Environmental Effects of Residue Storage Facility

12

URS

Gladstone Pacific Nickel LTD

9 Environmental Effects of the RSF (1, 20)

(1) *EPA advised that if this project is to succeed on the basis that has been put forward in this EIS then it must be accepted that a large groundwater mound of contaminated water will remain permanently under the RSF after closure. If the project is accepted on this basis, then failsafe methods of seepage control and long term groundwater containment are required.*

The RSF design as put forward in the EIS has been modified. Rather than one large RSF cell, it is now proposed to construct a number of smaller cells. This approach has the advantages of having a smaller footprint, smaller seepage volumes, less loss of catchment, less disturbance to Farmer Creek, and provides the opportunity for progressive rehabilitation. Details of the proposed concept design for the RSF are given in the report URS (2007a).

The results of a seepage analysis undertaken for the initial RSF cell (RSF-A) (URS, 2007a) show that the majority of the seepage will occur through the base of the RSF into the bedrock aquifer. This will increase annually as the depth of residue (and driving head) in the RSF increases. During this time the seepage to the alluvial aquifer will be minimal. Once residue deposition ceases and the top of the RSF is covered with a low permeability cover, the seepage rate to the bedrock aquifer will reduce as the phreatic surface in the RSF slowly drops. Correspondingly post closure there will be an initial increase in seepage to the alluvial aquifer as the phreatic surface rises to intercept the recovery trench. This will gradually reduce over time as the volume of water stored in the RSF reduces.

Any seepage that enters the groundwater system directly below the RSF would be expected to increase the salinity of the groundwater as the salinity of the seepage is approximately double that of the groundwater below the RSF site. The concentration of dissolved metals in the seepage is expected to be low and less than the concentrations in groundwater, apart from manganese and to a lesser extent nickel and chromium (Section 9.3). However, any increase in the concentration of dissolved nickel or chromium is expected to remain below the livestock drinking water and irrigation guideline values. Any increase in the manganese concentration may exceed the long term irrigation guideline depending on the relative proportions of seepage and groundwater mixing, however the groundwater from two of the monitoring bores (RSF13 and RSF17) already contains manganese at concentrations greater than the guideline value.

The RSF seepage management system will be designed to ensure that there will be no surface expression of seepage downstream of the RSF. To achieve this, the design incorporates a cut-off trench within the foundation along the alignment of the containment embankments. The trench shall be at least 4 m wide at the base and founded 200 mm into bedrock. The depth of the trench will vary depending on the thickness of alluvium and will be filled with low permeability clay. The installation of the cut-off trench through the alluvium in the embankments would effectively cut-off groundwater flow through the alluvium under the embankments.

In addition to the cut-off trench, a seepage collection system is also proposed to intercept any seepage that does occur through or under the embankments and to return the seepage to the RSF impoundment. The seepage collection system will consist of an excavated trench around the toe of the embankment (5 m deep and 1 m wide) fitted with a pump-back riser, lined with geotextile filter fabric, and backfilled with drainage aggregate. Drainage pipe shall be placed at the bottom of the trench with a riser pipe connected to the drain pipe at the low point in the trench to convey water to a submersible pump. A submersible pump will be installed in the riser pipe to pump the seepage back to the RSF impoundment. It may not be practical to construct a seepage collection trench in areas where shallow, hard bedrock is encountered. In these areas, the collection trench may be replaced with extraction wells, as required.

Further to the seepage collection trench, seepage monitoring will be carried by a network of monitoring bores to be positioned at strategic locations around the downstream perimeter of the RSF approximately 100 m from the toe. These bores will monitor seepage from both the alluvial and bedrock aquifers. If necessary, they can also be used as recovery bores to collect seepage and return it to the TSF. In this way downgradient contamination will be intercepted and prevented.

At closure of the RSF, a low permeability cover will be constructed across the RSF surface. The cover will comprise a four-layer system with a total thickness of the order of 1.7 m to maximise the long-term sustainability and performance of the cover (Section 9.5.2 of the EIS). The objective of the cover will be to minimise the inflow of water into the residue and therefore reduce any groundwater mound by decreasing the amount of water available to seep through the RSF and into the groundwater.

***(1)** The EPA asked for details on the operation and management of the residue and return liquor pipelines. Details must be included on the size and location of pumps. The EIS should include operational monitoring and contingency plans to address pump failure, pipeline leaks or ruptures, and for routine maintenance.*

Residue thickeners will be located at the southern side of the RSF approximately 1 km south of the initial residue storage bunded area. The two high rate process thickeners, a flocculant addition system and a return liquor tank will be located with in a bunded concrete pad with an area sump pump which will return spillage and washings to thickener feed/de-aeration tanks at the thickener feed launders.

A switchroom will be located adjacent the thickener pad to supply power to and allow isolation of the electric motors located on pumps and thickeners as well as the reclaim water pumps and pond and bore instruments and sampling devices used in the RSF.

The process thickeners will partially de-water the residue slurry from the refinery, prior to the thickened slurry being disposed of into the RSF. For Stage 1, neutralised slurry flowing at 2,740 m^3/h and containing 26.5% solids will be treated through the facility.

A flocculant will be added to the slurry prior to it being pumped into the process thickeners. The flocculant assists with the settling of the solids in the thickener.

Each thickener will have a diameter of 54 m with a conical base and a working slurry volume of 10,200 m^3. The overflow tank, servicing both thickeners will have a working volume of 600 m^3. The contained bunded area will be approximately 10,000 m^2. The bund height of 1.15 m will provide for 110% of the volume of one thickener (the largest tank). This area would capture the contents of up to one full thickener which then may be returned to the system through the existing operating one.

Spillage from piping and equipment within the bunded area will remain within the bunded area and will be collected in the area sump and pumped back into the thickener feed. Such spills could occur during regular pump or tank maintenance, or in the improbable event of a leak or overflow from a pipe, pump, thickener or tank.

In the event of the known requirement to take one thickener out of service, the contents of the thickener would be pumped to the second thickener prior to opening the decanted thickener into the bunded area. Under a normal operating regime only one thickener would be taken out of service at any time, with the second thickener remaining in service. If the flow capacity can not be handled by the operating thickener, then the slurry would be sent through a bypass to the RSF.

Supernatant water from the thickener overflows will be pumped back to the refinery for reuse via the return liquor (overflow) tank which will act as a collection tank for clear water and also as a header tank for the return liquor pumps. The capacity of the pumps returning residue liquor to the refinery will be nominally 2,340 t/hr (URS, 2007a).

Leaks from pipelines should not normally occur and would be cleaned up, together with pipe repair, when detected. Flow meters will be installed with comparators at the start and finish of the long pipeline lengths which would provide warning of any major flow excursions, allowing rapid detection and containment of anomalies. Spare pumps will be available in the event of a pump failure.

***(1)** EPA advised that the EIS should consider the alternative of installing above-ground pipelines (compared to burial of the pipes) and present the reason for supporting the preferred option.*

Whilst the construction of above-ground pipelines is less costly, underground pipelines are more secure from vandalism or accidental damage, are less visually intrusive, and have less impact on surrounding land uses than do above-ground pipelines. Leak detection mechanisms in buried pipelines are accurate enough to ensure that any leaks can be readily detected and remediated before any significant environmental harm can occur.

Since the release of the EIS, GPNL has undertaken further assessment of the alternative route identified in the EIS for the residue pipeline between the refinery and the RSF. GPNL has subsequently decided to pursue this alternate option for the residue pipeline and a detailed environmental assessment report has been prepared. A copy of the report is given in Appendix L.

The preferred options for the proposed route for the residue and return liquor pipelines is illustrated in Figure 2.1 in Appendix L and has a total length of 18.3 km. The pipeline commences at the refinery and then heads in a north westerly direction crossing Reid Road and then heading in a westerly direction. The pipeline route then crosses the North Coast Railway and heads in general westerly direction to Yarwun. From Yarwun, the pipeline route heads south and is contained within the Calliope River Road road reserve. The route crosses through private land and then into the Boyles Road road reserve and travels in a south and southwest direction. Near the RSF site, the pipeline route leaves the road reserve and heads in a westerly direction to the RSF thickener location.

Stage 1 of the project will require a residue pipeline and residue return pipeline to operate between the refinery and the RSF. Stage 2 of the project will require these pipelines to be duplicated.

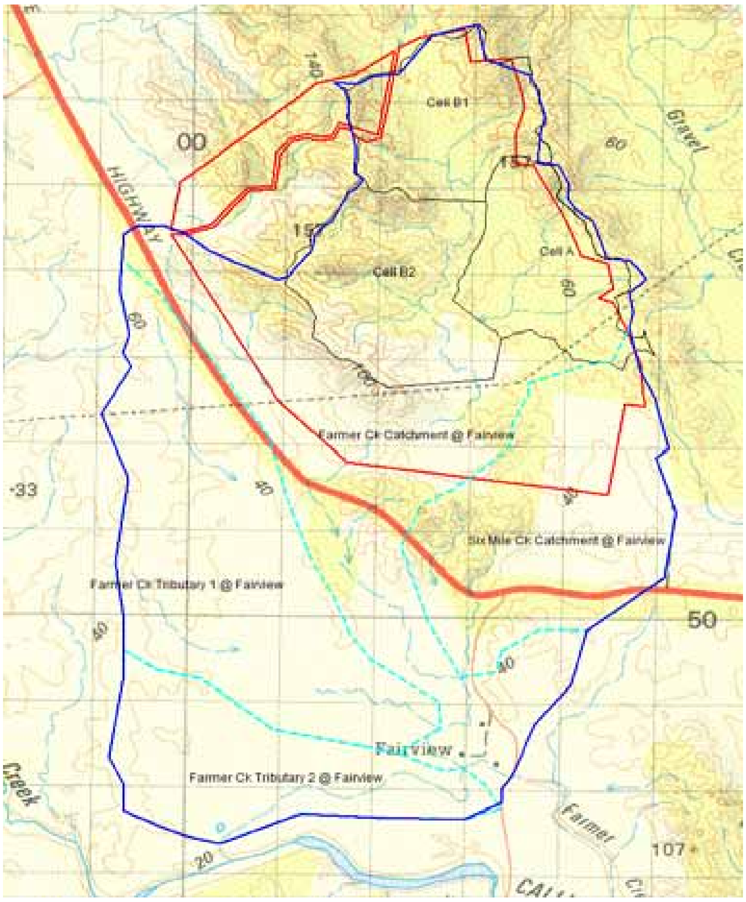
Details of the environmental effects of the pipeline on aspects such as flora, fauna, noise, dust, soils and land use are given in Appendix L.

***(20)** A respondent has advised that the EIS has not recognised or considered the impact of the construction of the RSF in the catchment of Six Mile Creek and the resultant impact it will have on "Fairview".*

The Fairview property is located adjacent to Farmer Creek downstream of the RSF. The catchments contributing to flows in Farmer Creek at this location are shown in the following figure.

The contributing catchments shown in the figure are:

- Residue Storage Facility (RSF) RSF-A;
- RSF RSF-B1;
- RSF Cell B2;
- Farmer Creek at Fairview Property;
- Farmer Creek Tributary 1 at Fairview Property;
- Farmer Creek Tributary 2 at Fairview Property; and
- Six Mile Creek at Fairview Property.



Farmer Creek and Six Mile Creek Sub-Catchments at Fairview

As each RSF cell is constructed it will remove a portion of the Farmer Creek catchment and potentially affect Farmer Creek flows at Fairview, the respondent's property downstream of the RSF. This loss of catchment area will last for the operational life of each cell. Once the cells are full, they will be covered and rehabilitated with the surface runoff being discharged back into Farmer Creek thus restoring most of the pre-RSF flows, except for RSF-A which would discharge into the adjacent catchment to the east.

The following table summarises the loss of catchment area from each of the three RSF cells and the percentage they represent of the total Farmer Creek and Six Mile Creek catchment area at Fairview. The percentages relate to the situation prior to cell rehabilitation and the return of runoff to the downstream catchment. The loss of catchment area approximates to the potential loss of water flow in Farmer Creek although that would depend on the extent of storm flow throughout the catchment.

Catchment Areas Affected by RSF

RSF Development	Area of Farmer Creek and Six Mile Creek Catchment at Fairview (km^2)	Percentage of Total Catchment Remaining
Before RSF	48.2	100
After RSF-A	45.4	94
After RSF-B1	42.2	88
After RSF-B2	38.4	80

Should this 20% loss of catchment area result in an appreciable loss of water supply at Fairview, GPNL will enter into an agreement with the entitlement holder for alternative supplies.

GNPL is studying the use of the land to the south of the currently proposed cells, which could lead to an estimated additional 11% loss of catchment. A possible footprint for an additional cell in this area is shown on Figure 9.17. This is conceptual only and its feasibility and design are yet to be confirmed. No approvals are currently being sought for this possible future cell.

(20) *The same respondent has advised that the construction of the RSF will have a devastating impact on Fairview both by denying the inflow of water into Farmer Creek which is necessary to enable irrigation and grazing activities or by causing irreversible contamination of Farmer Creek.*

See response above.

9.1.1.2 Site Geology (1)

EPA advised that investigations should be undertaken so that geological sections can be presented showing the stratigraphic units present under the RSF site. Maps and plans should be presented showing the locations of any fissure lines, fault zones, or permeable layers. The potential of these features to carry flow from under the proposed RSF to down gradient areas should be investigated. Sub-surface conditions upstream and downstream of the main southern embankment of the proposed RSF should be included in the investigation. The regional groundwater table should be mapped and the groundwater contours for the area under and around the site should be shown on a suitable plan.

Investigation holes should be located both inside and outside the proposed footprint to allow ongoing monitoring of areas potentially causing, and areas potentially affected by groundwater fluctuation. The groundwater contours and directions of flow both inside and outside the RSF should be established. This data should be collected from all sides of the RSF site. Enough geological and hydrogeological information should be collected to establish current groundwater gradients and likely future gradients inside and outside the RSF. Bore logs should be presented and hydraulic conductivity testing should be undertaken for all permeable strata which is intersected by drilling.

The locations of bore holes or investigation trenches used in this investigation and the reasons for their locations should be recorded. All of the drill holes should be deep enough to reach an aquifer connected to the water table. The bore holes should be cased and capped in such a way that future access is possible, and that fluctuations of water levels in the bores can be measured as required in the future.

A further geological and groundwater assessment of the RSF site has been undertaken and is presented in Appendix K. It has been based on a review of available information and data collected on-site. Nine groundwater monitoring bores were installed in April 2006 and a further fifteen bores were installed in August 2007. The locations of these bores are shown on Figure 9.1 and the bore logs are presented in Appendix K.

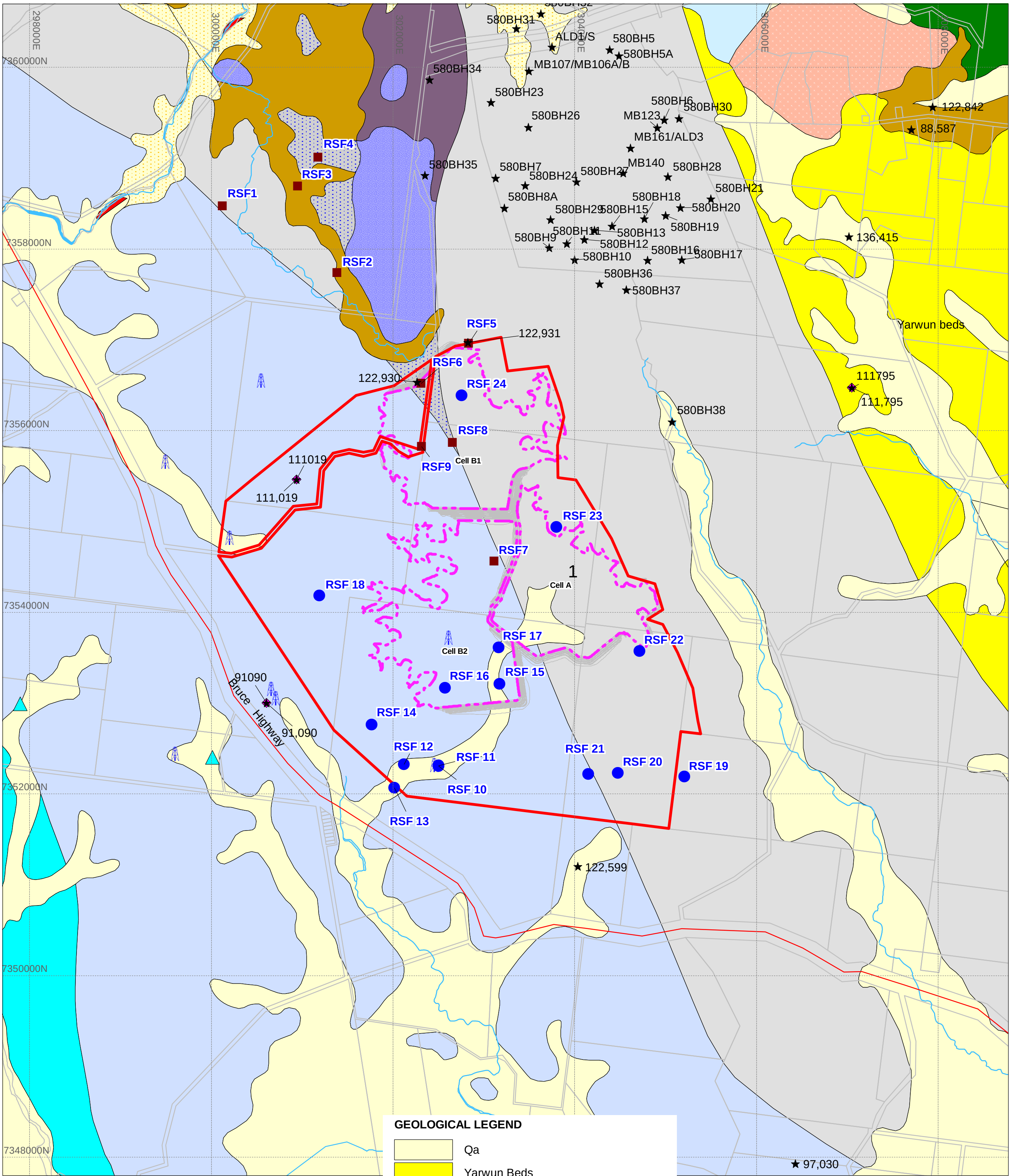
Groundwater Geology

Groundwater in the vicinity of the RSF site mainly occurs within fractures and pore spaces 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 sandstone and siltstone, and conglomerate with andesitic to dacitic volcanic clasts and siltstone rip-up clasts. This formation is found in the western portion of the project area and is separated from the Rockhampton Group in the east by the Ambrose Fault.

The Rockhampton Group is comprised of mudstone and siltstone, felsic volcaniclastic sandstone, polymictic conglomerate, oolitic and pisolitic limestone and minor skeletal limestone.

The faulted contact between the two bedrock units trends northwest-southeast through the RSF site. The contact is along a regional fault system, with a Late Permian gabbro intrusion 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. Structural deformation in the area has produced dips in the strata of the Mount Alma



GEOLOGICAL LEGEND

- Qa
- Yarwun Beds
- TQa
- TQr
- Targinie Quartz Monzonite
- PRg/b
- Chalmers Formation
- Rockhampton Group, Berserker Group
- Rockhampton Group
- Mount Alma Formation

- URS Groundwater Bore (2007)
- URS Groundwater Bore (2006)
- Comalco Groundwater Bore
- DNRW Registered Bore
- Unregistered Bores
- Unregistered Bores - Fairfield
- RSF Site Boundary - Lot 4
- Cell Footprints

N

0 750 1500m

Scale 1:60 000 (A4)

MGA Z56, GDA94

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT	**GROUNDWATER BORES, TERRAIN UNITS AND GEOLOGICAL REGIMES - RESIDUE STORAGE FACILITY**
URS	Drawn: VH / Approved: CDP / Date: 29-01-2008	Figure: **9.1** / Rev: A
	Job No: **4262 5791** / File No: 42625791-g-228.wor	A4

Formation of between 20^{O} and 50^{O} in a north-easterly direction toward the fault and in the Rockhampton Group of 57^{O} to 82^{O} in a south-westerly direction toward the fault.

The lithology encountered during drilling in the Mount Alma Formation and the Rockhampton Group tended to be hard fine grained sedimentary rocks (siltstone and fine grained greywacke which have been silicified), chert, and minor limestone. Due to the steep dips and complex history of structural deformation of the strata, correlation of strata between the monitoring bores cannot be undertaken. The primary permeability of the strata appears to be low due to the fine grain sizes and secondary mineralisation infilling between the grains. Fractures in the strata were observed during the investigations, some of which were infilled with silica or calcite. Hence the permeability and porosity of the Mount Alma Formation and Rockhampton Group strata is likely to be highly variable, depending on the degree of secondary mineralisation and the intensity of fracturing. Those fractures which are unfilled are likely to be the main conduits for groundwater flow through the formations. Open fractures are not pervasive throughout the area with some monitoring wells remaining dry. Recharge of these formations is generally by direct infiltration of rainfall and overland flow, and by downward leakage from overlying aquifers in unconsolidated alluvium/colluvium.

A thin layer of surficial unconsolidated alluvium/colluvium exists within the topographically low drainage lines which trend north to south within the RSF site. Along Farmer Creek they consist of 3 to 6 m of poorly sorted clay, silt, sand and gravel mixtures with occasional well sorted sand or gravel layers. Potential for groundwater exists within sandy and gravely sections of the alluvium, which represents an unconfined to semi-confined aquifer. Groundwater movement within the alluvium is predominantly via inter-granular flow. Recharge to the shallow alluvial aquifer is likely to come from two main sources - seepage from creek beds and banks during strong surface water flow or flooding; and surface infiltration of rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface. Due to their shallow depth and their lack of continuity and thickness, the alluvium is not considered a significant aquifer within the area of the RSF.

Hydraulic Parameters

Falling head tests were conducted on the monitoring wells installed to provide details on the hydraulic conductivity of the various rock and soil materials. Analysis of the data using standard analytical methods is provided in Appendix K.

The poorly sorted alluvium has a low permeability, with a hydraulic conductivity (K) of 5.01×10^{-4} to 3.48×10^{-3} m/day. The well sorted sand and gravel has a high permeability, with a hydraulic conductivity of greater than 10 m/day (the rate of fall in the falling head test was too quick to determine and accurate hydraulic conductivity with the methods employed). As the alluvium is confined to the drainage lines and is not regionally extensive, groundwater extraction at high rates would not be sustainable in the long term.

The hydraulic conductivity values of the consolidated rock formations ranges from 1.43×10^{-4} to 9.46×10^{-1} m/day with an average of 1.01×10^{-1} m/day and a median of 9.04×10^{-3} m/day. Primary permeability in the consolidated rock strata is likely to be limited due to the fine grain size and secondary mineralisation of the formations. Aquifer permeability will be controlled by the spacing, aperture size and interconnectivity of the discontinuities. Where the strata are more fractured, the unit may have local zones of moderate to high hydraulic conductivity. As the consolidated rock formations are variably fractured and the extent of any high hydraulic conductivity fracture zones is not expected to be regionally extensive, groundwater extraction at high rates would not be sustainable in the long term.

Groundwater Levels

Groundwater levels in alluvium were between 2.96 and 4.51 metres below ground level (mbgl), with some of the bores in alluvium being dry. Where the monitoring bores were dry the alluvium may not act as an aquifer, or the alluvial aquifers may be dry due to the extended dry conditions encountered during the field investigations. The groundwater level in the alluvium is generally above the piezometric water level in the bedrock at the same location which indicates groundwater movement may be downwards, with the alluvium recharging the bedrock aquifers. Due to the heterogeneity and discontinuity of the alluvial aquifers, the groundwater flow direction cannot be determined on a regional scale for these aquifers; however, locally groundwater flow is expected to be down gradient along the drainage lines.

Groundwater levels in the bedrock Mount Alma Formation and Rockhampton Group were between 4.01 and 48.21 mbgl, with some of the bores in these formations being dry at depths up to 50 mbgl. A contour map of groundwater levels in the bedrock units is shown in Figure 9.2. Groundwater flow within the bedrock units is primarily in fractures, and the direction of groundwater flow generally mirrors topography, flowing from topographically higher to topographically lower areas.

As aquifer permeability and groundwater flow is controlled by the spacing, aperture size and interconnectivity of fractures, there may be zones of higher groundwater flow in highly fractured areas, and zones where the bedrock is unfractured and hence is not an aquifer. The effects of faults on local and regional groundwater flow patterns are not known, but could be substantial. Faults may either restrict or enhance flow, depending on the transmissivity of the fault zones, which is not possible to predict with the current level of information.

Travel time velocity estimates for the consolidated rock formations were calculated using the analytical Darcy's Law equation. An average hydraulic conductivity of 9.04×10^{-3} m/day was assumed based on the median result of the falling head tests. A drainable porosity range of 1 to 5 % was assumed for the sake of conservatism (i.e. to project the maximum potential off-site velocity). The range of hydraulic gradient on-site was 0.3 to 3 % from the water levels observed in the monitoring wells. The range of calculated groundwater flow velocities varied from 0.2 m/y to 9.9 m/year.

9.1.2 Topsoil Resources (1)

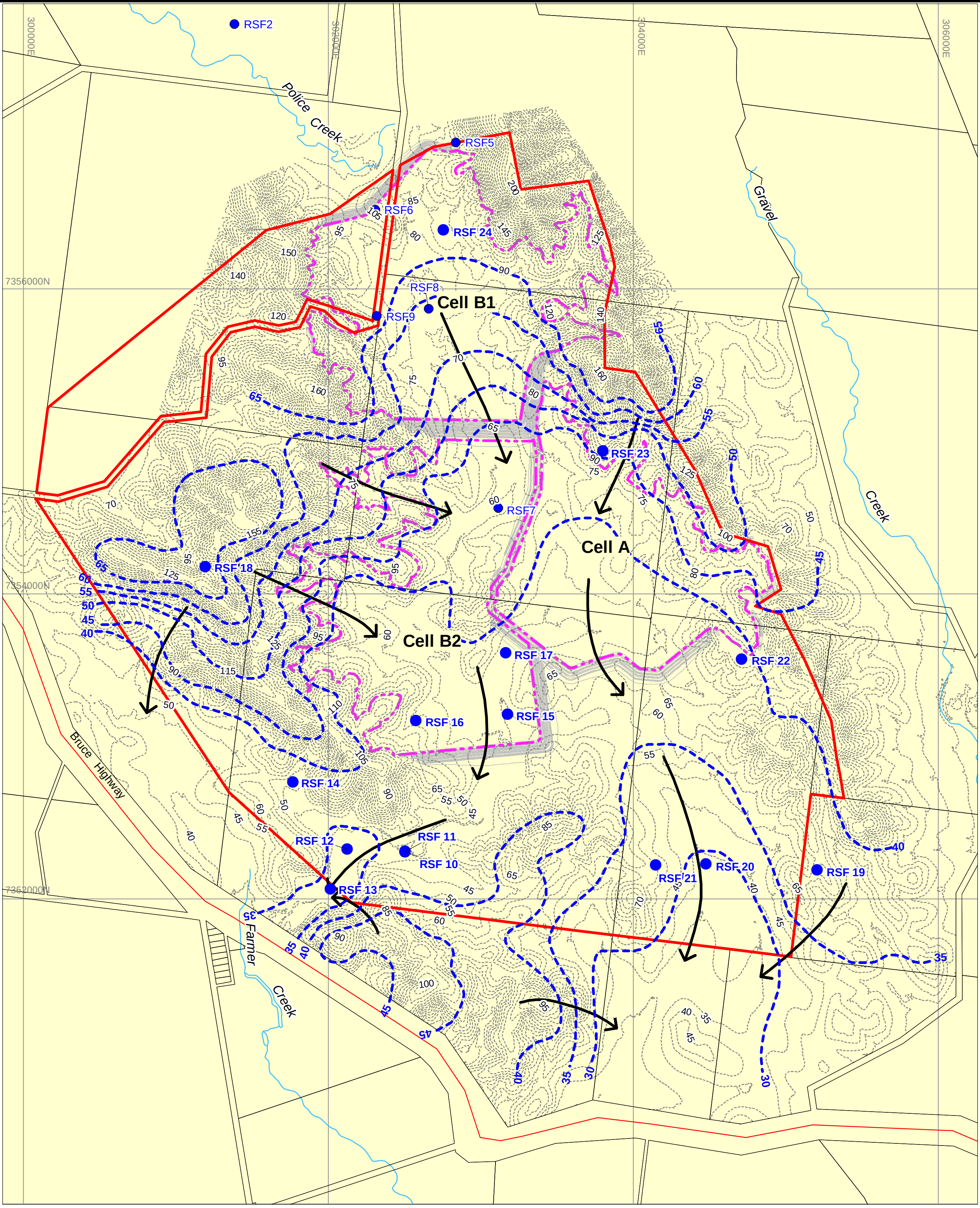
EPA has asked that details of the topsoil resources should be revised including: 1) the figures for topsoil resources in s9.1.2 be checked and amended as required. 2) A formal definition of the term 'RSF Study Area' should be included in this part of the EIS.

As discussed in Section 1.2.5, the design of the RSF has been modified from that described in the EIS. Consequently, the areas and volumes of topsoil and subsoil given in Table 9.1.2 of the EIS are no longer relevant. The soil types to be affected by the revised RSF layout are shown on Figure 9.3. The footprint of the now proposed RSF cells A, B-1 and B-2 is 679 ha. This area encompasses terrain units with topsoil resources of 1.168 million m^3 and subsoil supplement resources of 1.606 million m^3. Details of the terrain units and their respective soil volumes are given in the following table.

Topsoil Resources

Terrain Units	Area (ha)	Topsoil		Subsoil	
		Depth (m)	Volume (m3x1,000)	Depth (m)	Volume (m3x1,000)
Qa2-7.2	56.6	0.3	170	0.3	170
Cr4-6.2	21.2	0.15	32	0.15	32
Cr6-6.1	152.3	0.15	228	0.15	228
Cr8-(1-6.1)	59.4	0	0	0.1	59
Dca6-(5.1-1)	79.6	0.15	119	0.35	278
Dca7-(5.1-1)	53.5	0.15	80	0.35	187
TQr5-(6.2-7.1)	103.0	0.15	154	0.15	154
CPk6-(5.1-7.1)	16.6	0.3	50	0.2	33
DCa5-5.2	83.6	0.4	334	0.3	251
DCa8-(1-5.1)	53.2	0	0	0.4	213
Total	**678.9**		**1,168**		**1,606**

Based on the estimate given in the above table there are enough topsoil and subsoil resources available to cover the three RSF cells to an average depth of 0.4 m.



0 500 1000m

Scale 1:35,000 (A4)

MGA Z56, GDA94

N

40 Inferred Groundwater Contour and Value

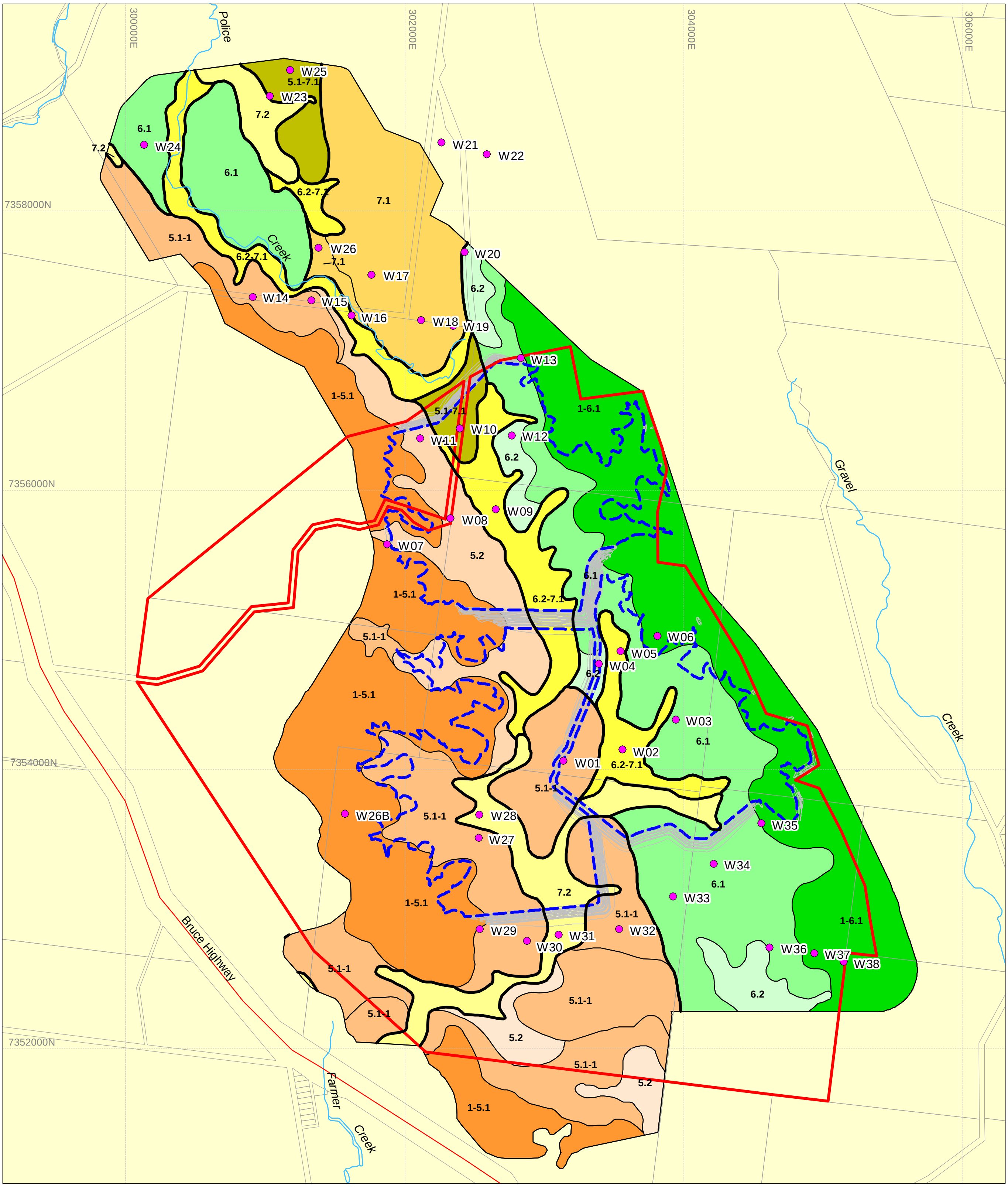
Inferred Groundwater Flow

URS Groundwater Bore (2007)

RSF Site Boundary - Lot 4

Cell Footprints

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT	INFERRED GROUNDWATER CONTOURS AND INFERRED GROUNDWATER FLOW - RESIDUE STORAGE FACILITY
URS	Drawn: VH; Approved: CDP; Date: 29-01-2008	Figure: 9.2; Rev:B
	Job No: 4262 5791; File No: 42625791-g-230b.wor	A4



NOTE:
This Figure 9.3a must be viewed with Figure 9.3b (Legend -Soil Mapping Units - RSF)

N

0 500 1000m

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

W29 — Soil sampling location

Geological Regime Boundary

Cr4-6.2 — Terrain Unit and Terrain Unit Boundary

RSF site boundary

RSF Cell footprint

Client	Project	Title
Gladstone Pacific Nickel Ltd	GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT	**SOIL TYPES RESIDUE STORAGE FACILITY**
URS	Drawn: VH · Approved: CMP · Date: 29-01-2008 · Job No: **4262 5791** · File No: 42625791-g-235.wor	Figure: **9.3a** · Rev: A · **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: Gladstone Pacific Nickel Ltd	Project: GLADSTONE NICKEL PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT	Title: **LEGEND - SOIL MAPPING UNITS - RESIDUE STORAGE FACILITY**
URS	Drawn: VH · Approved: CMP · Date: 29-01-2008	Figure: **9.3b** · Rev: A
	Job No: **4262 5791** · File No: 42625791-g-235.wor	A4

9.2 Residue Characterisation (13)

DNRW advised that Castlehope is a major water source development option in the Gladstone region and it is prudent that the damsite be preserved for future development. While the RSF is just outside the full supply area, it is believed that it would be within the flood margin required to provide a flood equivalent to a 1:500 year return period. NRW does not support development which has the potential to severely limit or potentially contaminate a future damsite.

As part of its role in planning for the long-term water supplies around Queensland, DNRW has identified a number of long range potential water storage sites. Each of these options requires substantial additional investigation.

In the Gladstone region, one such potential future water storage site is referred to as Castlehope Dam on the Calliope River, the impoundment wall for which could be situated approximately 7-8 km south of GPNL's proposed residue storage facility (RSF). The Queensland Government does not intend to proceed with the development of the Castlehope Dam in the foreseeable future. Nonetheless, DNRW's long term scenario planning for future water supply to Gladstone identifies Castlehope as one of several potential options that could be pursued in future decades.

Planning by both DNRW and the Gladstone Area Water Board (GAWB) has identified a water pipeline from the Fitzroy River and further raising of Awoonga Dam as the most likely future supply enhancement options for Gladstone over the next 2-20 years.

Despite this analysis, the Queensland Government cannot, at the present time, categorically rule out ever pursuing a Castlehope Dam option. Therefore, impact assessment for the GNP must consider any potential interaction between the RSF and such a future dam.

In discussions with DNRW, certain criteria have been put forward to GPNL for the development of the RSF adjacent to a potential Castlehope Dam. Currently, criteria associated with a larger dam size option would potentially inundate land north of the Bruce Highway and conflict with the effective and efficient use of the RSF area. In that circumstance, the currently proposed three-cell RSF development may only satisfy approximately 12 years of residue storage requirements for both Stages 1 and 2 of the GNP (assuming the earliest possible development of Stage 2). The maximum utilisation of the RSF site is required by GPNL to ensure sufficient capacity for residue volumes for 20+ years (at Stage 2 residue generation rates).

Key considerations with respect to interaction between the possible Castlehope Dam and the RSF are:

- In the event of a maximum 35 m full supply level (FSL) for Castlehope Dam, there would be inundation of the southern portion of the RSF site which would impact on the structural integrity of some vital RSF retention structures and any buffer zone required for environmental controls. Also possible realignment of the Bruce Highway above the 35 m FSL would further restrict the RSF area available to GPNL.
- A pre-feasibility study on the viability and approximate cost of a 'saddle dam' on the southern side of the Bruce Highway as a means to ensure appropriate separation of Castlehope Dam water from the Bruce Highway and the RSF has been initiated by DNRW. This study is likely to deliver preliminary information by March 2008.
- GPNL has an agreement to purchase State-owned freehold land for the RSF over the area identified as Lot 4 in Figure 2.4.
- While several other long term nickel residue storage options exist in the Gladstone region, the Queensland Government is not able to nominate a specific additional land parcel for residue storage by GPNL at this time.
- GPNL will need to maximize the use of the existing RSF site to satisfy storage capacity requirements of the GNP.

GPNL is seeking support in principle from the Coordinator-General that, if a viable proposal to avoid physical overlap between a future Castlehope Dam (with associated infrastructure realignments) and the nominated RSF site with its appropriate buffer zones cannot be identified, then:

- The existing three-cell design be approved as a minimum; and
- The Queensland Government will work proactively with GPNL within an appropriate timeframe to identify another suitable storage site of at least similar volumetric capacity to the conceptual fourth cell at the current RSF site.

9.2.2 Residue Characteristics (1)

EPA requested a geochemical characterisation of individual and combined process residues generated from the combined Marlborough and overseas ores. It is necessary that the material tested mimics the residues to be generated as closely as possible including appropriate proportions of the wastes listed in Table 4.7.1 as being disposed of in the RSF.

Additional geochemical testing has been undertaken on a residue sample generated from a combination of nickel ore from both Marlborough and New Caledonia. The results of this testing are given in Appendix B.

EPA requested a report on leaching tests run on the solids that will allow estimation of the type and quantity of metals and salts potentially leached out of the material. In addition, geochemical modelling of metal behaviour in the residues under anoxic conditions and under wetting and drying regimes needs to be included to assist in the assessment of impacts from residue storage.

Additional leach testing has been undertaken on a residue sample generated from a combination of nickel ore from both Marlborough and New Caledonia. The results of this testing are given in Appendix B.

EPA requested an analysis of the process liquor that includes total suspended solids, ammonia and nitrate nitrogen, phosphate, total organic carbon, and chemical oxygen demand.

Additional liquor testing has been undertaken on a residue sample generated from a combination of nickel ore from both Marlborough and New Caledonia. The results of this testing are given in Appendix B.

EPA requested that the cooling water after treatment be analysed for biochemical oxygen demand, chemical oxygen demand and total suspended solids concentration of the treated water.

The proposed cooling water system for the refinery has been changed from the open circuit seawater system described in the EIS to a closed circuit freshwater system. The only treatment to be applied to the cooling water will be the use of sodium hypochlorite to control build-up within the cooling water circuit. The dosage of this material is relatively low and it decomposes into sodium chloride which is present in large quantities in seawater. Blowdown from the cooling water system will be reused in the process as much as possible and will not be discharged to Port Curtis.

9.3 RSF Design (8, 13)

***(8)** QR has noted that the RSF is located near where QR's proposed Moura Link Line will run. GPN should provide details of the proposed location to QR showing the extent of the proposed works and the likely impacts.*

GPNL has shown detailed information in the EIS associated with the RSF proposed works to QR and has also discussed likely impacts. Furthermore changes to the RSF property boundaries have been agreed with the Queensland Government to reflect the proposed Moura rail route.

(13) *DNRW advised that further investigation is required into the permeability of the storage facility. Soils under the proposed storage area and suitability of construction and cut-off materials are required to be further investigated. NRW consider that the site should be a closed system. If releases or seepage from the RSF should occur, these should conform to the ANZECC human drinking water standards not livestock drinking water standards.*

Further detailed investigations of the soils and geology of the RSF site have been undertaken. This work has been summarised in Section 9.1.1.2 above with further details provided in Appendix K.

Seepage Quality

During the operational phase of the project there is potential to impact groundwater by seepage from RSF. Further geochemical characterisation of the residue has been undertaken, the details of which are given in Appendix B. The geochemical characteristics of the residue leachate are provided in the following table including a comparison against drinking water standards.

In summary the geochemical characterisation found that:

- The residue is non-acid forming.
- 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.
- Leachate derived from the residue is moderately saline with approximately double the salinity (TDS) of local groundwater as well as elevated sulphate concentrations.
- The concentrations of metals in leachate derived from the residue are generally low and, with the exception of manganese, are comparable to or less than metals concentrations in local groundwater. Nickel and chromium concentrations in leachate are marginally above local groundwater concentrations, but below applied guideline values for both drinking water and livestock water.
- The concentration of soluble metals in the residue liquor is generally low and within EPA hazardous dam acceptance criteria and ANZECC (2000) livestock drinking water criteria. However, the elevated concentrations of soluble cadmium, fluoride and nickel are indicated. The concentration of soluble salts in the residue liquor solution is generally high. The soluble sulphate concentration exceeds both the applied guideline criteria. Soluble chloride also exceeds the applied hazardous dam acceptance criteria.
- The residue solid is marginally sodic, is generally cohesive and unlikely to disperse.

Chemistry of Process Residue Leachate

Parameters	Laboratory detection limit for Residue[8] soluble analytes	Water Quality Guidelines				Local Groundwater Quality [4]			Soluble concentrations in Residue leachate[5]	Exceedances*
		NHMRC/ ARMCANZ Australian drinking water (ADW) guideline levels[1]	ANZECC Livestock drinking water (LDW) guideline levels[2]	ANZECC Irrigation water (LTV) guideline levels[3]	ANZECC Irrigation water (STV) guideline levels[3]	Groundwater bore RSF17[4] (alluvium)	Groundwater bore RSF14[4] (Mount Alma Fm - quartzite + siltstones)	Groundwater bore RSF24[4] (Rockhampton Grp - Qzt siltstones)		
pH (leachate)	0.01 pH unit	6.5 to 8.5 [6]	-	-	-	7.90	7.72	7.88	7.22	
Electrical Conductivity	1 uS/cm	-	-	crop dependent	crop dependent	3,150	1,980	2,380	3,710	local GW
Total Dissolved Solids (TDS)	1 mg/L	500 [6]	4000 [7]	crop dependent	crop dependent	1,920	1,520	1,430	3,170	ADW + local GW
Alkalinity as $CaCO_3$	1 mg/L	-	-	-	-	548	759	706	16	
Acidity as $CaCO_3$	1 mg/L	-	-	-	-	-	-	-	4	
Soluble Major Cations	mg/L									
Calcium (Ca)	1	-	1,000	-	-	86	102	71	556	local GW
Magnesium (Mg)	1	-	-	-	-	96	97	68	204	local GW
Sodium (Na)	1	180 [6]	-	crop dependent	crop dependent	432	236	352	153	
Potassium (K)	1	-	-	-	-	13	12	8	6	
Soluble Major Anions	mg/L									
Chloride (Cl)	1	250 [6]	-	crop dependent	crop dependent	627	272	338	240	
Sulphate (SO_4)	1	500	1,000	-	-	148	33	70	2,000	ADW + LDW + local GW
Soluble Metals & Metalloids	mg/L									
Aluminium (Al)	0.10	0.2 [6]	5	5	20	-	-	-	<0.10	
Antimony (Sb)	0.01	0.003	-	-	-	-	-	-	<0.01	
Arsenic (As)	0.01	0.007	0.5	0.1	2.0	0.001	0.002	0.002	<0.01	
Beryllium (Be)	0.01	-	-	0.1	0.5	<0.001	<0.001	<0.001	<0.01	
Boron (B)	0.1	0.3	5	0.5	crop dependent	-	-	-	<0.1	

Cadmium (Cd)	0.005	0.002	0.01	0.01	0.05	0.0003	<0.0001	<0.0001	<0.005	
Chromium (Cr)	0.01	0.05	1	0.1	1	0.001	<0.001	0.002	0.02	local GW
Cobalt (Co)	0.01	-	1	0.05	0.1	0.029	0.002	0.003	<0.01	
Copper (Cu)	0.01	2	0.5	0.2	5	0.013	<0.001	0.002	<0.01	
Fluoride (F)	0.1	1.5	2	1	42	-	-	-	0.5	
Iron (Fe)	0.05	0.3 [6]	-	0.2	10	-	-	-	<0.05	
Lead (Pb)	0.01	0.01	0.1	2	5	0.002	0.021	0.017	<0.01	
Manganese (Mn)	0.01	0.5	-	0.2	10	0.213	0.100	0.092	7.28	ADW + LTV + local GW
Mercury (Hg)	0.0001	0.001	0.002	0.002	0.002	<0.0001	<0.0001	<0.0001	<0.0001	
Molybdenum (Mo)	0.01	0.05	0.15	0.01	0.01	-	-	-	<0.01	
Nickel (Ni)	0.01	0.02	1	0.2	2	0.027	0.010	0.013	0.02	local GW
Selenium (Se)	0.01	0.01	0.02	0.02	0.05	-	-	-	<0.01	
Silica (Si)	0.1	-	-	-	-	-	-	-	20.7	
Silver (Ag)	0.01	0.1	-	-	-	-	-	-	<0.01	
Strontium (Sr)	0.1	-	-	-	-	-	-	-	0.6	
Thallium (Tl)	0.01	-	-	-	-	-	-	-	<0.01	
Tin (Sn)	0.01	-	-	-	-	-	-	-	<0.01	
Uranium (U)	0.001	-	0.2	0.01	0.1	-	-	-	<0.001	
Zinc (Zn)	0.01	3 [6]	20	2	5	0.041	0.010	0.042	<0.01	

Notes:

< indicates less than the analytical detection limit.

* Result concentrations that exceed applied guideline values and/or local groundwater concentrations.

1. NHMRC & ARMCANZ, Australian Drinking Water Guidelines. National Health and Medical Research Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (1996).

2. ANZECC and ARMCANZ, Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Livestock drinking water (cattle).

3. ANZECC and ARMCANZ. Water Quality for Irrigation and General Use. STV = short-term trigger value. LTV = long-term trigger value. STV assumes continuous irrigation for up to 20 years. LTV assumes 100 years of continuous irrigation.

4. Selected representative bores. Refer to URS report (Appendix K) for full groundwater assessment.

5. Standards Australia (1997). AS4439.3-1997 Wastes, sediments and contaminated soils. Part 3: Preparation of leachates – Bottle leaching procedure. Homebush, NSW.

6. Aesthetic guideline value. No health-based guideline value.

7. TDS limit based on tolerance for beef cattle, sheep, horses and pigs.

8. Residue sample tested was G 200 NRS

Seepage Flows

There is potential for seepage water to enter the deeper bedrock aquifers by direct seepage through the base of the RSF. Taking into account the maximum calculated travel time for groundwater in the bedrock of 9.9 m/y and a minimum distance of 5 km to the Calliope River (assuming that the bedrock aquifer flows towards the river, the aquifer is continuous, and that the Calliope River is a gaining river at this location), it would take approximately 500 years for water seeping through the bedrock aquifer to reach the river. This time could reduce if a preferential flow path was found via a fault or fracture in the bedrock.

If seepage was to occur through the alluvium for the length of Farmer Creek, the travel time to the Calliope River would be in the order of 500 years if the alluvium was consistently like that at monitoring bores RSF17 or RSF 3 (silty sand and sandy clay). However there are areas where sandy and gravely alluvium is present (such as at monitoring bore RSF13). In these areas seepage travel time would be much shorter. It is for this reason (the variability of the hydraulic conductivity of the alluvial aquifer) that a recovery trench is proposed to intercept any seepage in the alluvial aquifer.

Any seepage that entered the groundwater system would be expected to increase the salinity of the groundwater as the salinity of the leachate is approximately double that of the groundwater below the RSF site. The concentration of dissolved metals in the seepage is expected to be low and less than the concentrations in groundwater, apart from manganese and to a lesser extent nickel and chromium. However, any increase in the concentration of dissolved nickel or chromium is expected to remain below the livestock drinking water and irrigation guideline values. Any increase in the manganese concentration may exceed the long term irrigation guideline depending on the relative proportions of seepage and groundwater mixing, however the groundwater from two of the monitoring bores (RSF13 and RSF17) already contains manganese at concentrations greater than the guideline value.

Seepage Management

As discussed in the EIS, the proposed mud-farming method will reduce the potential for RSF seepage because it accelerates the residue dewatering process by creating preferential surface drainage and increasing the opportunity for evaporation. By accelerating the dewatering process, the area required for residue operations is reduced, final residue densities are higher, and the total volume required for residue storage is reduced. As mud-farming also accelerates the consolidation of the residue and generally produces a higher density of residue, the hydraulic conductivity of the residue is reduced, decreasing the rate of seepage through the residue.

As the residue particles are classified as silt, when the residue is disposed of sub-aerially in thin layers it compacts and has a very low permeability. Although cracking in dried residue can increase permeability in the surface layers, subsequent residue layers tend to seal these cracks as further residue is deposited onto already deposited layers.

The deposited residue is expected to have a low permeability, in the order of 5.0×10^{-7} m/s (unconsolidated) to 5.0×10^{-12} m/s (consolidated or long term). Using the conservative permeability of 1×10^{-8} m/s used for the seepage modelling for the RSF design, and assuming a depth of water of 1 m over a 1 m thick layer of residue, infiltration would be approximately 1 L/day/m^2. This rate would result in approximately 1000 m^3/day of seepage over a 1 km^2 storage area. These conditions would only exist in the unlikely event that the entire storage area was inundated. As the residue will be discharged in stages over only a relatively small portion of the total residue storage area and its surface will be designed to have limited ponded water, seepage rates less than those given above are likely.

The design of the RSF incorporates a cut-off trench within the foundation along the alignment of the containment embankments. The trench shall be at least 1 m wide at the base and founded 200 mm into bedrock. The depth of the trench will vary depending on the thickness of alluvium and will be filled with low permeability clay. The installation of the cut-off trench through the alluvium in the embankments would effectively cut-off groundwater flow through the alluvium under the embankments.

In addition to the cut-off trench, a seepage collection system is also proposed to intercept any seepage that does occur through or under the embankments and to return the seepage to the RSF impoundment. The seepage collection system will consist of an excavated trench around the toe of the embankment (5 m deep and 1 m wide) fitted with a pump-back riser, lined with geotextile filter fabric, and backfilled with drainage aggregate. Drainage pipe shall be placed at the bottom of the trench with a riser pipe connected to the drain pipe at the low point in the trench to convey water to a submersible pump. A submersible pump will be installed in the riser pipe to pump the seepage back to the RSF impoundment. It may not be practical to construct a seepage collection trench in areas where shallow, hard bedrock is encountered. In these areas, the collection trench may be replaced with extraction wells, as required.

At closure of the RSF, a low permeability cover will be constructed across the RSF surface. The cover will comprise a four-layer system with a total thickness of the order of 1.7 m to maximise the long-term sustainability and performance of the cover (Section 9.5.2 of the EIS). The objectives of the cover are to minimise the inflow of water into the residue and therefore reduce the amount of water available to seep into the surrounding environment; and stabilise the surface of the RSF.

9.3.1 RSF Design Criteria (1)

EPA advised that in Table 9.3.1:

1) The Design Storm Event (full containment) for the spillway design should be the 1 in 1000 year, 3 month wet season;

2) The Hazard Category of the Dam should be "High"; and

3) The RSF Operational Spillway Capacity should be the 1 in 10 000 AEP storm of critical duration for the contributing catchment above the spillway, plus the wave run up.

The impoundment design will include an operational spillway to allow controlled discharge of excess water from the impoundment, should it be needed under extreme climatic conditions. No discharge from the impoundment is anticipated under normal operating conditions. The RSF was evaluated using both ANCOLD (1999) and Department of Minerals and Energy (1995) guidelines. The RSF was assessed as a "High" hazard dam according to the DME guidelines because of the potential for "high" economic loss and environmental impact from a failure of the containment dam. Using ANCOLD the RSF was assessed as "Significant". As such, the operational spillway is sized to safely pass the flood with an Annual Exceedance Probability (AEP) of 1 in 10,000, 72-hour rainfall event, the conservative (upper bound) of the guidelines. ANCOLD (1999) recommends an additional freeboard of 0.3 m for "significant" hazard dams or the worst wet season on record plus wave run-up.

Further design details are given in the report URS, 2007a.

9.3.2 RSF Spillway Location (1)

EPA advised that Figure 9.3.2 should be withdrawn and replaced with another General Layout of the RSF showing feasible spillway locations. It is not acceptable to pass the spillway over a constructed embankment. It may be that different spillway locations are required for each raising of the main embankment.

The former RSF configuration has been superseded by staged sequencing of smaller RSF cells. As such, Figure 9.3.2 in the EIS is no longer current. The currently proposed RSF configuration consists of three cells (RSF-A, RSF-B1 and RSF-B2). Details of the proposed design are documented in report URS (2007a). Locations of the spillways for each cell are presented in Figures 9.4-9.7. Design details of the spillway for RSF-A are shown in Figures 9.8 and 9.9, which show the proposed spillway located safely away from the containment dam abutment. Potential overflows would cascade down a natural slope (grades up to 5H: 1V) consisting of shallow alluvium (roughly 1-2 m) over bedrock, to convey waters away from the containment dam. Note that future dam raisings will require new spillway locations, as shown in Figures 9.4-9.7.