5.1 Drilling and Testing Programmes

Two separate drilling and testing programmes were conducted at North Point and Princess Louise to determine the hydrogeology of the deposits. The programmes comprised the installation of aquifer test bores and completion of pumping tests to asses the nature of the hydrogeology of both deposits. Numerical groundwater modelling was then used to predict groundwater drawdown and mine dewatering rates. The detailed methodology and results of the drilling and testing programmes are presented in Appendix E.

5.2 Hydrogeology

Aquifers at North Point and Princess Louise occur primarily (from surface) within fractured greywacke, vuggy quartz veining and weathered greywacke and tuff in the bedrock. The most significant aquifer occurs within greywacke, which appears to have a moderate permeability at Princess Louise and high permeability at North Point.

Faults and shear zones that intersect the deposits are also probably transmissive and will contribute groundwater inflow to the proposed pits where they intersect the walls below the groundwater level.

Groundwater levels are relatively flat at both deposits with slight increases associated with topography. Groundwater levels at North Point are approximately 14 m below ground surface, and between 16 and 26 m below ground surface at Princess Louise, depending on the topography.

Groundwater within each of the prospects is fresh with total dissolved solids ranging between 130 and 210 mg/L, and elevated iron and arsenic concentrations, especially at the North Point deposit.

Groundwater is not considered potable at either site, as it exceeds NHMRC drinking water guidelines for arsenic of 0.007 mg/L (0.392 mg/L North Point, 0.053 mg/L Princess Louise) and aesthetic iron values of 0.3 mg/L (0.48 mg/L, North Point).

Detailed chemical analyses of the groundwater at Princess Louise and North Point are presented in Table 5.1.

Table 5-1 Detailed chemical analyses of groundwater

Analyte	Unit	NPPB1	PLPB1
pH	pH Unit	6.43	7.09
TDS	mg/L	132	206
Hydroxide Alkalinity as $CaCO_3$	mg/L	<1	<1
Carbonate Alkalinity as $CaCO_3$	mg/L	<1	<1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	67	101
Total Alkalinity as $CaCO_3$	mg/L	67	101
Sulphate as $SO4^{2-}$	mg/L	14	7
Sulphur as S	mg/L	5	2
Chloride	mg/L	2.1	10.2
Calcium	mg/L	4	3
Magnesium	mg/L	11	19
Sodium	mg/L	12	17
Potassium	mg/L	3	4
Arsenic (dissolved)	mg/L	0.392	0.053
Cadmium (dissolved)	mg/L	0.0002	<0.0001
Chromium (dissolved)	mg/L	<0.001	<0.001
Copper (dissolved)	mg/L	<0.001	<0.001
Lead (dissolved)	mg/L	<0.001	<0.001
Nickel (dissolved)	mg/L	<0.001	<0.001
Zinc (dissolved)	mg/L	0.017	0.012
Iron (dissolved)	mg/L	0.48	0.29

5.3 Groundwater Modelling

A conceptual hydrogeological model was developed for both deposits based on the interpreted geology. Interpretations of conceptual hydrogeology models for both the North Point and Princess Louise pits are described below.

5.3.1 North Point

The interpreted hydrogeology of the North Point deposit is as follows:

- The local groundwater flow direction is towards the north-west and regionally towards the north, following topography and the associated drainages to the north.
- Groundwater levels are generally 14 m below ground surface.
- Surficial cover is generally thin or non-existent near the pit and does not contain significant aquifer zones.
- The bedrock comprises a 25 m wide shear/fracture zone through the pit, associated with the mineralisation and vuggy quartz fracturing.
- The bedrock weathering profile deepens in the vicinity of the pit, associated with the shear zone.
- The detailed geology beyond the mining area is generally unknown. Therefore, the modelled geology in regional areas is based on large-scale mapping.

5.3.2 Princess Louise

The interpreted hydrogeology of the Princess Louise deposit is as follows:

- The deposit is located on a groundwater divide and local groundwater flow direction is to the south-west and regionally towards the north, following topography and associated drainages to the north.
- Groundwater levels are generally 25 m below ground surface, depending on topography.
- Surficial cover is generally thin or non-existent in the vicinity of the pit and does not contain significant aquifer zones.
- The bedrock comprises a 15 m wide shear/fracture zone though the pit, associated with the mineralisation and vuggy quartz fracturing.
- The weathering profile deepens throughout the pit area, associated with the shear zones.
- The detailed geology beyond the mining area is generally unknown. Therefore, the modelled geology in regional areas is based on large-scale mapping.

5.3.3 Groundwater flow model details

The model code selected was MODFLOW. MODFLOW is a three-dimensional block-centred finite-difference code commonly used to simulate groundwater flow in the saturated subsurface. The model was constructed based on the assumptions and conceptual hydrogeological model as described above.

The models were calibrated to demonstrate it could reproduce measured groundwater levels and flows during aquifer testing, i.e. the models could reasonably represent the conceptual hydrogeology at each deposit. Both transient model calibrations demonstrated an acceptable correlation of modelled versus measured conditions.

Table 5.2 summarises the hydraulic parameters derived from the calibrated models.

Table 5-2 Hydraulic parameters derived from the calibrated groundwater flow models

Material Type	Model Layer	Descriptions	Hydraulic Conductivity (Permeability) Kx	Ky	Kz	Specific Storage	Specific Yield
			(m/d)	(m/d)	(m/d)	(1/m)	(-)
North Point							
1	1	Weathered Bedrock	5	5	1	2E-04	0.05
2	1	Weathered Shear	20	60	20	5E-04	0.1
3	2	Fresh Shear	20	60	20	1E-05	0.015
4	2	Bedrock	0.01	0.01	0.001	5E-06	0.007
Princess Louise							
1	1	Weathered Bedrock	0.5	0.5	0.05	5E-05	0.004
2	1	Weathered Shear	10	20	10	6E-05	0.1
3	2	Fresh Shear	2.5	4	1.4	6E-06	0.01
4	2	Bedrock	0.01	0.01	0.001	1E-06	0.001

Recharge was not applied to the models as mining is to occur only during the dry season.

The developed groundwater flow model has limitations. These limitations result from generalisations, interpretations and assumptions made in attempting to simulate the interpreted hydrogeology. The model limitations include:

- MODFLOW is a fully saturated groundwater flow model code, which can lead to an overestimation of the dewatered areas;
- The area occurs within a fractured rock environment, where the only major aquifers in the bedrock are secondary structures, such as faults and shear zones in the weathered zones. The models only represent the major secondary structures (faults and shear zones) in the area; and
- The limited data surrounding the deposits and the complexities of the hydrogeological regime mean that these models should only be used as a guide to determine impact areas and the likely groundwater abstraction rates required for dewatering. The interpretation of predictive simulations needs to take account of the assumptions made.

5.4 Predicted Pit Dewatering Requirements

To ensure dry working conditions and assist with slope stability for both pits, it will be necessary to install a dewatering system of in-pit sumps or interception bores around the pit, to remove groundwater that would otherwise flow into the pits.

The groundwater models were used to estimate dewatering rates for both deposits to ensure that groundwater levels were below the depth of mining after four months of mining, and also allowing for a one month lead time prior to mining.

North Point

Three production bores were used to simulate the required drawdown based on the mining schedule at North Point. Each bore was pumped at a rate of 692 kL/day (8 L/sec) for 120 days (four months).

The estimated required dewatering rates at North Point are 2,074 kL/day (24 L/sec), sustained throughout the anticipated mining duration of three months with a one month lead time prior to mining.

The long-term dewatering rates will decrease as the aquifer interval is progressively dewatered.

Princess Louise

One production bore was used to simulate the required drawdown based on the mining schedule at Princess Louise. The bore was initially pumped at the estimated required dewatering rate of 425 kL/day (4.9 L/sec), sustained throughout the anticipated mining duration of three months with a one month lead time prior to mining.

The long-term dewatering rates will decrease as the aquifer interval is progressively dewatered.

5.5 Simulated Drawdown from Open Pit Development

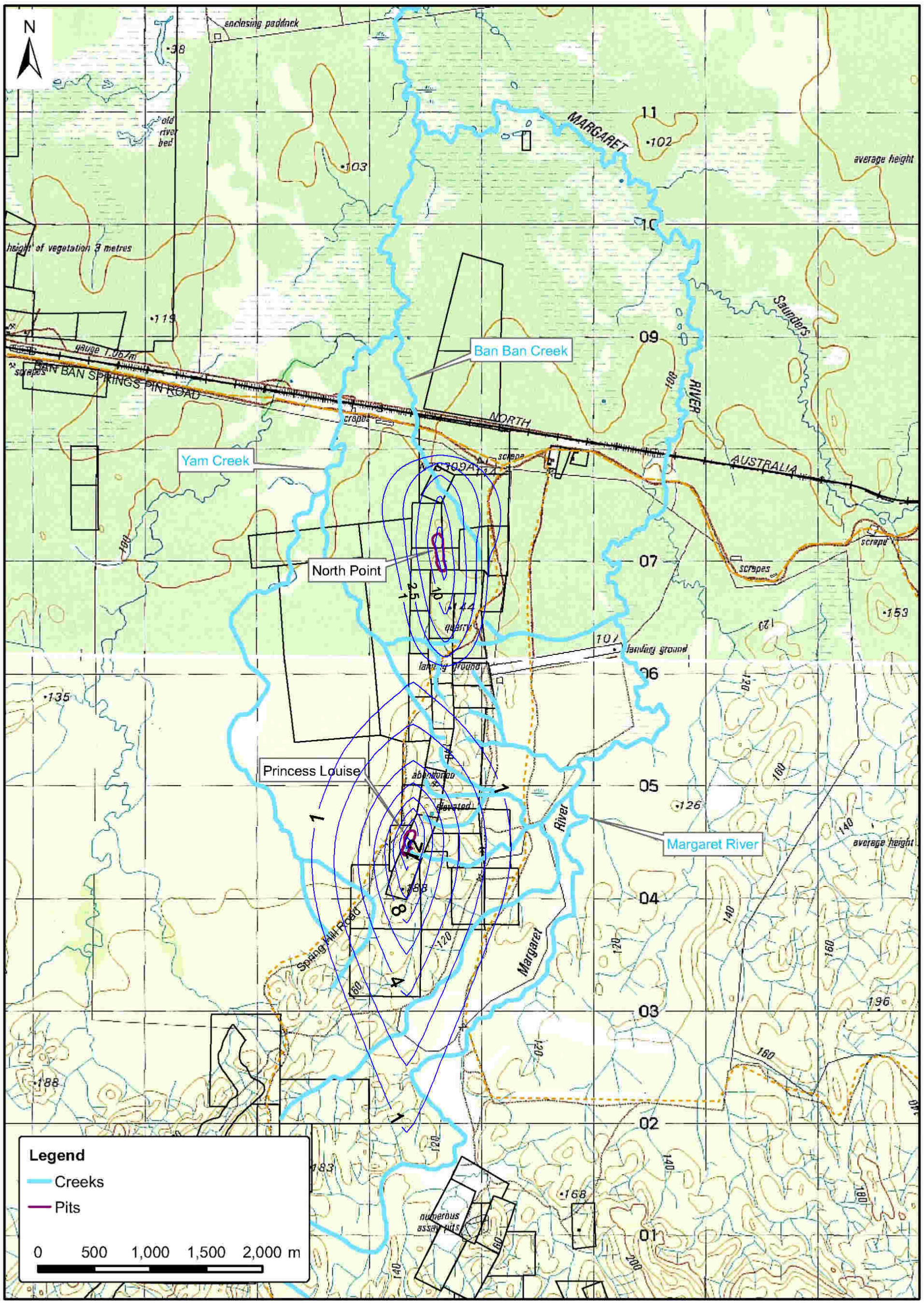
Figure 5.1 shows the simulated extent of drawdown for North Point and Princess Louise after 300 days (10 months) of groundwater abstraction at the anticipated dewatering rates.

North Point

The extent of drawdown after 4 months of abstraction at 2,074 kL/day from three production bores indicated 1 m reductions in groundwater level between 680 and 810 m to the north and south of the planned pit, and between 360 and 425 m to the east and west. Most of the abstraction will occur from within the shear zone, weathered bedrock and permeable zones within the bedrock. By the end of mining, the groundwater level within the pit will be 15 m below the original static groundwater level or approximately 30 m below ground level.

Princess Louise

The extent of drawdown after 4 months of pumpage at 425 kL/day from one production bore indicated 1 m reductions in groundwater level between 1.1 km and 2.1 km to the north and south of the planned pit, and between 700 m and 720 m to the east and west. Most of the abstraction will occur from within the shear zone, weathered bedrock and permeable zones within the bedrock.



Source:

Client:	Project:	Title:
Burnside Operations Pty Ltd	Hydrogeological Assessments of the North Point and Princess Louise Deposits for Mine Development	**Predicted Extent of Drawdown**
URS	Drawn: CMAC · Approved: RIJV · Date: 16/2/2007 · Job No: 42213762 · File No: Figure 5.1.srf	Figure: **5.1** · Rev A · A4

5.6 Potential Impacts from Mine Dewatering

Based on the simulated drawdown in the groundwater modelling, bedrock/shear zone groundwater levels will be lowered in the immediate area of the open pits because of the groundwater abstraction required for mine dewatering.

Groundwater lowering associated with dewatering of the proposed pits can cause drawdown in groundwater supply bores/stock wells if these are in close proximity to the proposed pits. Based on current knowledge, no existing users are located within the predicted cone of depression for both North Point and Princess Louise.

Groundwater lowering associated with dewatering of the proposed pits can also impact:

- Groundwater dependent ecosystems (GDEs) such as wetlands and swamps, features that are largely supported by groundwater and the position of the water table. We are unaware of any such features near the mining developments.
- Stream flows in surface drainages, although most of the pit dewatering will occur during the dry season, when such drainages are dry.

Our preliminary assessment indicates that dewatering of the two open-pits will have little impact on the groundwater resources of the region or features that are supported by groundwater. Both of these mining developments require only minor dewatering for a relatively short period of time, which will minimise potential impacts on groundwater.

On cessation of pit dewatering at each deposit, groundwater levels will begin to recover to pre-mining levels. The water in the pit voids are likely to have similar quality to the groundwater sampled during pumping tests. Princess Louise groundwater is fresh; similarly for North Point. The quality of the water in the pit voids is likely to be acceptable for consumption by stock or short term irrigation (< 20 yrs), as defined by the ANZECC Guidelines for livestock drinking water, and irrigation.

5.7 Monitoring and Management

BOPL will incorporate the existing groundwater monitoring bores into a groundwater monitoring system to ensure that any groundwater-related impacts are recognised and can therefore be mitigated. BOPL will also incorporate any stock wells within the area of mine influence into the groundwater monitoring network.

Monitoring of groundwater levels and production, electrical conductivity and pH will be measured from all production sources at monthly intervals, during mining operations. A more detailed chemical analysis including major cat/anions and metals (as outlined in Table 5.1) will be completed on a six monthly basis during mining operations.

5.8 Commitments

BOPL commits to the monitoring of groundwater quality prior to commencement, during and following the completion of mining activities.

On commencement of mining and during operations, BOPL commits to monitoring groundwater level fluctuations to assess any impacts on the groundwater, especially in areas where lowered water table could occur.

On commencement of mining, and during operations, BOPL commits to monitoring of groundwater abstraction from the dewatering system.