilitated RSF will be unsuitable for grazing (at least in the short to medium term) due to its height, the newly establishing vegetation, and the steepness of the embankments. It will be revegetated using native shrub and grass species for establishment of bushland. The aim is to return some of the conservation values of ecosystems such as *Eucalyptus creba* and *E. moluccana* woodlands which are currently present on the site.

Disturbed areas outside of the RSF footprint that are currently being used for grazing will be returned to grazing use post-project.

9.8.3 Rehabilitation Strategy

9.8.3.1 Final RSF Landform Design

Drainage

The RSF will be designed and constructed to be stable against long-term failure and to provide adequate safety factors that meet ANCOLD Guidelines (1999). Drainage will be provided to manage surface water flows and control erosion across the landform. Drainage and landform design will be appropriate for the substrate/soils used in the RSF to promote structural integrity, and will ensure that the RSF has similar erosional characteristics to undisturbed areas in the vicinity of the site.

The RSF drainage will be designed to ensure that no permanent water pondage occurs on the surface and stormwater is removed from the landform as quickly as possible to minimise seepage. The drainage design will include a system of contour drains and rock-lined drainage channels and drop structures. The runoff collected from the surface will be discharged in a controlled manner. A collection system at the toe of the RSF will operate to capture seepage until key constituents meet the applicable regulatory standards (refer Section 9.3).

Outer Walls

The proposed RSF design is for the outer embankment walls to be constructed at a slope of 1V:2H. The outer walls will be constructed of rock-fill with an average diameter (D_{50}) of 550 mm. The RSF will be progressively raised by upstream lifting over time to accommodate the ongoing production of residue, although the footprint of the RSF will remain the same. The upstream lifts will be constructed with slopes of 1V:3H to a height of approximately 5 m. The lifts will comprise predominately rock fill of D_{50} of 300 mm. It is unlikely that the outer walls of the RSF (including the upstream lifts) will be able to be revegetated due to the rocky nature and steep slopes. Further investigation will be undertaken as to whether these slopes can support growth of specific grasses in the interstitial spaces of the embankment.

Surface Cover

Because of the peripheral discharge of residue, the surface of the RSF cannot be rehabilitated until the end of its life (i.e. year 25). Progressive rehabilitation is unlikely. Once decommissioned, the RSF will be graded where necessary to promote stability and to obtain a surface gradient of 1V:150H, sloping toward the north.

Once the surface has been re-contoured, a low-permeability cover layer will be constructed as discussed in Section 9.5. The cover will comprise a mulit-layered system to maximise its long-term sustainability and performance in reducing the potential for acid generation from oxidation of the residue material, minimising the inflow of water into the residue material (thereby reducing the amount of water available to seep into the surrounding environment) and stabilising the RSF surface.

A surface water drainage system will be installed over the surface of the RSF as described in Section 9.5. This will consist of a system of contour drains and rock-lined channels and chutes.

Revegetation

The surface of the RSF will be revegetated using native grass and shallow-rooted shrub species to stabilise the cover surface, to assist in the removal of water stored within the cover following extended wet periods, and to provide habitat. The establishment of trees on the RSF is not recommended as tree roots (and tree falls) can affect the integrity of the cover layer. Although rehabilitated in part with native grasses, grazing of the RSF will be prevented (at least initially) due to access difficulties and the potential for erosion. Sterile exotic grasses that are quicker growing than native grasses may be used initially to assist in surface stabilization.

9.8.3.2 Topsoil Management

The project will maximise the recovery of topsoil ahead of site disturbance for use in subsequent rehabilitation. Available topsoil resources have been identified in Section 9.1.2. Should vegetation to be cleared be burnt, investigations will be undertaken as to the benefits of incorporating the ash into the topsoil resource. Investigations will also be undertaken into the viability of mulching cleared vegetation. Mulch would be placed as a thin layer over topsoil stockpiles and/or over re-spread topsoil to increase nutrient levels and water retention of the soil.

The following management techniques will be implemented where possible to prevent excessive soil deterioration:

- Material will be stripped in a slightly moist condition (moisture content of 10 to 15%). Wet or dry material will not be stripped (Keipert *et al.,* 2004). Topsoil will be stripped carefully to ensure that suitable and unsuitable soil is not mixed.
- Less aggressive soil handling systems will be employed where possible, such as moving soil into windrows with graders or dozers for later collection by elevating scrapers, or for loading into rear dump trucks by front-end loaders. This will minimise the compression effects of heavy equipment often used for transport of soil material. Soil transported by dump trucks will be placed directly into storage. Soil transported by bottom dumping scrapers will be pushed to form stockpiles by other equipment (e.g. dozer) to avoid tracking over previously laid soil by the scraper.
- Stockpiles will be located so that: machinery, vehicles and stock are excluded; there is no water runoff into or across the stockpile site; and so that protection is provided from prevailing winds to reduce wind erosion.
- As a general rule, a maximum stockpile depth of 3 m will be maintained. The surface of soil stockpiles will be left in a rough condition to promote infiltration and minimise erosion until vegetation is established. Stockpiles will be free-draining where possible to prevent anaerobic zones forming (Keipert *et al.*, 2004).
- Stockpiles will be seeded and fertilised as soon as possible. An annual sterile cover crop species (e.g. Silk Sorghum) will be sown initially on the stockpiles with DAP fertiliser, to provide sufficient competition for emerging weed species and enhance the desirable microflora and fauna activity in the stockpiled topsoil. Additional seeding of appropriate species will be undertaken. Species selection will focus on native plants that

provide a good level of cover and therefore erosion control, and those that will assist in the supply of bio-available nitrogen to the soil, such as legumes.

- Appropriate erosion control measures (i.e. silt fences etc) will be installed to ensure any erosion from the stockpiles does not impact on site water quality.
- Prior to re-spreading onto the landforms to be revegetated, an assessment of weed infestation on stockpiles will be undertaken to determine if individual stockpiles require herbicide application and/or "scalping" of weeds.

9.9 Terrestrial Flora

9.9.1 Study Aim and Objectives

The aim of the flora study was to map the vegetation communities of the RSF site and to identify areas of conservation significance. In meeting these aims the objectives were to:

- Review existing terrestrial vegetation data for the local area and region.
- Provide baseline data on vegetation communities occurring in the study area.
- Identify the occurrence or expected occurrence of conservation significant plant species.
- Describe weed species present.
- Assess the value of areas that may be disturbed by the proposed RSF for vegetation conservation.
- Determine impact of the RSF on the surrounding vegetation and develop appropriate management strategies.

9.9.2 Data Review and Field Survey

9.9.2.1 Data Search

In order to identify the range of species and communities that may be present, reviews of existing data from the Queensland Herbarium and the Commonwealth Department of Environment and Heritage (DEH) databases were conducted.

Existing data on flora of the RSF area were compiled through acquisition of the following key references:

- EPA Herbarium flora database (HERBRECS).
- EPA Wildnet Database.
- EPA 1:100 000 Regional Ecosystems mapping.
- EPA Ecomap environmentally sensitive areas database.
- Commonwealth DEH 'Matters of National Environmental Significance' Environment Protection and Biodiversity Conservation Act (EPBC) database.

9.9.2.2 Target Species

Threatened, significant or otherwise noteworthy flora[1] potentially occurring in the locality were identified from previous studies and the above databases (Appendix K). From this list, an assessment of potential presence was made based on suitable habitat present on site. Species identified as being potentially present in the project area were targeted for identification during the field assessment.

9.9.2.3 Field Survey

The flora survey employed an assessment of floral taxa and vegetation communities in keeping with the methodology employed by the Queensland Herbarium for the survey of Regional Ecosystems (REs) and vegetation communities (Nelder *et al.*, 2004). Preliminary identification of the vegetation communities of the project areas was conducted prior to the commencement of fieldwork. It included vegetation community definition from stereo image 1:25,000 colour aerial photography (DNR, 1999) and interpretation of 1:100,000 Regional Ecosystems coverage Version 5.0 for the region (EPA, 2005(a)). The results were used to identify locations for representative field survey sample plots to obtain floristic and structural data and ground-truth the vegetation communities.

Fieldwork for the floral survey was conducted during an 8-day period (13-20 June 2006) within the area shown in Figure 9.9.1. Further details are provided in Appendix K.

9.9.3 Regional Context

9.9.3.1 Bioregion

The RSF site is situated within the Brigalow Belt bioregion. The bioregions of Queensland are based on landscape patterns that reflect changes in geology and climate, as well as major changes in floral and faunal assemblages at a broad scale and are used as the fundamental framework for the planning and conservation of biodiversity.

Nature conservation of the Brigalow Belt bioregion has received increasing attention due to the rapid and extensive loss of habitat that has occurred. Major impacts upon vegetation of the Brigalow Belt include tree clearing, high grazing pressure and the proliferation of exotic species such as the prickly pear (Young *et al*, 1999).

9.9.3.2 Sub-regions

The Brigalow Belt bioregion contains 36 sub-regions or provinces that delineate significant differences in geology and geomorphology (Young *et al*, 1999). The RSF site is situated within the Mount Morgan Ranges sub-region.

The hilly landscape of the Mount Morgan Ranges province is formed on the Paleozoic rocks of the coastal ranges. The steeper areas are dominated by *Eucalyptus crebra* (narrow-leaved ironbark) woodlands with *Corymbia erythrophloia* (red bloodwood), *C. citriodora* (spotted gum) and *Acacia rhodoxylon* (rosewood). Lower slopes generally support woodlands of *Eucalyptus melanophloia* (silver-leaved ironbark) and colluvial slopes support *E. moluccana* (gum-topped box) woodlands. *E. tereticornis* (forest red gum) and *C. tessellaris* (moreton bay ash) occur on the alluvial soils (Young *et al*, 1999).

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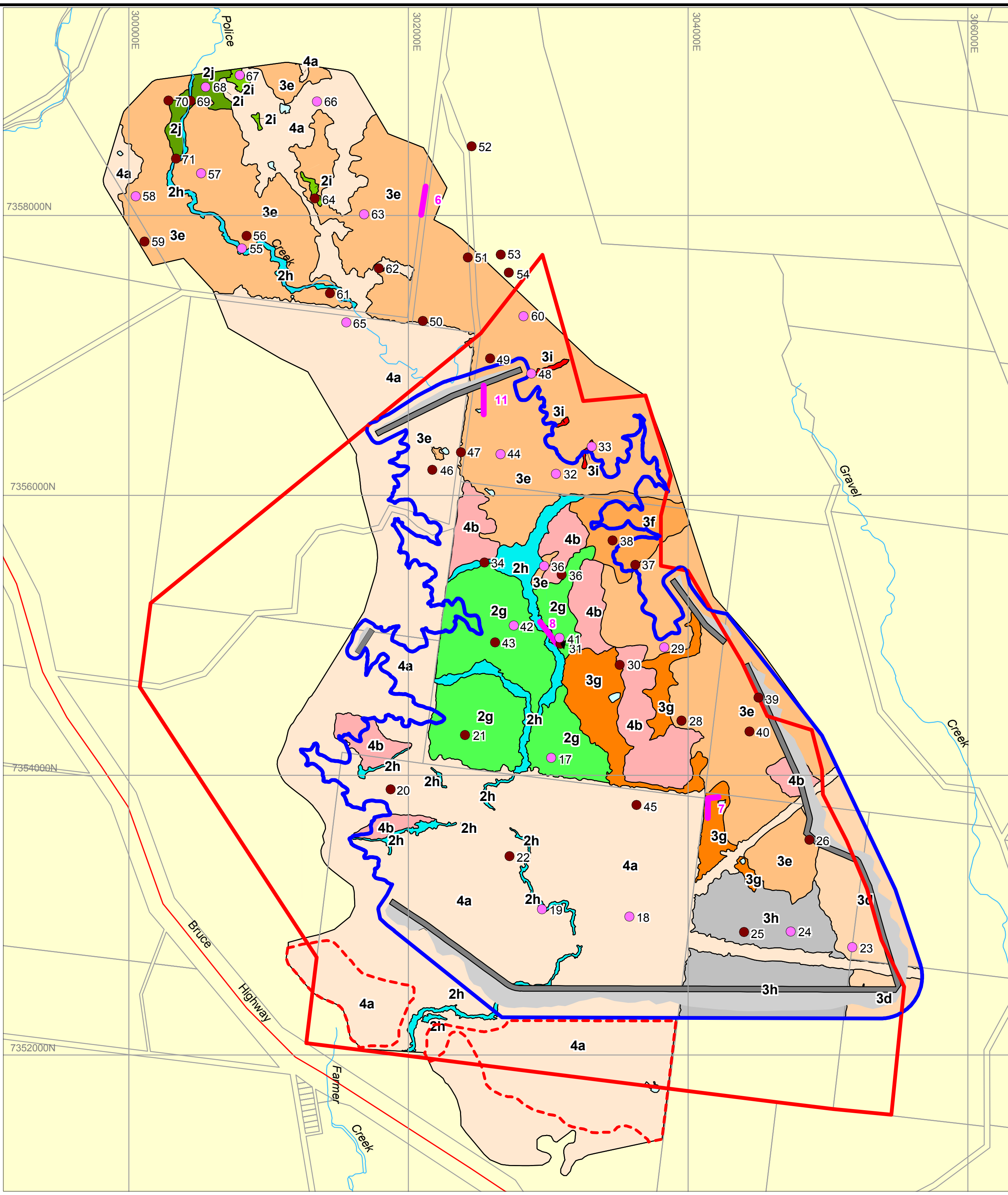
[1] Threatened species relate to species identified by Queensland State government (*Nature Conservation (Wildlife) Regulation 1994* under the *Nature Conservation Act 1992*) and Commonwealth (*Environment Protection & Biodiversity Conservation Act 1999)* legislation as critically endangered, endangered or vulnerable. Significant species are species that carry other legislation status or those that occur at the extent of the natural geographic range.



NOTE: Refer to Figure 9.7.1b for Vegetation Communities Legend

0 500 1000m
Scale 1:40,000 (A4)

MGA Z56, GDA94

11 Flora primary sampling site

6 Flora secondary sampling site

1 Fauna transect

RSF site boundary

RSF footprint

Topsoil stockpile

RSF embankment

Client	Project	Title
Gladstone Pacific Nickel Ltd / URS	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	**VEGETATION COMMUNITIES AND FLORA/FAUNA SAMPLE SITES - RESIDUE STORAGE FACILITY**

Drawn: VH	Approved: CMP	Date: 26-10-06	Figure: **9.9.1a**	Rev:A
Job No: **4262 5791**	File No: 42625791-g-050.wor			**A4**

	Community Description	Regional Ecosystem
2g	*Eucalyptus tereticornis* and/or *Eucalyptus spp.* tall woodland on alluvial plains	RE 11.3.4
2h	*Melaleuca leucadendra* and/or *M. fluviatilis, Nauclea orientalis* open forest fringing drainage lines	RE 11.3.25b
2i	*Melaleuca bracteata* woodland to open-forest. Occurs on fringing alluvial soils or near-channel levees on heavy wet clays	RE 11.3.25d
2j	*Eucalyptus moluccana* woodland to open forest on margins of alluvial plains	RE 11.3.26
3d	*Corymbia citriodora, Eucalyptus crebra,* open forest on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.3
3e	*Eucalyptus crebra* woodland on old sedimentary rocks with varying degrees of metamorphism metamorphism and folding. Coastal ranges	RE 11.11.4
3f	*Eucalyptus tereticornis* woodland on old sedimentary rocks with varying degrees of metamorphism metamorphism and folding. Coastal ranges	RE 11.11.4a
3g	*Eucalyptus moluccana* woodland on old sedimentary rocks with varying degrees of metamorphism metamorphism and folding. Coastal ranges	RE 11.11.4c
3h	*Eucalyptus crebra* woodland on deformed and metamorphosed sediments and interbedded volcanics. Undulating plains	RE 11.11.15
3i	Vine thicket, with no *Araucaria cunninghamii* emergents on old sedimentary rocks in hilly terrain	RE 11.11.5a
4a	Modified pastoral grassland with scattered emergent Eucalypt spp.	n/a
4b	Non remnant shrubby regrowth of Acacia and / or Eucalypt spp.	n/a

Client: Gladstone Pacific Nickel Ltd

URS

Project: GLADSTONE NICKEL PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title: **LEGEND FOR VEGETATION COMMUNITIES - RESIDUE STORAGE FACILITY**

Drawn: VH | Approved: CMP | Date: 02-10-06

Job No: **4262 5791** | File No: 42625791-g-050.wor

Figure: **9.9.1b** | Rev:A | **A4**

9.9.3.3 Regional Ecosystems

REs describe the relationships between major floral species and the environment at the regional scale. These are mostly derived from linking vegetation mapping units recognised at a scale of 1:100,000 to land zones that represent major environmental variables, in particular geology, rainfall and landform.

There are 91 REs identified for the Mount Morgan Ranges sub-region. Of these, 39 are currently of conservation significance as these are listed as either Of Concern (23) or Endangered (16) under the *Vegetation Management Act 1999*.

9.9.4 Existing Conservation Values

This section documents the floristics and vegetation communities of the RSF site. Detailed community descriptions and quantitative data including floristics and structure for each survey site are detailed in Appendix K. Appendix K also includes a complete flora species list for all taxa identified.

9.9.4.1 Species Diversity

The survey identified the presence of 165 taxa representing 126 genera and 54 families. This result represents a relatively moderate floral diversity typical of the ecosystems found within the region. Families represented by three or more genera included Adiantaceae (3), Apocynaceae (4), Asclepiadaceae (5), Asteraceae (6), Celastraceae (3), Cyperaceae (7), Euphorbiaceae (7), Fabaceae (4), Lauraceae (3), Malvaceae (6), Mimosaceae (5), Moraceae (5), Myrtaceae (15), Oleaceae (3), Poaceae (28), Rubiaceae (7), Sapindaceae (3), Smilacaceae (3) and Solanaceae (4).

Genera represented by 3 or more species included *Acacia* (5), *Aristida* (4), *Corymbia* (4), *Cyperus* (5), *Eucalyptus* (5), *Melaleuca* (3), *Sida* (4) and *Solanum* (4).

There was a relatively moderate diversity of weed species within the study area with 20 exotic species found. Families with the most exotic weed taxa were Asclepiadaceae (2), Asteraceae (2), Cactaceae (2), Malvaceae (2), Poaceae (4), Solanaceae (2) and Verbenaceae (2). A weed species list and a list of exotic species is provided in Appendix K.

9.9.4.2 Vegetation Communities

Twelve vegetation communities were described and mapped for the study area (Figure 9.9.1) on the basis of aerial photo stereo image interpretation and field survey results. Table 9.9.1 lists the total area of each community found within the study area and the total extent for each vegetation community within the sub-region[2] (as defined by RE types within the Mount Morgan Ranges sub-region). Full community descriptions including floristics, structure, location, ecological integrity and disturbance notes are given in Appendix K.

[2] Data on the extent of REs within the sub-region is based on an analysis of remnant vegetation estimated for 2003 (Accad *et al*. 2006).

.Table 9.9.1 Extent of Vegetation Communities found on the RSF Study Site and within the Sub-region

	Community Description	Regional Ecosystem	Area in Footprint (ha)	Area within sub-region[1] (ha)
2g	*Eucalyptus tereticornis* and/or *Eucalyptus spp.* tall woodland on alluvial plains	RE 11.3.4	128.7	15,772
2h	*Melaleuca leucadendra* and/or *M. fluviatilis*, *Nauclea orientalis* open forest fringing drainage lines	RE 11.3.25 b	47.3	[2] 12,276
2i	*Melaleuca bracteata* woodland to open-forest. Occurs on fringing alluvial soils or near-channel levees on heavy wet clays	RE 11.3.25 d	3.4	[2] 12,276
2j	*Eucalyptus moluccana* woodland to open forest on margins of alluvial plains	RE 11.3.26	9.9	6611
3d	*Corymbia citriodora, Eucalyptus crebra,* open forest on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.3	74.8	54,810
3e	*Eucalyptus crebra* woodland on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.4	595.5	26,471
3f	*Eucalyptus tereticornis* dominated woodland on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.4 a	32.3	[2] 26,471
3g	*Eucalyptus moluccana* dominated woodland on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.4 c	54.4	[2] 26,471
3h	*Eucalyptus crebra* woodland on deformed and metamorphosed sediments and interbedded volcanics. Undulating plains	RE 11.11.15	89.7	112,417
3i	Vine thicket, with no *Araucaria cunninghamii* emergents on old sedimentary rocks in hilly terrain	RE 11.11.5 a	1.7	[2] 14,500
4a	Modified pastoral grassland with scattered emergent *Eucalypt spp.*	n/a	999.2	n/a
4b	Non remnant shrubby regrowth of *Acacia* and / or *Eucalypt spp.*	n/a	93.4	n/a

[1]Derived from RE data for the Mount Morgan Ranges sub-region as per Accad *et al.* (2006)
[2] RE data does not specify statistics for sub RE designations i.e.: 11.3.25 b.

All vegetation associations surveyed have been disturbed or modified to some degree by grazing practices. The west and south of the site has been cleared for grazing and is now dominated by modified grasslands supporting a mix of native grasses (e.g. *Bothriochloa bladhii subsp. bladhii*, *Heteropogon contortus* etc.) and exotic species (e.g. *Melinis repens*, *Malvastrum americanum* etc).

The centre of the site supports open woodlands dominated by *Eucalyptus tereticornis* (forest red gum) with an open grassy understorey occurring on alluvium. These areas have been highly modified by grazing and selective clearing. The forest red gum woodlands are dissected by *Melaleuca leucadendra* (long leaved teatree) dominated riparian vegetation that fringes the banks of the ephemeral watercourses crossing the site. This riparian vegetation is also highly disturbed from grazing, especially within the south of the site where it is surrounded by modified pasture, and as such provides only limited corridor value (Section 9.9.4.3).

To the east of the forest red gum woodlands the substrate changes from alluvium to metamorphics. This area supports tall open woodland dominated by *Eucalyptus moluccana* (gum-topped box) with an open grassy understorey. A substantial portion of this vegetation community has been cleared and now supports shrubby regrowth.

The hilly terrain within the south-east of the site supports two distinct vegetation communities. The lower hill slopes are dominated by *Eucalyptus crebra* (narrow-leaved ironbark) woodlands and the upper slopes support an open forest co-dominated by *Corymbia citriodora* (lemon-scented gum) and *E. crebra* (narrow-leaved ironbark). The ground layer of this community is in relatively good condition in comparison to other communities at the site and supports a diversity of native grass and herb species including *Aristida queenslandica, Grewia latifolia* and *Lomandra longifolia*. It is likely that the steep rocky terrain of this area has limited the grazing impact on this community. The low hills occurring along the east and north of the site support *Eucalyptus crebra* (narrow-leaved ironbark) woodlands with a diversity of sub-dominant canopy species include *E. tereticornis, E. exserta, Corymbia tessellaris, C. erythrophloia* and *C. clarksoniana. Eucalyptus crebra* was the most common vegetation community within the subject site (after the modified grassland). The steep gullies occurring in the north-east of the site supported small areas of vine thicket. This community is characterised by a dense canopy dominated by vine thicket species including *Pouteria sericea* and *Drypetes deplanchei.*

The north of the site supports localised areas of *Melaleuca bracteata* (black teatree) dominated forest that are restricted to the alluvial plains and banks of the small ephemeral water courses. Also restricted to the north of the site are small areas of *Eucalyptus molucanna* (gum-topped box) open forest on alluvium. These areas have very sparse mid-storey and an open grassy understorey.

9.9.4.3 Weeds of Concern

Of the 20 exotic weed species described in this survey for the study site, 6 species were identified as being of management concern (Table 9.9.2). These are currently listed as pest species by DNRW under the Queensland *Land Protection (Pest and Stock Route Management) Act 2002.* Two of these species, rubber vine and lantana, are listed as Weeds of National Significance. This is a list of exotic weed species developed by ANZECC (1997(a)) which are identified as weeds causing significant environmental damage on a national scale. All exotic weed species identified for the study are listed within the full floral species list in Appendix K.

Table 9.9.2 Declared Exotic Weed Species identified at the RSF site

Species Genus	Common Name	[1]Declared Status
Cryptostegia grandiflora	rubber vine	Class 2
Lantana camara	lantana	Class 3
Lantana montevidensis	creeping lantana	Class 3
Opuntia stricta v stricta	prickly pear	Class 2
Opuntia tomentose	velvety tree pear	Class 2
Sporobolus natalensis	giant rat's tail grass	Class 2

[1] Declared under the Queensland *Land Protection (Pest and Stock Route Management) Act 2002*

Rubber Vine

Rubber vine was found in a number of isolated locations across the RSF site, predominantly within or close to riparian vegetation. Rubber vine is a Weed of National Significance and is regarded as one of the worst weeds in Australia because of its invasiveness, potential for spread, and economic and environmental impacts. Its main impact on pastoralism is the loss of grazing country, which in 1995 was estimated to cost the Queensland beef industry $18 million (Weed Management CRC, 2003(a)).

Rubber vine threatens waterways, woodlands and rainforests throughout north-eastern Australia. It also severely threatens riparian vegetation, and can potentially displace the plants and animals that inhabit riverbanks, thereby affecting the water quality of streams (Weed Management CRC, 2003(a)).

Lantana

Lantana was widespread on the RSF site and was recorded in all vegetation communities although its abundance was generally low. Lantana is a Weed of National Significance and is regarded as one of the worst weeds in Australia. Lantana forms dense, impenetrable thickets that take over native bushland and pastures throughout the east coast of Australia. It competes for resources with, and reduces the productivity of, pastures and forestry plantations. It adds fuel to fires, and is toxic to stock (Weed Management CRC, 2003(b)).

Creeping Lantana

Creeping lantana was uncommon on the RSF site but was found in the drier vegetation communities on ridges. The species is a popular ornamental plant but is considered a weed when in natural ecosystems. Creeping lantana occurs in coastal and sub-coastal Queensland and as far south as Sydney. It is fairly similar to lantana but does not have thorns, has mainly pink or purple flowers and trails along the ground, only growing to a height of half a metre. It is also toxic and readily displaces native vegetation (Weed Management CRC, 2003(b)).

Prickly Pear

Prickly pear was found in a number of vegetation communities across the RSF site. However, densities of this species were low. Prickly pear was previously a major weed problem in central Queensland in the early 1900s. This cactus is now found over a larger area but is rarely a problem. During the 1920s and 1930s various biological control agents were released and now control this cactus in most areas.

Velvety Pear Tree

Velvety pear tree was found in a number of vegetation communities across the RSF site; however, densities of this species were low. Velvety pear tree was previously a major weed problem in central Queensland in the early 1900s. This cactus is now found over a larger area but is rarely a problem. During the 1920s and 1930s various biological control agents were released and now control this cactus in most areas.

Giant Rat's Tail Grass

Giant rat's tail grass was limited to the northern section of the RSF site. It was relatively uncommon and was restricted to small patches within modified grasslands and grassy eucalypt communities. Giant rat's tail grass is an aggressive grass that can reduce pasture productivity and out-compete desirable pasture grasses. Introduced from Africa during the 1960s as a contaminant in pasture seed, it has adapted well to large areas of Queensland (DNRM&E, 2006).

9.9.4.4 Vegetation of Conservation Significance and Matters of National Environmental Significance

Significant Species

The desktop literature review (Section 9.9.2) identified 14 flora species of conservation significance as potentially occurring in the region (Appendix K).

None of the species identified in the survey area (Appendix K) are listed as threatened species under the *Queensland Nature Conservation (Wildlife) Regulation 1994* or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

None of the species identified in the flora survey that are present within vegetation potentially impacted by the project have significance from a commercial or recreational standpoint.

Significant Communities

One vegetation community (Table 9.9.3) is identified as having Of Concern conservation status as listed under the Queensland *Vegetation Management Act 1999*. A full description for this community is provided in Appendix K.

Table 9.9.3 Vegetation Communities of Conservation Significance at the RSF site

Community Description		Regional Ecosystem	Conservation Status
2g	*Eucalyptus tereticornis* and/or *Eucalyptus* spp. tall woodland on alluvial plains	RE 11.3.4	[1] Of Concern

[1] Queensland *Vegetation Management Act 1999*

Vegetation communities are listed as Of Concern REs under the Queensland *Vegetation Management Act 1999* if the remnant vegetation for the community is 10% to 30% of its pre-clearing extent across the bioregion; or more than 30% of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares.

9.9.4.5 Regional Connectivity

Continued grazing practices and tree clearing throughout the region have greatly reduced the presence of integral contiguous stands of vegetation to principally open modified grasslands and discrete patches of disturbed eucalypt woodland. Grazing impacts and invasion of exotic species have left the majority of forest and woodland habitat in the region with a highly modified and mostly absent mid strata. Remnant vegetation of the study site does not represent a significant pathway of habitat connectivity within the corridor system at a regional scale. Regional connectivity is currently represented in a limited capacity by woodland communities that persist on ridgelines to the east of the RSF site.

At a local scale, vegetation within the RSF site representing connectivity of habitat primarily consist of vegetated hills along the east of the site and riparian corridors associated with the local creek systems. Connectivity to the north, south and east is provided by stands of vegetation on the east of the site which are contiguous with a relatively large tract of remnant vegetation adjacent to the site. This tract of vegetation has been afforded some protection from clearing in recent times by the hilly topography and provides a marginal link northwards with vegetation of Mt Larcom, approximately 8 km north of the RSF site. The significance of the vegetation of Mt Larcom has been recognised at both the state and local government levels, being identified in the Calliope Strategic Plan (1991) as a Reservation Area and previously being made the subject of a National Park proposal (URS 2003). However, the link between the RSF site and Mt Larcom is dissected by numerous roads and the CAR RMA thus reducing its value as a habitat corridor.

Other important extents of core habitat in the region are represented by the Rundle Range National Park 20 km to the north of the site.

The ephemeral creek passing through the middle of the site continues south beyond the site boundary. This creek is highly modified to the south of the site and has been entirely cleared of native vegetation in sections. As such the creek system provides minimal connectivity to the south.

Connectivity of habitat at the local scale has been effectively eliminated to the west of the study site by vegetation clearing and grazing disturbance.

9.9.5 Potential Impacts and Mitigation Measures

9.9.5.1 Vegetation Clearing

An area of up to approximately 1,316 ha will be cleared as a result of the construction of the RSF. Vegetation removal will be required for various components of the RSF including:

- Embankment construction.
- Spillway construction.
- Clearing of RSF storage area.
- Topsoil stockpiles.

Table 9.9.4 presents a breakdown of the disturbance to vegetation communities as a result of the proposed clearing, indicating the disturbance to each community as a percentage of its extent within the sub-region.

Table 9.9.4 Areas of Vegetation Communities to be Cleared

Community Description		Regional Ecosystem	Potential Disturbance	
			Ha	Sub-region[1] %
2g	*Eucalyptus tereticornis* and/or *Eucalyptus spp.* tall woodland on alluvial plains	RE 11.3.4	124.3	0.8
2h	*Melaleuca leucadendra* and/or *M. fluviatilis*, *Nauclea orientalis* open forest fringing drainage lines	RE 11.3.25 b	35.6	0.3
2i	*Melaleuca bracteata* woodland to open-forest. Occurs on fringing alluvial soils or near-channel levees on heavy wet clays.	RE 11.3.25 d	0	0
2j	*Eucalyptus moluccana* woodland to open forest on margins of alluvial plains	RE 11.3.26	0	0
3d	*Corymbia citriodora, Eucalyptus crebra,* open forest on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.3	74.8	0.1
3e	*Eucalyptus crebra* woodland on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.4	231.4	0.9
3f	*Eucalyptus tereticornis* dominated woodland on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.4 a	14.5	0.1
3g	*Eucalyptus moluccana* dominated woodland on old sedimentary rocks with varying degrees of metamorphism and folding. Coastal ranges	RE 11.11.4 c	54.4	0.2
3h	*Eucalyptus crebra* woodland on deformed and metamorphosed sediments and interbedded volcanics. Undulating plains	RE 11.11.15	89.7	0.1
3i	Vine thicket, with no *Araucaria cunninghamii* emergents. on old sedimentary rocks in hilly terrain	RE 11.11.5 a	0.3	0.0
4a	Modified pastoral grassland with scattered emergent *Eucalypt spp*.	n/a	602.1	n/a
4b	Non remnant shrubby re-growth of *Acacia* and/or *Eucalypt spp*	n/a	89.3	n/a

Table 9.9.4 Areas of Vegetation Communities to be Cleared

Community Description	Regional Ecosystem	Potential Disturbance	
		Ha	Sub-region[1] %
Total	-	1316.4	-

[1] Indicates disturbed % of vegetation community within Mount Morgan Ranges sub-region as per Accad *et al.* (2006).

As can be seen from Table 9.9.4, the largest vegetation community to be cleared will be Vegetation Unit 4a: Non-remnant modified pastoral open grassland (602.1 ha). This community is does not have any significant conservation value. This community is highly disturbed due to grazing practices, and its floristic assemblage has been significantly modified by clearing and the introduction of a number of exotic pastoral species.

Vegetation unit 2g: *Eucalyptus tereticornis* and/or *Eucalyptus* spp. tall woodland on alluvial plains ('Of Concern' RE 11.3.4) is the only community of conservation significance recorded on the site. This community occurs within the alluvial plains at the centre of the site and 124.3 ha of it will be cleared. This disturbance constitutes 0.8% of the area of this community found within the sub-region.

Construction of the proposed RSF will result in the clearing of approximately 35.6 ha of vegetation unit 2h: *Melaleuca leucadendra* and/or *M. fluviatilis, Nauclea orientalis* open forest fringing drainage lines ('Not of Concern' RE 11.3.25d). This disturbance constitutes 0.3% of the community's extent within the sub-region. This riparian vegetation is highly modified to the south of the site and provides limited connectivity at a local scale.

In summary, vegetation at the RSF site is composed predominantly of remnant vegetation, modified pastoral grasslands and non-remnant shrubby re-growth. The site has a high degree of disturbance due to grazing, thinning, frequent fires, and exotic weed invasion. The majority of vegetation in the RSF site is currently grazed and exhibits degraded ground cover and mid-strata.

9.9.5.2 Clearing Management

Areas of vegetation to be cleared will be restricted to the minimum area required. Areas to be cleared will be clearly delineated prior to commencement of clearing with tape, pegs or other markers. Particular attention will be paid when delineating clearing areas in proximity to Of Concern vegetation communities that will not be disturbed.

Where clearing of vegetation involves the removal of any expansive stands of woodland vegetation, clearing will be undertaken in stages to ensure that isolated stands of vegetation are not created and the connectivity of habitat remains intact to allow for the dispersal of fauna. That is, clearing will be undertaken towards the direction of any adjacent contiguous vegetation that is not to be cleared to ensure connectivity of habitat is not disrupted.

Any clearing within or in close proximity to riparian vegetation communities will employ adequate erosion and sedimentation mitigation measures to ensure that downstream aquatic ecosystems are not impacted and riparian vegetation is not unduly effected.

9.9.5.3 Dust Impacts

Dust deposition may have potential impacts on vegetation if excessive levels are sustained over extended periods. Physical effects could potentially include blockage and damage to stomata, shading, and abrasion of the leaf cuticle. Reduction in the ability to photosynthesise due to physical effects may result in reduced growth rates of vegetation and decreases in floral vigour and overall community health. The potential effects of dust deposition on vegetation are determined by a number of factors including:

- Characteristics of leaf surfaces, such as surface roughness, influencing the rate of dust deposition on vegetation.
- Concentration and size of dust particles in the ambient air and its associated deposition rates.
- Local meteorological conditions and the degree of penetration of dust into vegetation.

The dominant woodland species of the vegetation communities in close proximity to the proposed RSF typically exhibit physiological qualities that are not sensitive to dust deposition. The sclerophyllous foliage of eucalypt and corymbia species is generally pendulous (i.e. points down) with a thick smooth cuticle that does not encourage particulate matter to remain on the surface. The dominant woodland species are also generally hardy and well adapted to adverse conditions (e.g. extended dry conditions and low nutrient soils).

It is unlikely that potential effects of dust deposition on vegetation within close proximity to RS will be significant. If dust deposition is deemed likely to be significant, control measures will be implemented to mitigate potential impacts.

9.9.5.4 Weed Control

Current grazing stocking rates at the RSF site are not excessive and the native ground layer and shrub species is relatively abundant for grazed land. However, there is a degree of moderate weed invasion which includes the presence of the significant pastoral weed giant rat's tail grass (*Sporobolus natalensis*). The introduction of vehicles and heavy machinery to the RSF site has the potential to introduce new declared weeds to the site, and adds to the risk of spreading giant rat's tail grass and other weeds within the site and off site to other areas.

If incidences of weed species are detected, appropriate measures will need to be implemented to mitigate the spread of weed species including continued monitoring of weed occurrence. An effective weed control program will be implemented for the RSF site including:

- Effective management methods to control the spread of declared weed species[3] (in particular giant rat's tail grass) in keeping with regional management practice or DNRW pest control fact sheets.
- Ongoing monitoring of the project site to identify any new incidences of weed infestation.
- Provision of information for project staff on the identification of declared weeds.
- Wash down protocols for any vehicles/ machinery entering and leaving site during plant construction.

9.9.5.5 Rehabilitation of Disturbed Areas

A rehabilitation strategy outlining the approach for the rehabilitation of the RSF is detailed in Section 9.8.3.

9.10 Terrestrial Fauna

9.10.1 Study Aim and Objectives

The aim of the fauna study was to document the terrestrial vertebrate fauna (amphibians, reptiles, mammals and birds) of the area, with particular reference to the occurrence of endangered, vulnerable, rare or significant fauna.

The objectives of the fauna study were to:

[3] *Land Protection (Pest and Stock Route Management) Act, 2002*

- Review existing terrestrial fauna data for the study areas and local area.
- Describe the species diversity and abundance of animals, including amphibians, birds, reptiles and bats.
- Identify endangered/vulnerable/rare (EVR), threatened or poorly known species.
- Identify feral or exotic animals in the study area.
- Identify habitat requirements for EVR or threatened or noteworthy species.
- Describe the use of areas by migratory birds and terrestrial fauna.
- Discuss potential impacts and mitigation measures.

The RSF study area is shown on Figure 9.9.1. Topography in this area is dominated by low undulating hills and valley flats. Several ephemeral tributaries drain the RSF area, including Police Creek to the north and Farmer Creek to the south. During the survey period the creeks within the RSF study area were dry. The only other surface water within the RSF study area was several farm dams.

9.10.2 Data Review and Field Survey

9.10.2.1 Data Sources

Ecological Management Services Pty Ltd undertook a study of the terrestrial vertebrate fauna at the RSF site.

Existing fauna data were reviewed from a number of sources. These included:

- EPA Wildnet database (EPA 2006(d)).
- Terrestrial vertebrate records from the Queensland Museum (Queensland Museum 2006).
- Environment Australia online EPBC database (EPBC Protected Matters Report, 1 May 2006).
- Existing fauna studies from the Aldoga and Yarwun precincts of the GSDA, including Barden & Martin (1997), Dames & Moore (1998), Connell Wagner (2002), Connell Wagner (2005 and 2005(a)), Connell Hatch (2005) and Envirosciences (1993).

9.10.2.2 Target Species

Following a review of the above existing data, target species potentially occurring in RSF study area, including endangered, vulnerable, rare/threatened fauna, were identified. Details of these identified species are given in Appendix L.

9.10.2.3 Field Survey

The fauna survey of the RSF study area was undertaken in May and June 2006. General observations were made across the study area as well as more detailed assessment at four transect sites (Figure 9.9.1). Standard biological survey techniques were used during field surveys, including a number of live capture/release trapping techniques, standard and general observational and habitat searches, as well as methods to indirectly detect the presence of terrestrial fauna. The survey focussed on terrestrial vertebrate taxa. Further details of the survey methodology are given in Appendix L.

9.10.3 Survey Results

A total of 106 native and 5 introduced terrestrial vertebrate species were recorded during field surveys in the RSF study area. Native species included 7 amphibian, 17 reptile, 63 bird and 19 mammal species. A complete fauna species list for all taxa identified within the RSF study area is provided in Appendix L.

9.10.3.1 Amphibians

Seven native and one introduced amphibian species were observed within the RSF study area (Appendix L). Amphibian species were generally associated with wetter microhabitats within the areas sampled, particularly artificial dams that sustained water during the survey period. A number of amphibian species were active or calling prior to and following rainfall in early June 2006, including *Pseudophryne major*, *Litoria inermis, Litoria rubella, Litoria latopalmata* and *Limnodynastes ornatus*.

Within the RSF study area the native species most frequently observed or identified from vocalisations were the bumpy rocketfrog (*Litoria inermis*) and great broodfrog (*Pseudophryne major*). Male *Pseudophryne major* were vocalising along creeks within the RSF study area following rainfall in early June. It is likely that additional amphibian species would be detected during surveys conducted in warm season conditions. Additional species that have been previously recorded in the vicinity of the study area include a number of common species, such as *Limnodynastes terraereginae*, *Limnodynastes ornatus* and *Uperoleia laevigata* (Barden & Martin, 1997).

9.10.3.2 Reptiles

Fifteen reptile species were identified within the RSF study area (Appendix L). The reptile taxa identified included four gecko species (Gekkonidae), two agamids (Agamidae), nine skink (Skincidae) and three snake species. Pitfall traps captured a number of skink species (*Cryptoblepharus virgatus*, *Carlia foliorum*, *Carlia vivax*, *Ctenotus taeniolatus*, *Menetia timlowi*) and the agamid species (*Diporiphora australis*). Most reptile observations were made during active reptile searches of habitats during the day and incidentally during the course of the trapping and bird census surveys. The richest habitat for reptiles was *Corymbia citriodora / E. crebra* open forest (Vegetation Unit 3d) on low rises (13 species).

Within the RSF study area the open-litter rainbow-skink (*Carlia pectoralis*) and cream-striped shinning-skink (*Cryptoblepharus virgatus*) were the most frequently observed and captured species. Less common species (recorded from a single or small number of observations) included *Menetia timlowi*, *Eulamprus martini*, freshwater snake (*Tropidonophis mairii*) and red-naped snake (*Furina diadema*).

Three snake species were recorded in the RSF study area. One species, the red-naped snake (*Furina diadema*), was located during timed reptile searches in *Corymbia citriodora* open forest on a rocky rise. A lesser black whipsnake (*Demansia vestigiata*) was observed in eucalypt open forest and a freshwater snake (*Tropidonophis mairii*) was observed during spotlight survey at a dam.

9.10.3.3 Birds

Sixty-three bird species were observed within the study area during the survey period (Appendix L). Of these, 50 species were recorded during the timed census counts at the four main RSF study area sites (transects 6, 7, 8 and 11 as shown on Figure 9.9.1) while the other species were observed opportunistically throughout the study area.

Results of bird census counts are included in Appendix L. The most species- rich habitat was low-lying floodplain forests on drainage lines (e.g. 40 species at transect 8). Birds in this habitat included a mixture of drier woodland species, generalist species and a small number of species associated with the denser vegetation of the drainage lines. Significant forest birds recorded in this habitat include the powerful owl (*Ninox strenua*), barking owl (*Ninox connivens*), black-chinned honeyeater (*Melithreptus gularis*), grey-crowned babbler (*Pomatostomus temporalis*) and speckled warbler (*Chthonicola sagittata*).

Sites supporting open woodland and forest on low rises, particularly with dominant canopy species including *Eucalyptus crebra* and *Corymbia citriodora*, generally supported lower bird species richness (e.g. transects 6 and 11). Flowering *Corymbia citriodora* in these habitats attracted numbers of lorikeets and honeyeaters. The most common species in these habitats included the noisy miner (*Manorina melanocephala*), white-throated honeyeater (*Melithreptus albogularis*) and laughing kookaburra (*Dacelo novaeguineae*).

Small areas of semi-evergreen vine thicket occur within the RSF study area on its eastern margin, predominantly along gully lines. During the survey period these areas did not support any vine forest dependent birds and are possibly too small to support populations of these species. In contrast, investigation of larger vine forest areas to the east, outside of the study area during the survey period indicated the presence of a range of vine forest dependant species, including the rose-crowned fruit-dove (*Ptilinopus regina*), emerald dove (*Chalcophaps indica*) and white-eared monarch (*Monarcha leucotis).*

The most species poor habitat for birds within the RSF study area was the non-remnant (cleared) agricultural lands. This area supported an overall low number of bird species. However, many of these species were restricted to, or more common in this habitat type, including the emu (*Dromaius novaehollandiae*), Australian bustard (*Ardeotis australis*), black-shouldered kite (*Elanus axillaris*), black kite (*Milvus migrans*), nankeen kestrel (*Falco cenchroides*) and brown falcon (*Falco berigora*).

The most frequently recorded and widespread species (in order of frequency of reporting in timed bird surveys) included the rainbow lorikeet (*Trichoglossus haematodus*), scarlet honeyeater (*Myzomela sanguinolenta*), white-throated honeyeater (*Melithreptus albogularis*), striated pardalote (*Pardalotus striatus*), scaly-breasted lorikeet (*Trichoglossus chlorolepidotus*), rufous whistler (*Pachycephala rufiventris*), grey fantail (*Rhipidura fuliginosa*) and brown honeyeater (*Lichmera indistincta*). Uncommon species recorded from single observations include the restless flycatcher (*Myiagra inquieta*), Australian bustard, speckled warbler and black-chinned honeyeater.

Three species recorded during the RSF survey, the squatter pigeon (*Geophaps scripta*), powerful owl and black-chinned honeyeater, are listed as EVR/threatened under the Queensland *Nature Conservation Act 1992* (NC Act) and/or EPBC Act.

9.10.3.4 Mammals

Nineteen native and four introduced mammal species were identified within the RSF study area during the survey (Appendix L). All of the species recorded are relatively common in the region.

Small ground-mammals were uncommon in the study area, with no rodents or small dasyurid species detected. This low abundance of small ground-mammals is typical of the local area, and similar results have been obtained during many previous studies (e.g. Dames & Moore 1998; Connell Wagner 2002). The most common ground mammal recorded in the study area was the northern brown bandicoot (*Isoodon macrourus*). The echidna (*Tachyglossus aculeatus*), listed as ‘special cultural significance’ under the NC Act, was recorded at sites within the RSF.

Four arboreal mammal species, the yellow-bellied glider (*Petaurus australis*), squirrel glider (*Petaurus norfolcensis*), greater glider (*Petauroides volans*) and common brushtail possum (*Trichosurus vulpecula*) were recorded within the RSF study area during the survey. The common brushtail possum (*Trichosurus vulpecula*) was the most common and abundant arboreal species and was recorded at a number of systematic survey sites and during vehicle spotlight transects. Although specific surveys were conducted to target the koala (*Phascolarctos cinereus*), this species was not recorded in the RSF study area during the survey period.

The eastern grey kangaroo (*Macropus giganteus*) was the most common large macropod in the RSF study area. Individuals were seen in a variety of eucalypt woodland and open forest habitats. The whiptail wallaby (*Macropus parryi*) was also relatively common within the RSF study area. However, this species was more frequently observed in drier grassland, open forest and woodland on higher hill slopes and ridgelines adjacent to the RSF study area. The swamp wallaby (*Wallabia bicolor*) and rufous bettong (*Aepyprymnus rufescens*) were less abundant.

During the survey period one species of flying-fox, the little red flying-fox (*Pteropus scapulatus*), was observed feeding on flowering *Corymbia citriodora* in open forest.

Eight species of microchiropteran bats were recorded by echolocation call detection (Anabat). However, some of the identifications are tentative due to overlapping call characteristics for some species that potentially occur within the study area. The most common and widespread bat species detected within the RSF study area were the little bentwing bat (*Miniopterus australis*) and Gould's wattled bat (*Chalinolobus gouldii*). The highest number of bat species (six species) was recorded in floodplain woodland adjacent to a dam (transect 7) and in general microchiropteran bat activity during the survey period was highest in the vicinity of dams throughout the RSF study area. Two species, the little bentwing bat and Gould's wattled bat, were captured in harp traps during the survey.

9.10.4 Species of Conservation Value and Matters of National Environmental Significance

9.10.4.1 Overview

The majority of the species recorded or expected within the study area are widespread in eastern Australia, while a small number of species are restricted or regionally uncommon. Fauna species occurring within the study area are assigned a threatened status of either endangered, vulnerable or rare according to Queensland and Commonwealth legislation and are described in the:

- NC Act.
- EPBC Act.

In addition to the threatened species, the EPBC Act also considers migratory species. These species are those that are listed under the following international agreements to which Australia is a signatory nation:

- Japan Australia Migratory Bird Agreement (JAMBA).
- China Australia Migratory Bird Agreement (CAMBA).
- Convention on the Conservation of Migratory Species of Wild Animals - (Bonn Convention).

Under the EPBC Act, Australia has an international obligation to protect significant populations and significant habitats for these species.

Significant species other than EVR species have also been identified. A number of action plans concerning fauna species were also reviewed for this study, and fauna species listed as 'near threatened' are identified in this report. Relevant action plans include the Action Plan for Australian Birds (Garnett & Crowley, 2000), the Action Plan for Australian Bats (Duncan *et al.*, 1999), the Action Plan for Australian Marsupials and Monotremes (Maxwell, *et al.* 1996) and the Action Plan for Australian Reptiles (Cogger *et al.*, 1993).

9.10.4.2 EVR / Threatened Species

Threatened species known to occur within the study area are listed in Table 9.10.1. No endangered or critically endangered species are known or expected to occur in the study area. One species is classified as Vulnerable under the EPBC Act. Two species are classified as Vulnerable and one is classified as Rare under the Queensland NC Act. An additional species recorded adjacent to the study area is listed as Rare under the Queensland NC Act.

Table 9.10.1 Threatened Fauna Species

Common Name	Scientific Name	Transect	EPBC Act	NC Act
Squatter Pigeon	*Geophaps scripta*	7, 8, 11	V	V
Powerful Owl	*Ninox strenua*	8, 11		V
Black-chinned Honeyeater	*Melithreptus gularis*	8		R

Regional records exist for a number of threatened reptile species that may occur in habitats that occur within the RSF study area, including the vulnerable brigalow scaly-foot (*Paradelma orientalis*) and Dunmall's snake (*Furina dunmalli*). None of these species have been recorded within the Aldoga Precinct of the GSDA during the current and previous assessments (e.g. Connell Wagner 2002; Dames & Moore 1998). The rare little pied bat (*Chalinolobus picatus*) and rare square-tailed kite (*Lophoictinia isura*) have previously been recorded in the local area and potentially occur within the RSF study area. The latter species was observed on the Mount Larcom Road to the north of the RSF study area during the survey period.

9.10.4.3 Squatter Pigeon (Geophaps scripta)

The southern sub-species of the Squatter Pigeon (*G. scripta scripta*) is distributed through inland areas from northern NSW to the Burdekin region of Queensland. It occurs patchily, mainly in grassy eucalypt woodland and gravel ridge habitats, and is a seed eater (Garnett & Crowley, 2000). The species has declined significantly in the southern parts of its range (NSW), but appears to be stable in central Queensland. The southern sub-species is listed as vulnerable under State and Commonwealth legislation. In the northern part of its range cattle grazing is thought to have had a lesser impact on this species than land clearing and subsequent fragmentation of populations (Garnett & Crowley, 2000). Predation by foxes, changes in availability of food plants and other impacts combined with drought have been identified as potential threats (Garnett & Crowley, 2000).

Squatter pigeons were regularly observed in grassy woodlands and adjacent pasture areas throughout the RSF study area. A number of sightings were associated with cattle watering points and artificial dams. Most sightings were of small groups, between two and six individuals, usually foraging on the ground or gathered near open water. This species has also been observed in adjacent areas (Barden & Martin, 1997).

9.10.4.4 Black-chinned Honeyeater (Melithreptus gularis)

The black-chinned honeyeater occurs throughout Queensland along the inland slopes of Great Dividing Range, extending to the coast between Brisbane and Rockhampton (Garnett & Crowley, 2000). It is identified as a declining species in western NSW and South Australia (Garnett & Crowley 2000). It primarily occurs in dry eucalypt woodland with an annual rainfall range of 400-700 mm, particularly associations containing ironbark and box (Garnett & Crowley, 2000). The main threat identified in south-eastern Australia is habitat clearing and fragmentation (Garnett & Crowley, 2000).

Within the RSF study area the black-chinned honeyeater was observed at one site within the central RSF in eucalypt forest dominated by *Eucalyptus tereticornis* and *Eucalyptus crebra* within the central RSF. This species has been previously recorded in the Aldoga area within the Gravel Creek catchment to the east of the RSF study area (Barden & Martin, 1997).

The black-chinned honeyeater is generally sedentary but groups forage over a large home range giving the impression of it being locally nomadic. Large areas of suitable habitat occur in the local area.

9.10.4.5 Powerful Owl (Ninox strenua)

The powerful owl occurs throughout eastern Australia from south-western Victoria to Eungella in central Queensland predominantly on the coastal side of the Great Dividing Range and adjacent inland slopes (Garnett & Crowley, 2000). The powerful owl generally occupies a large home range (up to 1000 ha), which include a number of roost and nest sites (Garnett & Crowley, 2000). Major prey items are arboreal marsupials and gliders, but birds, flying-foxes and other prey items are taken (Garnett & Crowley 2000).

The powerful owl was present at a number of sites in open forest habitat during the survey. Habitat where the powerful owl was recorded was dominated by tall eucalypts and corymbias (*E. tereticornis, E. crebra* and *C. citriodora*). It is possible that mature canopy trees within the eastern RSF study area support hollows suitable as nest sites for this species. These habitats supported moderate numbers of prey species during the survey period, including the flying-fox, common brushtail possum, greater glider and yellow-bellied glider. The powerful owl has been previously recorded in the Aldoga precinct of the GSDA to the north-east of the RSF study area (Barden & Martin, 1997).

9.10.4.6 Migratory Species

No significant migratory species were recorded within the RSF study area. A single bird species was identified, the rainbow bee-eater (*Merops ornatus*). This is listed as a migratory species under the EPBC Act (DEH, 2006). This species is common and does not require specific habitat management measures. None of the habitats present within the RSF study area are suitable for migratory wetland or shorebirds.

9.10.4.7 Other Significant Species

A number of fauna species present within the RSF study area are listed as 'near threatened' and protected under specific action plans produced by the Commonwealth DEH. These species are largely associated with open forest and woodland habitats in the RSF study area, particularly in alluvial areas. Table 9.10.2 lists these species.

Table 9.10.2 Other Significant Species

Common Name	Scientific Name	Transect	Action Plan Status
Australian Bustard	*Ardeotis australis*		Near Threatened (Garnett & Crowley 2000)
Speckled Warbler	*Chthonicola sagittata*	8	Near Threatened (Garnett & Crowley 2000)
Grey-crowned Babbler	*Pomatostomus temporalis*	8	Near Threatened (Garnett & Crowley 2000)
Barking Owl	*Ninox connivens*	8	Near Threatened (Garnett & Crowley 2000)
Squirrel Glider	*Petaurus norfolcensis*	6	Near Threatened (Maxwell *et al.* 1996)
Yellow-bellied Glider	*Petaurus australis*	South of 11	Near Threatened (Maxwell *et al.* 1996)

9.10.5 Exotic Animals

Several exotic animals were identified in the RSF study area including the:

- Dingo/dog (*Canis lupus dingo/Canis lupus familiaris*) - Class 2 Declared pest animal.
- Rabbit (*Oryctolagus cuniculus*) - Class 2 Declared pest animal.
- Feral pig (*Sus scrofa*) - Class 2 Declared pest animal.
- Cattle (*Bos spp.*) - non-declared animal.
- Cane toad (*Bufo marinus*) - non-declared animal.

A number of these animals (dingo/dog, rabbit, feral pig) have been declared as class 2 Declared pest animals under the Queensland's *Land Protection (Pest and Stock Route Management) Act 2002*. These class 2 animals are established in Queensland and have or could have a substantial adverse economic, environmental or social impact and require control by the landowner (DNRMW, 2006(a)).

9.10.6 RSF Habitat Conservation Values

9.10.6.1 Modified Pastures

Modified pastures within the RSF study area generally supported a low diversity of fauna species when compared to areas of remnant forest and woodland. However, two significant bird species, the 'vulnerable' squatter pigeon and the 'near threatened' Australian bustard, were recorded in this habitat. The squatter pigeon was generally associated with grassy areas in the vicinity of cattle watering points and artificial dams.

9.10.6.2 Open Forests and Woodlands in Alluvial Plains, Lowland Areas and Drainage Margins

Eucalyptus moluccana open forest in the southern RSF study area (mapped as vegetation unit 3g) supported a relatively high diversity of fauna species, with the highest diversity of mammals recorded in the study area (transect 7). A number of sightings of the vulnerable squatter pigeon were recorded in this habitat.

Both *E. tereticornis* open forest on alluvial plains and riparian vegetation (vegetation unit 2h and 2g) supported the highest diversity of fauna species, particularly birds (transect 8), including EVR/threatened fauna species and number of near threatened fauna species.

These habitats supported a high diversity of species, particularly birds, and supported a range of species that are of regional and national significance (e.g. vulnerable, rare and near threatened species). Fauna species listed as threatened or significant observed in this habitat included two vulnerable species (squatter pigeon and powerful owl), one rare species (black-chinned honeyeater) and three near threatened species (speckled warbler, grey-crowned babbler and barking owl). These habitats potentially support a higher density of prey items for the powerful owl due to the higher productivity of soils on floodplains and drainage margins. Prey species recorded in these areas included greater gliders, flying-fox, common brushtail possum and yellow-bellied glider.

9.10.6.3 Open Forests and Woodlands on Rises and Ridges

Eucalyptus crebra woodland (vegetation unit 3e) supported a relatively high diversity of fauna species, with the highest diversity of reptiles recorded in the study area (transect 11). This habitat also supports EVR and near threatened fauna, including the vulnerable powerful owl.

Open forest and woodland habitats on slopes and ridges generally display lower species diversity for most fauna groups, including birds, mammals and amphibians. These habitats tend to be drier and less productive; however, flowering of canopy trees in these areas does attract large numbers of nectivorous birds and bats.

9.10.6.4 Vine Forests

Vine forests represent a minor habitat to be disturbed (0.3 ha) and are restricted to a few very small patches on the eastern margin of the study area. Investigations during the survey suggest that these remnants are too small to support populations of habitat specialists, such as rainforest birds. As such it is considered unlikely that any significant vine forest species (e.g. black-breasted button-quail) occur within the RSF study area. These areas may however be used as shelter or daytime roost sites for species that forage in open forest and woodland habitats (e.g. powerful owl).

9.10.7 Potential Impacts and Mitigation Measures

9.10.7.1 Clearing

The proposed RSF and associated topsoil stockpiles will require the removal or disturbance of approximately 1,316 ha of habitat. Approximately 602 ha are occupied by modified pastoral grassland (vegetation unit 4a) and 89 ha by non-remnant shrubby re-growth (vegetation unit 4b). Neither of these vegetation units (53% of the total area to be cleared) have any significant conservation value.

The remaining habitats within the area to be cleared (625 ha) have been impacted by past land clearing and land use. A significant proportion of the study area has been cleared for cattle grazing, and clearing and ongoing cattle grazing have impacted remnant forest areas. Areas of the remaining open forest and woodland support low number of senescent trees with hollows for wildlife.

9.10.7.2 Effects on Habitats of Significant Species or Matters of National Environmental Significance

Clearing for the RSF will require the removal of open forest/woodland and other habitat with the following habitat values:

- *E. tereticornis* open forest on alluvial plains and riparian vegetation (vegetation units 2h and 2g : 160 ha to be cleared) supporting the highest diversity of fauna species, particularly birds, including EVR/threatened fauna species and number of near threatened fauna species.

- *Eucalyptus moluccana* open forest (vegetation unit 3g : 54.4 ha to be cleared) supports a relatively high diversity of fauna species, with the highest diversity of mammals recorded in the study area. A number of sightings of the vulnerable squatter pigeon were recorded in this habitat. However, this species was also recorded in adjacent grasslands and non-remnant areas and in other components of the RSF study area. Areas of open forest and grassland in the vicinity of open water appear provide habitat for the squatter pigeon.

- *Eucalyptus crebra* woodland in the northern RSF area (vegetation unit 3e : 231.4 ha to be cleared) supporting a relatively high diversity of fauna species, with the highest diversity of reptiles recorded in the study area. This habitat also supports EVR and near threatened fauna, including the vulnerable powerful owl.

The above clearing will remove open forest or woodland and other habitat for three EVR/threatened species listed under the NC Act. These species are the squatter pigeon, powerful owl, and black-chinned honeyeater. Potential impacts on these species are discussed below:

- Squatter pigeons were relatively common within the RSF study area. Clearing and modification for the RSF would remove an area of habitat for this species that includes open modified pasture and grassy open forests and woodlands, predominantly associated with the lower alluvial areas of the Farmer Creek catchment. This species was also recorded in the northern RSF study area and in agricultural land to the west of the RSF study area which will not be disturbed by the project. Previous impact assessment studies in the Aldoga area (Connell Wagner, 2002) have suggested that squatter pigeons are "sedentary" and would be forced to "relocate to adjacent areas of vegetation". The level of impact will depend on the ability of squatter pigeons within the RSF impact area to relocate and survive in adjacent habitats and in habitats that are currently occupied by other squatter pigeon populations.

- The powerful owl is known to occur across the GSDA, including sites to the north-east and east of the RSF study area (Barden & Martin, 1997; and Dames & Moore, 1998). The loss of potential foraging habitat may impact powerful owls that currently forage in the vicinity of the RSF. However, it is likely that the area impacted by the RSF represents only a small component of a wider foraging area. The powerful owl prefers large tracts of forest or woodland habitat but can occur in fragmented landscapes. The preferred habitat is open or closed sclerophyll forest or woodlands dominated by eucalypt species (NSW Department of Environment and Conservation, 2005). Open forests on alluvial plains are likely to be of more importance as foraging areas as these sites are likely to support higher numbers of prey species (e.g. arboreal marsupials). Any loss of old growth trees used as nesting sites would represent an impact on the local population.

- The black-chinned honeyeater has been recorded within the RSF area and adjacent areas of the GSDA. The black-chinned honeyeater is generally sedentary but groups forage over a large home range giving the impression of being locally nomadic (Schodde & Tidemann, 1988). Large areas of suitable habitat occur in the local area; however, clearing for the RSF will remove potentially suitable habitat for this species.

The squatter pigeon (*G. scripta scripta*) is also listed as Vulnerable under the EPBC Act. An assessment of the significance of impacts on this species under the significant impact guidelines on matters of national environmental significance (DEH, 2006) is provided below in Table 9.10.3.

Table 9.10.3 Assessment of Impacts on the Squatter Pigeon

Criteria	Assessment of Impact
Leading to a long term decrease in the size of an important population of a species.	Squatter pigeons were found near water sources in the middle and north of the RSF area at sites 7, 8 and 11 (Figure 9.9.1) as well as being opportunistically observed in grassy woodlands and adjacent pasture areas throughout the RSF area. A number of sightings were associated with cattle watering points and artificial dams. Most sightings were of small groups, between two and six individuals, usually foraging on the ground or gathered near open water An 'important population' as defined by the EPBC guidelines (DEH, 2006) as a population either identified in a recovery plan or one that is: • considered a key source for breeding and dispersal; • necessary for maintaining genetic diversity; or • near the limit of its range. It is not definitively known from the current or previous studies of the locality if the local population under consideration is a key source for breeding and dispersal or for maintaining genetic diversity. However, as this species is known to be common within the region it is considered unlikely that the population utilising habitat within the project area is an important population in this respect, as populations are commonly known from adjoining localities throughout central coastal and central inland Queensland. The population utilising habitat of the project site is not near the limit of the known range for this species which is distributed from inland areas from northern NSW to the Burdekin region of north Queensland (Garnett & Crowley, 2000). The species has declined in the southern parts of its range (NSW), but appears to be stable in central Queensland. In the northern part of its range cattle grazing is thought to have had a lesser impact on this species than land clearing and subsequent fragmentation of populations (Garnett & Crowley, 2000). Predation by foxes, changes in availability of food plants and other impacts combined with drought have been identified as potential threats (Garnett & Crowley, 2000). On this basis, squatter pigeons utilising habitat of the RSF are not considered to be an 'important population' in the context of the EPBC guidelines (DEH, 2006).

Table 9.10.3 Assessment of Impacts on the Squatter Pigeon

Criteria	Assessment of Impact
Reduction in the area of occupancy of an important population.	During the survey, squatter pigeons were relatively common within the RSF area. Clearing and modification of vegetation for the RSF would remove an area of habitat for this species that includes open modified pasture and grassy open forests and woodlands, predominantly associated with the lower alluvial areas of the Farmer Creek catchment. Squatter pigeons were also recorded in agricultural areas to the north and west of the RSF area. Previous studies in the Aldoga Precinct of the GSDA (Connell Wagner, 2002) have suggested that squatter pigeons are sedentary and would be required to relocate to adjacent areas of vegetation. The level of impact will depend on the ability of squatter pigeons within the RSF impact area to relocate and survive in adjacent habitats and in habitats that are currently occupied by adjacent squatter pigeon populations.
Fragmentation of an existing important population into two or more populations.	The loss of grassland and open woodland habitat of the RSF site currently utilised by the squatter pigeon is not expected to fragment the local population into two or more populations. The current population utilising habitat on the site will be able to disperse into adjacent grassland habitat to the north, south and west of the site. Impacts from the project are not likely to reduce connectivity of the adjacent habitat and no significant restriction to movement of the population is expected.
Adverse effect on habitat critical to the survival of a species.	The grassland and open woodland habitat at the RSF site is not considered critical to the survival of this species within its known national distribution. Within the context of its national distribution, the population of squatter pigeons in the region is strongly established and any impacts incurred from the loss of habitat associated with the RSF are not considered critical to the survival of the species.
Disruption of the breeding cycle of an important population.	The squatter pigeon nests on the ground and so is particularly vulnerable to predation by foxes. Foxes are known to be active in the region. However, it is not expected that impacts from the project will lead to an increase in fox numbers or heighten predation on breeding squatter pigeons.
Modification, destruction, removal, isolation, or decrease in the availability or quality of habitat to the extent that the species is likely to decline.	The loss of open grassland and open woodland habitat will impact the movements of this species in the locality of the RSF. The level of impact will depend on the ability of squatter pigeons to relocate and survive in adjacent habitats and in habitats that may be currently occupied by adjacent squatter pigeon populations. It is not considered likely that these impacts would lead to a species decline.
Resulting in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species habitat.	It is not expected that impacts from the construction or operation of the RSF will result in the introduction of an invasive species that will be in direct competition, or predation of the squatter pigeon. Mitigation measures outlined for the control of invasive species include the monitoring and control of declared pest weeds, such as giants rats tail grass *(Sporobolus pyramidalis)* to ensure that the spread of invasive exotic flora does not affect open grassland and woodland habitat for the squatter pigeon. Similarly the implementation of the feral animal monitoring / control program will mitigate any noted increase in any fox numbers in the locality that would result in increased predation of the squatter pigeon.
Introduction of disease that may cause the species to decline.	The impacts associated with the construction and operation of the RSF are not expected to directly or indirectly lead to the introduction of a disease likely to cause a species decline.
Interfere substantially with the recovery of the species.	A recovery plan has not as yet been prepared for the squatter pigeon under the provisions of the EPBC Act. Some studies suggest there may be a reduction in numbers of the squatter pigeon on a regional scale, likely due to loss of habitat caused by overgrazing during dry periods. The recovery of this species on a regional scale would need to address the issue of overgrazing.

9.10.7.3 Mitigation Measures

Specific management strategies relating to EVR/threatened species and habitats within the RSF area include:

- Squatter Pigeon:
  - Preservation and rehabilitation of known or likely habitats in project areas adjacent to the RSF footprint area.
  - Contribution to any regional monitoring and assessment program for the squatter pigeon within the GSDA, in conjunction with Government and other land users.
- Powerful Owl:
  - Protection of potential roost or nesting trees in project areas adjacent to the RSF footprint area.
  - Contributing to any regional monitoring and assessment program for the powerful owl within the GSDA, in conjunction with Government and other land users.
- Maintenance and management of habitat:
  - During construction of the RSF, already established access tracks will be utilised where possible and laydown areas will be positioned to avoid disturbance to potential roost or nesting trees within project areas adjacent to the RSF footprint area.
  - Protection and management of terrestrial habitats in project areas adjacent to the RSF footprint area.
  - Monitoring and control of declared pest animals and non-declared animals in project areas adjacent to the RSF footprint area.

9.11 Freshwater Ecology

9.11.1 Introduction

Ecological Management Services Pty Ltd investigated the aquatic ecology at the RSF site.

The freshwater aquatic survey was undertaken in June and July 2006. Details of survey methodology employed are provided in Appendix L.

The objectives of the freshwater aquatic study were to:

- Describe the aquatic fauna occurring in the project areas including fish species, crustaceans and aquatic invertebrates in waterways within the affected areas, and habitat downstream of the project.
- Identify the occurrence or expected occurrence of any significant species, or any aquatic sites or habitats of significance.
- Assess the status of introduced aquatic fauna species in the area.

9.11.2 Overview

The Gladstone area is a relatively dry part of the Queensland coast, receiving an average of about 1,011 mm of rain annually, most of which falls in the summer months between December and March. Smaller streams in the region are generally intermittent, ceasing to flow late in the dry season and forming isolated refuge pools that are often densely vegetated. The principal land use in the area, cattle grazing, has contributed to the addition of a number of artificial water sources, in the form of farm dams. Sixteen species of freshwater fishes have been recorded from the upper reaches of the Calliope River catchment (SKM, 1999).

The northern portion of the RSF study area is drained by Larcom Creek, while the southern portion is drained by Farmer Creek. These two streams flow into the Calliope River, which is the largest permanent freshwater system in the region. No permanent freshwater systems were present within the RSF study area, and during the survey period surface water was only present in artificial farm dams. Downstream of the RSF study area, pools of water were only present in the lower reaches of Larcom Creek and Farmer Creek.

Baseline freshwater surveys of these systems have been previously undertaken by WBM Oceanics (1992) and Martin and Barden (1997) who sampled fishes, plankton, macroinvertebrates and birds at sites in Larcom, Boat, Gravel and Oaky Creeks, and the Calliope River. Additional records have been collated in additional studies and databases, including SKM (1999) and Connell Wagner (2002).

During the current survey, the four aquatic survey sites shown on Figure 9.11.1 (AQ1 to AQ4) were sampled in the Larcom and Farmer Creek catchments. Habitat and environmental parameters recorded at each site are detailed in Appendix L.

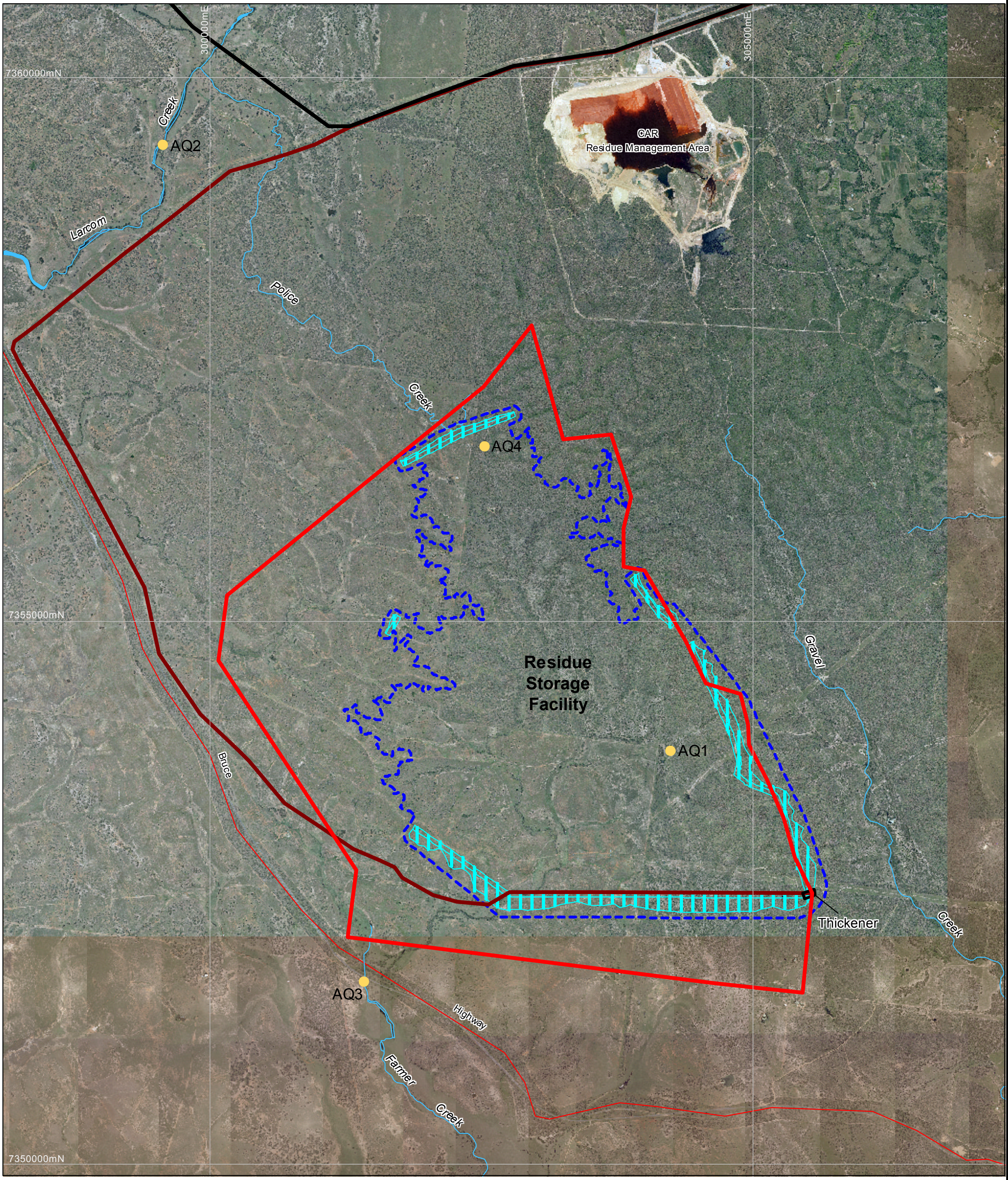
Overall results of macroinvertebrate surveys are given in Appendix L. A total of 25 macroinvertebrate families were identified in the samples collected. The majority of fauna was typical of macroinvertebrate communities inhabiting freshwater standing waterbodies, with some genera also found in slow flowing streams. Numbers of macroinvertebrate families and individuals were higher at sites with less impacts from cattle, with better developed in-stream aquatic vegetation indicating a longer term availability of surface water at these sites (e.g. AQ1, AQ2). In contrast, site AQ3 on the lower reaches of Farmer Creek displayed a low diversity of families and low numbers of macroinvertebrates. However, this site was influenced by a significant rainfall event between the 8 and 11 June 2006 (102.4 mm of rainfall recorded at Gladstone Station, Bureau of Meteorology 2006) and flushing prior to the sampling.

All of the sites displayed relatively low numbers of macroinvertebrate families and individual macroinvertbrates when compared to sampling undertaken in the area during previous surveys (e.g. Martin & Barden, 1997). However, the results are likely to have been influenced by the extended dry period experienced in the region prior to the 2006 survey. Analysis of results using the SIGNAL 2 scoring system (Chessman, 2003) indicates that all of the sites sampled have been impacted by agricultural pollution and drought conditions. The most abundant families present are generally tolerant of relatively poor in-stream conditions, including common forms of water pollution.

Nine species of fishes were identified in the RSF study area and downstream sites in the Farmer and Larcom Creek catchments (Table 9.11.1).

Table 9.11.1 Freshwater Fishes Survey Results

Common Name	Scientific Name	Larcom Ck	Farmer Ck		
		AQ2	AQ4	AQ1	AQ3
Fly-specked Hardyhead	*Craterocephalus stercusmuscarum*	***			
Eastern Rainbowfish	*Melanotaenia splendida splendida*	*			
Agassiz's Perchlet	*Ambassis agassizi*	**		*	
Spangled Perch	*Leiopotherapon unicolor*	*		*	
Mouth Almighty	*Glossamia aprion*	***			
Empire Gudgeon	*Hypseleotris compressa*			*	
Firetail Gudgeon	*Hypseleotris galii*			*	
Purple-spotted Gudgeon	*Mogurnda adspersa*			*	
Bony Bream	*Nematolosa erebi*	**			*
Total All Sites		6	0	5	1



AQ1 — Aquatic ecology sampling location

Slurry pipeline route

Residue and return liquor pipeline route

RSF site boundary

RSF footprint

Embankment

0 750 1500m

Scale 1:50,000 (A4)

MGA Z56, GDA94

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT	**AQUATIC ECOLOGY SAMPLING LOCATIONS RESIDUE STORAGE FACILITY**
URS	Drawn: TN / Approved: CMP / Date: 26-10-06	Figure: **9.11.1** / Rev: A
	Job No: **4262 5791** / File No: 42625791-g-066.wor	**A4**

Overall, the most numerically abundant fish species recorded were Agassizi's perchlet (*Ambassis agassizi*), fly-specked hardyhead (*Craterocephalus stercusmuscarum*), mouth almighty (*Glossamia aprion*), empire gudgeon (*Hypseleotris compressa*) and firetailed gudgeon (*Hypseleotris galii*).

Freshwater turtles were not recorded within the RSF study area. However, *Emydura krefftii* has been previously observed and trapped in Larcom Creek and Gravel Creek (P. Barden personal observation).

9.11.3 Farmer Creek

9.11.3.1 Habitats and Sites

Farmer Creek is a minor tributary of the Calliope River that has its headwaters partly in the proposed RSF study area and flows south through grazing land to the Bruce Highway. No natural permanent waterholes were present in the upper reaches within the RSF study area, and in the lower reaches (south of the Bruce Highway), several large pools were present during the survey period.

Within the RSF study area the only freshwater surface water was located in a number of farm dams. Two dam sites within the RSF Farmer Creek catchment were sampled during the survey (AQ1 and AQ4). The pH at these sites was close to neutral (7.3, 7.4) and EC low (180μs/cm). AQ1 displayed moderate levels of disturbance from cattle and feral pigs.

The site sampled on the main creek channel below the RSF study area (AQ3) consisted of a long pool (>200 m in length) with an average depth of 1.5 m. The stream was located within agricultural land and supported a narrow band of fringing riparian vegetation, dominated by *Callistemon viminalis* with occasional *Eucalyptus tereticornis*. The pH was 7.6 and conductivity relatively low (168 μS/cm). No aquatic macrophytes were observed at this site.

9.11.3.2 Fishes

Six species of fish were recorded at sites within the Farmer Creek catchment. Freshwater fishes were not present in dams higher in the Farmer Creek catchment (AQ4). Lower in the catchment, the most abundant species were the empire gudgeon (*Hypseleotris compressa*), fire-tail gudgeon (*Hypseleotris gallii*), purple-spotted gudgeon (*Mogurnda adspersa*) and Agassiz's perchlet (*Ambassis agassizi*). Only one species, the bony bream (*Nematolosa erebi*), was recorded in the main creek below the RSF study area (AQ3); however, additional species are likely to be present.

9.11.3.3 Other Fauna

Cane toads were observed in the area but were not abundant. The only other semi-aquatic species recorded on Farmer Creek was the eastern water dragon (*Physignathus lesueurii*) at AQ3.

9.11.4 Larcom Creek

9.11.4.1 Habitats and Sites

Larcom Creek is a major tributary of the Calliope River that is sourced to the west of Mount Larcom and flows to the north of the northern RSF study area. The northern RSF study area occurs within the catchment of Larcom Creek. North of the Bruce Highway the creek is characterised by a series of large, deep waterholes. Several small ephemeral tributaries feed the creek from the northern RSF study area and a number of highly disturbed artificial farm dams are also present. Surface water was not present in the tributaries within the Larcom Creek catchment of the RSF study area during the survey period. Artificial dams within the Larcom Creek catchment of the RSF study area were not sampled due to high levels of disturbance from cattle. Consequently only one site (AQ2) was sampled in this system, downstream of the RSF study area. Observations at the dams within the Larcom Creek catchment of the RSF study area recorded bony bream and a number of amphibian species.

Environmental parameters at the Larcom Creek sample site are shown in Appendix L. The pH was neutral (7.0) and prior to the rainfall event in June 2006 conductivity was relatively high (1140 μS/cm). Dense aquatic vegetation was present in some section of the lagoon sampled at AQ2, including lilies, emergent edge vegetation and submerged plants such as *Vallisneria gigantea* and *Myriophyllum* sp.

9.11.4.2 Fishes

Six species of freshwater fishes were recorded at Larcom Creek. The fly-specked hardy-head (*Craterocephalus stercusmuscarum*) and Agassiz's perchlet (*Ambassis agassizi*) and mouth almighty (*Glossamia aprion*) were the most abundant fishes at this site. Less commonly trapped or observed species include the eastern rainbowfish (*Melanotaenia splendida splendida*), bony bream (*Nematolosa erebi*) and spangled perch (*Leiopotherapon unicolor*). Additional species recorded from the Larcom Creek drainage during previous surveys include barred grunter (*Amniataba percoides*), striped gudgeon (*Gobiomorphis australis*) (WBM Oceanics, 1992), sea mullet (*Mugil cephalus*), empire gudgeon (*Hypseleotris compressa*) and firetail gudgeon (*Hypseleotris galii*) (Martin and Barden, 1997).

9.11.4.3 Other Fauna

Within the Larcom Creek catchment a number of amphibian species were observed at dams and creeks, including cane toads, *Litoria inermis*, *Litoria latopalmata*, *Litoria rubella* and *Limnodynastes ornatus.* Previous surveys have recorded the freshwater turtle *Emydura krefftii* on this tributary.

9.11.5 Discussion

Generally the macroinvertebrate fauna of the creek systems comprised taxonomic groups that commonly inhabit still to slow-flowing fresh waterbodies and are adapted to ephemeral conditions. When compared with larger and more permanent freshwater streams in tropical Australia, the communities in the ephemeral creeks in the survey area and downstream areas are relatively poor in terms of species numbers. Results indicate that all of the sites sampled have been impacted by agricultural pollution and drought conditions. The most abundant families present are generally tolerant of relatively poor instream conditions, including common forms of water pollution.

The survey recorded a total of nine freshwater fishes species from streams draining components of the RSF study area. Earlier surveys (SKM, 1999) have recorded a number of additional species, such as the barred grunter and lesser salmon catfish (*Arius graeffei*) and SKM (1999) lists 16 species of freshwater fishes as occurring in the upper Calliope River. Martin and Barden (1997) suggest that the freshwater fish variety of the upper catchment of the Calliope River is probably about twenty species, most of which are confined to the larger or more permanent waterbodies.

None of the fish species recorded in surveys are listed as Endangered, Vulnerable or Poorly Known (Wager, 1993). No species occurring in the area are listed in the NC Act or the EPBC Act under any category, and examination of existing data indicates that the likelihood of such fishes occurring in the area is low.

The fish species recorded are generally common and widely distributed in eastern Australia. None of the freshwater fish species recorded are especially significant angling targets, although some, such as the eastern rainbowfish and Agassiz's perchlet, are recognised aquarium species. No introduced or exotic species were recorded during the survey.

The streams draining the project area locations are considered to have conservation value only at a local level, since the species present are all common. In addition, habitat diversity is generally low due to the ephemeral nature of the streams and the close proximity to the coast. However, the streams do contribute to the ecological processes in the area by providing seasonal habitat to aquatic species, and movement, refuge and food corridors for terrestrial fauna such as birds, reptiles, and amphibians. The streams are not pristine, as these generally flow through highly disturbed cattle grazing country. However, these do represent typical freshwater habitats of the region.

The upper reaches of the Police Creek (tributary of Larcom Creek) are proposed to be modified during construction of the RSF study area. Within the RSF study area Police Creek is generally highly degraded, with riparian vegetation disturbed or removed and heavy impacts from cattle. This stream only flows during rainfall events and was dry during the survey period. The southern RSF study area is drained by the upper tributaries of Farmer Creek. Again, these tributaries are within grazing land and display degraded riparian vegetation and impacts from cattle. The loss of the upper reaches of Police and Farmer Creeks will not have any significant environmental impacts.

Environmental management strategies proposed to protect surface water quality in the RSF area will also assist in the protection of downstream aquatic habitats. These measures which are described in Section 9.6 include:

- Management and retention of any existing riparian vegetation in project areas adjacent to the RSF footprint.
- Control of erosion and sedimentation within the RSF study area, with active measures to minimise downstream impacts from erosion and sedimentation.
- Prevention of flows of any residue material or contaminated water into the downstream aquatic system.
- Management of surface and stormwater runoff from the RSF.
- Monitoring of downstream water quality.

9.12 Air Quality

9.12.1 Existing Air Quality

Details on the existing air quality of the Gladstone region are given in Section 8.7.4. However, there is no specific information on existing air quality at the RSF area. The only potential emission sources would be dust from grazing and rural activities, and emission from vehicles on the nearby Bruce Highway. The CAR RMA is to the north-east of the RSF area but as this facility is essentially a wet operation it is not expected to be a significant dust source.

9.12.2 Emissions

Residue is piped to the RSF as a wet slurry and hence the placement of residue will not be a dust source. However, dust emissions from the RSF may occur from sections of the RSF surface that may dry out.

Slurry residue will be discharged via spigot disposal around the RSF perimeter. The residue will form a beach as it flows away from the spigots and settles. The liquor entrained in the slurried residue will flow to a low point and the end of the residue beach and collect in a reclaim pond. Alternating spigotting points will be employed to promote thin-layer deposition, thereby enhancing consolidation and increasing the residue dry density. As the residue dries out it will be covered by another layer of wet residue. In this way most of the surface of the RSF will remain wet for most of the time.

The maximum surface area of the RSF when full will be 1,185 ha. To be conservative, dust emissions from the surface have been estimated on the basis that 40% of the surface area is dry and susceptible to wind erosion.

After the refinery operations cease, the RSF will be rehabilitated by capping and re-vegetating the surface. The air quality impacts after rehabilitation are expected to be minimal, as wind erosion of the surface will be minimised by the vegetation.

Emissions of total suspended particulates (TSP) and particulate matter less than 10 microns (PM_{10}) due to wind erosion have been estimated for the assumed dry surface area, based on emission factors in the NPI Handbook for Mining [4]. The estimated emission rates of PM_{10} and TSP from the RSF are 0.8 g/s and 1.7 g/s respectively. No dust controls have been assumed for the RSF surface, and the air quality modelling has assumed the worst-case scenario of dust emissions for every day of the year, neglecting the reduction in dust generation during and immediately following rain. Dust emissions from the RSF have been modelled from the whole surface of the RSF.

9.12.3 Dust

Air quality impacts from dust erosion at the RSF are presented in Table 9.12.1 for TSP and PM_{10} concentrations, and dust deposition results are presented in Table 9.12.2. Potential impacts have been predicted for rural-residential locations around the RSF site and at the township of Mt Larcom. Due to the lack of any alternative data, the background concentrations of PM_{10} at these locations were assumed to be the same as those measured at Targinie (Table 8.7.4). The predicted ground-level concentrations are low at all locations and no significant dust impacts are expected.

Table 9.12.1 Modelled Ground-level Concentrations of TSP and PM_{10} due to the RSF with a Constant Background Concentration [5]

Emission	Averaging time	Mt Larcom	Rural-residential	Guideline[1]
TSP (µg/m³)	Annual	23.2	23.5	90
PM_{10} (µg/m³)	24 hour	93.9	95.3	150
	Annual	23.2	23.4	50

[1] EPP (Air)

Table 9.12.2 Modelled Monthly Deposition rate of Dust due to the RSF in Isolation

Pollutant	Averaging time	Mt Larcom	Rural-residential	Guideline[1]
Dust deposition (g/m²/month)	Monthly	0.010	0.025	4

[1] EPA

There are negligible greenhouse gas emissions from the RSF operations and these have not been assessed.

9.13 Noise

During construction, noise will be generated by earthmoving equipment. This will be an intermittent noise source and will be spread across the construction area. Noise levels will be typical of major earthmoving projects and will occur during day-light hours only. Noise is unlikely to be heard at Mount Larcom but may be audible from local isolated rural residences. However, these noises will be masked to some extent by noise from vehicles on the nearby Bruce Highway.

[4] National Pollutant Inventory, *Emission Estimation Technique Manual for Mining*, Version 2.3, 5 December 2001

[5] Background concentration is estimated to be 93 µg/m³ for 24-hour average concentrations, and 23 µg/m³ for annual average concentrations (refer to Table 8.7.4).

During operations, noise sources will be limited to a few pumps associated with the thickener and the reclaim pond and infrequent inspections and maintenance vehicles. Noise generation from these sources will be minimal and no significant impacts on sensitive receptors are expected.