Cameco Australia Pty Ltd

Hydrogeological Investigations

Kintyre Joint Venture Project

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Cameco Australia Pty Ltd

Hydrogeological Investigations

Kintyre Joint Venture Project

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REVISION	AUTHOR	REVIEW	ISSUED	DESCRIPTION
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Rev 1	RT, LB, NT	DS	23 May 2012	Incorporated pit dewatering data and re-issued to Cameco and Tetra Tech for comment
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EXECUTIVE SUMMARY

The Kintyre Joint Venture (KJV), comprising Cameco Australia Pty Ltd (70%) and Mitsubishi Development Pty Ltd (30%), is developing a 4.4 kTpa uranium project on the western edge of the Great Sandy Desert in the East Pilbara region of Western Australia. Water supply will be sourced from groundwater and is required for ore processing, plant construction and camp water supply. Annualised demand for years 3 to 11 of the 13.5 year project life is estimated at 3,100 kL/day.

Hydrogeological analysis in this report draws on an extensive water exploration program undertaken by the KVJ between 2009 and 2012, as well as information from other investigations undertaken over several decades. The KJV investigations incorporated exploration drilling, construction and hydraulic testing of eleven test production bores, and detailed numerical modeling.

The hydrogeology of the Project area is dominated by a Permian glacial valley that has been filled by predominantly glaciofluvial and glaciolacustrine deposits of the Paterson Formation. The main aquifer units are located in Permian sand, gravel and conglomerate deposits of the Paterson Formation and the underlying Coolbro Sandstone, a Proterozoic fluvial-deltaic succession comprised mostly of fine to coarse grained quartz sandstone.

The Paterson Formation occupies a broad flat glacial palaeovalley about 5 km wide through the central and lower reaches, rapidly narrowing to under 2 km in its upper reaches. The formation is divided into two broad units referred to as the upper Paterson and lower Paterson, each representing episodes of glacial advance and retreat. The upper unit generally forms an extensive clayey sand aquifer with a lower aquitard associated with the fine-grained glacio-lacustrine facies. However, sand and gravel lenses, present within the unit, are capable of forming appreciable local aquifers. The lower unit comprises beds of glacial tillite, glaciofluvial and glaciolacustrine deposits, which are generally unsorted and held within a suspended matrix of mud or sand and sparse gravel. The unit is typically thickest in the deepest parts of the palaeovalley, reaching a maximum of thickness of 105 m, and increases northward forming a laterally continuous aquifer or series of aquifers along the length of the palaeovalley. Both units are considered productive aquifers.

Numerical groundwater modelling of the aquifer system demonstrates that:

- The maximum design Project demand of 3,100 kL/day can be drawn from a proposed borefield comprising 10 production bores (7 active water supply bores, plus 3 standby bores);
- With the proposed borefield, there will be more than sufficient borefield capacity and contingency to sustain an overall abstraction 3,100 kL/day over the mine life without causing unacceptable drawdown or loss of bore productivity;

An appraisal of the potential environmental and social issues arising from the borefield development and operation indicates that:

- There are no other groundwater users within 80 kilometres of the KJV. Since borefield depressurisation will not extend beyond 10 km from the borefield, the KJV will not adversely impact other water users;

There should be no impact on waterholes and vegetation associated with Rudall River and Lake Dora as they are far outside of the zone of drawdown related to the Project;

- The hydrology of the Yandagooge Creek and its catchment is dominated by seasonal rainfall and is unlikely to be affected by groundwater drawdowns;
- There is unlikely to be groundwater dependent vegetation in the area of drawdown impact. Two tree species that possibly could have some groundwater dependence are considered robust to groundwater level changes and would likely be able to adapt to water level changes of 0.5-1.0 m/year;
- Several ephemeral river pools along the Coolbro and Yandagooge creeks are likely to be perched on clayey alluvial strata, fed by surface flows and therefore not affected by groundwater abstraction for the Project. Further monitoring will take place to confirm these findings in the next stage of the project, and develop triggers and contingencies if required; and
- Of the stygofauna species which have been identified in the Project area all or most are likely to occur elsewhere and are not likely to be threatened by development. Even if a species were localised, only a small fraction of the potential habitat within the aquifers impacted by the Project will be affected by drawdown.

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1. BACKGROUND

The Kintyre Joint Venture (KJV), comprising Cameco Australia Pty Ltd (70%) and Mitsubishi Development Pty Ltd (30%), is developing a 4.4 kTpa uranium project on the western edge of the Great Sandy Desert in the East Pilbara region of Western Australia, referred to as the 'Project' (Figure 1-1). The Project lies 90 km south of Telfer and 270 km northeast of Newman and encompasses five mineralisation bodies; the Kintyre, Kintyre East, Whale, Whale East and Pioneer deposits. The Project is expected to have a minimum life of 13.5 years and involves the development of open cut pits; waste landforms, evaporation ponds, an acid leach processing facility and tailings storage facility (TSF) within the operational area.

Water requirements for the Project include water for ore processing purposes as well as plant construction and camp water supply. Table 1-1 summarises the project water demands over the 13.5 year mine life. The project will have a peak total demand of up to 3,100 kL/day in years 3 to 11, the production years.

Table 1-1: Project water demand

Year (Inclusive)	Construction water kL/day	Potable Camp Water kL/day	Process water kL/day	Dust suppression kL/day	Total Project demand kL/day
1	500	300	0	0	800
2	500	300	200	800	1,800
3-11	0	200	1,500	1,400	3,100
11-13	0	200	0	800	1,000

Water demand for the Project will be met by the following sources, in order of precedence:

- mine dewatering from bores and sumps;
- opportunistic capture of stormwater runoff; and
- make-up water from the process water supply borefield.

The proposed make-up water borefield is in a Permian glacial aquifer located 2 to 10 km north of the project area, covered under pending miscellaneous license for groundwater exploration, L45/314.

The KJV partners engaged Pennington Scott (hydrogeological consultants), Tetra Tech (Geotechnical and hydrogeological consultants) and MWH to undertake the necessary hydrogeological investigations of the pit dewatering and water supply borefields to support an Environmental Risk Management Plan (ERMP). The KJV partners, together with all their contractors and consultants are hereinafter referred to collectively as 'Cameco'.

This report is the Hydrogeological Appendix to the Environmental Review and Management Programme (ERMP) for the Kintyre Uranium Project. The report represents the feasibility and impacts assessments for the Project dewatering and makeup water supply in support of a 1,400,000 kL/year 5C water licence application to the WA Department of Water from the sedimentary aquifer in the East Pilbara Groundwater Management Area.

Table 1-2 summarises the scope of the hydrogeological investigations. The report draws on the knowledge gathered from previous investigations undertaken over several decades plus studies commissioned by Cameco specifically for the ERMP. Studies carried out as part of the ERMP are included in separate appendices to the ERMP, however, sub-studies carried out specifically for this hydrogeological Appendix are included as attachments at the back of this report.

Table 1-2 Scope of the hydrogeological investigation

Water scope task	Where it's reported in the ERMP	Study Reference
Review project water requirements	A separate Appendix of the ERMP	Tetra Tech (2012d)
Collate and review all previous literature	Section 1.1 of this report	
Undertake infill field investigations		
Exploration drilling in makeup water source area	Summarised in Attachment A	MWH (2010,2011a)
Test 2 dewatering bores around Kintyre pit	Attachment A of this report	Pennington Scott (2012a)
Test 3 production bores in makeup water borefield	Attachment A of this report	
Install groundwater monitoring bore network	Attachment A of this report	
Groundwater level and water quality monitoring program	Attachment A of this report	
Undertake baseline groundwater chemistry analysis	Attachment A of this report	
Develop a conceptual hydrogeological model		
Environmental setting	Section 2 of this report	
Geological setting	Section 3 of this report	
Hydrogeological setting	Section 4 of this report	
Recommend water development strategy	Section 5 of this report	
Undertake Numerical Groundwater Simulation		
Simulate makeup water borefield	Attachment B of this report	Tetra Tech (2012b)
Simulate dewatering	Attachment B of this report	Tetra Tech (2012b)
Simulate final void post closure	Attachment B of this report	Tetra Tech (2012b)
Simulate pit lake geochemistry	Attachment B of this report	Tetra Tech (2012c)
Evaluate environmental impacts and contingency measures	Section 6 of this report	
Stygofauna	A separate Appendix of the ERMP	Bennelongia
Groundwater dependant ecosystems	A separate Appendix of the ERMP	Environ (2011)

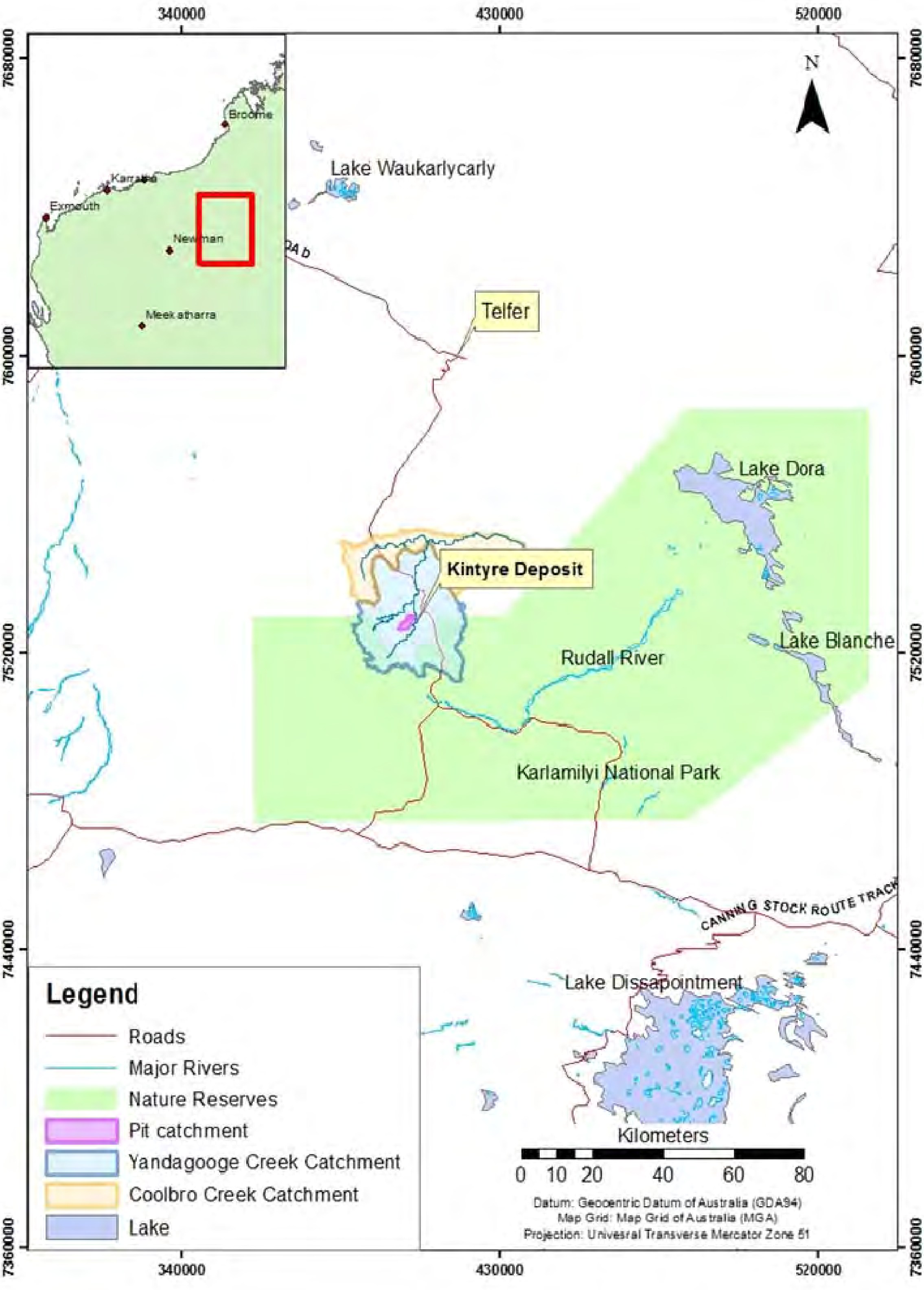

Figure 1-1: Kintyre area location

1.1 Previous Work

The Project area was largely unexplored until the early 1970's when the discovery of gold at Telfer outlined the region's resource potential. In 1982 CRA Exploration Pty Ltd (now Rio Tinto Ltd) flew airborne radiometric and magnetic surveys over a portion of the Paterson Orogen primarily in search of kimberlites (Jackson & Andrew, 1990). It was this work that lead to the discovery in April 1985 of a small area of secondary uranium mineralisation known as the Kintyre deposit (Ferguson et al., 2005). Collectively, this deposit includes the Kintyre, Kintyre East, Whale, Whale East and Pioneer deposits.

In 1987 Dames and Moore undertook a groundwater exploration drilling and testing program to establish an extensive water monitoring network within a 10 km radius of the Kintyre deposit. Fifty monitoring bores were installed and monitored, providing baseline data for their 1988, 1993 and 1996 feasibility reports (Dames & Moore, 1988, 1993, 1996). In 1988 Groundwater Resource Consultants (GRC) developed a Preliminary Open Pit Dewatering Study of the Kintyre deposit, which was later reviewed and built upon by Golder Associates (Golder, 1989), Hydro-Resources (1997) and Minenco Water Management (1997).

Project development slowed during the 90's due to social and political issues as well as low uranium prices at the time (McKay & Miezitis, 2001). In 1994, an area enclosing the deposit which lay within the Karlamilyi National Park (formerly Rudall River National Park) was excised allowing further investigations to progress. The Kintyre Advancement Programme was initiated in September 1995 to advance the project to a full feasibility study, and in August 2008 the KJV acquired the Project including the existing exploration licences.

In 2007 an opportunity to investigate buried palaeovalley's was provided by Geoscience Australia's Onshore Energy Security Program. The investigation used Airborne Electromagnetic (AEM) surveys over the Paterson–Canning Region, flown using the Fugro TEMPEST system between September 2007 and August 2008, and covered areas of the Palaeoproterozoic Rudall Complex and Neoproterozoic Yeneena Basin, as well as the eastern Pilbara Block and parts of the Officer and Canning Basins (Geoscience Australia, 2007). A total area of 45,330 km^2 was flown with line spacing of 200 m, 1 km, 2 km and 6 km. Greater discretisation was applied to the Paterson North survey area, particularly around Kintyre, which contributed to furthering groundwater exploration in the area.

1.2 Water Licensing

Cameco is seeking a 5C licence for 1,400,000 kL/year from the East Pilbara Groundwater Area. This document represents the 'H3' hydrogeological report in support of this licence under DoW *Statewide Operational Policy 5.12 - Hydrogeological Reporting Associated with a Groundwater Well Licence* (2009). An operating strategy has also been prepared in accordance with *Operational Policy 5.08 - Use of operating strategies in the water licensing process (2011)*, which will be submitted with the new 5C license application.

Cameco has one existing 5C licence and two 26D Permits to Construct and Alter Wells, which are summarised in Table 1-3. Details of the requested water licence are provided in Table 1-4.

Table 1-3: Summary of existing water permits and licences

Licence type	Licence no.	Issue date	Annual water entitlement (kL)
26D Permit to Construct or Alter Well	CAW168652(1)	17/06/2009	-
26D Permit to Construct or Alter Well	CAW171498(1)	10/06/2010	-
5C Licence to Take Water	GWL168697(3)	10/06/2011	200,000

Table 1-4: Details of 5C water licence application

Applicant	Cameco Australia Pty Ltd
Groundwater Area	East Pilbara
Groundwater Subarea	
Water Source Description	Paterson Formation, Sedimentary Aquifer
Requested Allocation	1,400,000 kL/yr
Location of Water Source	Exploration Licenses E45/1772 and E45/3745
Purpose of Use	Mineral Processing
Location of Water Use	Mining Leases M45/264; M45/266; M45/267; M45/420;

2. ENVIRONMENTAL SETTING

2.1 Climate

The Project area has an arid climate with hot wet summers and warm dry winters. Mean maximum temperatures at Telfer, approximately 90 km north of the Project area, average about 40°C in summer while winter minima are around 26°C. Evaporation exceeds precipitation for most of the year, peaking during the months of October to January. The annual pan evaporation at Telfer averaged over the period from 1974 to 1995 is 4,137 mm.

Rainfall is highly variable in timing, duration and intensity, and is related both to locally generated thunderstorms and to dissipating tropical cyclones tracking southeast. Historical rainfall ranges from 114 to 817 mm/year and a long term average of 367 mm/year (measured at Telfer Aero) (Figure 2-1). Rates are highest in the cyclone season between January and May, reflecting the tropical wet season in the north of the state and thunderstorm activity, and again between October and December, when cool airflows from the south wedges beneath humid north-westerly winds. These two mechanisms of rainfall generation help to distribute rainfall over half the year; however, this is very infrequent and only accounts for about 30 rain days per year. Typically, most of the annual rainfall is received in one or two significant events, and many years have close to zero rainfall.

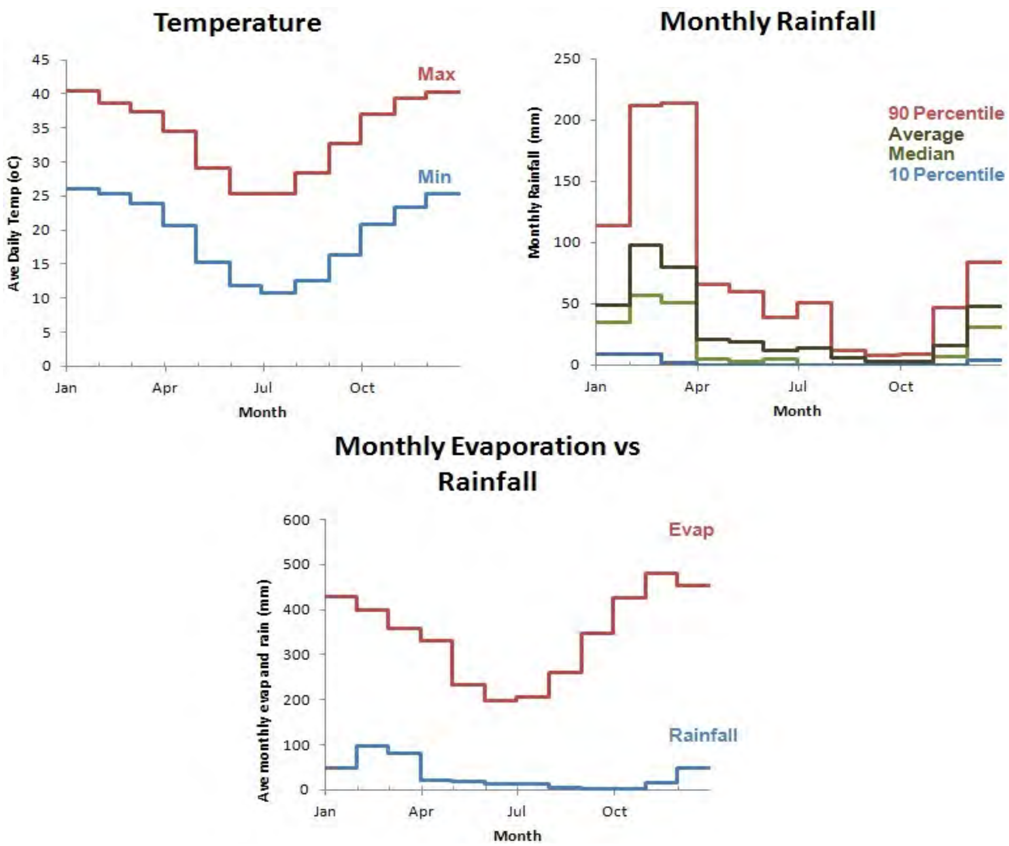

Figure 2-1: Monthly rainfall distribution and maximum temperature at Telfer over the years 1974 to 2012, 90 km to the north of the Project area

2.2 Geomorphology

The Project area occupies a northward oriented valley system surrounded by a dissected upland plateau (Figure 2-2), referred to as the Throssell Range to the west, Broadhurst Range in the east, and Watrara Range south of the valley. The south-western edge of the Great Sandy Desert is situated to the immediate north. Physiographic features are closely correlated with geological units.

The plateau is an eastern continuation of the 'Hamersley Surface' (Campana et al., 1964; Hickman and Clark, 1994), representing a Cenozoic (Tertiary) plateau surface sloping gently to the northeast. It is principally preserved where underlain by sandstone and quartzite (mostly Proterozoic Coolbro Sandstone in Project area) which are more resistive to erosion. A Cenozoic laterite of siliceous and ferruginous duricrust has developed upon the plateau and most of the plateau is extensively dissected by creeks, which occupy deep rocky gorges. Still, the plateau attains an elevation of over 500 mAHD west of the valley (Throssell Range), while it is up to 480 mAHD to the south and east (Broadhurst Range and Watrara Range).

The valley represents a Permian glacial valley that has been mostly filled by predominantly glaciofluvial and glaciolacustrine deposits. Its surface now forms a broad flat valley about 5 km wide through the central and lower reaches, rapidly narrowing to under 2 km in its upper reaches. It falls from a little over 400 mAHD to 336 mAHD at the northern limit of the valley over a distance of almost 40 km. Surface runoff following heavy rainfall events is drained by Yandogooge Creek and its tributaries which follow the central sections of the valley. There is a cover of eolian and alluvial deposits over the valley, with coarse grained fluvial sand deposits within the creek channels. The valley flanks against the plateau are often very steep, along which scree and colluvial deposits form low angle fans. Benches and mesas fringing the plateau and at the stream headwaters are remnants of Permian tillite and fluvioglacial deposits.

Yandagooge Creek contains two branches, referred to as the western and southern branches, which converge north of the Kintyre site. The stream channel is incised by a couple of metres in its upper reaches, where it is about 40 m wide and filled with coarse sand and gravel. About 9 km north of Kintyre the stream discharges into a broad flood-plain where the channel becomes indistinct, reforming again about 15 km north of Kintyre. It then progresses north and joins Coolbro Creek north of the Project area where the system flows further northeast and dissipates into the Great Sandy Desert.

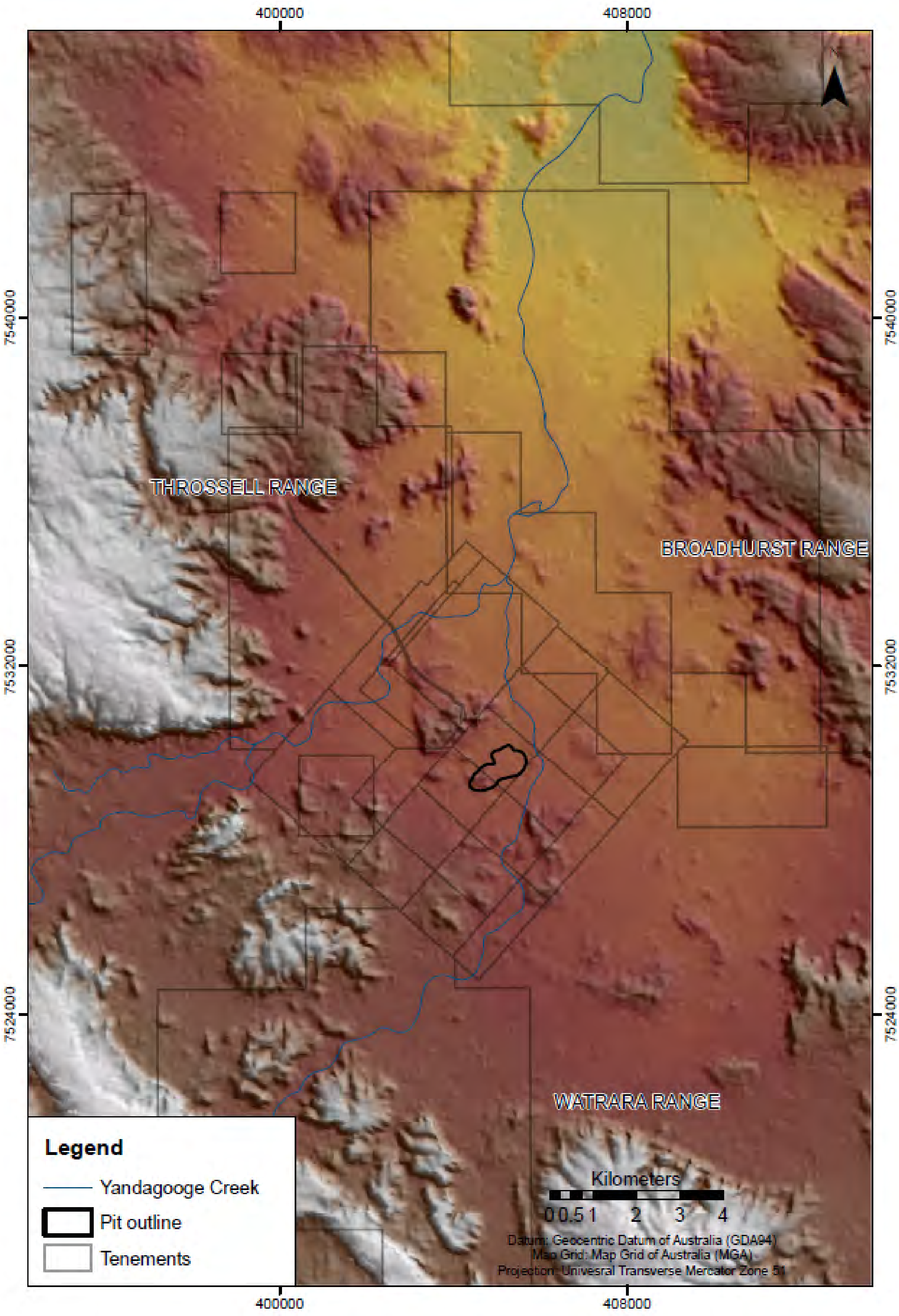

Figure 2-2: Project geomorphology

2.3 Hydrology

The Project lies within the Yandagooge Creek catchment (Figure 2-3), a major sub-catchment of Coolbro Creek, which it joins north of the Project area at the margin of the Great Sandy Desert. It is part of the internally draining Sandy Desert Basin. Yandagooge Creek has a catchment area of approximately 780 km^2, while the total catchment area for Coolbro Creek (including Yandagooge Creek) is around 1,240 km^2. Coolbro Creek dissipates into the desert surface approximately 17 km east of the Yandagooge Creek confluence, but during major flood events surface water accumulates within interdunal areas at the creek terminus and flows northward toward Lake Waukarlycarly (MWH, 2011b).

The Coolbro Creek catchment is recognised as an undisturbed river that has not been significantly altered since European settlement. It was identified for inclusion in the Wild Rivers project undertaken by the Australian Heritage Commission in 1998 as an area where it is desirable to preserve wild river values.

Yandagooge Creek has its headwaters in the Throssell and Watrara Ranges to the west and south, where deeply incised drainages discharge to the broad flat valley. Upon the valley the western and southern branches converge into the main Yandagooge Creek channel about 4 km north of the Kintyre site. The southern branch covers an area of approximately 300 km^2, which is almost twice the southern branch catchment area of around 170 km^2. Stream flow is ephemeral, flowing for up to several days following substantial rainfall that is mostly associated with summer cyclonic activity, but remains dry through most of the year (MWH, 2011b). Runoff is generated mainly over the sandstone plateau and quartzite outcrop areas (MWH, 2011b). The watertable is situated well below the creek bed, and therefore groundwater fed baseflow does not generally contribute to streamflow.

Several ephemeral water pools are present in the Coolbro/Yandagooge Creek catchment (Figure 2-3). Pinpi (or Pinbi) Rockhole is closest to the proposed Kintyre pit, being situated 2 km to the south. Pinpi Rockhole is a semi-permanent pool reaching about 2.5 m deep along the southern branch of Yandagooge Creek, and lies upon schistose bedrock that is exposed along the northern bank of the pool (Bennelongia, 2012). The pool is probably perched, with the watertable projected to be about 12 m deep. Figure 2-4 shows Pinpi Rockhole dry in October 1998 and inundated in March 2012. Another semi-permanent rockhole is Rock Pool, situated on the plateau flanks 840 m northwest of North Bore. It forms a 20 m wide pool that is up to 2.5 m deep within sandstone (Bennelongia, 2012), but also appears to be perched, lying approximately 20 m above the watertable level recorded in North Bore. Yarku Waterhole and Minti Waterhole, located about 4 km and 5.5 km north of Kintyre respectively, appear to be short-duration pools that are perched upon underlying clayey alluvial strata. The watertable is projected to be about 20 m deep at both of these sites.

The Karlamilyi National Park, south of the Project, includes the watershed of the Rudall River, Lake Blanche, Lake Dora and a number of surface water creeks, pools and water courses. Lake Dora is the only salt lake to regularly contain surface water, though it is not a groundwater dependent lake, with seasonal inundation solely due to rainfall events. The Rudall River has its head waters in a low, dissected plateau approximately 20 km southeast of Kintyre and flows northeast toward Lake Dora. It represents a significant wetland and ecological refuge that contains major permanent waterholes and soaks (Environ, 2010). Surface flow from the Coolbro/Yandagooge Creek is not part of the Rudall River catchment.

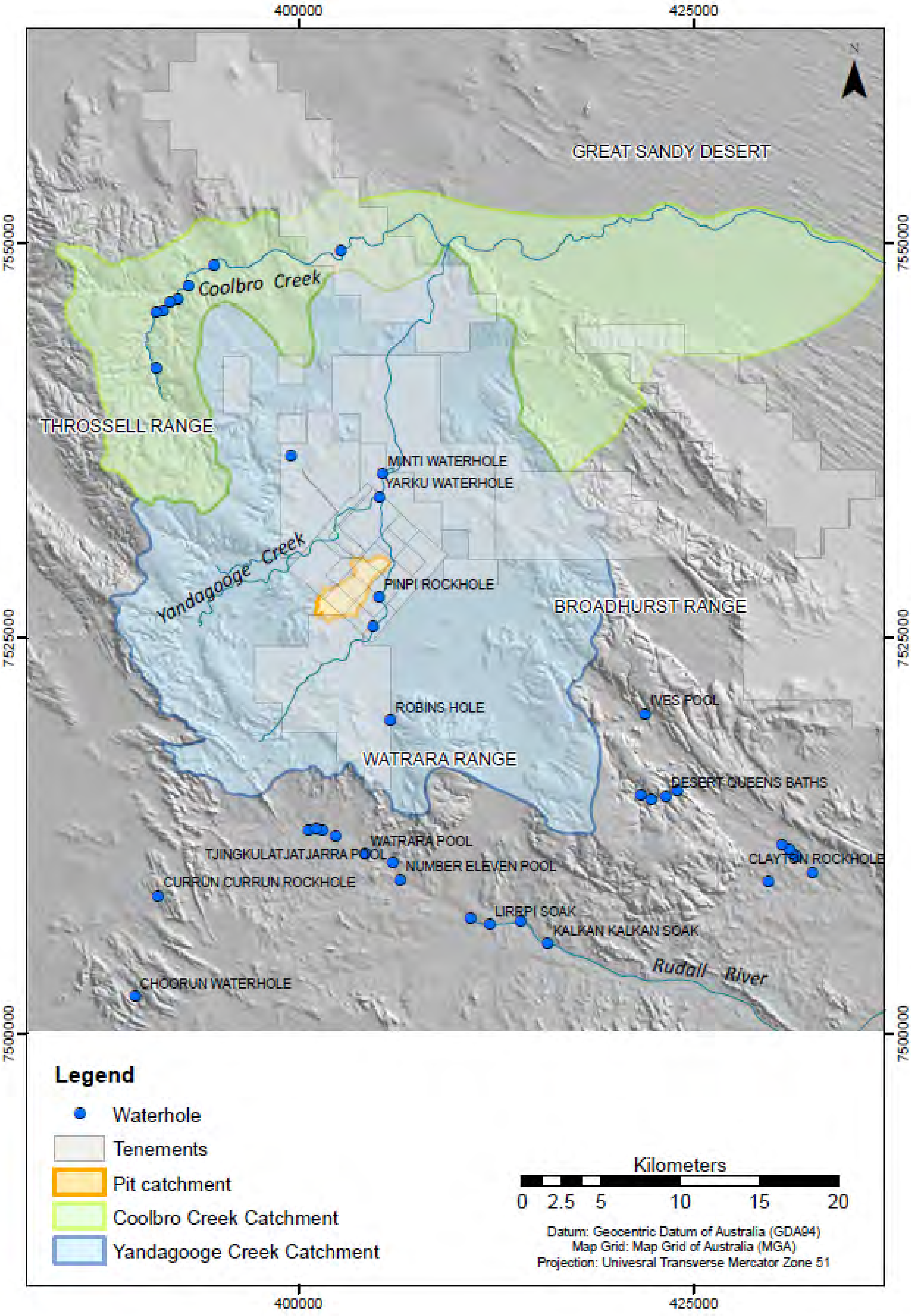

Figure 2-3: Surface hydrology

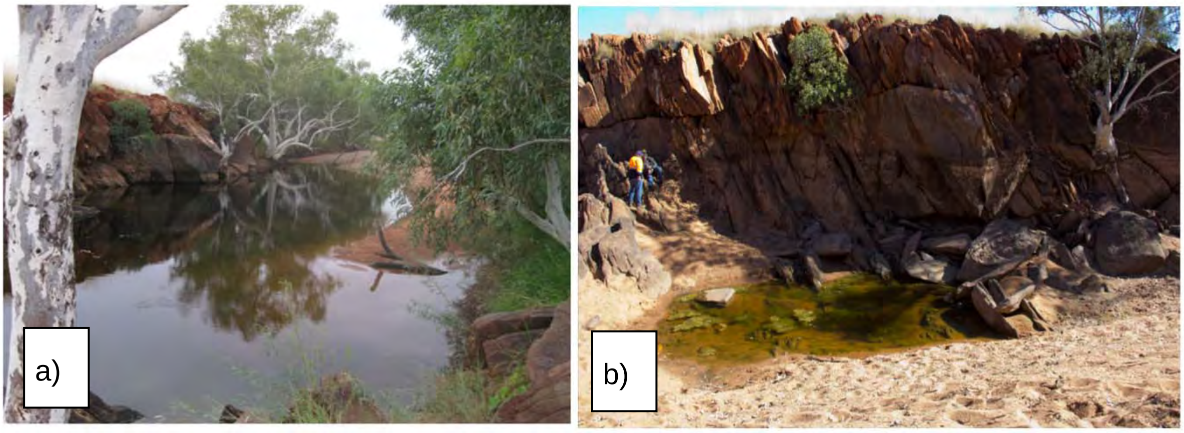

Figure 2-4: The site at Pinpi Rockpool in a) March 2012 and b) July 2012 during both inundated and dry conditions respectively.

2.4 Potentially Groundwater Dependent Ecosystems

2.4.1 Vegetation

The Project is located in the Little Sandy Desert, as classified by the Interim Biogeographical Regionalisation for Australia (IBRA) (Thackway and Cresswell, 1995). The LSD1 sub region comprises sparse shrub-steppe over *Triodia basedowii* (hard spinifex) on stony hills, with River Gum communities and bunch grasslands on alluvial deposits in and associated with ranges (Kendrick, 2001).

A total of 34 vegetation units were recorded within and around the pit area during 2007 and 2010 surveys for the Project, with distribution related to landforms ranging from hillsides and sand dunes to creek lines and clay pans (Bennett Environmental Consulting 2010). The surveys concluded that potentially groundwater dependent vegetation were limited to the creek line areas and included *Eucalyptus camaldulensis* (known in the surveys as Community 'D') and *Corymbia opaca* (known as Community 'C'). The distribution of these communities in the survey area around the pit is shown in Figure 2-5. As these initial surveys did not extend into the borefield area to the north, similar landforms in the borefield area have been mapped based on aerial photography where it is possible that the communities could also occur.

E. camaldulensis is commonly associated with both shallow groundwater (Strategen 2006, Loomes 2010) and deeper groundwater (up to 21 mbgl, Landman 2001). The lateral and tap roots of the tree enable it to use both groundwater and water held in the unsaturated vadose zone (above the watertable) depending on soil water availability (DoW, 2010). *E. camaldulensis* is capable of sinking new tap roots in response to groundwater drawdown. However, drawdown of greater than 10 m over a prolonged period may cause irreversible stress (Woodward-Clyde 1997). O'Grady et al. (2010) indicates that *Corymbia opaca* could be groundwater dependent in central Australia (Northern Territory), but there is no literature to indicate this is the case in Western Australia.

Analysis of surface drainage systems suggests that the area of possible occurrence of these communities in the borefield area supports a discharge basin, where the creek line dissipates and surface flows span out in a braided channel system. Fringing vegetation around the margins of the creek are likely to rely on fresh run-off surface flow and throughflows for most of their water requirements, and potentiometric water levels in the area indicate that this system is not groundwater fed. Further monitoring will be undertaken in the next stage of the Project to characterise the groundwater dependence of this vegetation.

2.4.2 Subterranean Fauna

Subterranean fauna include terrestrial species, known as troglofauna, and aquatic species, known as stygofauna. Troglofauna occur in the interstices and cavities in sand and soil above the watertable, while stygofauna occur within the groundwater in the pores and voids in the aquifer.

A subterranean fauna survey for the Project area involved taking around 200 samples for troglofauna and 150 samples for stygofauna (Bennelongia 2012). Samples were taken both within and outside of the area potentially impacted by the pit and drawdown in the aquifer from dewatering and the production borefield.

The survey identified 23 troglofauna species and 15 stygofauna species. Most are known to be widespread. Several were localised to the mine area including a species of cockroach, a pauropod and several crustaceans (copepods and syncarid).

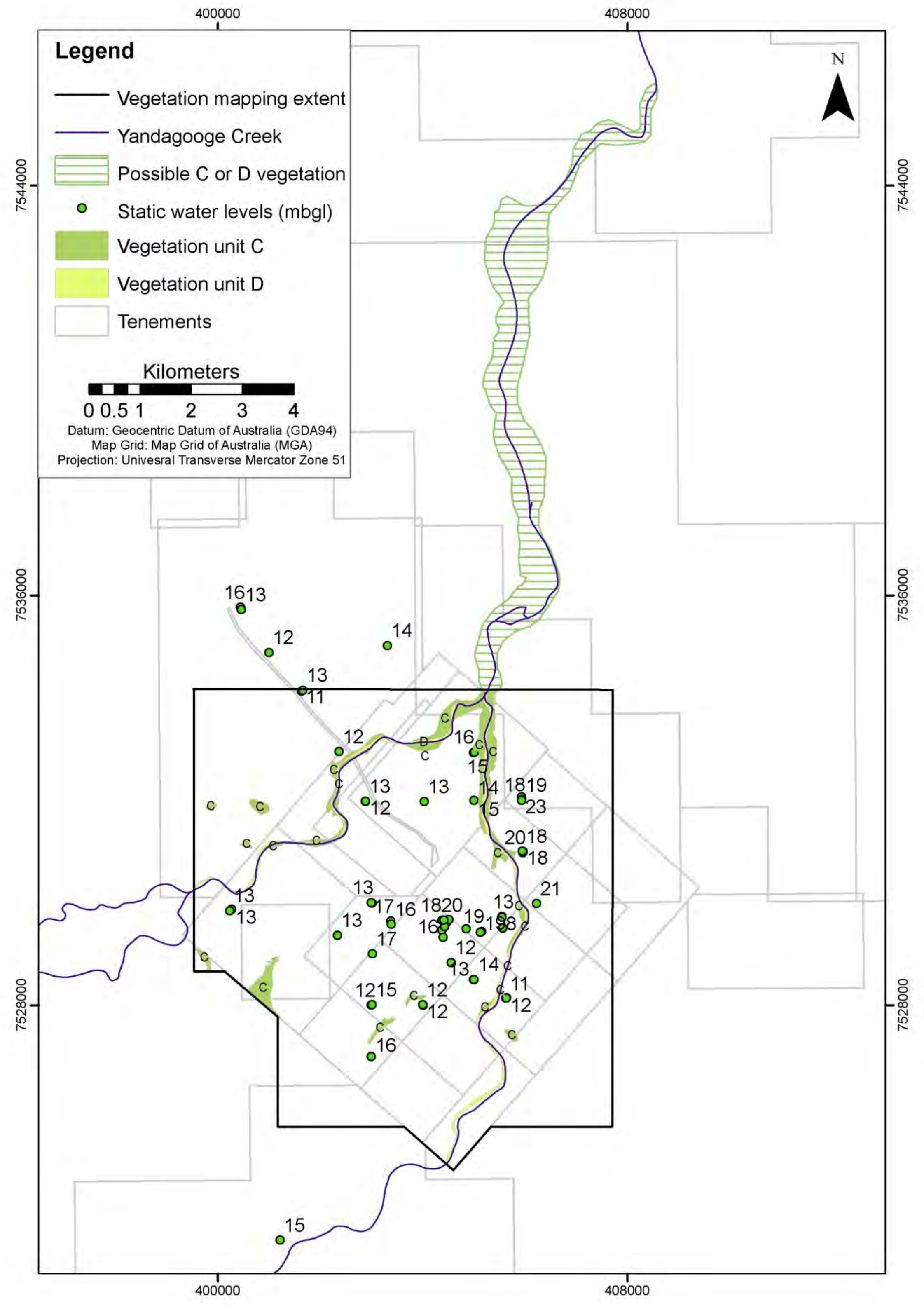

Figure 2-5: Potentially groundwater dependent vegetation

3. GEOLOGICAL SETTING

The Project area lies within the Neoproterozoic Yeneena Basin and is bordered to the northeast by the Canning Basin (Figure 3-1) and to the southwest by rocks of the Officer Basin. The region is dominated by multiple deformed rocks of the Paterson Orogen, and is divided into three main components; the Rudall Complex, the Yeneena Basin, and the Tarcunyah, Sunbeam, and Disappointment Groups of the Officer Basin (Bagas et al., 2000). Overlying these three tectonic units are fluvioglacial rocks of the Permian Paterson Formation and Cenozoic authigenic weathering products and valley fill. A simplified summary of the stratigraphy is provided in Table 3-1 below, and surface geology in the Project area shown by Figure 3-1.

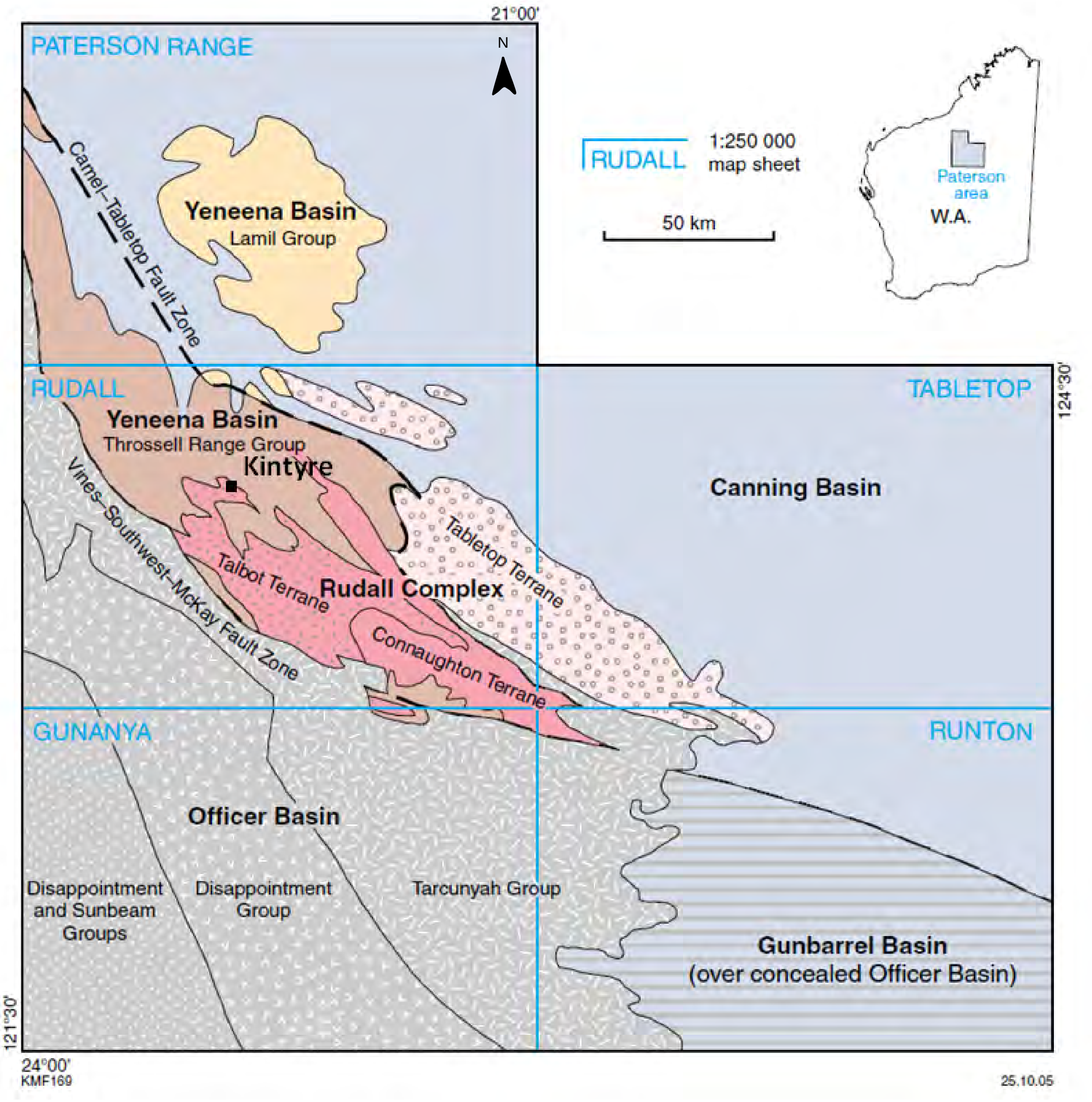

Figure 3-1: Regional geologic setting of the Project area (reproduced from Ferguson et al., 2005)

Table 3-1: Geologic summary of the Kintyre area

ERA		UNITS			LIHTOLOGIES	MAP SYMBOL	AGE (Ma)
CENOZOIC	Quaternary	Superficial deposits			Eolian sand Alluvium Colluvium Sheetwash deposits	Qs Qa Qc Qp	<30
PALEOZOIC	Permian	Paterson Formation (upper)			Fine grained glacio-lacustrine clay and silt sediments, minor sand present	Pp	~300
PALEOZOIC	Permian	Paterson Formation (lower)			Coarse glacio-fluvial sand interbedded with gravel and basal matrix-supported conglomerate	Pp	~300
NEOPROTEROZOIC		Yeneena Supergroup	Lamil Group	Isdell Formation	Carbonate-rich marine rocks		850–635
NEOPROTEROZOIC		Yeneena Supergroup	Throssell Range Group	Broadhurst Formation Coolbro Sandstone	Sandstone, siltstone, and shale Massive sandstone	PYc, PYcp	850–635
NEOPROTEROZOIC		Yeneena Supergroup			Pelite, psammite, and carbonate-rich rocks		1060–800
PALEOPROTEROZOIC – MESOPROTEROZOIC		Rudall Complex			Granitic rocks	PRgm	1400–1200
PALEOPROTEROZOIC – MESOPROTEROZOIC		Rudall Complex		Poynton Formation Butler Creek Formation Yandegooge Formation Fingoon Quartzite Larry Formation	Quartz–mica schist and quartzite Banded paragneiss and schist Quartz–mica schist and quartzite Micaceous quartzite Quartz–Mica schist and gneiss	PRym PRyr PRyc PR.. PRym	1800–1600
PALEOPROTEROZOIC – MESOPROTEROZOIC		Rudall Complex			metamorphosed granitic rocks	PRga PRgm	1765–1790
PALEOPROTEROZOIC – MESOPROTEROZOIC		Rudall Complex			metamorphosed sedimentary and volcanic rocks		~1910

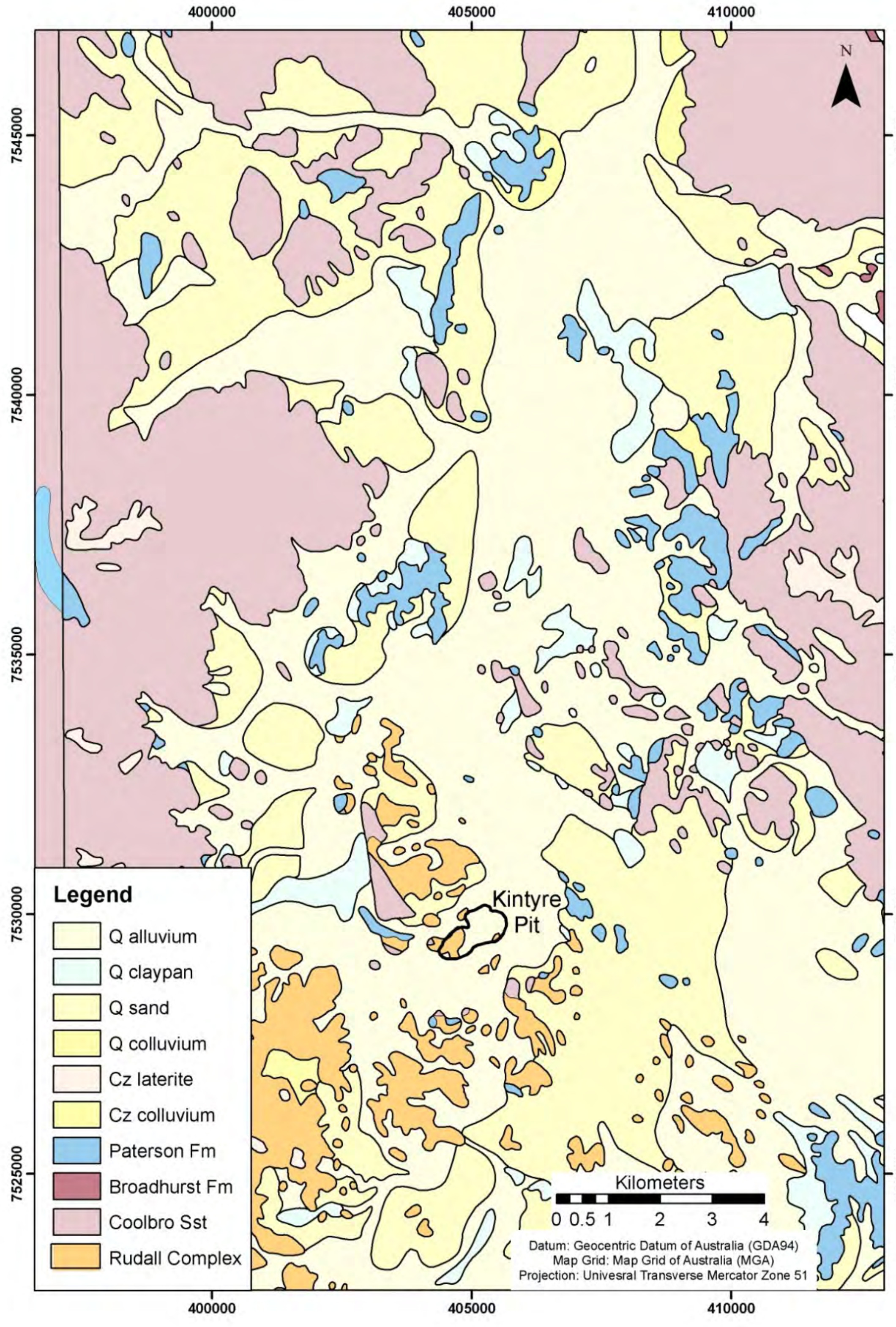

Figure 3-2: Simplified surface geology in the Project area (from Western Australia Geological Survey 1:100 000 geological mapping).

3.1 Stratigraphy

3.1.1 Rudall Complex

The Rudall Complex is a series of metamorphosed sedimentary and igneous rocks forming south-east to east-southeast trending blocks extending for about 150 km to the southeast from about Kintyre. It is Palaeo- to Mesoproterozoic age, probably between 2000 and 1300 Ma old (Hickman and Clarke, 1994), and composed of gneiss, schist and quartzite with interlayered orthogneiss. Metamorphism occurred during orogenic episodes between 1800 and 1250 Ma (Hickman and Bagas, 1998), reaching amphibolite facies and possibly a maximum grade of amphibolite-granulite transition (Hickman and Bagas, 1998). Subsequent retrograde metamorphism has formed greenschist facies mineral assemblages. The complex is folded and faulted, with the dominant strike to the northwest (Chin & de Laeter, 1981).

A series of stratigraphic formations are recognised in the Rudall Complex (Hickman, et al., 1994), but the succession is fragmented by granitoid intrusions and tectonism. The Yandagooge Formation is the only formation recognised in the Project area, which outcrops as elongated inliers of the Yeneena Group. It comprises dominantly quartz-muscovite schist, being metamorphosed pelitic and semi-pelitic rocks, and contains laterally limited banded iron-formation, chert, graphitic schist and biotite schist layers (Hickman and Clarke, 1994; Hickman, and Bagas, 1998). At Kintyre the Rudall Complex is situated upon the Yandagooge Inlier where the Yandagooge Formation also includes carbonate rocks (Hickman and Clarke, 1994).

Unconformably overlying and locally faulted against the Rudall Complex are sediments of the Throssell Range Group, which locally comprise a basal unit of Coolbro Sandstone and upper sequences of quartz sandstone.

3.1.2 Coolbro Sandstone – Yeneena Supergroup

The Coolbro Sandstone occupies the basal portion of the Yeneena Supergroup, disconformably overlying the Rudall Complex. It is part of the Throssell Group, which in the Project area also includes the overlying Broadhurst Formation. The sandstone is a fluvial-deltaic succession deposited during the early Neoproterozoic, or possibly late Mesoproterozoic (Hickman & Bagas, 1998), reaching a thickness of 4000 m. Metamorphism during the Miles Orogeny (c. 900–800 Ma.) attained greenschist facies, but the effect is not readily evident in the sandstone (Hickman & Bagas, 1998). Elevated metamorphic grades occur in shear zones and synclinal enclaves within the Rudall Complex. Tight folding of the group was associated with the Miles Orogeny and west-northwesterly and northwest-trending near vertical strike slip faulting developed in the later (c. 620–530 Ma.) (Hickman & Bagas, 1998). A generalised stratigraphy for the Project area is shown by Figure 3-3.

The Coolbro Sandstone is a fine to coarse grained quartz sandstone with minor amounts of polymictic conglomerate, siltstone and shale within bedded sequences up to 5 m thick and ubiquitous planar and trough cross-bedding throughout (Ferguson et al., 2005) (Figure 3-4). Commonly the lowest beds are a polymictic conglomerate with rounded boulders and pebbles. In the Project area the Coolbro Sandstone forms the main component of the upland plateau, where the unit has well-developed fractures that are particularly prominent in weathered sections near the top and bottom of the unit, and which are often hematite-filled. The Coolbro Sandstone forms a significant fractured rock unit that has potential as a productive aquifer. It is present extensively over the plateau areas flanking the

Yandagooge Creek area north-west and north-east of Kintyre, and is situated west of the Kintyre Shear zone adjacent to the proposed Kintyre Pit. A possible inlier of Coolbro Sandstone is present adjacent to the north-western margin of the pit area (Hydro-Resources, 1997), where it was intersected by bores KWX4, KWP1, KWX11 and KEB1, which are all in close proximity located north-west of the proposed pit area. Quartz veining is also prevalent.

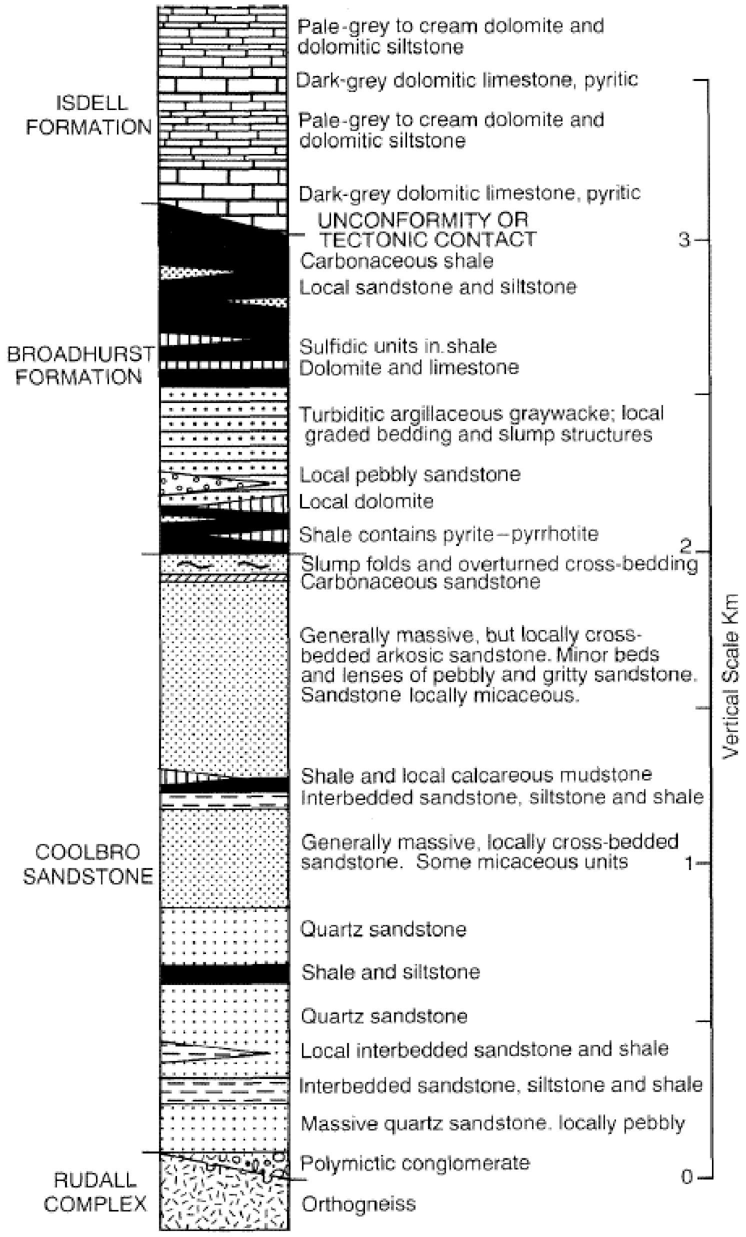

Figure 3-3: Generalised stratigraphy of the Yeneena Supergroup (after Hickman and Clarke, 1994)

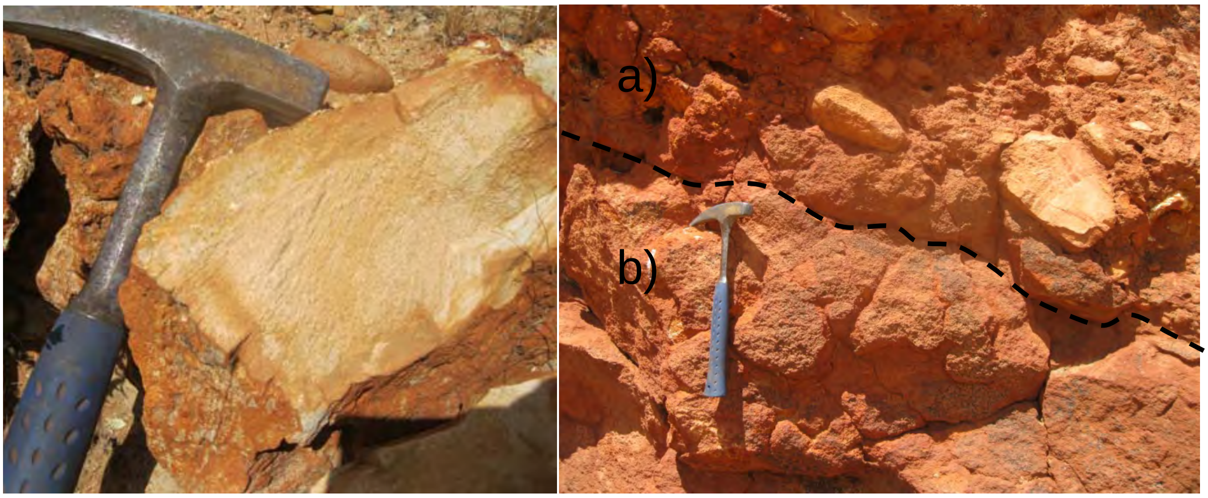

Figure 3-4: Fluvial sedimentary structures in outcropping Coolbro Sandstone; and exposed contact between the Permian Paterson Formation basal conglomerate (a) and Coolbro Sandstone (b) with inferred unconformity (dashed)

3.1.3 Broadhurst Formation and Isdell Formation – Yeneena Supergroup

The Broadhurst Formation represents shallow marine shelf deposits conformably overlying the Coolbro Sandstone. It dominantly comprises carbonaceous shale, turbidite sandstone-shale beds, and minor sandstone, dolomite and limestone units (Hickman and Clarke, 1994), with a transitional interval with the Coolbro Sandstone at the base containing interbedded sandstone. Pelitic schist or shale is the dominant lithology through the middle to upper portions of the formation. The sequence reaches up to 2000 m thick, with the closest outcrop about 14 km north-east of Kintyre in the Broadhurst Range.

Isdell Formation is a marine shelf deposit overlying the Broadhurst Formation, although the nature of the contact (conformable or unconformable) is uncertain (Hickman and Clarke, 1994). It is composed mostly of dolomitic limestone and dolomite with thin units of calcareous siltstone and shale, and is similar to carbonate intervals within the Broadhurst Formation. Its total thickness exceeds 1,000 m. The formation is present north of the plateau, but outcrops are limited by the extensive cover of Permian and Cenozoic deposits.

3.1.4 Paterson Formation (Permian)

Glaciation and glacial valleys

Widespread glaciation in the Late Carboniferous to Early Permian included several episodes of glacial advance and retreat of the continental ice sheets over Gondwana (Lowry et al., 1972). This included the Pilbara Ice Sheet covering the Pilbara–Yilgarn Cratons, which at times formed a continuous ice sheet with that over East Antarctica (Crowell and Frakes, 1971). Ice flow from the Pilbara Ice Sheet was toward the margins of the cratonic areas to the Officer, Canning, Carnarvon and Perth Basins. This process incised deep U-shaped valleys into the bedrock that extended up to several hundred kilometres into the craton area (e.g. to the Laverton area (Eyles and de Broekert, 2001)). Glaciofluvial to glaciolacustrine sediments of the Paterson Formation were deposited in these valleys, where they can be up to several hundred metres thick. A schematic illustration of the glacial valley formation is shown by Figure 3-5. In the Project area, the Paterson Formation rests unconformably upon Proterozoic rocks of the Yeneena Supergroup (mostly Coolbro Sandstone) or the Rudall Complex, occupying a glacial palaeovalley that trends northward to the Canning Basin.

The palaeovalley in the Project area comprises a main valley north of Kintyre that divides southward into western and southern branches in the upper reaches (Figure 3-5). The extent of the palaeovalley is clearly seen on an airborne geophysical Time Domain ElectroMagnetic induction (TDEM) survey flown in 2010 as part of Geoscience Australia's Onshore Energy Security Program (see Attachment A). TDEM images at different elevation slices show the palaeovalley as an area of predominantly high conductivity, with the main channel about 2 km wide. These images also reveal areas with relatively low conductivity within the palaeovalley forming a network of channels typically about 400 m wide. The channels may represent more sandy type lithology surrounded by flanking higher conductivity silt and mud, however this interpretation has not yet been confirmed by field observations.

Sediments of the Paterson Formation fill the palaeovalley to a maximum intersected thickness of 174 m in borehole 3PDD, which did not reach the base of the unit. The interpretive basal elevation of the Paterson Formation is shown by Figure 3-6, which has been compiled from borehole and TDEM data. The palaeovalley falls from around 255 mAHD at borehole 1P in the western branch and 200 mAHD at borehole CWB8 in the southern branch. It attains its lowest point in the western portion of the main channel, which is less than 187 mAHD at borehole 3P. At the northern limit of the dissected plateau the palaeovalley is restricted by ridges of outcropping Coolbro Sandstone, where the palaeovalley divides into two branches. TDEM data suggests that the palaeovalley floor rises across the restriction, although its elevation is speculative. The present day palaeovalley surface forms a wide flat-bottomed valley with a thin Cenozoic superficial cover of colluvial and alluvial sediments, and is occupied by the present day Yandagooge Creek.

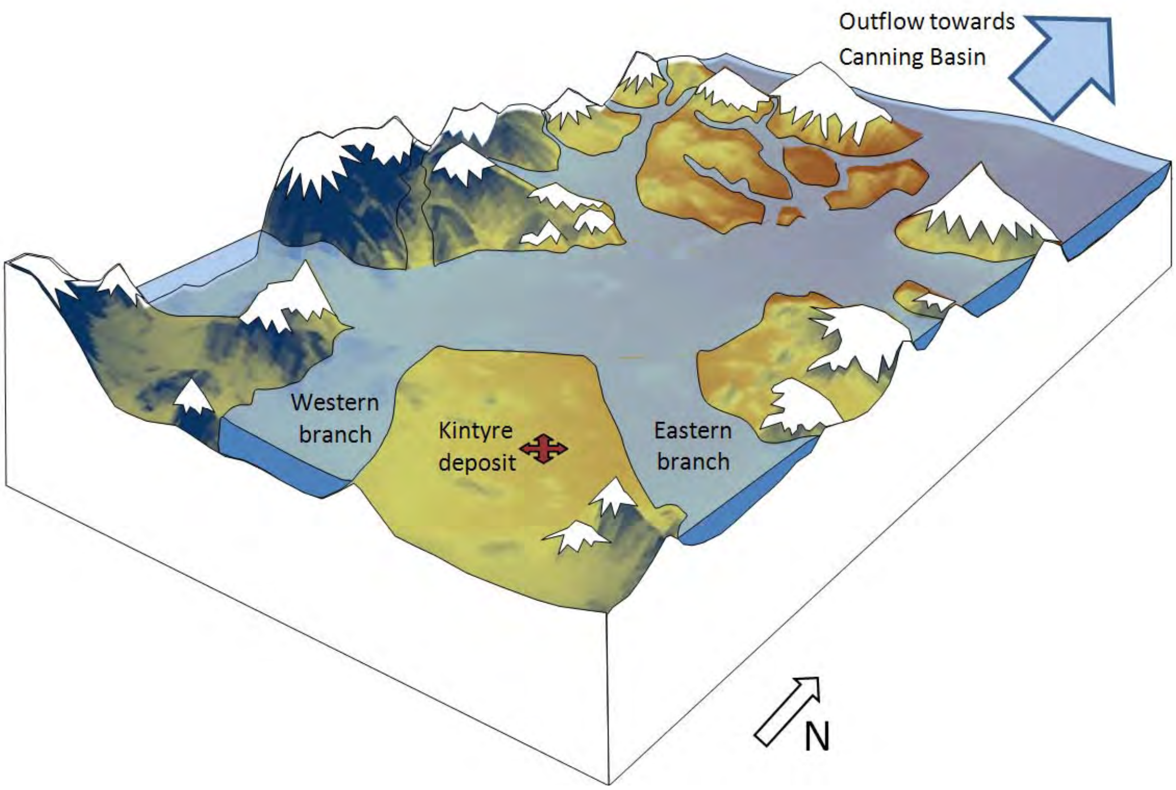

Figure 3-5: Project Area prior to deposition of the Paterson Formation, showing extent of glaciation and glacier movement.

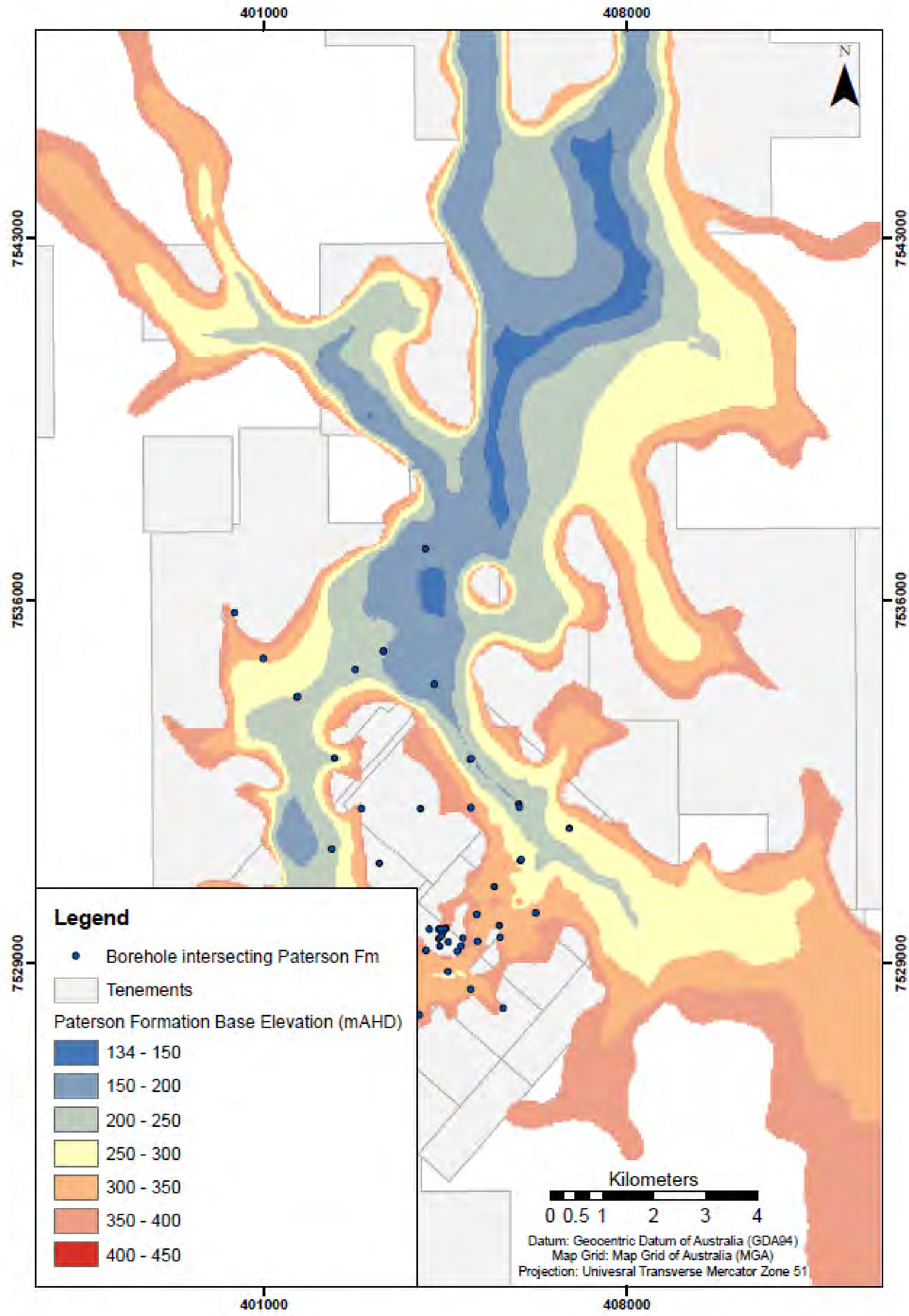

Figure 3-6: Paterson Formation - extent and basal elevation in the Project area

Depositional environment

The Paterson Formation comprises beds of glacial tillite, glaciofluvial and glaciolacustrine deposits. Tillite (also known as diamictite) is a moraine deposit containing conglomerate with cobbles and boulders suspended in a mud or sand matrix with sparse gravel. It is generally unsorted, although some redistribution and sorting by glacial melt-water discharge may occur. Tillite can form a variety of morphologies, ranging from ridges to hummocky sheets developed as accumulations along the glacier margins and at the various glacier terminal points of a stationary or retreating glacier (Figure 3-7). Linear channel fill deposits known as an esker can form a long winding ridge of stratified sand and gravel parallel to the glacial flow, which are deposited in ice-walled tunnels by streams flowing within or under glaciers (Eyles and Miall, 1984).

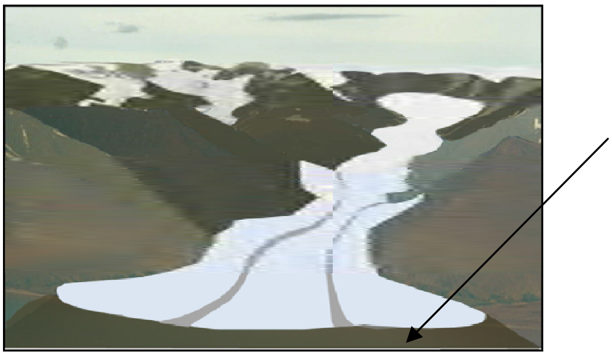

Figure 3-7: Moraine till deposition

Sand and gravel eroded from the moraine deposits by glacial melt-water is re-deposited upon outwash plains as bedforms and bars by braided stream systems that can extend for tens of kilometres from the glacier (Figure 3-8). Typically these glaciofluvial proximal deposits comprise dominantly gravel, with grain-size decreasing downstream from gravel to coarse sand. Where the braided stream discharges into a lacustrine environment fluvial sands of a prograding river delta are deposited over fine grained sand, silt and clay lacustrine sediments, resulting in an upward coarsening sequence.

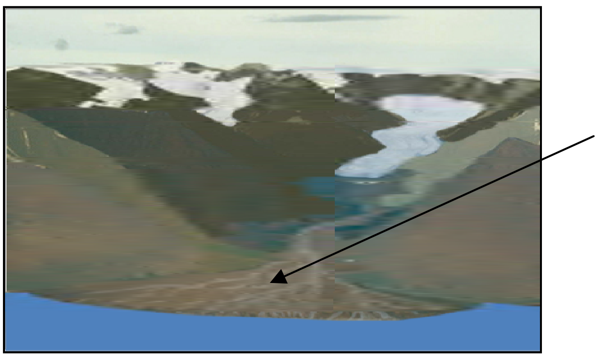

Figure 3-8: Deposition of the fluvial braided sand of the Paterson Formation

Lacustrine ponding is common within a glacial valley, developing in parts of the valley over-deepening by glacial erosion or by the damming of drainage by ice or moraine deposits. Periglacial lake deposition (Figure 3-9) is dominated by the development of coarse grained deltas along the lakes edges with a seasonal influx of sand or silt extending from the delta lobes that is followed by a winter deposit of clay. This seasonality in deposition may form an annual varve characteristic of glaciolacustrine facies. Glacio-isostatic depression or postglacial glacioeustatic sea level rise can result in a marine incursion flooding valleys to form fiords adjacent to the coast. The interaction of sediment plumes and tidal currents in the fiord can lead to the accumulation of finely laminated and graded silty mud and sand filling a significant portion of the fiord (Eyles and Miall, 1984), often burying wedge-shaped fan accumulations.

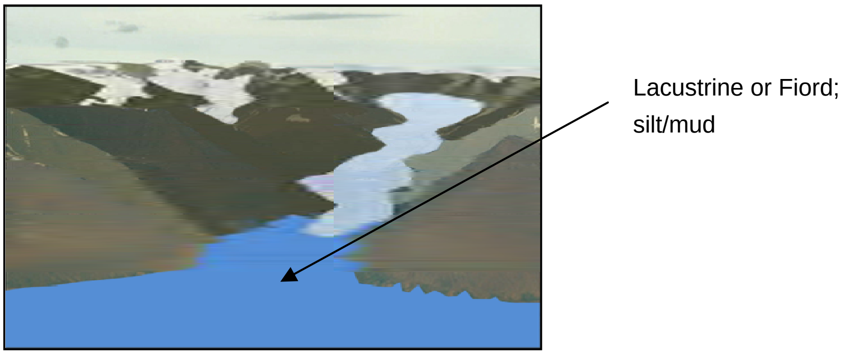

Figure 3-9: Deposition of the lacustrine silt/mud of the Paterson Formation

Lithology types in the Project area

Weathered outcrops of the Paterson Formation occur as isolated mesas and dissected benches flanking valleys (Ferguson et al., 2005). They are dominated by cross-bedded coarse to medium grained sandstone (Hickman and Clarke, 1994), frequently passing upward into finer grained sediments of mudstone and siltstone. Graded laminae in the mudstone and siltstone may represent varves, while conglomerate lenses in the sandstone suggest channel deposition (Williams and Trendall, 1998). Basal deposits comprise pebbles, cobbles and boulders embedded in cream-brown to red-brown clay, sandy clay and silt representing tillite (diamictite). A variety of rock types are represented in the deposit, indicating a mixed provenance. ***Figure 3-10*** shows an example of outcropping basal conglomerate and similar material found in borehole CWB17.

Figure 3-10: Outcropping Paterson Formation 7 km north of Kintyre, and polymictic paraconglomerate intersected in hole CWB17 at 28–42 m

Project boreholes drilled in the valley intersected the Paterson Formation to depths of between 7 and 174 m depth. These sediments are described variably as conglomerate, sandstone, siltstone/claystone and clayey sand. The conglomerate is brown to blue green brown and blue-grey, comprising mostly clayey fine to coarse grained sand and gravel with generally rounded pebbles of quartz, jasper, siliceous siltstone, schist and gneiss. Boulders are also encountered in the deepest parts of the palaeovalley, such as below 167 m depth in 3PDD. These deposits probably represent moraine till. In the western and southern palaeovalley branches conglomerate is present only in the deeper portions, being below 95 m depth at 1PD in the west branch and below between 54 and 102 m (CWB7D, CWB8D and CWB14) in the southern branch.

The sandstone is pale yellowish brown, brown to greenish grey, rounded to sub-angular, fine to coarse and medium to coarse grained sand that is generally poorly sorted, but may be well sorted over some intervals. Clayey and silty sandstone is prevalent within the upper 40 m of the formation, where it is mainly fine to medium grained and maybe thinly laminated.

Siltstone and claystone intervals intersected in the boreholes is light brown, grey to dark blue grey, forming thin laminations of claystone and fine sandstone (Figure 3-11). Occasional boulders are present. The deposits represent lacustrine or fiord depositional environments.

Figure 3-11: Example of siltstone intersected during drilling at CWB17 over 50-106 m depth

Depositional sequences

In the project area four general depositional sequences are recognised, which are divided into two broad units referred to as the upper Paterson and lower Paterson. These sequences represent episodes of glacial advance and retreat, where the preserved deposits are associated mostly with retreating glaciers. This results in a general fining succession in each sequence, progressing from conglomerates to gravels, sands, silt and clay as the upper-most lithology, which reflects a progression from tillite, glaciofluvial and glaciolacustrine depositional regimes. Frequently the upper portion of the sequences is truncated due to removal of the upper sediments through a subsequent glacial advance. The distribution of a particular lithology may also represent the channel extent that has been infilled. The generalised facies associations with each sequence are shown by Figure 3-12. Interpretative geological cross-sections through the Paterson Formation are presented in Figure 3-13 3-13 and Figure 3-14.

The glacial depositional sequence S1 is the lower-most unit at the base of the Paterson Formation. It is dominated by tillite conglomerate and fluvial sand deposits. Basal tillite including boulders extends up the entire tested length of the palaeovalley, but becomes absent up the valley flanks. A lacustrine siltstone unit is present within the lower portion of S1 in CWB18 (117-138 m) and 3PDD (148-167 m), but it appears to be truncated by an overlying conglomerate unit in the sequence at other sites. The thickest interpreted section of S1 intersected was 110 m in 3PDD, where it extends from 64 m to 174 m without reaching the base of the unit.

Sequence S2 is an extensive clayey siltstone and mudstone unit resting either upon S1, which it truncates, or Proterozoic basement. The sequence may be capped with clay where the upper portion is preserved. S2 extends throughout the palaeovalley except where it has been removed through later erosional (possibly glacial) episodes. It either represents deposition in a widespread lake filling most of the valley, or a marine incursion creating a fiord. Where fully preserved, it reaches a thickness of about 55 m (CWB19).

Sequence S3 consists of conglomerate and sand present in an interpreted channel cut into the underlying sequences in the main channel and extending part-way up the western branch. It has not been intersected in the southern branch. The conglomerate filled channel has fully truncated the S2 sequence at borehole sites WEX2 and WEX3 in the lower part of the western channel, so that conglomerate of S3 overlies S1 conglomerate. A clayey silt member is present at the top of the sequence toward the margins of the palaeovalley and in the upper reaches of the western and possibly southern channel branches. S3 probably represents till and out-wash fluvial deposits with some final lacustrine sedimentation. The thickest section of S3 is interpreted in WEX2 where it may be about 90 m, although it is difficult to identify the contact with the underling S1 sequence which has a similar lithology.

Sequence S4 is the upper-most sequence extending through-out the palaeovalley and its two branches. It appears to rest upon a relatively planar surface over S3, or upon Proterozoic basement about the margins of the palaeovalley. The sequence represents a predominantly low energy fluvial deposit comprising predominantly fine grained sand with some silt, and is very clayey. There are increasing amounts of medium and coarse grained sand toward base of unit. Clay is usually present at the top of the sequence, which is thickest in the southern branch where it reaches about 14 m in CWB8D. S4 reaches a maximum depth of 38 m in 3P (main branch) and 42 m in CWB8D (south branch). It is unconformably overlain by around 10 m of Cenozoic colluvium and alluvium.

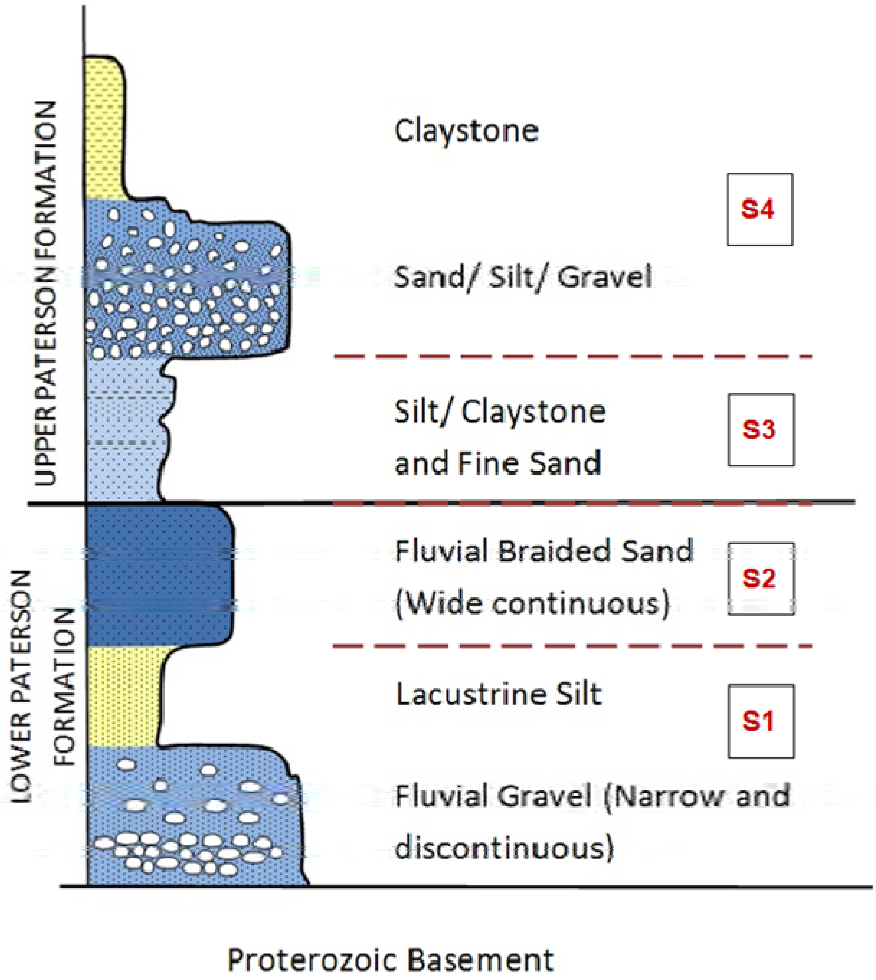

Figure 3-12: Paterson Formation facies present in bores in the Project Area

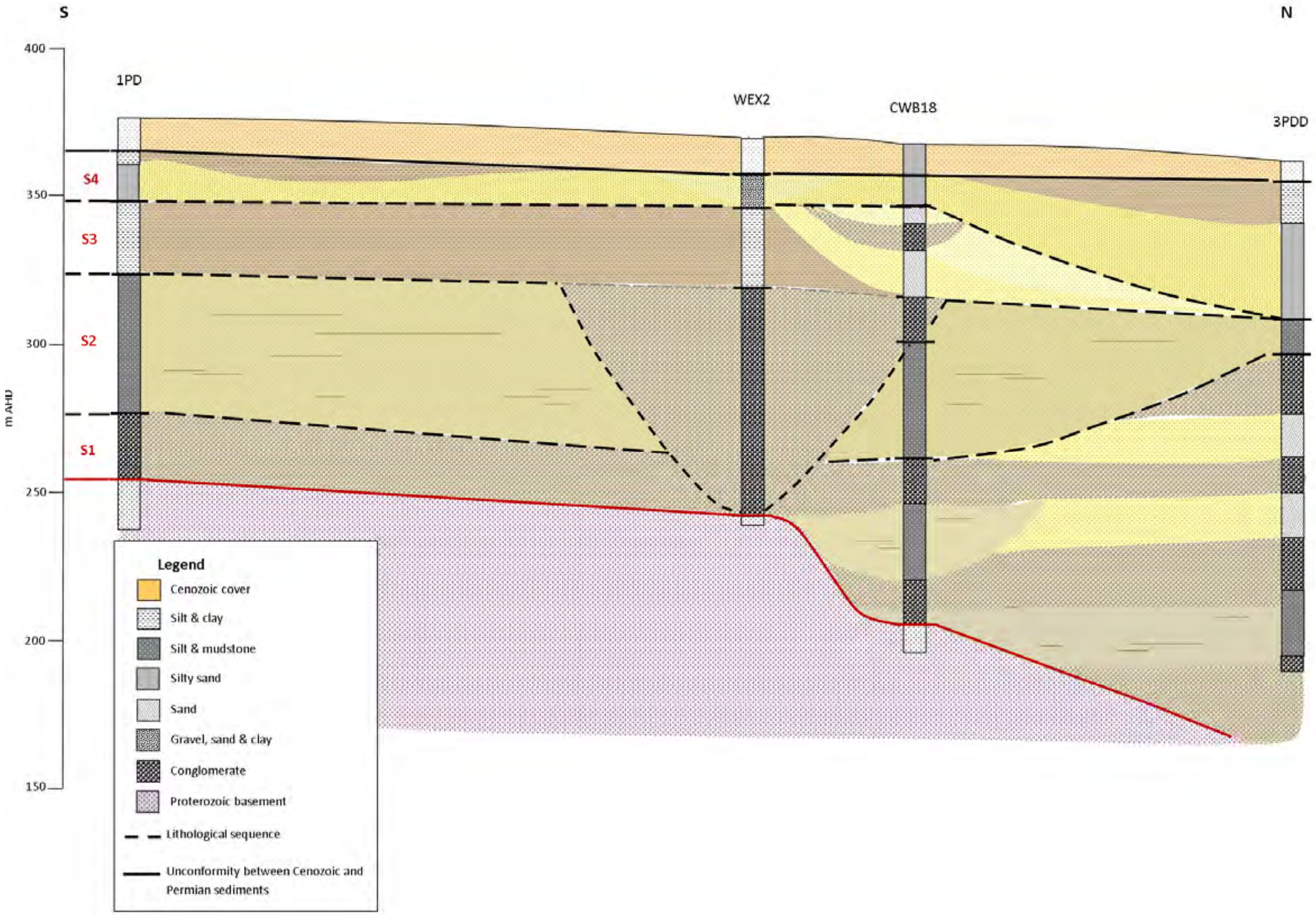

Figure 3-13 Geological cross-section; north-south

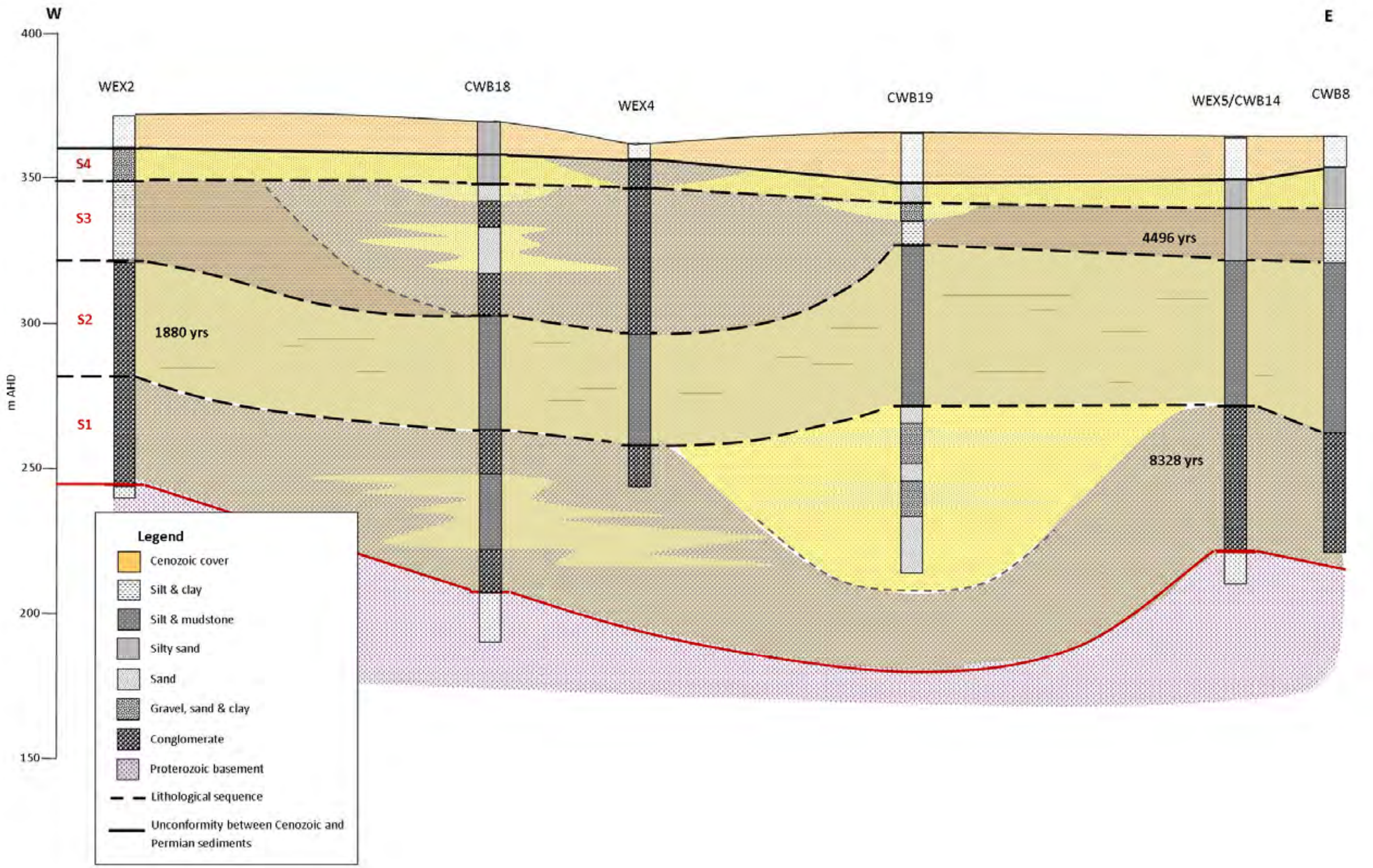

Figure 3-14 Geological cross-section; east-west

3.1.5 Cenozoic Deposits

Recent alluvial, colluvial and scree deposits form an extensive but relatively thin veneer over most of the Project area. Sediments infilling the valleys comprise red brown, fine to medium grained quartz sand and silt, which form sand plain deposits and an extensive dune system of elongate ridges up to 20m high with a general east-west orientation. The deposits range in thickness from 1 m on topographically high outcrops, to around 12 m in valley floor drainages. There is some evidence to indicate that a shallow Cenozoic palaeochannel containing thicker sand and gravel deposits may exist, but the extent and location of this possible palaeochannel is not well understood at this time.

Localised sections of coarser sand and gravel are likely to exist as more recent channel deposits in and around the current Yandagooge Creek flow path. These sequences comprise medium to coarse grained sand with traces of sandstone, quartzite and quartz gravel clasts up to 2 cm in diameter. It is likely that these deposits will also be found concentrated in central sections of the valley. Claypans of silt and clay are also found in some areas of the valley.

Calcrete deposits, reported 50 km north of Kintyre, form low mounds composed of massive, nodular and vuggy limestone (partly replaced by chalcedony), which formed in channels and lakes during the early Cenozoic (Ferguson et al., 2005).

Leaching and silicification of weathering material has created a recognisable lateritic profile over most of the Paterson and Rudall Provinces surrounding the Kintyre area (Ferguson et al., 2005), as shown by the schematic in Figure 3-15. At the top of the profile immediately beneath alluvium/colluvium cover, the ***upper saprolite*** (also known as the pallid zone; the smectite zone; or the zone of strong oxidation) is a zone where the rock has undergone complete chemical decomposition into heavy textured clay minerals. The transition into ***lower saprolite*** (the zone of joint oxidation) is characterised by a change from heavy textured clay to soft, decomposed, friable rock 10–20 m thick which may display remnant rock textures. The ***saprock*** is the zone of broken fresh rock between the lower saprolite and the hard fresh rock that can contain open or clay filled faults, shears and joints that tend to close with depth.

Subsequent erosion and etching of the lateritic profile has developed duricrust caps, ferricrete deposits and various forms of silcrete developed over sandstone and orthogneiss. The continual erosion and re-deposition of this material has formed observable colluvial, talus, sheetwash, alluvial and calcrete depositional structures throughout the area.

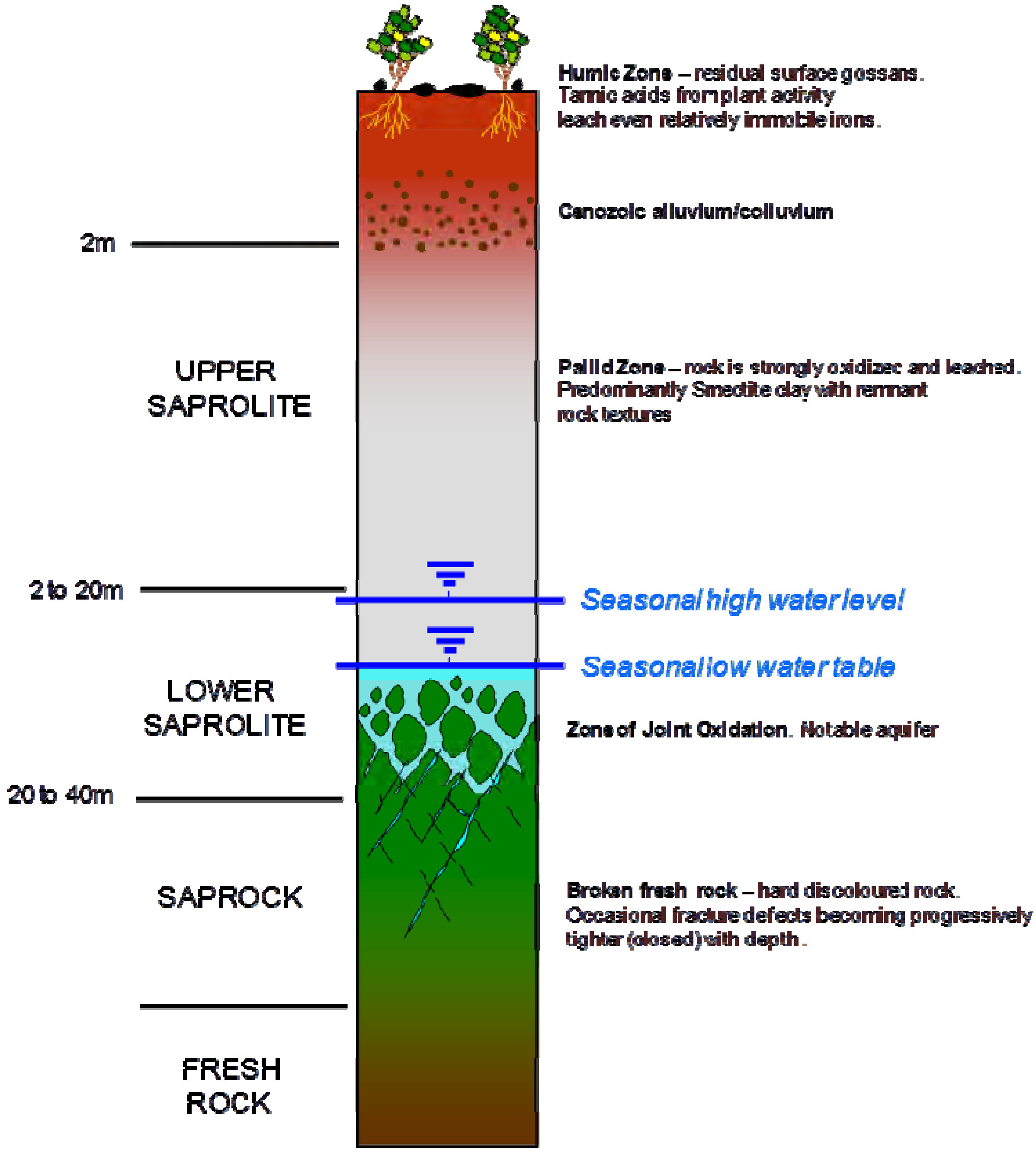

Figure 3-15: Typical saprolite profile observed in the Project area

3.2 Structural geology in the Kintyre pit area

Palaeo- to Mesoproterozoic rocks of the Rudall Complex experienced two periods of deformation prior to deposition of the Yeneena Group Coolbro Sandstone (Hickman and Clarke, 1994). The earliest event (D1) was metamorphism to amphibolite facies which produced tectonic fabrics, quartz-feldspathic banding and veining. Subsequent retrograde greenschist facies metamorphism (D2) was associated with tight recumbent to isoclinal folding. Four phases of deformation are recognised in the post-Yeneena Group deposits (Hickman and Clarke, 1994), including the inferred development of a major syncline (D3) which was followed by regional deformation (D4) associated with the Paterson Orogeny. Dominating the Paterson Orogeny were major upright to overturned, tight to isoclinal folds generally over-turned to the southwest and plunging about 30º to the northwest or southeast (Hickman and Clarke, 1994). Thrust faults partly replace the south-western limbs of the anticlines. A possible later folding event (D5) was followed by a final faulting event (D6) with northerly to northwesterly strike-slip dextral faults and east-northeasterly sinistral faults (Hickman et al., 1994). This faulting event may have been related to compression from the north-northeast to south-southwest.

The distribution of geological formations about Kintyre is mostly the result of the Paterson Orogeny folding (D4) that was later modified by faulting (D6), and are shown by Figure 3-16. Rudall Complex rocks of the Yandagooge Inlier form the exposed core of the Tracey Anticline, which is a D4 anticline fold plunging to the north-west, and which contains smaller fold structures within it. At Kintyre the Rudall Complex Yandagooge Formation is dominated by quartz-mica schists and quartzite, and includes carbonate (marble) rocks. Lithological units in the Yandagooge Formation follow the fold axis of a gently east-northeasterly plunging recumbent antiform (Andrew, 1988) probably related to the D2 event. The mineralisation occurs within the hinge zone of the antiform fold and is associated with zones of retrograde chlorite-quartz schists, chlorite-carbonate-quartz schists and variably chloritic and garnetiferous quartzite (metachert) containing some magnetite. At Kintyre the schist is structurally overlain by carbonates, while at the Whale deposit the schist overlies carbonate. Figure 3-17Figure 3-17 presents a generalised geological profile for Kintyre.

The Rudall Complex has a sheared or unconformable contact with the Coolbro Sandstone (Andrew, 1988), which is present westward across the Kintyre shear zone. An enclave of the Coolbro Sandstone is reported east of the shear zone, north of the pit area (Hydro-Resources, 1997), but it is described in boreholes (KWX4, SWP1 and KEB1) only in a small area north-west of the proposed pit area. Margins of the Paterson Formation on-lap the southern to central portion of the pit area, where over 20 m of mostly clayey sediment have been intersected.

The Kintyre shear zone is a northwest-trending structural zone dipping 70º to the north-east. It is present just west of the proposed Kintyre pit and is interpreted to pass through bores OBS16 and North Bore. This fault has been mapped on the Broadhurst surface geology sheet (Hickman & Clark, 1994), and is described as a thrust or reverse fault. Rock units to the east of the shear have been thrust up and eroded away, and those to the west are down-thrown. Several sub-parallel quartz veins that are stretched/boudinaged and enveloped by chlorite schist are thought to be associated with the shear (Hydro-Resources, 1997). Well-developed parallel axial planar cleavage in the schist lithology may also be associated with the shearing.

Other shear and faults around the deposit have a similar north-westerly trend. Fault zones have been described by CRA exploration from cored holes as steeply dipping zones of fractured and broken rock. These shear zones include a zone intersected by borehole 15P in the Whale deposit, and termed the 'Whale shear zone', and a shear zone coinciding with a lineament to the west of site 15P (GRC, 1988; Dames & Moore, 1988, 1989).

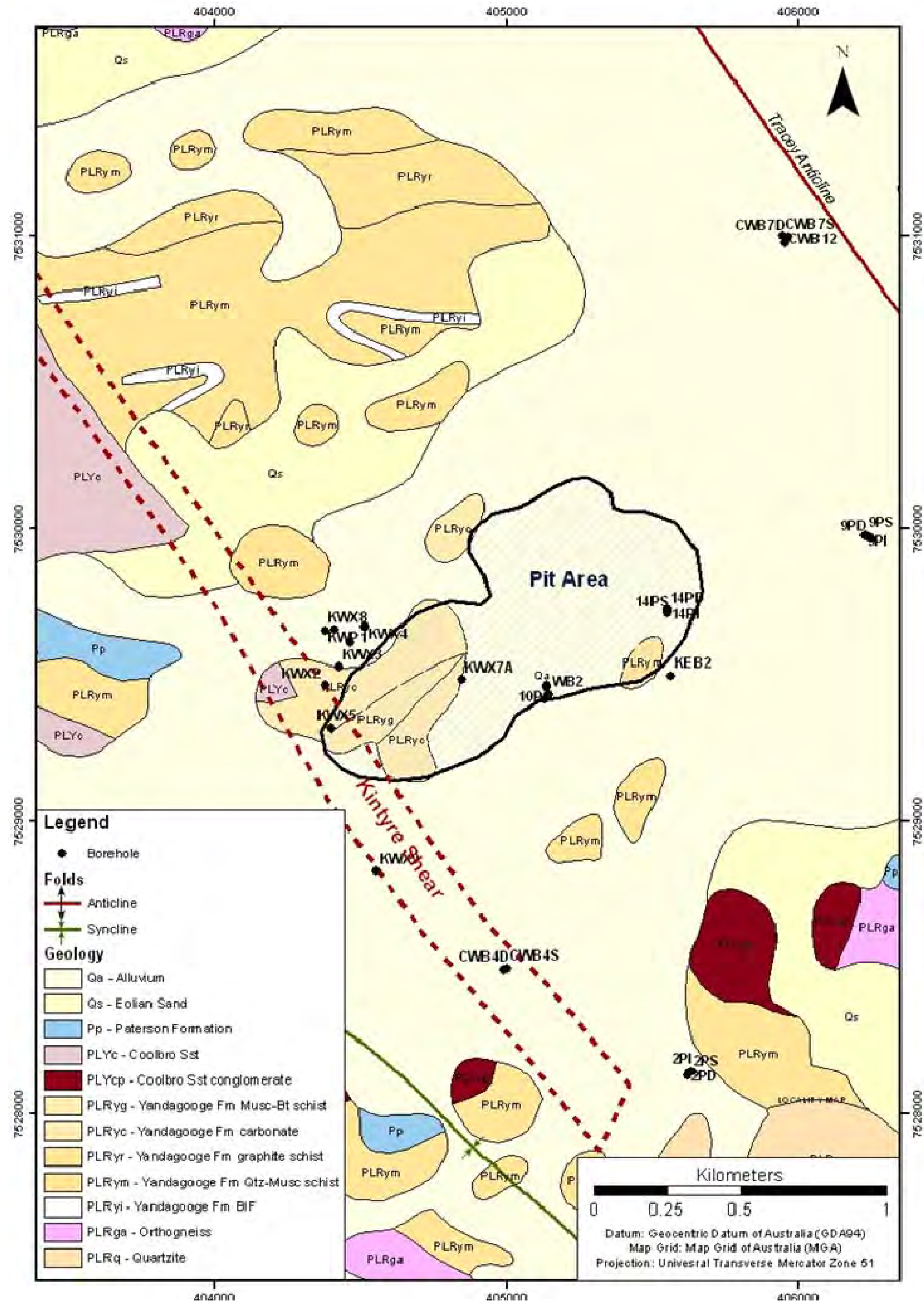

Figure 3-16: Geology about Kintyre

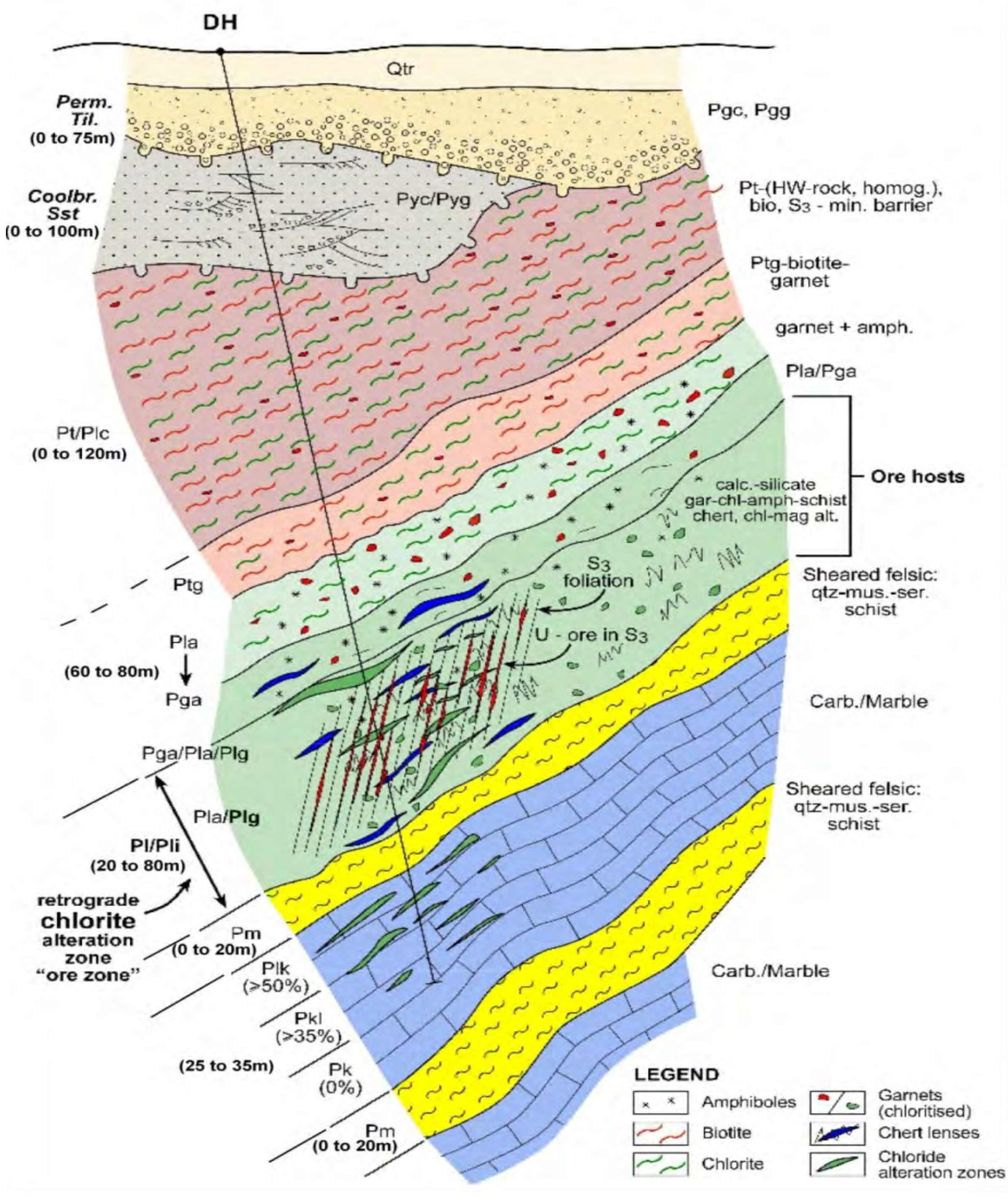

Figure 3-17 Generalised and interpreted composite-litho-stratigraphic rock succession at Kintyre – view is to the east with northerly dipping strata. (From Cameco 2010, unpublished.)

4. HYDROGEOLOGICAL SETTING

4.1 Groundwater Occurrence

The main aquifer units in the Kintyre area are located in Permian sand, gravel and conglomerate deposits of the Paterson Formation, and fractured and weathered sandstone of the Coolbro Sandstone. Smaller local aquifers are present in Cenozoic deposits where saturated, and in secondary permeability features within basement rocks of the Rudall Metamorphic Complex.

Regional and local aquifer qualities are summarised in
Table 4-1.

Table 4-1: Summary of Aquifer types in the Kintyre area

Aquifer	Geological unit	Average thickness (m)	Bore yield (kL/day)	Aquifer potential	Lithology
Cenozoic	Alluvium	15; generally unsaturated	Minor	Minor	Unconsolidated localised sedimentary aquifers
Upper Paterson	Paterson Formation (upper unit)	50	100 to 1,500	Minor to Major	Glacio-lacustrine clay, siltstone and sand
Lower Paterson	Paterson Formation (lower unit)	100	100 to 1,700	Minor to Major	Fluvioglacial sand, gravel and basal conglomerate
Coolbro	Coolbro Sandstone	>1,000	200 to 800	Major where sheared	Sandstone
Rudall fractured rock	Rudall Metamorphic Complex	>1,000	<50 to 250	Minor	Schists, carbonates, quartzite

4.1.1 Cenozoic Deposits

Cenozoic deposits are generally unsaturated over most of the Project area, although thicker, deeper deposits are coincident with branches of the Yandagooge Creek. Isolated lens-like aquifers form where sands are present below the watertable; saturated Cenozoic sediments have been identified during drilling along the western branch of the creek (CWB17; CWB19) but yielded only minor flow (<90 kL/day). Claypans are developed some sections of the valley. Generally, Cenozoic deposits do not form a significant aquifer.

Calcrete deposits represent a significant potential aquifer about 50 km north of Kintyre, but only minor traces have been intersected within the Project area.

It is common for water to be stored in the lower saprolite of this profile, which acts as a notable aquifer. A summary of the general hydrogeological properties follow:

The ***upper saprolite*** zone immediately beneath a cover of alluvium/colluvium which comprises typically massive heavy textured clays is mostly unsaturated. Seepage zones may be present beneath the watertable, but has a very low vertical and horizontal permeability (in the order of 0.001 m/day), and very low specific yield less than 0.1%.

The ***lower saprolite*** zone of soft, decomposed, friable rock typically 10–20 m thick is typically the most reliable water target within the weathered profile upon fractured rock, yielding around >1 to 300 kL/day, with occasional yields of around 700 kL/day. Hydraulic conductivity can be up to several meters per day, and specific yield is conservatively estimated at between 0.5% and 1%. Water inflow up to 20 kL/day measured in bore KWX3 is thought to have come from the weathered/fresh rock interface around 70 m depth, and a similar yield was obtained from bore KWX5 in weathered quartz–chlorite schists in the Kintyre shear zone.

The ***saprock*** zone of broken fresh rock between the lower saprolite and the hard fresh rock can contain open water bearing faults, shears and joints. These features characteristically act as high permeability groundwater conduits, but have very low groundwater storage. They tend to close with depth and the prospect of obtaining significant water bearing fractures diminishes below around 60 meters depth.

4.1.2 Upper Paterson aquifer

The upper unit of the Paterson Formation has significant storage potential, and generally forms an extensive clayey sand aquifer with a lower aquitard associated with the fine-grained glacio-lacustrine facies. However, sand and gravel lenses present within the unit are capable of forming appreciable local aquifers. The upper unit of the Paterson Formation appears to have higher permeability and storage than initially suggested in literature (Dames & Moore 1989; MWH 2011a). Based on pump test analyses and field mapping (MWH, 2011a), appreciable lenses of loose medium quartz sand within the upper unit of the Paterson Formation have been shown to permit leaky storage to underlying hydrogeological units. Analysis of pumping tests (Dames & Moore, 1988) suggested that the aquitard was leaky based on the response of shallow piezometers in the upper Paterson Formation during constant rate tests of the Paterson Formation lower aquifer.

4.1.3 Lower Paterson aquifer

Tillite and fluvioglacial sand and gravel form aquifers of varying spatial extent in the lower portion of the Paterson Formation. Sequences of interbedded sand with loose running basal sand and gravel (intersected in WEX4, CWB17 and CWB19) will probably be the highest yielding for groundwater, although the lateral extent and sustainability of these lenses is yet unknown. Conglomeratic layers display little intergranular permeability due to a fine matrix. Yields obtained from the lower Paterson aquifer during the various investigation programs have shown that the unit is capable of producing up to 1700 kL/day upon airlift yield (in bore CWB14). The unit has a saturated thickness of up to 105 m and is typically confined beneath glacio-lacustrine sediments of the upper Paterson Formation.

The unit is thickest in the deepest parts of the palaeovalley, reaching a maximum of 105 m in bore WEX3, and increases northward forming a laterally continuous aquifer or series of aquifers along the length of the palaeovalley. Basal conglomerates have been intersected as far north as CWB17 and are expected to extend to at least 33 km north of Kintyre based on TDEM data interpretation.

4.1.4 Coolbro Sandstone aquifer

Several bores drilled into the Coolbro Sandstone aquifer have targeted potentially high permeability areas within the Kintyre Shear Zone. The only bore to have been constructed into the main body of Coolbro Sandstone in the vicinity of Kintyre Pit is 13P, which was test pumped at 180 kL/day with a drawdown of about 9.5 m after about 30 hours (Dames and Moore, 1988). A dewatering trend was apparent after about 100 minutes of pumping, suggesting that the aquifer is well bounded. A good vertical and lateral hydraulic connection was evident between this bore and the nearby monitoring bores (M, 13PO and 13PS).

Bores TPB16 and North Bore, located about 8 km north-west Kintyre, are also situated on what is believed to be an extension of the Kintyre Shear Zone. TPB16 yielded 800 kL/day during a constant rate test with just over 10 m drawdown after 2 days (Dames and Moore, 1988). The test showed confined conditions but no evidence of any hydraulic boundary effects, suggesting that the aquifer is extensive in this area. The North Bore was pumped at a rate of 310 kL/day for 219 minutes with an 18 m drawdown observed by the end of the test (MWH, 2010). The drawdown curve from this test shows leaky conditions were experienced after 10 minutes and that there were no hydraulic barriers encountered during testing.

4.1.5 Rudall fractured rock aquifer

Proterozoic rocks in the Rudall area have little or no inter-granular permeability, but secondary permeability exists within the rocks as fault and shear structures. The region contains strong northwest to north-trending faults and shear zones that allow groundwater to flow laterally towards valleys and northeast to the Canning Basin. Rocks of the Rudall Metamorphic Complex are generally less productive and contain poorer quality groundwater than the Coolbro Sandstone (Dames & Moore, 1993).

Investigation drilling in Proterozoic schists immediately north and south of the resource area respectively encountered yields of up to 200 and 350 kL/day during airlifting; these rock aquifers are considered incapable of yielding sufficient groundwater to supply the Project needs.

Up to 56 m of weathered rock interfaces have been documented in hard-rock around the resource area (bores KWX1 to KWX6). However, most areas around the resource area feature very thin weathered profiles and the potential for useful groundwater yields out of lithological contacts and weathered saprolite is considered minimal.

Proterozoic carbonate rocks have similarly not proved productive. Exploratory drilling into the carbonate-rich hanging wall revealed an absence of voids within the massive carbonate and only minor oxidation to 44 m (Hydro Resources, 1997). No water has been produced from these rocks.

4.2 Hydraulic Parameters

Hydraulic parameters for aquifer units in the Kintyre area have been calculated for 24 pumping tests conducted by Pennington Scott (2012a), MWH (2010; 2011), Hydro-Resources (1997) and Dames and Moore (1988), which are presented in Attachment A and summarised in Table 4-2. Values of hydraulic conductivity and storativity determined from the analysis are included. Storativitity and specific storage are important parameters in the evaluation of the sustainable yield for a borefield, and where possible have been determined from observation bore data. Details of step-drawdown and short term pump tests undertaken by MWH (2010; 2011) and Pennington Scott (2012a) are provided in Attachment A.

No pumping tests have been undertaken to calculate the hydraulic parameters of the Cenozoic deposits, which are mostly unsaturated. Unconsolidated sands like those in the Cenozoic deposits present in the Project area typically have hydraulic conductivities of 0.1 to 10 m/day.

Table 4-2: Summary of hydraulic parameters (bulk for the whole unit) derived from pumping tests and estimated values

		K_h (m/d)		K_v (m/d) ^{E}		Sy (%)^{E}		S		Ss ^{E}	
Unit	**Description**	**min**	**max**	**min**	**max**	**min**	**Max**	**min**	**max**	**min**	**max**
Cenozoic surficial deposits	Upper unconsolidated alluvium - mostly unsaturated	0.1 ^{E}	10 ^{E}	1x10^{-3}	0.1	3	10	N/A			
Paterson Formation (upper)	Glaciofluvial and glaciolacustrine with minor tillite (conglomerate)	0.1	1	1x10^{-4}	1x10^{-3}	2	5	1x10^{-4}	1.5x10^{-3}	1x10^{-7}	5x10^{-5}
Paterson Formation (lower)	Glaciofluvial, glaciolacustrine and tillite (conglomerate)	0.05	0.4	1x10^{-4}	5x10^{-3}	1	5	1x10^{-5}	1x10^{-3}	1x10^{-7}	5x10^{-5}
Upper Saprolite	Heavy textured clay	1x10^{-4} ^{E}		1x10^{-5}		0.01		1x10^{-5} ^{E}		not specified	
Lower Saprolite	Zone of joint oxidation — decomposed medium–hard rock	0.05 ^{E}	0.5 ^{E}	0.02	0.1	0.5	1	1x10^{-5} ^{E}		not specified	
Saprock	Joints, faults and shears in otherwise fresh hard rock	not specified				0.01	1	not specified			
Coolbro Sandstone	Porous sandstone	0.1	1	0.001	0.1	not specified		1x10^{-5}	1x10^{-4}	1x10^{-7}	1x10^{-5}
	Shear zone	1	6	0.01	1	not specified		1x10^{-5}	3x10^{-3}	1x10^{-7}	5x10^{-5}
Rudall Complex	Tight, hard rock – practically non-existent primary permeability and storage, very minor fracture permeability and storage	0.001 ^{E}	0.05	not specified		0.001	1	<1x10^{-5}		1x10^{-7}	1x10^{-6}
	Shear – fault zone	0.1	0.5	not specified		0.005	3	not specified		not specified	

Notes:
Kh – horizontal hydraulic conductivity
Kv – vertical hydraulic conductivity
E – estimated value
Sy – specific yield
S – storativity
Ss – specific storage

4.2.1 Paterson Formation aquifers

Results from pumping tests show differences in hydraulic properties for the upper and lower Paterson aquifers, and between each of the western, southern and main portions of the palaeochannel. The upper Paterson aquifer tested in the main channel appears to be more permeable than the lower Paterson aquifer. A bulk hydraulic conductivity of around 0.6 to 0.7 m/day is estimated for the upper Paterson aquifer from limited testing, but through different intervals of the unit may be up to 2 m/day for the sandy component and less than 0.1 m/day for the clay component. The lower Paterson aquifer tends to thicken and become more permeable downstream of CWB15/19 in the main channel (Dames and Moore, 1988), where pumping tests indicate a bulk hydraulic conductivity a little over 0.2 m/day, but is equivalent to 0.3 to 0.5 m/day over the conglomerate, gravel and sandstone portion. Similar hydraulic properties are obtained for the lower Paterson aquifer in at least the down-stream portion of the southern channel. In the western channel the lower Paterson aquifer may be less permeable, with a hydraulic conductivity of a little over 0.1 m/day derived from pumping tests at two sites. Tillite may have a similar permeability as siltstone and claystone.

It has not been possible to evaluate the vertical hydraulic conductivity for the aquifer from pumping test data, but it is apparent that conditions are variable due to pumping from the deeper aquifer portion resulting in an observed drawdown in the shallow portion of the aquifer at some sites and not others. Siltstone and claystone intervals will act as aquitards through the aquifer portions, being intervals of low vertical hydraulic conductivity with values of around 10^{-3} to 10^{-6} m/day anticipated. The vertical hydraulic conductivity through fluvial sand intervals will be much greater, with values of approximately 10^{-2} to 0.2 m/day equivalent to between 1/10th and 1/1000th of the horizontal hydraulic conductivity. Bulk vertical hydraulic conductivity will therefore be very much a function of the distribution of the low permeability confining aquitard units.

Specific yield is a critical groundwater storage parameter that dictates the overall sustainability of supply and magnitude of interference drawdown in the aquifer. It is, however, not possible to evaluate specific yield values from pumping test data in the Project area, although values are available for the Paterson Formation from AngloGold Ashanti Tropicana borefield located 770 km south-southeast of Kintyre. At Tropicana the aquifer is within fine-grained glaciolacustrine sand deposits, for which the specific yield was found to be greater than 3.5% from a 10 day aquifer test (under represents the actual value as unconfined hydraulic conditions were not achieved), but less than 21% which was a laboratory measured value of effective (drainable) porosity (Pennington Scott, 2012b). It is anticipated that the bulk specific yield in the Project area will be around 5% when the aquifer component is portioned against the aquitard.

Specific storage is more consistent through the different parts of the palaeochannel, with a value of around 1×10^{-6} to 1×10^{-5} calculated for pumping test observation bores.

4.2.2 Coolbro Sandstone aquifer

Highly variable values for transmissivity and hydraulic conductivity have been derived for the Coolbro Sandstone aquifer from pumping tests about Kintyre and the water supply bore North Bore about 7.6 km to the north-west. Water level responses observed during these tests have been influenced by the degree of fracturing within the sandstone, while delayed yield responses were evident in some tests. Transmissivity of the Coolbro Sandstone aquifer within shear zones appear to be around 20 to

60 m^2/day, with a corresponding hydraulic conductivity of about 1 to over 6 m/day. Outside the shear zones the aquifer permeability is an order of magnitude lower.

Pumping tests undertaken at the camp water supply bores, North Bore and TPB16, north-west of Kintyre demonstrates the significant changes in permeability that can occur in the Coolbro Sandstone over short distances. A transmissivity of 66 m^2/day has been determined for TPB16, with a corresponding hydraulic conductivity of 2.4 m/day, while a transmissivity of 32 m^2/day (hydraulic conductivity of 1.1 m/day) was calculated for North Bore situated only 43 m from TPB16. If the early-time data before leakage effects is used, then the transmissivity at North Bore is calculated as 5 m^2/day and the hydraulic conductivity 0.17 m/day.

Storativity values of 3.7×10^{-4} to 2.9×10^{-3} have been determined from pumping test observation bores, but these values may be elevated due to the influence of unconfined conditions. Specific storage values of between 1.3×10^{-5} and 5×10^{-5} (/m) are derived from these storativity values, but these are probably an over-estimate of specific storage.

4.2.3 Rudall fractured rock aquifer

The Palaeoproterozoic schist rocks have practically no intergranular permeability (GRC, 1988), with permeability through most of the rock associated with secondary jointing and fractures. The weathered profile developed within the upper portion of the schist may also be of higher permeability. Zones of higher permeability are controlled by the presence of faults and shear zones, but are generally less permeable than those in the Coolbro Sandstone (Dames and Moore, 1988).

Background values of hydraulic conductivity for the schist have been estimated based on falling head tests in the deposit area to be 0.01 to 0.05 m/day (GRC, 1988), and expected to be in the range of 0.001 to 0.3 m/day (Golder Associates, 1989). Pumping test results from bores KEB1 and KEB2 yielded values for hydraulic conductivity of 0.03 and 0.02 m/day, which appear consistent with background permeability. Pumping tests of bores in fault and shear zones have yielded hydraulic conductivity values of around 0.2 to 0.6 m/day, and is comparable to values obtained from falling head tests of 0.4 and 0.6 m/day for holes intersecting steeply dipping faults (Groundwater Resource Consultants, 1988).

The confined storativity for the fractured rock aquifer is low, reflecting the low compressibility of the aquifer. Conditions may, however, change to semi-confined and unconfined relatively rapidly. Storativity values of 1.3×10^{-5} to 6.2×10^{-3} have been obtained from pumping tests, although it is suspected that the influence of semi-confined conditions has resulted in calculated values higher than the actual storativity. A storativity of less than 1×10^{-5} is considered likely for the fractured rock aquifer, with a specific storage of between 10^{-6} and 10^{-7} (/m). The long-term specific yield for the Palaeoproterozoic fractured rock aquifer was estimated as 3% (GRC, 1988). A value of less than 1% is probably more appropriate for the tight fractured rock at Kintyre.

4.3 Groundwater Dynamics

4.3.1 Groundwater Recharge

Groundwater is recharged directly by rainfall over the Cenozoic deposits, unconfined portion of the Paterson aquifer and outcropping fractured rock units (Coolbro Sandstone and Rudall Complex) by the downward infiltration from infrequent and often heavy rainfall events. Most rainfall is lost through evaporation from the soil or surface inundation, and by plant evapotranspiration, and only a small portion of the water permeates through the weathered profile, sand or through fractures to the watertable to recharge the groundwater system. Higher infiltration recharge rates are possible about the valley margins from surface runoff discharging from the plateau area, and along Yandagooge Creek and other tributary channels.

In the Project area recharge rates are low, which is typical of an arid climate. The average annual groundwater recharge rates have been estimated to range from 0.35 mm over the Rudall Complex, up to 2.8 mm for the Paterson Formation, and 3.5 mm over the Coolbro Sandstone. Since 1994 the average rainfall has been about 50% higher than the preceding 20 years, which has resulted in an increased rate of recharge over this period that may have been up to 5 times the long-term recharge rate.

Groundwater in the confined portions of the Paterson aquifer is recharged via slow downward movement of water where there is a downward hydraulic gradient from the unconfined portion through the intervening low permeability lacustrine siltstone and claystone. The rates of downward recharge will be larger where the confining beds are thin or absent, as seen in the upper valley catchment at sites 9P, 10P and CWB3D. Groundwater may also recharge the lower Paterson aquifer by upward leakage from the underlying fractured rock aquifer where there is an upward hydraulic gradient between the units. This appears to be a significant means of recharge over the western portion of the valley adjacent to the plateau area comprising Coolbro Sandstone, but is only minor toward the centre of the Palaeochannel where there is a small vertical hydraulic gradient (Dames & Moore, 1988).

Recharge areas

Groundwater recharge rates in the Project area are influenced by the surface geology, topography, depth to watertable and vegetation cover. Higher recharge rates are associated with outcrop areas of the Coolbro Sandstone where it forms a dissected plateau. Over the plateau rainfall can directly infiltrate into the fractured rock and along many of the small drainage lines where surface runoff would concentrate and infiltration may be greatest. The lowest groundwater salinity obtained in the Project area has been obtained from the Coolbro Sandstone adjacent to the plateau outcrop areas, which is an indication of relatively high groundwater recharge rates.

Modest rates of groundwater recharge are anticipated over the valley surface which comprises Cenozoic silts and sand over subcropping Paterson Formation. The initial infiltration of rainfall over the valley surface may be significant, but subsequent losses via plant evapotranspiration will account for most of this water, reducing the net rate of groundwater recharge. Seepage of runoff from the adjacent Coolbro Sandstone plateau appears to be an important source of recharge water to the aquifer, contributing low salinity groundwater over the western portion of the palaeochannel (Dames and Moore, 1988). Infiltration of ephemeral stream flow along Yandagooge Creek may also contribute to groundwater recharge.

Elevated groundwater salinity is associated with the Rudall Complex outcrop, including the Kintyre pit area. This high groundwater salinity reflects the low rates of groundwater recharge experienced over this poorly permeable fractured rock aquifer unit.

Recharge rates

Recharge rates in semi-arid to arid climates mostly range from 0.1 to 5% of long-term average annual precipitation (Scanlon, et al., 2006). There are several methods for the calculation of groundwater recharge rates, of which the chloride mass balance method is the most widely used in semi-arid to arid climates. The watertable fluctuation method may also be applied at Kintyre.

The chloride mass balance method calculates the recharge rate of groundwater as a portion of rainfall by using the ratio of chloride ion in rainfall relative to that in groundwater.

Precipitation of chloride for inland areas of north-west Australia is reported to be 2-3 kg/ha for 1973 (Hingston & Gailitis, 1976). At Kintyre, taking chloride precipitation as 2.5 kg/ha and an average annual rainfall of 350 mm (Telfer is 369 mm for 1974-2012), the chloride concentration in rainfall is about 0.7 mg/L. There is, however, uncertainty in what the actual chloride precipitation is at Kintyre (approx. ±20%) and the long-term average annual rainfall for the area (approx. ±10%). For the chloride mass balance method to be applicable for calculating groundwater recharge rates, precipitation (as rainfall and dry-fall) would be the only source of chloride in the groundwater, there should be no other sources of chloride in the aquifer, such as an area of evaporative groundwater discharge up-gradient, and there would be no surface runoff from the aquifer area. The method should be applied to the unconfined aquifer with water sampled from near the watertable.

Table 4-3 presents groundwater salinity and chloride data for bores considered most suitable for the chloride mass balance method, for which recharge rates are calculated. There are no water bores constructed within the unconfined portion of Coolbro Sandstone, however, water from bores 2PS and OB16 within the Coolbro Sandstone adjacent to the outcrop area are considered representative for recharge. Runoff from the plateau area is likely to result in the chloride mass balance method somewhat overestimating the recharge rate due to a portion of the rainfall and associated chloride anion being removed from the aquifer area. The chloride mass balance indicates recharge rates of 5% and 1.2% of rainfall. A recharge value of around 1% rainfall seems likely, which would be equivalent to an annual recharge rate of about 3.5 mm.

For the Paterson Formation, most monitoring bores are within confined portions of the aquifer, with only 5 existing monitoring bores (1PS, 9PS, CWB3s, WEX3 and WEX4) slotted over relatively shallow portions of the unconfined aquifer. Bores 9PS and WEX3 are located adjacent to branches of the Yandagooge Creek which may have influenced the groundwater salinity and chloride content through the infiltration of surface flow, and are also located in close proximity to the Rudall Complex. Groundwater from these bores is of a higher salinity, suggesting an input of high salinity water from the creek, an evaporative concentration of groundwater in the area or contribution from the adjacent Rudall Complex. The remaining bores, 1PS, CWB3s and WEX4, indicate recharge rates of between 0.5 and 0.8% of rainfall, which is equivalent to 1.8 to 2.8 mm per year. In most of the area, groundwater within the deeper portions of the Paterson aquifer appear to be influenced by plumes of higher salinity groundwater emanating from the area about bore sites 4P-5P and 9P, and therefore are not suitable for estimating groundwater recharge rates.

Table 4-3: Recharge rates calculated using Chloride Mass Balance (CMB) method

Bore	Interval (mbgl)	Salinity (mg/L)	Chloride (mg/L)	Date	Recharge (%annual rainfall)
Coolbro Sandstone					
2PS	37.5-43.5	103[a]	14	Nov 2010	5%
OB16	40.75-64.75	252 [a]	60	Sept 2010	1.2%
Paterson Formation					
1PS	23.6-29.6	646 [a]	120	Oct 2011	0.6%
9PS	32.8-38.8	4,640 [a]	1,600	Nov 2010	0.04%
CWB3s	12-30	884 [a]	88	Oct 2011	0.8%
WEX3	28-124	2,750 [a]	1,100	Oct 2011	0.06%
WEX4	28.5-118.5	608 [a]	140	Oct 2011	0.5%
Kintyre pit area					
13PS	32.6-38.6	2,298[b]	747	Jan 1988	0.09%
KWP1	23.9-119.9	6,440 [a]	2,300	Oct 2011	0.03%
KWX4	24-96	5,527 [a]	1,800	1997	0.04%
KWX11	39-75	1,050[c]	320	March 2010	0.2%

Notes: a – sum of ions; b – TDS by calculation
c – Field salinity 3680 mg/L in May 1997

Monitoring bores in the Kintyre pit area which mostly represent the Rudall Complex are slotted over an extensive section of the unit, so that groundwater yielded from each bore is a mixture from shallow to deep portions. It is anticipated that the salinity of water about the watertable will be less than from deeper sections. Chloride ratio values of between 0.02% and 0.2% have been obtained, with the most representative value considered to be about 0.1% of rainfall from bore 13PS which is slotted over the shallowest interval. This is equivalent to about 0.35 mm/year annual recharge.

Long-term monitoring of water levels shows that there has been a significant rise between 1988 and 2010, which corresponds to a period of higher annual rainfall commencing in 1994. In the unconfined portion of the Paterson aquifer water levels have risen between 1.3 and 3.4 m (1PS 1.3 m; 3PS 3.4 m; 9PS 1.4 m) over this period. This implies an average annual net rise of 81 mm to 212 mm over the 16 years, which is equivalent to a recharge rate of about 8 to 21 mm since 1994, assuming a specific yield of 0.1 for the upper Paterson or Cenozoic aquifer. Rainfall records for Telfer show that the annual rainfall has been significantly greater since mid-1994. Since 1994, Telfer experienced an average annual rainfall of 452 mm compared to an average of 300 mm before that period (1974-1993). There have been eight years when the seasonal rainfall (July to June) has exceeded 500 mm after 1994, with 800 mm recorded during 1999-2000. It is concluded that recharge rates have been significantly higher than the long-term average during the period from 1994, with the increase in groundwater recharge being proportionally much larger than the 50% increase in rainfall.

Bore 9PS is the only suitable bore slotted in a shallow portion of the unconfined Paterson aquifer for which down-hole transducer monitoring data has been collected that could be used to assess gross groundwater recharge in response to separate rainfall events. A series of rainfall events during late-March to mid-April 2012 (totaled 56 mm in Telfer) were associated with a water level rise of about 0.1 m in 9PS. This would imply a gross recharge pulse of approximately 10 mm (aquifer specific yield of 0.1), while later losses due to evapotranspiration would result in a lower net recharge to the aquifer. There are no other obvious correlations between rainfall and increased water levels in the monitoring data.

4.3.2 Groundwater Levels and Flow

Water level data is compiled from investigation boreholes in the Project area, which are limited to within about 8 km of Kintyre. There are no stock bores in the area from which additional water level data could be obtained. The watertable is typically 10 m to 20 m below ground level.

An interpretive watertable contour plan for the Yandagooge Creek valley area is shown by Figure 4-1, which is based on static water level readings during 2011 from bores screened in the upper Paterson Formation. The figure shows that the watertable typically reflects the existing topography, with an average north-northeast gradient of 1:300. In the upper portion of the catchment the watertable exceeds 360 mAHD, and declines to about 348 mAHD around the convergence of the western and southern channels, reaching 344 mAHD in the northern-most bore 3PS. The watertable continues to decline northward beneath the main channel toward the Canning Basin, although there are no observational data to define the levels.

Figure 4-2 shows the interpreted potentiometric head within the confined Paterson Formation aquifer present beneath the Yandagooge Creek valley. The potentiometric head is similar to the watertable, and is typically within one or two metres of the watertable. Groundwater flow is to the north in the west branch and to the northwest in the south branch, and then converges to flow northward along the main valley trunk toward the Canning Basin.

The complexity of groundwater flow through the Paterson aquifer is reflected by the variability seen in groundwater ages. As part of the Palaeovalley Groundwater Project, Geoscience Australia collected groundwater samples and undertook ^{14}C isotopic analysis on four samples collected from boreholes WEX2, CWB8d, WEX5s and WEX5d in the Project area (Lewis, 2011). All samples were from confined portions of the Paterson aquifer, and yielded groundwater ages of between 1,880 and 15,915 years Before Present (Table 4-4).

As would normally be expected, groundwater ages are younger in the shallower portions of the aquifer, noted at site WEX5, due to the downward infiltration of young recharging water and possibly more rapid groundwater flow through the upper part of the aquifer. The youngest groundwater of 1,880 years was found from WEX2 located at the lowest point of the western palaeochannel branch. Groundwater at this site would have been mostly recharged upon the plateau flanks about 2 km to the west, which implies a groundwater flow rate of about 1 m per year in this part of the aquifer. Groundwater in the south palaeochannel branch from CWB8 is almost twice the age of that at WEX5D within the same portion of the lower Paterson aquifer. This pattern of groundwater becoming younger in the direction of groundwater flow is the reverse of what would be expected, and suggests that there is an influx of younger groundwater to the aquifer down-gradient of CWB8.

Table 4-4: Carbon-14 isotope age dates from the Paterson aquifer near Kintyre (after Lewis, 2011)

Bore	Age (years)	PMC	Interval (mbtoc)	Geological unit
WEX2	1,880 +/- 15	78.56 +/- 0.16	44-128	Lower Paterson Formation
CWB8D	15,915 +/- 40	13.69 +/- 0.07	103-139	Lower Paterson Formation
WEX5S	4,496 +/- 20	56.72 +/- 0.13	20-38	Upper Paterson Formation
WEX5D	8,328 +/- 20	35.21 +/- 0.1	93.5-129.5	Lower Paterson Formation

Note: PMC – Percentage Modern Carbon

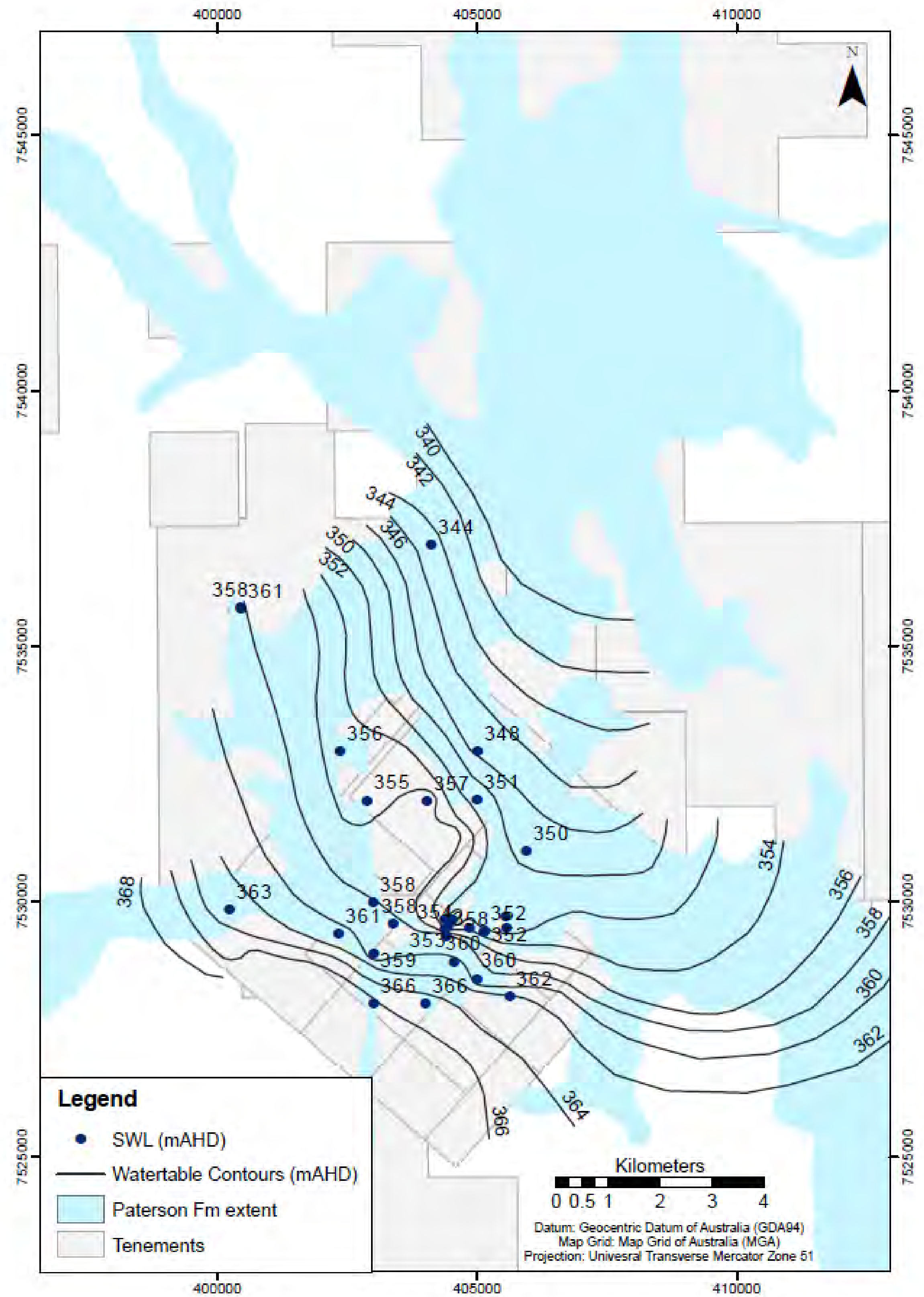

Figure 4-1: Interpretive watertable contours for the Yandagooge Creek valley

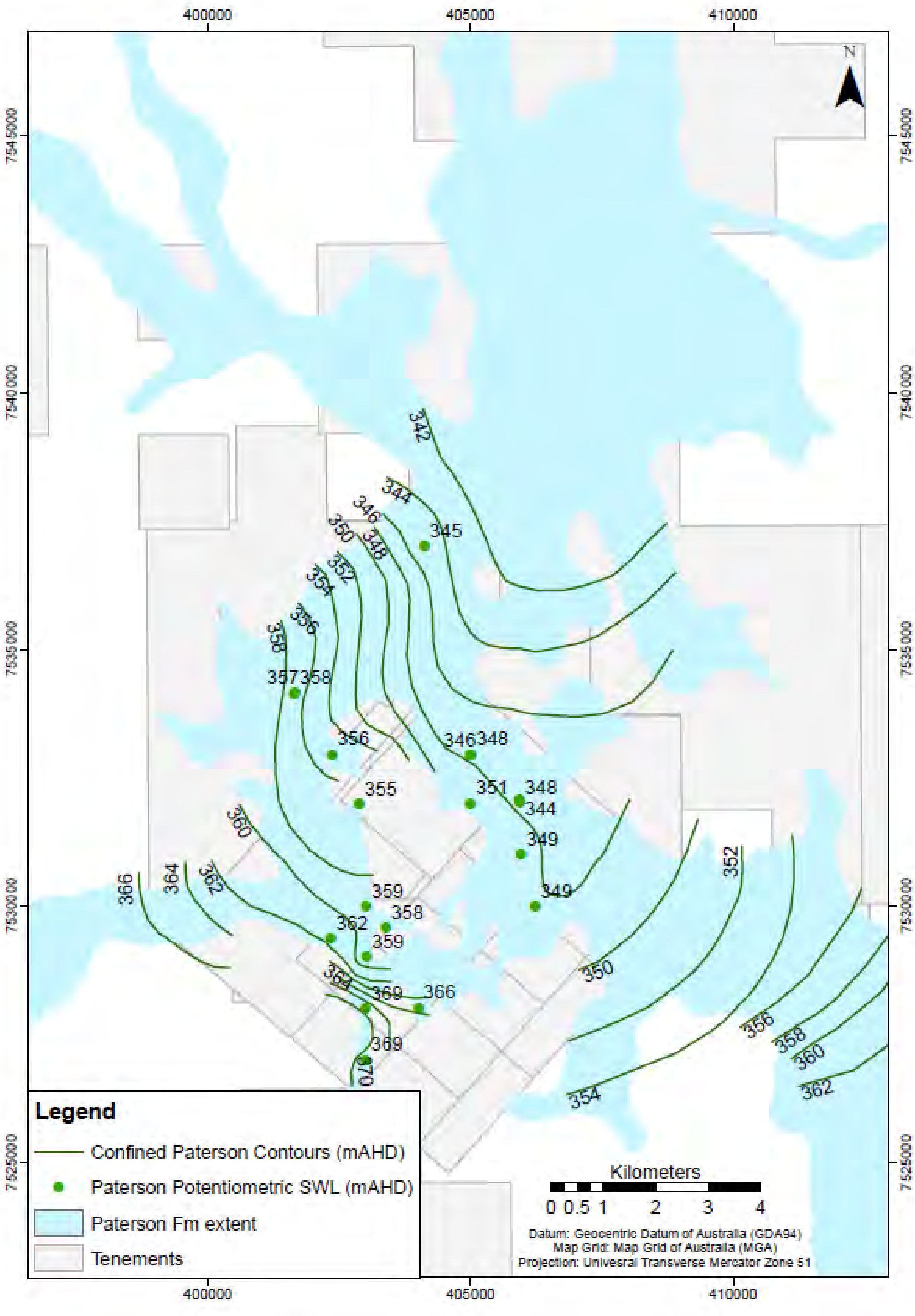

Figure 4-2: Interpretive potentiometric heads in the Paterson Formation

4.3.3 Groundwater Discharge

Groundwater may be lost from about the watertable through the up-take and evapotranspiration by plants where the watertable is sufficiently shallow. Evapotranspiration discharge of groundwater from the watertable is unlikely to be significant in an area of relatively dense vegetation situated along Yandagooge Creek about 2 km north-east of borehole site 3P, due to the watertable depth that is anticipated to be approximately 20 m based on the northward extrapolation of water levels (Figure 4-1). The watertable is too deep for direct evaporation in the Project area. Groundwater contained in the confined Paterson Formation aquifer and possibly underlying fractured rock aquifer can leak upward to the watertable where there is an upward vertical hydraulic gradient through the aquifer, which is expected to be more prevalent through northern portions of the main channel. A small portion of groundwater is also currently withdrawn from the aquifer by pumping bores for water supply requirements at Kintyre.

A component of groundwater flows northward and passes into the Canning Basin north of the plateau.

4.4 Groundwater Quality

Groundwater salinity in the Project area is variable, but is generally fresh to moderately saline. The best quality water (TDS <1,000 mg/L) is found in Coolbro Sandstone and in the Paterson aquifer about the western portion of the valley between 5 to 10 km west and north of Kintyre. Data is available from 56 bores in the vicinity of the deposit and across three distinct hydrogeological units.

The data from these bore clusters reveal groundwater interaction and movement in the region is complex. Most bore clusters show groundwater salinity increasing with depth, but this is not consistent across the Project Area. The piper diagram in Figure 4-3 provides a summary of analyses since monitoring began in 1987. The diagram shows that the groundwater in the region varies from sodium bicarbonate, to sodium chloride, to calcium sulphate. Figure 4-4 displays the spatial distribution of these classes across the Project area. Most waters lie in the sodium chloride field, which is expected of groundwater recharged by rainfall. Figure 4-5 shows that sulphate, bicarbonate and chloride concentrations are elevated in bores surrounding the Rudall Complex at Kintyre. The groundwater chemistry distribution suggests that there is interaction between the groundwater and aquifer materials. Dissolution of carbonate rocks may contribute to calcium and carbonate ions, while sulphate may have been mobilised through oxidation of sulphide minerals. The groundwater chemistry pattern suggests that groundwater flow is away from the proposed Kintyre pit area.

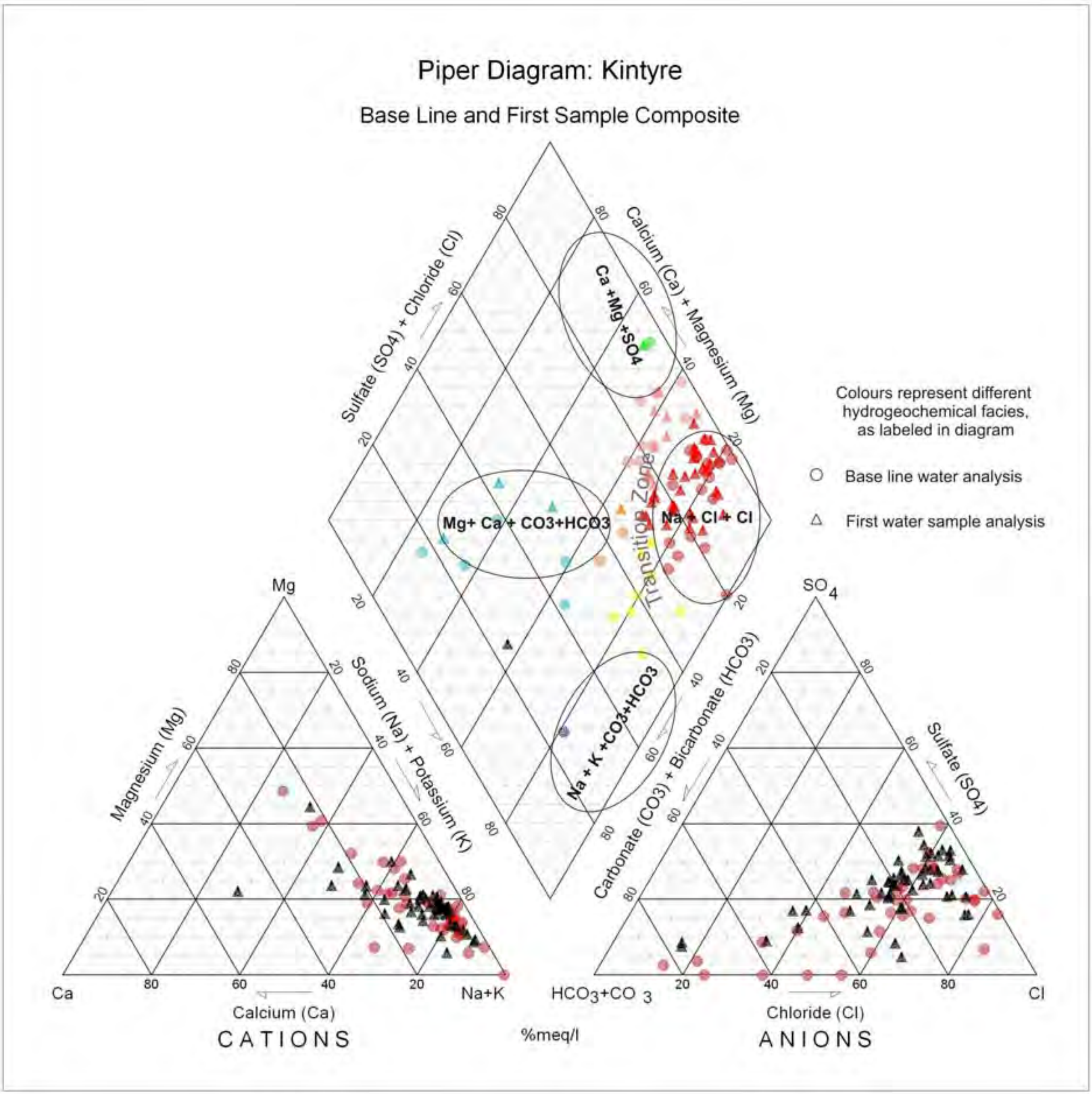

Figure 4-3: Piper diagram showing variation in water quality speciation

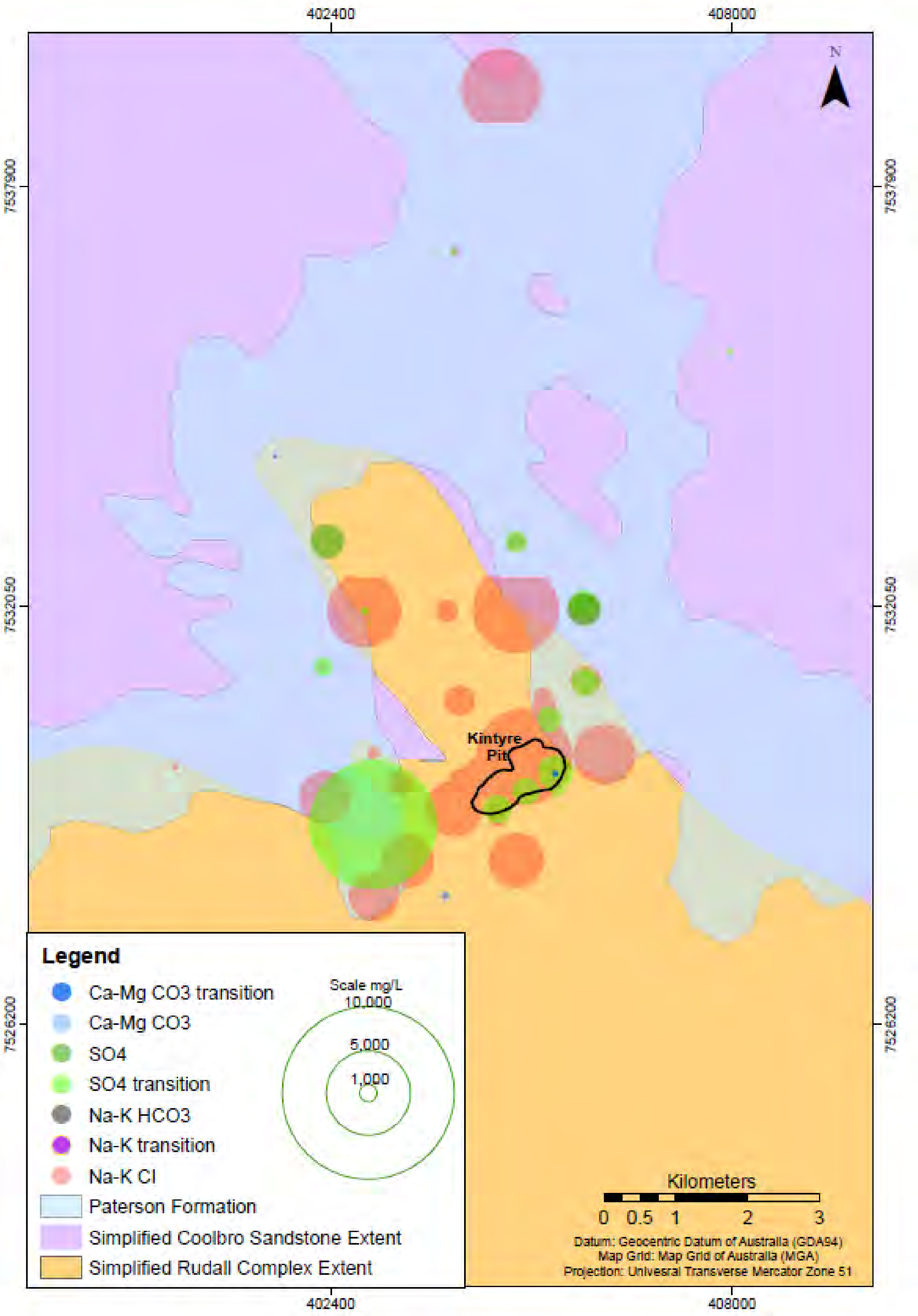

***Figure 4-4*: Groundwater class distribution**

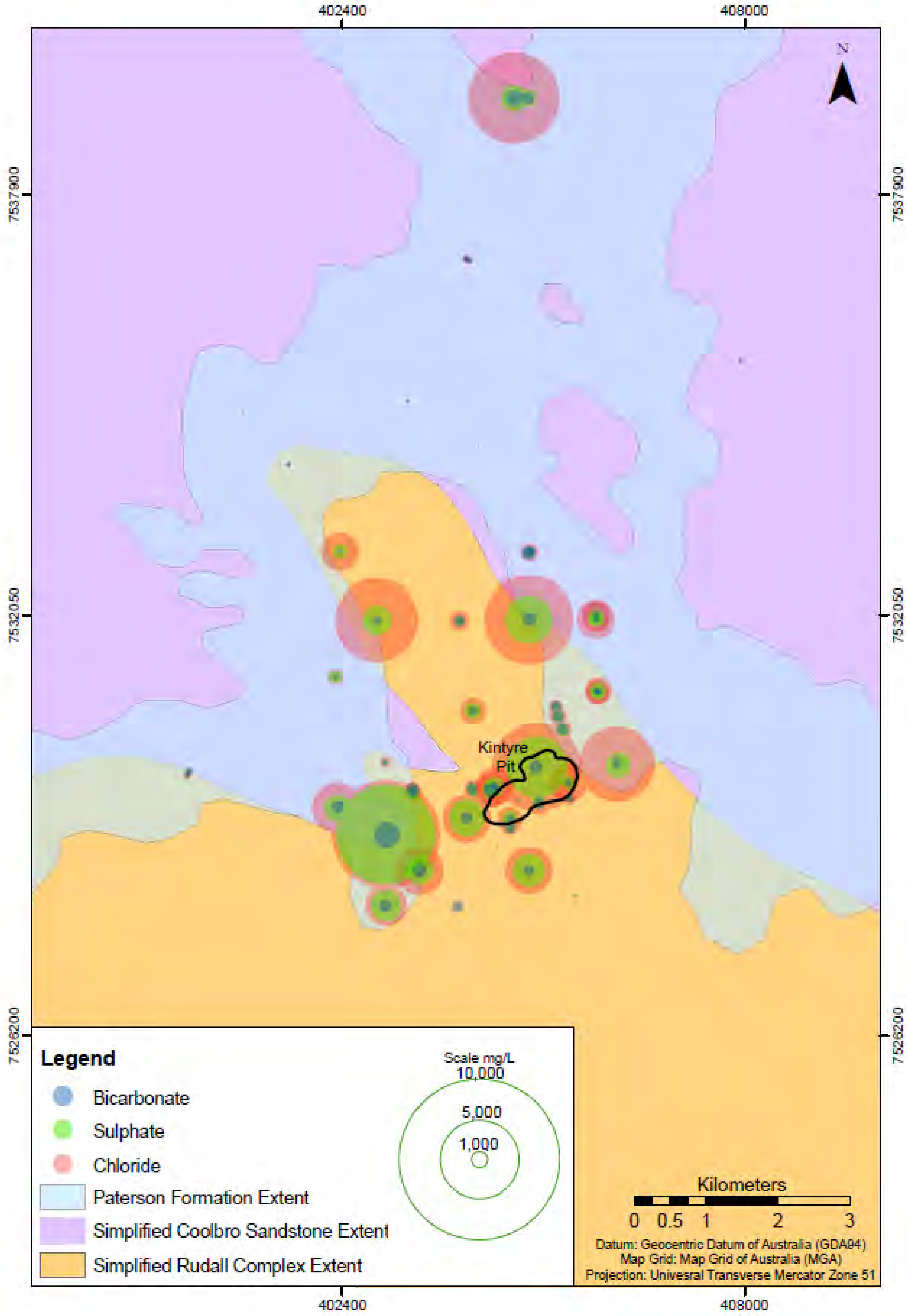

Figure 4-5: Chloride, Sulphate, and Bicarbonate ion concentration in groundwater

4.4.1 Upper Paterson aquifer

Groundwater from the upper Paterson Formation has elevated levels of sodium, chloride, sulphate, hardness and alkalinity compared to the rest of the Project area. Groundwater salinity ranges from 550 to 12,270 mg/L TDS, with concentrations generally increasing downstream toward the northeast. Seasonal salinity fluctuations of about 200 mg/L TDS is probably related to watertable recharge from runoff over nearby Coolbro Sandstone outcrops.

Uranium (U) concentrations range from 1–130 µg/L and tend to increase toward the Kintyre uranium deposit. Higher concentrations centred east of the deposit were interpreted as being down-gradient from the zone of mineralization, resulting in accumulation of U in upper reaches of the Paterson Formation. These levels reached concentrations up to 10 times (100 µg/L) typical background levels.

Radium^{226} concentrations in the upper Paterson Formation are relatively constant throughout the monitoring period (1987 to 2012), and do not appear to be influenced by the uranium mineralisation.

4.4.2 Lower Paterson aquifer

Groundwater chemistry from the basal section of the Paterson Formation is less variable relative to the upper Paterson aquifer or from the Palaeoproterozoic Rudall Complex. As with the upper Paterson Formation, groundwater is generally of the sodium chloride type, containing high sulphate concentrations in some samples. Groundwater salinity ranges between 500 and 5,000 mg/L, with the lowest salinity around recharge zones associated with nearby Coolbro Sandstone outcrop.

Uranium concentrations are greatest surrounding the zone of mineralization (100 µg/L) and decreases spatially in all directions from the deposit until returning to background levels (~10 µg/L). Groundwater through flow and dispersion emanating from the deposit or possibly through mineralized boulders associated with basal conglomerates may have led to the development of this concentration halo (Dames & Moore, 1993).

4.4.3 Coolbro Sandstone aquifer

Groundwater within the Coolbro Sandstone aquifer adjacent to the plateau outcrop area in the western portion of the valley has relatively low groundwater salinity from boreholes (North Bore, TPB16 and 7PD) of between 230 and 733 mg/L. Groundwater salinity is higher beneath the southern portion of the western branch where values of 750 – 820 mg/L TDS have been recorded in CWB6D.

Within the Kintyre Shear Zone near the proposed mine pit groundwater salinity increases with depth from around 2,200 mg/L TDS in 13PS (33-39 mbgl) to over 4,000 mg/L TDS in 13PD (62-68 mbgl). In near-by bore ‘M’ a similar groundwater salinity of around 2,500 mg/L TDS was found. The inlier of Coolbro Sandstone east of the Kintyre Shear Zone adjacent to the proposed mine pit area has yielded groundwater salinity of between 1,050 mg/L and 6440 mg/L TDS from slotted intervals variously over 24 to 127 m depth (bores KWP1, KWX11 and KEB1). A pattern of increasing salinity with depth is evident, with around 1,000 mg/L about the watertable to over 6,000 mg/L below 120 m depth.

Although the groundwater chemistry is typically sodium–chloride type, it also contains a significant portion of bicarbonate and variably sulphate.

4.4.4 Rudall Fractured Rock aquifer

Groundwater from the Palaeoproterozoic Rudall Complex rocks in the Project area show the largest chemical composition range. Generally these waters are rich in sodium chloride with appreciable sulphate and bicarbonate content. Groundwater salinity exceeds 10,000 mg/L in proximity to the mineralised zone, but decreases with distance away from the Kintyre deposit to between 1,000 and 5,000 mg/L TDS. The lowest salinity groundwater is typically found along permeable sheared rocks near drainage channels, although the actual distribution is complicated and not yet fully understood.

Uranium content and radioactivity are highest in the area of mineralisation, declining down-gradient to background levels of about 10 µg/L (Dames & Moore, 1988). About the mineralised zone, Dames & Moore (1988) quote an upper activity value of 130 000 Bq/m^3 and uranium concentrations up to 500 ug/L.

5. WATER DEVELOPMENT PLAN

5.1 Pit Dewatering Strategy

Advanced dewatering of the pit area will commence during the construction phase over a period of two years, following which progressive dewatering will occur over 9.5 years as the pit floor is deepened. Pumping from dewatering bores will cease at the end of mine activity and water allowed to seep into the pit. The site will then undergo rehabilitation over a two year period as part of the site closure plan.

The volume of water produced and timing from bores and sumps of pit dewatering depends on the choice of dewatering approach, which would in turn be determined by cost-benefit analysis of the various dewatering options. The dewatering options include: in-pit sumps, out-of-pit dewatering bores, and horizontal seep wells. Figure 5-1 represents a schematic of pit dewatering operations and theoretical groundwater response, described below:

- **In-pit sumps** are by far the most cost effective means of dewatering an excavation, but mean that the excavation floor is always wet, which can cause a significant nuisance value during mining. A wet floor can also preclude the use of some of the lower cost dry mining methods such as continuous miners.
- **In pit dewatering bores** are effective at keeping the floor of the excavation dry, but cause extensive logistical impact on mining operations because of the need to install and then remove the pipework and pumps between the blast and cut of each flitch of the excavation.
- **Out-of-pit dewatering bores**, especially those that target deep fault structures beneath the excavation, have minimal impact on mining operations, but also tend to be the least effective means of dewatering an excavation due to their distance from centralised areas of the pit.
- **Horizontal seep wells** are important for lowering the pore pressure on the pit walls and thus increasing wall stability, however they do little to increase the effectiveness of dewatering.

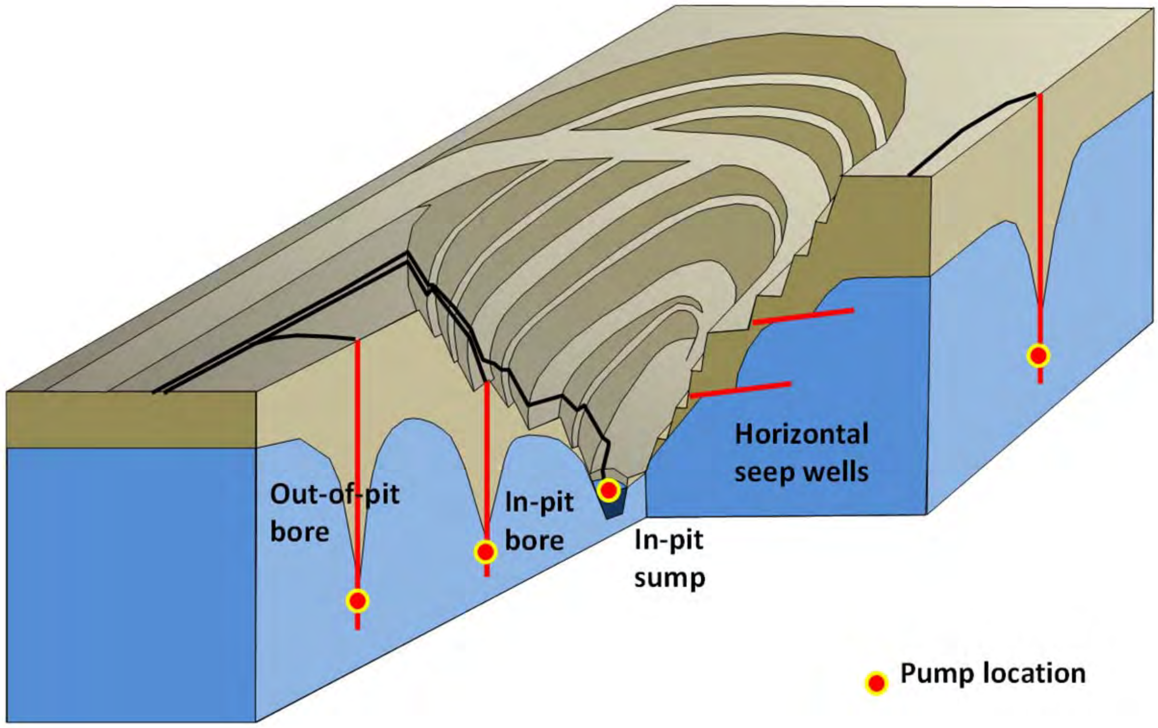

Figure 5-1: Schematic of dewatering operations

5.1.1 Basis of dewatering design

The Kintyre pit will be progressively mined to a depth of 270 metres below ground (being 250 metres below the watertable) over a period of 9.5 years. The final pit shell will be an ellipsoid with 1,450 m on the long axis and 730 m on the short axis, with a total excavated footprint area of 72 hectares.

The pit is hosted by schistose Rudall Complex and Coolbro Sandstone that have a low to moderate primary permeability and storage. Groundwater permeability occurs mainly in secondary faults, shears zones and fractures, of which there are at least three prominent structural targets identified. A minor tributary palaeochannel of the Paterson Formation extends into the southern portion of the pit area with an interpreted saturated thickness of up to 40 m.

Previous bores around and within the pit area have mostly yielded less than 25 kL/day, but bores intersecting fractures have yielded more than 160 kL/day. One bore located in a shear zone to the northwest of the pit recorded a yield of 180 kL/day. It is anticipated that at least 3 in every 4 bores will fail to make more than 100 kL/day.

5.1.2 Dewatering development plan

Not every hole drilled in fractured rock aquifers produces an economic yield or water quality. Based on a cut-off yield of 100 kL/day, we anticipate that the Rudall Complex rocks are likely to have a targeting success rate of 1 successful bore for every 4 exploration holes drilled, with an anticipated average successful bore yield of between 100 kL/day and 200 kL/day.

- Eight (8) exploration air holes will be drilled to target deep fault or shear structures around the pit, including the apparently productive Kintyre Shear Zone (see Figure 5-2). Only those holes yielding more than 100 kL/day on airlift will be completed as fully screened with either 155 mm i.d. or 205 mm i.d. uPVC as production dewatering bores. All other pilot holes will be completed as 100 mm i.d. uPVC monitor holes. We anticipate that there will be between 3 and 4 out-of-pit dewatering holes.
- One exploration bore will be drilled within the palaeochannel tributary adjacent to the southern portion of the pit and completed as a production dewatering bore.
- Out-of-pit dewatering holes will be pumped to a central turkey's nest dam, which will be used as the main construction and dust suppression water source in the 6 months prior to mining;
- If significant yields are intersected in the out of pit bores, three (3) supplementary in-pit dewatering bores may be constructed once the pit excavation reaches the watertable. These bores will target the continuation of productive structural features beneath the pit. The discharge from the in-pit dewatering bores will be piped out of the pit;
- As the excavation progresses beneath the watertable, 50 metre long horizontal seep wells (slightly inclined) will be drilled into the foot wall and hanging wall to improve the wall stability. The discharge from the seep wells will be allowed to free drain to the in-pit sump at the base of the pit.
- All seepage into the pit will drain to the base of the pit, where it will be collected in an in-pit sump. A float mounted surface pump in the sump will used to pump the discharge from the pit.

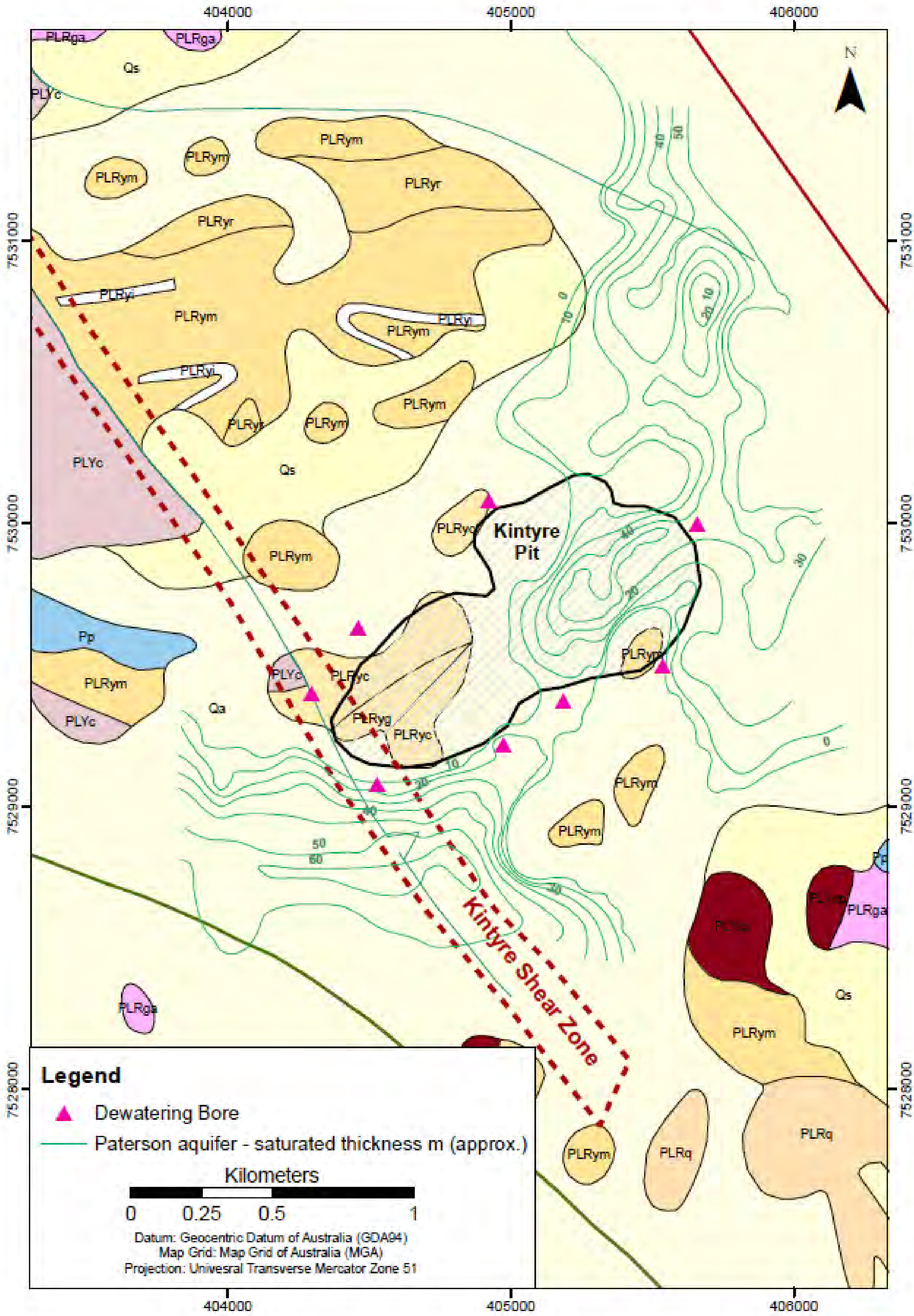

Figure 5-2: Potential layout of dewatering bores (see Figure 3-16 for geologic legend)

5.2 Process Water Borefield Development Strategy

The main source of makeup water for the Project will be a borefield developed in the Paterson Formation and Coolbro Sandstone.

5.2.1 Basis of borefield design

- The design peak demand for the borefield is 3,100 kL/day with a salinity less than 5,000 mg/L TDS. Based on an average bore yield of 500 kL/day, sustainable over a period of 13.5 years, the borefield will comprise a minimum of seven (7) duty bores, plus three (3) standby bores;
- Each bore will be located nominally 1.5 km apart (+/- 500 m) to minimise borefield drawdown interference;
- Final design drawdown in each bore should be no more than 50% of the total saturated depth above the base of screens in each bore;
- Each bore will have a minimum internal diameter of 205 mm, to be able to house a 6" pump submersible pump with a cooling shroud capable of delivering a yield of up to 1,300 kL/day from a static lift of 100 m; and
- The target aquifer in each bore will be a combination of Paterson and underlying Coolbro Sandstone. The Department of Water licences these units as being part of the same connected sedimentary aquifer and as such there is no requirement to seal between the units.

5.2.2 Borefield development plan

A registered Australian Drilling Industry Association (ADIA) drilling contractor holding a Western Australian Class 1 water well licence with mud rotary endorsement will be mobilised to site. The contract will complete an exploration pilot hole/monitor bore and a 205 mm i.d production water bore at each of the seven (7) drill sites, marked on as sites A to G (***Figure 5-3***). All holes will be drilled using a rotary air blast (RAB) / mud rotary drilling rig under the direct supervision of a hydrogeologist. Bore construction procedures will be in accordance with the following protocols, which comply with the *Minimum Construction Requirements for Water Bores in Australia – Version 3"* (ARMCANZ, 2012).

- **Pilot holes/monitor bores:** a nominal 165 mm diameter pilot hole will be drilled at each site using the rotary air blast (RAB) approach. Each hole will be drilled to whichever of the following occurs first: a nominal maximum depth of 200 m; or 50 m below the contact between the Paterson Formation and Coolbro Sandstone; or 6 m below the contact between the Paterson Formation and the Rudall Complex basement. Un-sieved rock chip samples will be collected every metre and logged to the AS1726-1993 standard (*the Australian Standard for Geotechnical Site Investigations)*. Airlift bore yields will be measured at each change in rods (every 6 metres) using a V–notch weir. Upon completion of the hole, the hole will then be geophysically logged to full depth using a gamma-long short normal resistivity sonde. The hole will then be completed as either a:
    - o (i) a **standpipe piezometer**; - in which case, the hole will be cased to full depth with 100 mm id Class 12 uPVC with 12 metres of machine slotted liner set opposite the

main water bearing zone. The annulus backfilled with 8/16 gravel stabiliser fill and the piezometer developed until the water discharge runs free of fines; or

- (ii) **multilevel grouted VWP piezometer**: - in which case a 32 mm i.d. uPVC tremmie pipe will be installed to full depth containing two (2) or three (3) vibrating wire automated water level monitoring piezometers at different depths. The hole will then be fully pressure grouted to surface in accordance with the VWP manufacturer's installation protocols.

- **Mud Rotary Production Bores**: a production water bore will be constructed 20 metres from each pilot hole. A 424 mm to 434 mm i.d. hole will be drilled to competent soil in the first 18 m depth and 340 mm i.d. steel surface casing installed and cement grouted in place to prevent loss of circulation. A 311 mm hole will then be drilled using mud-rotary methods and a PCI tungsten carbide bit to the combined Paterson Formation/Coolbro target. The hole will then be cased to full depth with 205 mm i.d. Class 12 uPVC, with machine-slotted (1 mm aperture) from 50 metres below ground to final depth. The annulus of the hole will then completely backfilled with 1.6 to 3.2 mm (sieve 8/16) graded gravel with a cement grout seal (minimum thickness 5 m) installed at ground surface. Finally, the bore will be developed by airlifting for up to 20 hours (occasionally up to 50 hours) to remove drilling mud and fine sediment. Airlift bore yields will be measured during development using a V–notch weir.
- **Hydraulic Testing:** Upon completion of each bore, the hole will be hydraulically tested with a minimum of 6 hrs of step rate tests, 72 hrs of constant rate and 4 hrs of recovery measurements.

5.3 Mine Closure

At the completion of the project, access to the mining area will be blocked off, stockpiles will be reshaped into stable landforms and surface water run-off from the waste landforms will be directed to the mining area via a series of drains. All pit dewatering will cease, dewatering bores will be decommissioned, and water levels in the pits will gradually recover.

The water level in the mining area is expected to rise due to the influx of direct rainfall recharge and groundwater seepage, until it comes to an equilibrium point where this influx is balanced by evaporation from the void forming terminal sink. The pit configuration could allow for the development of two independent pit lakes, one in the deeper northeast section of the pit and one in the shallower southwest section of the pit.

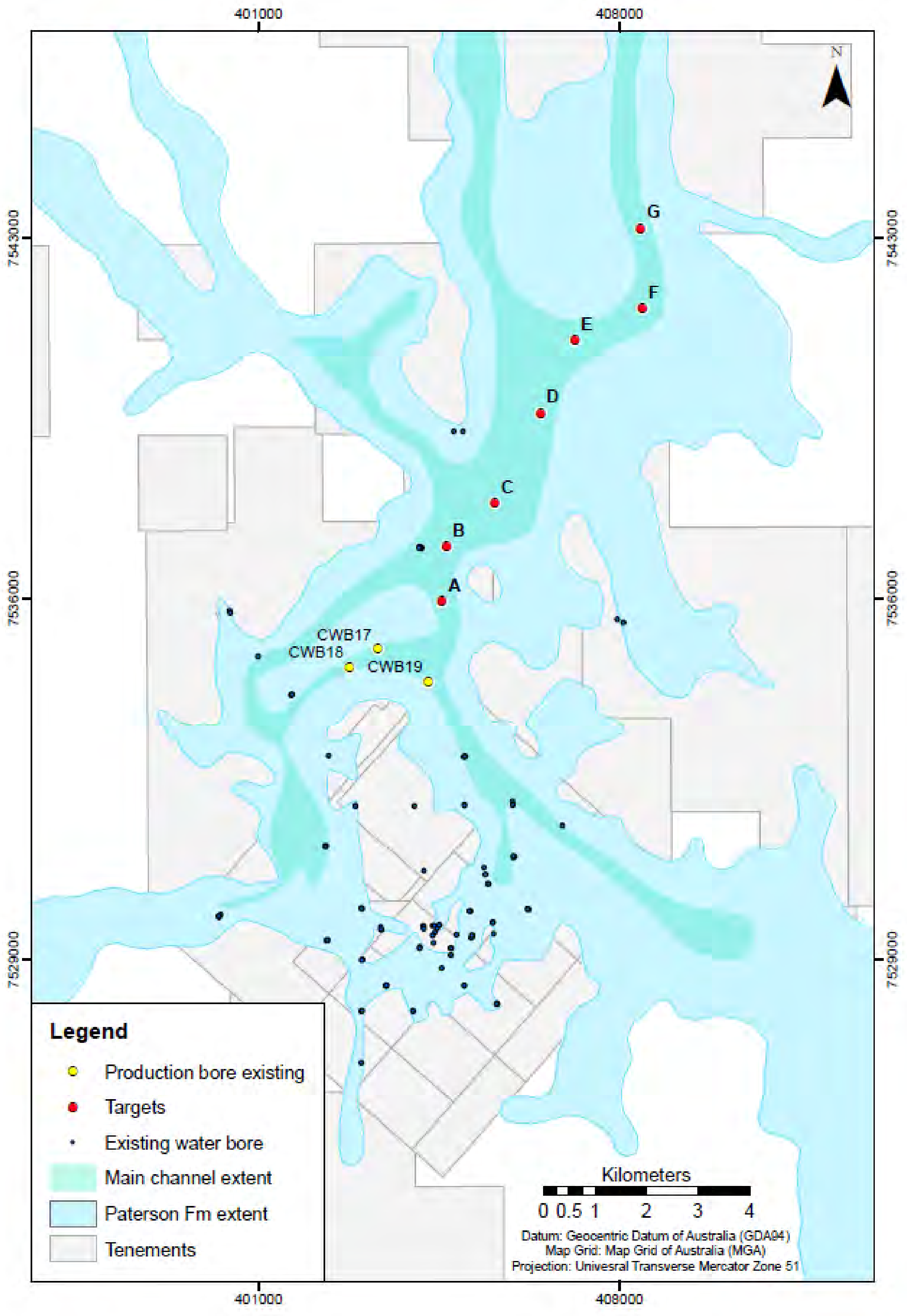

Figure 5-3: Proposed production drill sites

6. NUMERICAL MODELLING

A numerical groundwater simulation model was developed to evaluate abstraction from both the borefield and pit dewatering, and assess the likely impact from depressurisation of the associated aquifers. The model was developed using MODFLOW-SURFACT (HydroGeoLogic, 2010). A separate model was adopted to analyse pit dewatering and pit lake formation. Both models are discussed in detail in Tetra Tech (2012b).

6.1 Model Design and Calibration

An eleven layer model was developed to simulate the main stratigraphic units of the regional and local pit area. The model domain covers an area of 806 km^2 at a 500 m grid, with enhanced discretisation to 50 m around the pit (Tetra Tech, 2012b). Model parameterisation includes:

- The model boundaries are assigned a general head boundaries (GHB), albeit with one small horizontal flow barrier representing a fault near KEB1.
- Ten conductivity zones were used. Increased permeability was assigned to sediments of the Paterson Formation, Coolbro Sandstone and weathered sections of Proterozoic material.
- Cenozoic sediments were assigned the highest conductivity, representing unconsolidated sandy channels with gravel; however these are mostly unsaturated within the project area.
- Recharge was distributed across the domain in four units, commensurate with recharge calculations performed from chloride data in Section 4.3.1.
- The spatial permeability distribution was adjusted on a trial and error basis within the tight limits determined during the conceptual hydrogeology phase, Section 4.2, to achieve the best empirical matching between the observed recharge regime and the observed steady state regional water level distribution in observation and production bores.
- Vertical permeability distribution and storage parameters were further calibrated by adjusting values within tight limits to best match the observed transient water level response to several pump tests and recoveries.

An automated parameter estimation model (PEST; Doherty, 2012) was used to perform sensitivity analysis on each model parameter. Abstraction has been simulated at 5,000 kL/day, which is inclusive of a borefield 40% contingency. The final calibrated parameters are summarised in Table 6-1.

The final calibration is designed to be conservative (erring toward worst case) by overestimating water level drawdowns. Nonetheless, the overall difference between the observed and simulated water level elevations due to pumping is within 6% of measured data, which is considered to be an excellent calibration.

Table 6-1: Calibrated model parameters

Model Zone	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Storage (1/m)	Specific Yield
Cenozoic (higher K)	9.5	0.021	-	0.03
Cenozoic (lower K)	0.026	0.0017	-	0.03
Upper Permian (0-50 metres thick)	0.36	0.050	5.00E-07	0.03
Upper Permian (central channel)	0.097	0.050	5.00E-07	0.03
Lower Permian (>50 metres thick)	0.067	0.0021	5.00E-07	0.005
Weathered Basement	0.01	0.01	5.00E-07	0.0001
Broadhurst Formation	0.001	0.005	1.00E-06	0.01
Coolbro Sandstone	0.40	0.0001	1.00E-07	0.01
Basement Rock (higher K)	0.080	0.067	5.00E-07	0.0001
Basement Rock (lower K)	0.007	0.26	1.00E-07	0.001

6.2 Process water supply simulations

The maximum design Project demand is 3,100 kL/day, which will be drawn from a proposed borefield comprising 10 production bores (7 active water supply bores, plus 3 standby bores), pumping at an average rate of 500 kL/day over the mine life.

As a contingency measure, the borefield abstraction has been simulated at 5,000 kL/day, being 1,900 kL/day more than required.

The results of the model simulations of the water supply area demonstrate that there is more than sufficient borefield capacity and contingency to sustain an overall abstraction 3,100 kL/day over the mine life without causing unacceptable drawdown or loss of bore productivity.

6.3 Pit dewatering simulations

The cumulative impact of dewatering the Kintyre pit was simulated using the calibrated regional model in conjunction with the water supply simulation. Abstraction from out-of-pit dewatering bores was simulated using the MODELFLOW-SURFACT fracture well package, while dewatering from in-pit sumps was simulated using drain nodes,

The results of the cumulative dewatering simulations suggest that pit influx would stabilise at about 1,100 kL/day after the first 1.5 years, increasing only marginally as the pit is mined deeper. The cone of water table depressurisation will be a maximum of 220 m in the centre of the pit, decreasing away from the pit, with the limits of discernible drawdown impacts (nominally the 1 m drawdown contour) at the end of mining predicted to extend about 5 km from the pit (Tetra Tech, 2012b).

6.4 Pit lake water balance

Upon cessation of mining activities and active pit dewatering, the water table will partially rebound in the void forming two “pit lakes” (northeast and southwest) at the base of the void separated by a “land bridge". The bottoms of these lakes sit at final floor elevations of 128 and 210 m respectively, with both pits predicted to become a terminal sink for groundwater flow.

Pit lake simulation was undertaken using the LAK3 package (Merritt and Konikow, 2000), which couples both the lake water balance and groundwater flow models to allow transient stages of lake fill across multiple model layers.

Results show that lake water elevations will rise rapidly after cessation of mining and approach a steady state of around 267 mAHD in the northeast pit and 269 m in the southwest pit, after periods of 120 and 80 years, forming lakes of 5,710 and 1,890 ML in volume respectively (Tetra Tech, 2012b). At that time, both lake stages are predicted to have recovered to 99.5% of the maximum drawdown at the end of mining and evaporation rates to have stabilised. Water balance results also indicate that groundwater inflow accounts for about 57% of the total inflow to the northeast pit lake, and 70% of the total inflow to the southwest pit lake with outflow solely the result of evaporation.

7. IMPACT ASSESSMENT

The proposed Project will include pit dewatering of the Kintyre Pit, capture of all surface water runoff from disturbed mined areas, and the development of a 3,100 kL/day makeup water borefield in the water supply area over a mine life of about 10 years. After this time, pumping will cease, the aquifer will be allowed to recover and water levels in the pit void will be allowed to recover.

A detailed appraisal of the environmental and social impacts arising from groundwater development and operations highlights that:

- There is unlikely to be groundwater dependent vegetation in the area of drawdown impact. Two tree species that possibly could have some groundwater dependence are fairly robust to groundwater level changes and would likely be able to adapt to water level changes of 0.5-1.0 m/year;
- In areas where the drawdown rate is greater than 1 m/year (e.g. >10 m drawdown contour at the end of mine life, such as near North Bore and the Open Pit), possible localised impacts may occur on vegetation if these species are groundwater dependent.
- There should be no impact on waterholes and vegetation associated with Rudall River and Lake Dora as they are far outside of the zone of drawdown related to the Project;
- Several ephemeral river pools along the Coolbro and Yandagooge creeks are likely to be perched on clayey alluvial strata, fed by surface flows and therefore not affected by groundwater abstraction for the Project. Further monitoring will take place to confirm these findings in the next stage of the project, and develop triggers and contingencies if required;
- Of the stygofauna species have been identified in the Project area all or most are likely to occur elsewhere and are not likely to be threatened by development. Even if a species were localised, only a small fraction of the potential habitat within the aquifers impacted by the Project will be affected by drawdown.
- There are no other groundwater users within the area of potential impact and there will therefore be no impacts on other users.
- There are no sites of Aboriginal heritage significance that are anticipated to be impacted by the groundwater abstraction. Prior to bore construction, Aboriginal heritage surveys will be carried out for all areas to be disturbed, and infrastructure locations adjusted to avoid impact if required;
- Following mine closure, groundwater levels will gradually recover to a new equilibrium and two terminal pit lakes will form in the pit void. The minor changes in long-term groundwater levels relative to pre-development should have no significant impacts on groundwater dependent ecosystems, and as groundwater flow direction will be toward the pit there will be no impact from the pit lakes on groundwater quality.

A detailed Groundwater Operating Strategy has been prepared defining triggers and contingency actions for each potential impact. This is a living document that will be adapted in consultation with regulators as more information is obtained in each stage of the Project. A detailed analysis of these potential impacts is presented below.

7.1 Impacts During Mining

7.1.1 Environmental Impacts

7.1.1.1 Groundwater dependent vegetation

As outlined in Section 2.4.1, mapping of vegetation in the pit area indicated two tree species that have some potential to be groundwater dependent, Eucalyptus camaldulensis and Corymbia opaca. The species occur mainly along drainage lines. Similar geomorphological and soil conditions occur to the north of the pit area in the water supply area indicating that this species may also occur in these areas (Figure 2-5 2-5). Water levels in the known and potential areas of these species form 12-20 m below ground level. These deeper water levels indicate that these species are most likely mainly accessing water held in the unsaturated vadose zone; however it is possible that they also access some groundwater through deeper tap roots.

Tree species in the Pilbara that access groundwater are generally robust to moderate changes in water levels, provided the changes are slow enough that the trees can adapt by increasing their rooting depth (Woodward Clyde 1997).

Modelled water table drawdowns at the end of the Project are shown along with the actual and possible distribution of these tree species in shown in Figure 7-2. A modelled hydrograph in the centre of this possible vegetation zone is also shown in Figure 7-1. The results show moderate drawdowns in the vicinity of these tree species mainly in the range of 2 to 10 m, although some larger drawdowns (up to 50 m) occur in the immediate vicinity of the pit. The hydrograph shows that drawdowns are gradual at rate of about 0.5 to 1.0 m/year indicating that, if there is groundwater use by trees in these zones, adaption to the new regime is possible.

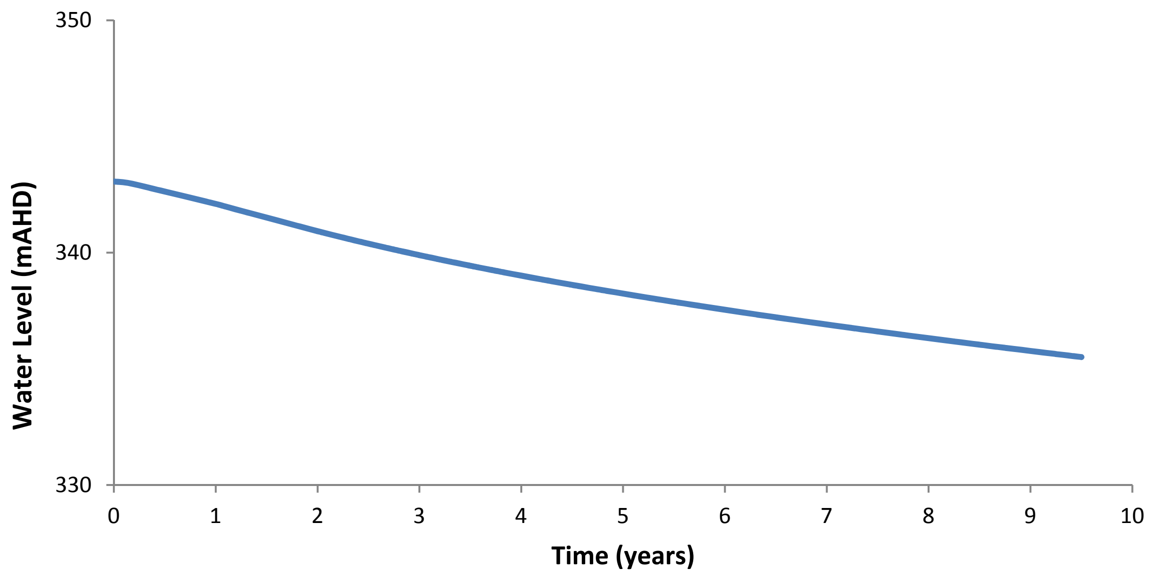

Figure 7-1: Modelled water table in the centre of the vegetation area, 6 km north of the pit

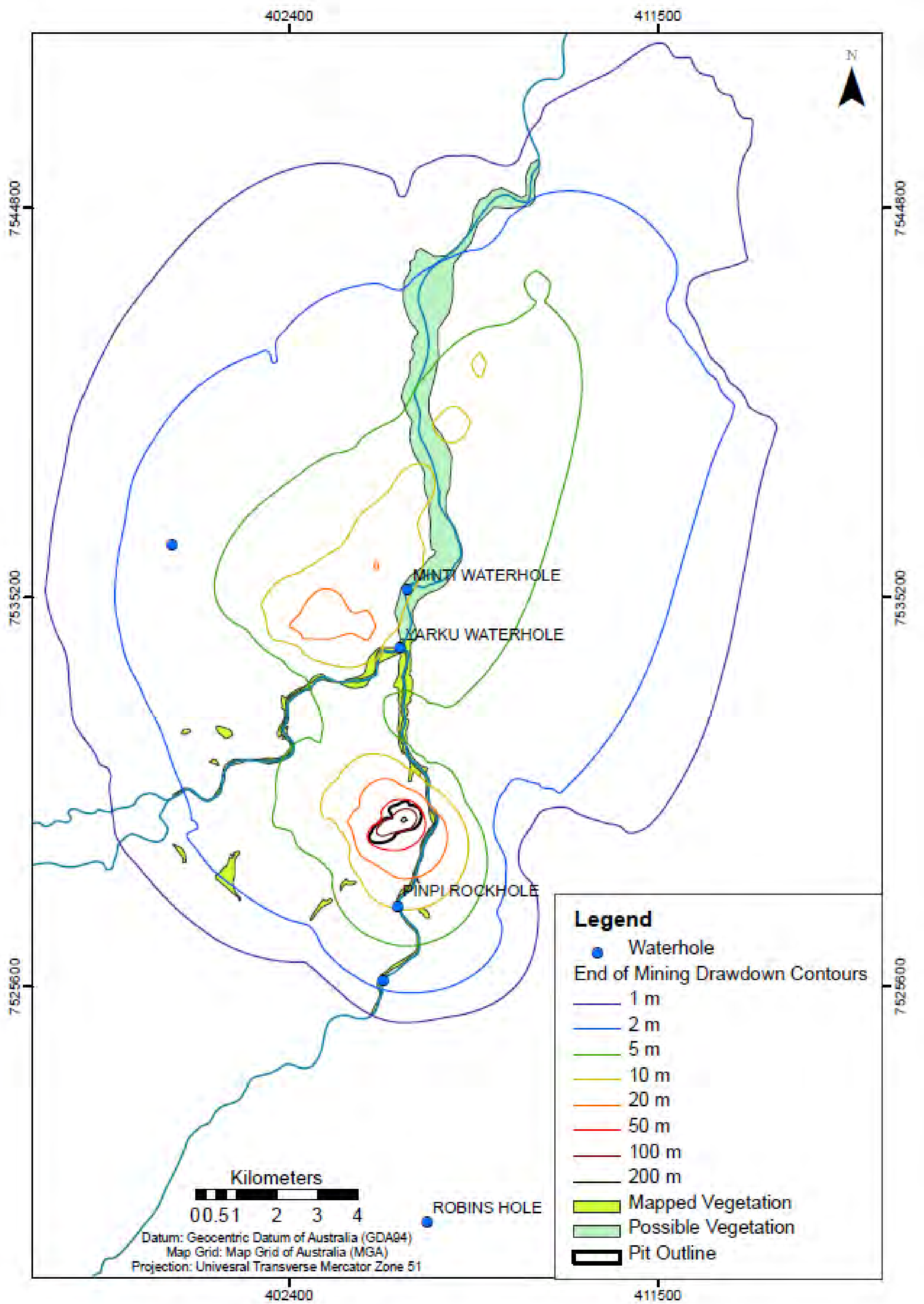

Figure 7-2 Modelled water table drawdown at end of mining (Project area)

In the next stage of the Project, further survey of vegetation will be undertaken in the water supply area to map potentially groundwater dependent species, and baseline monitoring water levels will be undertaken in these areas. Based on the baseline surveys, triggers for water levels near potential dependent vegetation and for vegetation condition indicators will be included in the Groundwater Operating Strategy along with associated contingency actions. Contingencies could include changing the distribution of abstraction among the bores in the borefield to reduce abstraction in sensitive areas; expanding the borefield to reduce the draw in sensitive areas; or developing alternative aquifers.

7.1.1.2 Rudall River/Lake Dora

The lower reaches of the Rudall River before it terminates at Lake Dora comprise a number of waterholes and soaks (Environ, 2010) which may be groundwater dependent. These are located about 60 km to the east of the water supply area.

Figure 7-3 shows the modelled drawdown at the end of the Project over the broader regional area. The 1 m drawdown contour, representing the extent of impact detectable relative to natural variability, extends about 10 km from the borefield area at its furthest. Given that this is more than 50 km from the lower reaches of the Rudall River, there will be no impacts on these waterholes and soaks.

7.1.1.3 River pools

Several ephemeral river pools occur along the Coolbro and Yandagooge Creek in the pit area and water supply area (Figure 2-3). As outlined in Section 2.3 these pools are ephemeral, filling only following significant streamflow events. They appear to be perched on clayey alluvial strata and fed by surface flows.

As mapped in Figure 7-2, drawdowns in these pool areas at the end of mining are modelled to range from negligible to about 10 m. However as the pools are not believed to be connected to the water table, no significant impacts on the pools are anticipated.

To confirm the relationship between the pools and the aquifer, in the next stage of Project, baseline monitoring of water levels and water quality will be initiated at key pool sites. Should the monitoring indicate a potential connection triggers and contingencies will be developed for pool impacts in the Groundwater Operating Strategy. Contingencies include changing the distribution of abstraction among the bores in the borefield to reduce abstraction in sensitive areas; expanding the borefield to reduce the draw in sensitive areas; developing alternative aquifers; or actively supplementing flows in the pools from groundwater pumping.

7.1.1.4 Subterranean fauna

Subterranean fauna include terrestrial species, known as troglofauna, and aquatic species, knowns as stygofauna. A subterranean fauna survey for the Project area involved taking around 200 samples for troglofauna and 150 samples for stygofauna (Bennelongia 2012). Samples were taken both within and outside of the area potentially impacted by the pit and drawdown in the aquifer from dewatering and the production borefield. The survey identified 23 troglofauna species and 15 stygofauna species. A comprehensive assessment of potential impacts on subterranean fauna is provided in Bennelongia (2012).

Troglofauna occur above the watertable in the unsaturated or vadose zone. While water level fluctuations may have some impact on humidity in troglofauna habitat, troglofauna are generally thought to be fairly robust to changes in water levels (Bennelongia 2012). Groundwater abstraction for the Project is therefore not likely to have unacceptable impacts on troglofauna.

The key objective of stygofauna conservation is ensuring that individual species are not threatened by development. Of the 15 stygofauna species identified in the Project area, 11 either have widespread occurrence or were identified outside of the zone of significant drawdown, and are therefore not threatened by the Project (Bennelongia 2012).

The remaining 4 are likely to be more widespread as well, but have just not yet been identified elsewhere. The aquifers with the most significant drawdown impacts, the upper and lower Paterson and Coolbro Sandstone, are all widespread and laterally connected. Because of the extent and continuity of this potential habitat, any stygofauna that occur within the impact zone in these aquifers are likely to occur elsewhere as well. This is supported by the observation that other similar species of the same genus have widespread distributions (Bennelongia 2012). Even if the species are localised to the impact zone, average drawdown at the end of the Project is only around 2m representing only a small fraction of the aquifers' saturated thickness, leaving significant remaining habitat to support stygofauna. Consequently, groundwater abstraction for the Project is not likely to have unacceptable impacts on stygofauna.

7.1.2 Social Impacts

7.1.2.1 Other Users

There are no surface water users within several hundred kilometres of the Project. The nearest groundwater user is the Telfer mine, about 90 km to the north. Other regional users include the Punmu (Lake Dora) community about 100km to the northeast and Balfour Downs Station about 60 km to the west (Figure 1-1). Figure 7-2 shows the modelled drawdown at the end of the Project. The 1 m drawdown contour, representing the extent of impact detectable relative to natural variability, extends at its maximum about 10 km from the borefield area. Given that the nearest groundwater user is 50 km from this impact zone, there will be no detectable impacts of the Project on other users.

7.1.2.2 Aboriginal Heritage

Review of the Department of Indigenous Affairs heritage site register indicates a number of sites through the water supply area. The sites are listed as artefacts, quarry, scatter, ceremonial or mythological sites. Some river pools are also noted as being camp water sources.

Prior to bore construction, Aboriginal heritage surveys will be carried out for all proposed bore pads, pipelines and access roads. Should any sensitive sites be identified, infrastructure locations will be adjusted to avoid impact.

The only potentially groundwater dependent heritage sites on the heritage register are the rock pools. As discussed in Section 7.1.1.3. these pools are not believed to be connected to the water table and no significant impacts on the pools are anticipated. Further investigation of the pool-aquifer relationship and baseline monitoring of water levels and water quality will be undertaken in the next stage of the Project. Should there be evidence of a connection, detailed triggers and contingency actions will be incorporated into the Groundwater Operating Strategy.

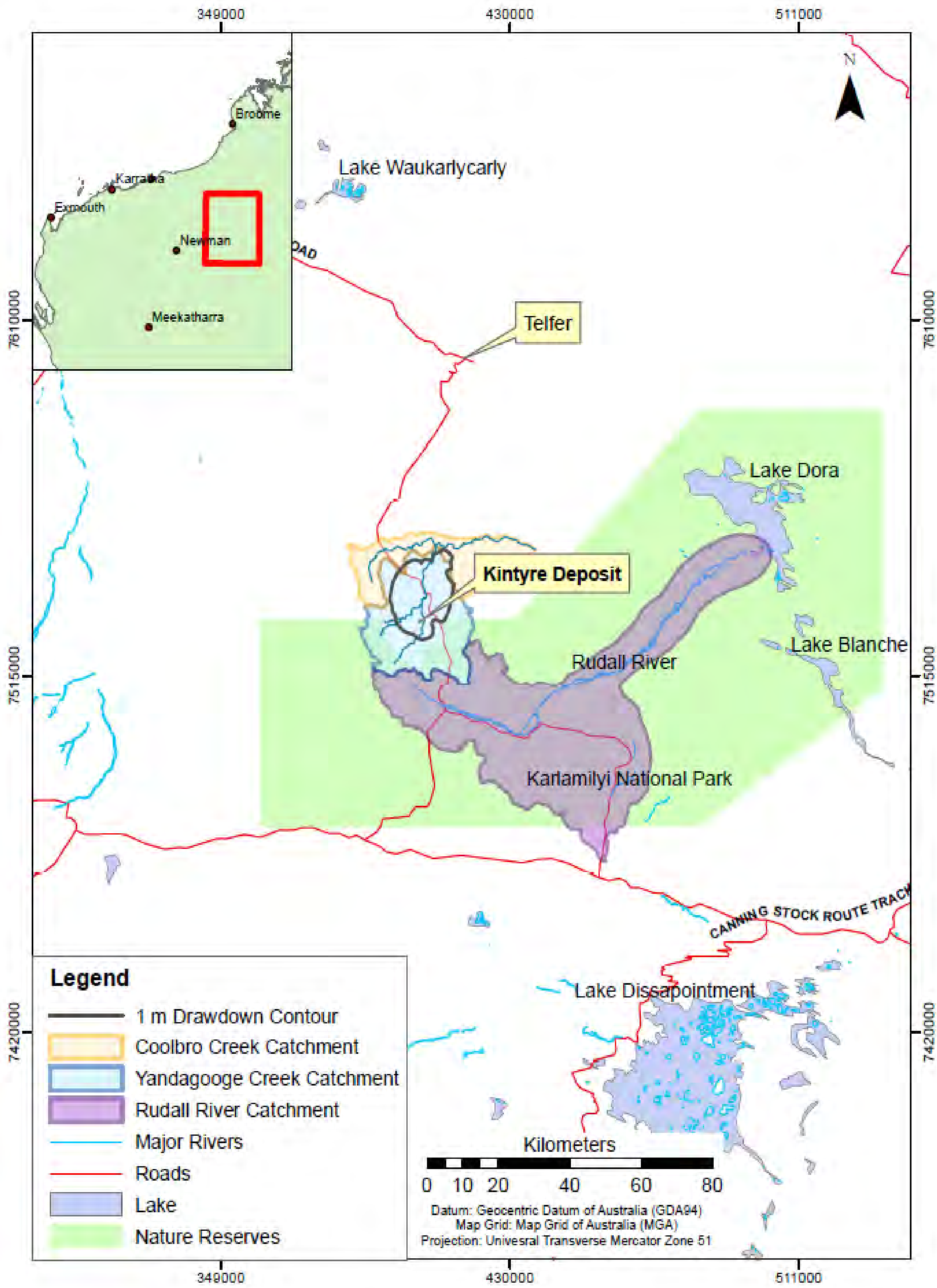

Figure 7-3 Modelled water table drawdown at end of mining (broader region)

7.2 Impacts Following Mine Closure

At the completion of the project, water abstraction for pit dewatering and water supply will cease and water levels in the aquifer and the pit will gradually recover. Within the pit, two terminal pit lakes (northeast and southwest) will form separated by a sill at about 300 mAHD. The water level will slowly rise with groundwater seepage and rainfall inputs until the inputs balance evaporation from the void.

Modelled water balances and water levels for the pit lakes are presented in Tetra Tech (2012b), and an example for the northeast lake shown in Figure 7-4. Water levels in both pits are modelled to gradually rise over about 100 years before stabilising around 270 mAHD. Groundwater inflows decline over this period, stabilising at a total of about 800 kL/day (300 ML/year).

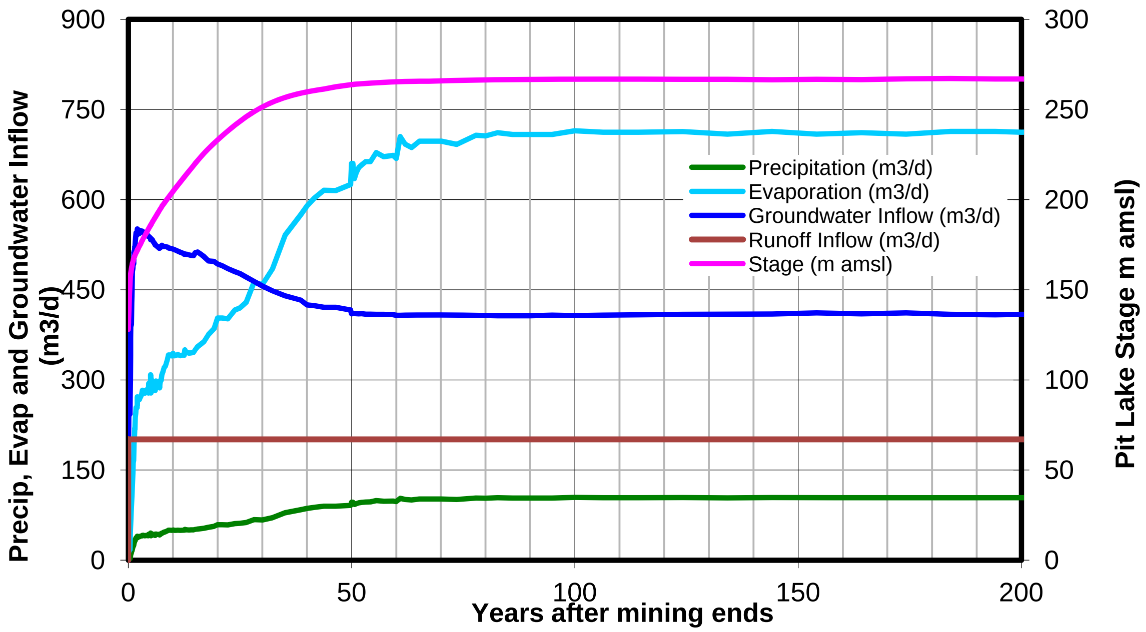

Figure 7-4 Modelled water balance and water levels for northeast pit lake

7.2.1 Water Quality after closure

The quality of seepage migration to the pits during mining will be brackish, reflecting the natural surrounding groundwater quality which is between 4,500 and 5000 mg/L total dissolved salts. The chemistry and salinity of the groundwater will change close to and within the pit due to two processes:

- Chemical reactions such as acid rock drainage, metal leaching (ARD/ML) and acid neutralisation reactions within the wall rock geochemistry; and
- Physical salinity changes within the pit void itself due to evaporative concentration and/or rainfall dilution.

Chemical modelling of pit lake was undertaken by Tetra Tech (2012c) using PHREEQC modelling software (Packhurst & Appelo, 1999). Based on results from the groundwater flow model (Tetra Tech, 2012b), each pit lake was treated as a separate individual sink with no hydrological connection between them. The chemical modelling results suggest that:

- oxidisation of sulphide minerals in the pit walls will cause ARD/ML increasing the proportion of metal ions in the pit water relative to the natural groundwater, such as arsenic, manganese, lead, molybdenum, nickel and uranium;
- direct rainfall contributions to the pit lake with enhance the proportions of sodium and chloride levels relative to surrounding groundwater chemistry;
- excess acid neutralising potential of carbonate and clay materials in the wall rock will neutralise the ARD, causing the pH in both lakes to become neutral to slightly alkaline over 100 years;
- as the pH in pit lakes changes, complexing agents and "scrubbing" minerals such as ferrihydrite and alunite will precipitate from solution, reducing the proportions of metal ions in solution; and
- precipitation of gypsum and other mineral phases will reduce the proportions of calcium, magnesium and sulphate in solution.

Tetra Tech's model (2012c) indicates that apart from the chemical speciation of the pit lake, the overall salinity will approach an equilibrium over a period of about 100 years after closure based on the net evaporative concentration, rainfall dilution, and input/output of salts from groundwater influx and precipitation.

Water filled voids after closure can be a concern for attracting and supporting feral animal populations, or impacting the health and diversity of the natural fauna In this case the presence of nearby fresh water pools, coupled with the brackish to hypersaline quality of the pit lakes themselves, is sufficient to ensure that the pit lakes will not be a source of drinking water natural or feral fauna after closure. Nonetheless, Cameco will fence off the final void with cyclone mesh fencing after closure.

7.2.2 Water Levels after closure

Following the cessation of mining, groundwater levels will gradually recover around the process water borefield and the pit, eventually stabilising over several decades in a new regime that incorporates the evaporation from the pit lakes. Model results indicate that the new regime includes drawdowns in the water table relative to pre-development, of 5 m or more within about 2 km, and between 1 and 5 m between 2 and 5 km from the pit.

There are no other users within this drawdown area. As discussed in Section 7.1.1, there are unlikely to be any groundwater dependent ecosystems in this area. However if there were any that did occur, they would likely be able to adapt to the relatively small and gradual effect.

8. CONCLUSIONS

The Kintyre Joint Venture (KJV), comprising Cameco Australia Pty Ltd (70%) and Mitsubishi Development Pty Ltd (30%), is developing a 4.4 kTpa uranium project on the western edge of the Great Sandy Desert in the East Pilbara region of Western Australia. Water supply will be sourced from groundwater and is required for ore processing, plant construction and camp water supply. Demand peaks at 3,100 kL/day in years 3 and 11 of the 13.5 year project life.

Hydrogeological analysis in this report draws on an extensive water exploration program undertaken by the KVJ between 2009 and 2012, as well as information from other investigations undertaken over several decades. The KJV investigations incorporated exploration drilling, construction and hydraulic testing of eleven test production bores, and detailed numerical modeling.

Numerical groundwater modelling of the aquifer system demonstrates that:

- There is more than sufficient borefield capacity and contingency to sustain an overall abstraction 3,100 kL/day from sediments of the Paterson Formation and Coolbro Sandstone over the mine life, without causing unacceptable drawdown or loss of bore productivity;
- Modelled water table drawdowns at the end of the Project will reach a maximum of 220 m depth in direct proximity to the pit, while the 1 m drawdown contour, representing the extent of impact detectable relative to natural variability, is expected to extend up to10km from the borefield area at its furthest;
- There are no other groundwater users within 80 kilometres of the KJV. Since borefield depressurisation will not extend beyond 10 km from the borefield, the KJV will not adversely impact other water users;
- There should be no impact on waterholes and vegetation associated with Rudall River and Lake Dora as they are far outside of the zone of drawdown related to the Project;
- The hydrology of the Yandagooge Creek and its catchment is dominated by seasonal rainfall and is unlikely to be affected by groundwater drawdowns;
- There is unlikely to be groundwater dependent vegetation in the area of drawdown impact. Two tree species that possibly could have some groundwater dependence are considered robust to groundwater level changes and would likely be able to adapt to water level changes of 0.5-1.0 m/year;
- In areas where the drawdown rate is greater than 1 m/year (e.g. >10 m drawdown contour at the end of mine life, such as near North Bore and the Open Pit), possible localised impacts may occur on vegetation if these species are groundwater dependent;
- Several ephemeral river pools along the Coolbro and Yandagooge creeks are likely to be perched on clayey alluvial strata, fed by surface flows and therefore not affected by groundwater abstraction for the Project. Further monitoring will take place to confirm these findings in the next stage of the project, and develop triggers and contingencies if required; and

- Of the stygofauna species have been identified in the Project area all or most are likely to occur elsewhere and are not likely to be threatened by development. Even if a species were localised, only a small fraction of the potential habitat within the aquifers impacted by the Project will be affected by drawdown.

Further surveys of potential groundwater dependent ecosystems will be undertaken in the next stage of the Project to assess aquifer dependency. This is addressed in a detailed Groundwater Operating Strategy, which has identified and defined triggers and contingency actions for the management of potential groundwater dependent systems. This is a living document that will be adapted in consultation with regulators as more information is obtained in each stage of the Project.

In summary, there are no technical, social or environmental factors identified in this investigation program which would suggest cause not to grant the Applicant a 5C licence to take 1,400,000 kL/a of groundwater from the Paterson Formation Sedimentary Aquifer.

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Attachment A

Kintyre ERMP Bore Completion Summary Report

Cameco Australia Pty Ltd

Attachment A – ERMP Bore completion summary report

Kintyre Uranium Project

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Attachment A – ERMP Bore completion summary report

Kintyre Uranium Project

1122 | Rev 1
August 2012

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Rev 0	RT, LB, NT	DS	12 June 2012	Issued to Cameco and TT for comment
Rev 1	RT, LB, NT	DS	19 June 2012	Issued with Hydrographs for comment
Rev 1	RT, LB, NT	DS	18 July 2012	Issued to the client

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1. BACKGROUND

The Kintyre Uranium Project, located 90 km south of Telfer and 260 km northeast of Newman, lies on the western edge of the Great Sandy Desert in the East Pilbara region of Western Australia. The Project is expected to produce 4.4 kTpa over a minimum life of 13.5 years and involves the development of open cut pits; waste landforms, evaporation ponds, an acid leach processing facility and tailings storage facility (TSF) within the operational area.

Dames and Moore (1993) and Hydro Resources (1997) undertook the early project hydrogeological investigations on behalf of the previous Project owners, Rio Tinto. Cameco acquired the Project in 2008 and engaged Pennington Scott, Tetra Tech and MWH to undertake the necessary hydrogeological investigations of the pit dewatering and water supply borefields to support their own Environmental Risk Management Plan (ERMP). The field investigations undertaken by Cameco for the ERMP include:

- ***Exploration holes***: Twelve (12) exploration test bores were constructed by MWH in the water supply area between October 2009 to March 2011. Each of the holes were variously cased with either 100 mm i.d. Class 12 PVC-U or 355 i.d. ABS;
- ***Monitoring Bores****:* A separate network of twenty (20) 100 mm i.d. Class 12 PVC-U monitoring bores were constructed around Kintyre between October 2009 to February 2010;
- ***Production Bores****:* Three (3) high yield production water bores constructed in the water supply area between March and April 2012, and cased with 205 mm i.d. Class 12 PVC-U;
- ***Hydraulic Aquifer Testing****;* A total of sixty (60) test bores, monitoring bores and production water bores underwent hydraulic testing between 2009 and 2012. Tests included step drawdowns; 24 hr to 72 hr constant rate tests and recovery measurements;
- ***Groundwater Monitoring****:* Water levels, field EC and pH were monitored in seventy four (74) bores periodically between May 1987 and June 2012. In addition, major ions and groundwater isotopes were monitored in fifty four (54) of these installations on a quarterly basis;
- ***Baseline Groundwater Chemistry****:* Forty one (41) monitoring and production water bores around Kintyre were purged and sampled during April 2012. Samples were submitted to a NATA registered chemical laboratory for analysis of major ions, major metals and other laboratory parameters; and
- ***Airborne Exploration Methods****:* An Airborne Electromagnetic (AEM) survey over the Paterson-Canning Region flown by Fugro between September 2007 and August 2008.

This document forms Attachment A of the Hydrogeological Appendix of the ERMP and primarily represents the Bore Completion Summary Report for the hydrogeological field investigations undertaken by Cameco for the ERMP.

For completeness sake, bore completion details and hydraulic testing results from previous hydrogeological investigations by Dames and Moore (1993) and Hydro Resources (1997) also appear in summary form within this document.

Copies of the Licenses to Construct Bores are included in Appendix A.

2. DRILLING AND BORE CONSTRUCTION

Dames and Moore (1993) and Hydro Resources (1997) describe the field investigations and bore construction details of exploration, production, and monitoring bores constructed prior to Cameco acquiring the Kintyre project in 2008. This section describes the protocols used to design and construct all groundwater installations commissioned by Cameco as part of the ERMP (Figure 2-1). However the bore construction summary table, Table 2-1, includes construction details of all one hundred (100) groundwater installations on the Kintyre Project, including the ones constructed prior to Cameco's own drilling program.

The Cameco groundwater drilling program was developed in four phases between October 2009 and April 2012 using rotary air blast (RAB) drilling methods, including the construction of:

- **Phase 1 – Exploration Drilling** (Oct 2009 and Feb 2010): One (1) production bore for potable water supply and six (6) exploration bores;
- **Phase 2 – Monitor bore network** (Oct 2009 to Feb 2010): A network of twenty (20) 100 mm i.d. Class 12 PVC-U monitor bores at eleven (11) sites around Kintyre;
- **Phase 3 – Low Yield Test Production bores** (Sep 2010 and Dec 2011): Five (5) test production bores and two (2) test dewatering bores constructed by MWH in the water supply are, each of the holes cased with 254 mm i.d. ABS; and
- **Phase 4 – High Yield Production Bores** (Jan 2012 to Mar 2012): Three (3) high yield production water bores in the water supply area between March and April 2011, cased with 205 mm i.d. Class 12 PVC-U.

Drilling contractor Australian Drilling Solution (ADS) was engaged to undertake phases 1 to 3 using a rotary air blast (RAB) drilling method. Phase 4 of the Drilling program was completed by drilling contractor Kimberley Water between January and March 2012 using a rotary air blast (RAB) drilling method. Bore construction was in accordance with the following protocols, with all field operations being under the direct supervision of a hydrogeologist:

- **Exploration bores:** A 203 mm diameter air rotary hole was drilled to nominal depth, with variable surface casing depth depending on ground conditions. Each hole was cased with 50 mm diameter Class 12 PVC-U casing with machine slotted liners set opposite the aquifers targeted for monitoring. The hole annulus was then backfilled with 1.6 to 3.2 mm graded gravel to 15 m below ground and a cement grout installed to the surface. The bore was airlifted to remove sand and silt.
- **Potable water bore (North Bore):** a 305 mm diameter pilot hole was to nominal depth of 82 metres with chip samples taken every 2 m for logging by the superintendent. The hole was reamed out and 12 m of 356 mm i.d. steel surface casing installed and grouted in place to prevent hole collapse. The hole was cased with 205 mm i.d. Class12 PVC-U pressure pipe, compliant with AS1477, with machine slotted liners set opposite the main water bearing intervals. After installation of the casing, the annulus of the hole was backfilled with 1.6 to 3.2 mm graded gravel to 15 m below ground and a cement grout installed to the surface. The bore was airlifted for 15 hours to remove sand and silt. At the end of airlift development a sample of groundwater was collected and submitted to SGS Newburn Environmental laboratories for chemical analysis.

- **Monitoring bores:** A 203 mm diameter air rotary hole was drilled to nominal depth, with variable surface casing depth depending on ground conditions. Each hole was cased with 100 mm i.d. Class12 PVC-U casing with machine slotted liners set opposite the aquifers targeted for monitoring. In locations involving both a shallow and deep monitoring bore, the same drill pad was used, with cement grout installed between adjacent holes to ensure separation between the two aquifer units. After installation of the casing, the annulus of the hole was backfilled with 1.6 to 3.2 mm graded gravel to 15 m below ground and a cement grout installed to the surface. The bores were airlifted to remove sand and silt.
- **Low yield test production bores:** 405 mm i.d. steel surface casing was installed to between 6 and 48 m and cement grouted in place to prevent loss circulation. A pilot hole was not required as the bores were selected in close proximity to existing monitoring or exploration holes. The holes were reamed to 380 mm i.d. using mud rotary techniques, except for CWB15 which was drilled using RAB methods, to total depth and cased with 254 mm i.d. ABS casing, with inline stainless steel screens placed opposite the most water bearing interval. A 2–5 m bentonite seal was cemented above the screened casing string and the remainder of the annulus backfilled with 3.2 to 6.4 mm gravel with a minimum 1 m of cement grout at the surface. The bores were airlifted to remove sand and silt.
- **Test dewatering bores:** a 431 mm collar hole was drilled to accommodate 405 mm i.d. steel surface casing to between 18 and 22 m depths. A 200mm i.d. pilot hole was then drilled using RAB methods to a nominal depth of 150m or until suitable groundwater yields were confirmed. The holes were then reamed to 378 mm i.d. and cased with 254 mm ABS casing with 2 mm aperture machine slotted liners set opposite the main water bearing intervals. After installation of casing, the hole was backfilled with 3.2 to 6.4 mm gravel to surface with a minimum 1 m of cement grouting installed at the surface. A 5 m bentonite seal was installed in one of the bores just above the screened casing string. The bores were then developed using a combination of airlift and surging.
- **High yield production bores:** a 411 mm i.d. hole was drilled to competent soil (nominally 30 m depth) and 343 mm i.d. steel surface casing installed and cement grouted in place to prevent loss circulation. Foam was required to stabilise the formation (Figure 2-2) during drilling of the collar due to fine running surface silt and sand. A 216 mm RAB method pilot hole was then drilled to a nominal depth of 150 m, or until recognisable basement material. On completion of the pilot hole, the hole was lithologically logged to AS1726-1993 standards (*the Australian Standard for Geotechnical Site Investigations)* based on chip samples collected every metre. The holes were then reamed to 343mm and cased using 203 mm (i.d.) class 12 PVC with 1 mm aperture machine slotted liners over the main water bearing intervals of the hole. After installation of the casing, the annulus of the hole was backfilled with 1.6 to 3.2 mm or 1.2 to 3.2 mm graded gravel to surface with a minimum 1 m of cement grout at the surface. Finally, the bore was developed for at least 2 hours to remove sand and silt. Airlift yields were determined during the course of bore development using a V-notch weir.

Completion logs for all bores completed as part of the Cameco ERMP groundwater drilling programs are included in Appendix B.

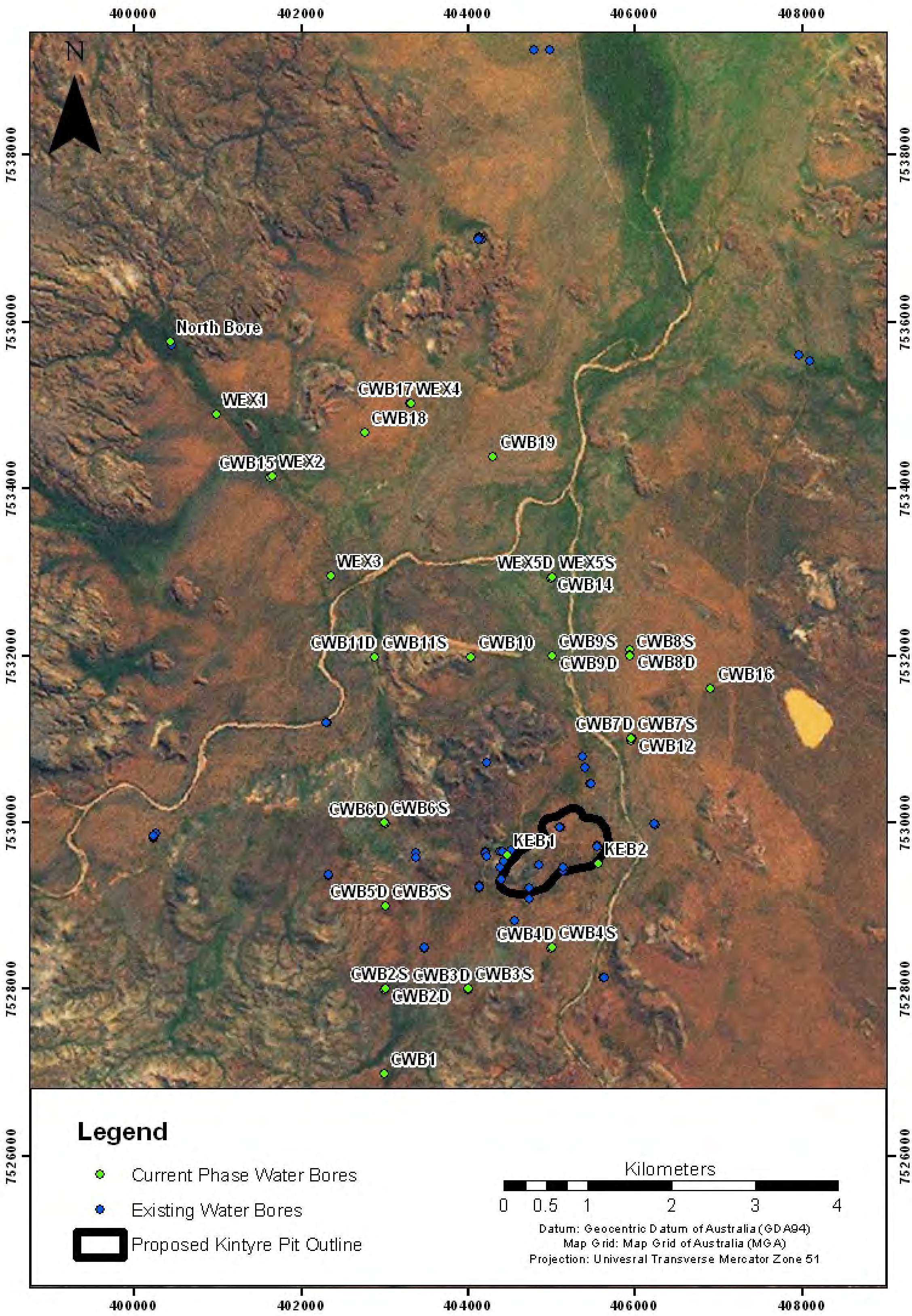

Figure 2-1: Current Phase Bore locations in the water supply area

Table 2-1: Summary details of all groundwater installations in the Kintyre Project

Bore ID	Bore Status	Drilled Date	Easting	Northing	Drill Method	Driller	Screened unit	Depth Drilled (m)	Depth cased (m)	Casing i.d. (mm)	Screened Interval (m)	Airlift Yield (L/s)	TDS (mg/L)	SWL (mbgl)	TOC (magl)
3PS	Piezometer	26/07/1987	404118	7536990	RAB	Gearhart	Paterson Fm	33	33	100	27-33	No flow	2128	19.6	0.75
3PD	Piezometer	26/07/1987	404121	7536998	RAB	Gearhart	Paterson Fm	145.7	143.5	100	131.5-143.5	6	839	19	0.66
9PS	Piezometer	31/07/1987	406227	7529979	RAB	Gearhart	Paterson Fm	45	38.8	100	32.8-38.8	7.6	4571	23.3	0.77
4PS	Piezometer	5/08/1987	402330	7529380	RAB	Gearhart	Paterson Fm	44.9	44.8	100	38.8-44.8	No flow	4322	18.5	-
4PI	Piezometer	5/08/1987	402330	7529371	RAB	Gearhart	Paterson Fm /Proterozoic	87.1	87.1	100	75.1-87.1	No flow	6900	18.7	-
4PD	Piezometer	5/08/1987	402330	7529362	RAB	Gearhart	Paterson Fm /Proterozoic	145.6	134.9	100	122.9-134.9	No flow	6263	19	0.29
6PS	Piezometer	9/08/1987	403380	7529580	RAB	Gearhart	Paterson Fm	40	40	100	34.9-40	No flow	3206	21.5	-
6PI	Piezometer	9/08/1987	403382	7529575	RAB	Gearhart	Paterson Fm /Proterozoic	111	63	100	52.2-63	No flow	3164	21.6	0
6PD	Piezometer	11/08/1987	403375	7529635	RAB	Gearhart	Paterson Fm /Proterozoic	110	91.8	100	79.8-91.8	0.6	3312	21.9	0.15
5PS	Piezometer	14/08/1987	403477	7528495	RAB	Gearhart	Paterson Fm	48.3	47.2	100	41.2-47.2	0.1	4463	18.1	-
5PI	Piezometer	14/08/1987	403480	7528500	RAB	Gearhart	Paterson Fm /Proterozoic	108.3	106.3	100	95.2-106.3	0.1	5422	18.3	-
5PD	Piezometer	18/08/1987	403474	7528489	RAB	Gearhart	Paterson Fm /Proterozoic	132.7	130.5	100	118.5-130.5	0.1	7119	18.1	-
1PS	Piezometer	25/08/1987	400227	7529841	RAB	Gearhart	Paterson Fm	78.5	35.6	100	23.6-29.6	1	546	15.7	-
1PI	Piezometer	25/08/1987	400230	7529832	RAB	Gearhart	Paterson Fm	108.5	107.2	100	95.2-107.2	5.6	671	19.3	1.06
1PD	Piezometer	25/08/1987	400230	7529815	RAB	Gearhart	Paterson Fm /Proterozoic	139.6	138.8	100	132.8-138.8	3.4	972	27.7	-
7PS	Piezometer	31/08/1987	402293	7531188	RAB	Gearhart	Paterson Fm	80.2	80.2	100	74.2-80.2	No flow	2118	15.3	-
7PI	Piezometer	31/08/1987	402303	7531195	RAB	Gearhart	Paterson Fm	126.2	126.2	100	120.2-126.2	No flow	2440	15.7	-
7PD	Piezometer	31/08/1987	402310	7531200	RAB	Gearhart	Paterson Fm /Proterozoic	150.2	148.7	100	136.7-148.7	No flow	733	15.8	-
8PS	Piezometer	6/09/1987	405464	7530460	RAB	Gearhart	Paterson Fm	46	41.5	100	35.5-41.5	1.6	3154	22.6	-
8PI	Piezometer	6/09/1987	405461	7530464	RAB	Gearhart	Paterson Fm /Proterozoic	90.2	88.3	100	76.3-88.3	No flow	2755	22.2	-
8PD	Piezometer	6/09/1987	405454	7530473	RAB	Gearhart	Paterson Fm /Proterozoic	138.3	137.7	100	125.7-137.7	No flow	2974	22.7	-
2PS	Piezometer	18/09/1987	405626	7528137	RAB	Gearhart	Paterson Fm	43.6	43.5	100	37.5-43.5	No flow	220	15.8	0.89
2PI	Piezometer	18/09/1987	405634	7528144	RAB	Gearhart	Paterson Fm/Proterozoic	91	90.1	100	78.1-90.1	No flow	233	17.1	0.77
2PD	Piezometer	18/09/1987	405621	7528132	RAB	Gearhart	Paterson Fm /Proterozoic	147	143.7	100	131.7-143.7	No flow	83	16.3	0.81
9PI	Piezometer	19/09/1987	406224	7529979	RAB	Gearhart	Paterson Fm /Proterozoic	54	53.6	100	41.6-53.6	1	9573	23.7	0.83

Bore ID	Bore Status	Drilled Date	Easting	Northing	Drill Method	Driller	Screened unit	Depth Drilled (m)	Depth cased (m)	Casing i.d. (mm)	Screened Interval (m)	Airlift Yield (L/s)	TDS (mg/L)	SWL (mbgl)	TOC (magl)
9PD	Piezometer	20/09/1987	406245	7529968	RAB	Gearhart	Paterson Fm /Proterozoic	66	65.8	100	59.8-65.8	5	8,629	23.5	0.63
10PD	Piezometer	23/09/1987	405129	7529418	RAB	Gearhart	Paterson Fm /Proterozoic	135	133.6	100	121.6-133.6	No flow	3,682	23.5	0.64
10PS	Piezometer	8/10/1987	405137	7529464	RAB	Gearhart	Paterson Fm /Proterozoic	54	36.5	100	24.5-36.5	No flow	2,110	23.3	0.86
10PI	Piezometer	8/10/1987	405138	7529459	RAB	Gearhart	Paterson Fm /Proterozoic	96	95	100	83-95	No flow	2,154	23.3	0.66
11PS	Piezometer	12/10/1987	404733	7529212	RAB	Gearhart	Proterozoic	54	54	100	48-54	No flow	3,758	16.6	-
11PI	Piezometer	12/10/1987	404733	7529220	RAB	Gearhart	Proterozoic	126	124	100	112-124	No flow	3,605	22.2	-
11PD	Abandoned	12/10/1987	404733	7529082	RAB	Gearhart	Proterozoic	144	-	-	-	-	-	-	0.33
13PS	Piezometer	22/10/1987	404210	7529637	RAB	Gearhart	Coolbro Sst	38.6	38.6	100	32.5-38.6	2.5	2,240	25	-
13PI	Piezometer	22/10/1987	404198	7529625	RAB	Gearhart	Coolbro Sst	48	43.9	100	38-43.9	2.5	2,287	25.2	-
13PD	Piezometer	22/10/1987	404198	7529650	RAB	Gearhart	Coolbro Sst	67.5	67.5	100	61-5-67.5	2.5	2,376	25.2	-
12PI	Piezometer	25/10/1987	404134	7529220	RAB	Gearhart	Proterozoic /carbonate	66.5	66	100	60-66	No flow	7,600	17.8	-
12PD	Piezometer	27/10/1987	404132	7529244	RAB	Gearhart	Proterozoic /carbonate	90	90	100	84-90	No flow	6,276	18.7	-
12PS	Piezometer	28/10/1987	404127	7529226	RAB	Gearhart	Proterozoic	57	57	100	51-57	No flow	6,572	17.9	-
15PS	Piezometer	2/11/1987	405095	7529937	RAB	Gearhart	Proterozoic	54	54	100	48-54	No flow	7,799	23.4	-
15PI	Piezometer	2/11/1987	405100	7529936	RAB	Gearhart	Proterozoic	72.5	72.5	100	63.5-72.5	3.4	12,822	23.2	-
15PD	Piezometer	2/11/1987	405110	7529936	RAB	Gearhart	Proterozoic	102	102	100	90-102	3.4	13,209	23.5	-
14PS	Piezometer	8/11/1987	405548	7529711	RAB	Gearhart	Paterson Fm /Proterozoic	54	54	100	48-54	0.5	2,728	21.9	-
14PI	Piezometer	8/11/1987	405549	7529726	RAB	Gearhart	Paterson Fm /Proterozoic	78.5	78.5	100	66.5-78.5	0.5	5,004	21.9	-
14PD	Piezometer	8/11/1987	405549	7529720	RAB	Gearhart	Paterson Fm /Proterozoic	132.5	132	100	120-132	0.5	4,227	22	-
3PI	Piezometer	10/11/1987	404131	7536999	RAB	Gearhart	Paterson Fm	96	96	100	85.6-96	6	905	19.3	0.84
3PDD	Piezometer	16/11/1987	404131	7537009	RAB	Gearhart	Paterson Fm	174	173.5	100	167.5-173.5	10	960	19.22	0.74
TPB3	Production	21/11/1987	404163	7536983	RAB	Gearhart	Paterson Fm	142	135.3	155	107.7-135.3	5	1,100	19.6	0.2
OB3	Observation	21/11/1987	404161	7536988	RAB	Gearhart	Paterson Fm	132.5	132	50	114-132	5	1,100	18.9	-
OB1	Observation	2/12/1987	400266	7529872	RAB	Gearhart	Paterson Fm /Proterozoic	119	118.5	50	100.5-118.5	0.5	1,100	18.9	-
TPB1	Abandoned	2/12/1987			RAB	Gearhart	Paterson Fm	117	-	-	-	No flow	-	-	-
KWX1	Observation	22/04/1997	404563	7529406	RAB	Montague	Proterozoic	138	138	20	66-138	<0.1	-	-	0.41
OB16	Observation	10/12/1987	400452	7535723	RAB	Gearhart	Paterson Fm /Coolbro Sst	66	64.8	100	40.8-64.8	5.8	340	20.7	-
KWX2	Observation	24/04/1997	404377	7529464	RAB	Montague	Proterozoic	108	108	40	48-108	0.1	-	28.97	0.63
KWX3	Observation	26/04/1997	404427	7529529	RAB	Montague	Proterozoic	140	140	40	68-140	0.2	-	24.12	0.52

Bore ID	Bore Status	Drilled Date	Easting	Northing	Drill Method	Driller	Screened unit	Depth Drilled (m)	Depth cased (m)	Casing i.d. (mm)	Screened Interval (m)	Airlift Yield (L/s)	TDS (mg/L)	SWL (mbgl)	TOC (magl)
KWX4	Observation	27/04/1997	404513	7529669	RAB	Montague	Coolbro Sst	96	96	20	24-96	1.9	-	23.15	0.56
KWX5	Observation	29/04/1997	404397	7529320	RAB	Montague	Proterozoic	130	130	40	58-130	<0.1	260	15.11	0.46
KWX6	Observation	6/05/1997	404810	7529325	RAB	Montague	Proterozoic	120	120	50	60-120	0.3	-	12.68	0.74
KWX7A	Observation	4/05/1997	404847	7529484	RAB	Montague	Proterozoic	143	143	50	71-143	<0.1	360	25.98	0.57
KWX8	Observation	24/05/1997	404377	7529653	RAB	Montague	Proterozoic	37	37	20	13-37	0.0	-	18.61	0.56
KWP1	Production	24/05/1997	404513	7529665	Mud	Montague	Coolbro Sst	120	119.9		23.9-119.9	2.7	5,600	22.71	0.3
KWX9	Observation	25/05/1997	404554	7528829	RAB /Mud	Montague	Paterson Fm /Proterozoic	84	84	20	24-84	<0.1	-	15.75	0.46
KWX10	Observation	27/05/1997	403230	7530920	RAB	Montague	Proterozoic	167	167	20	107-167	0.3	-	23.83	0.46
KWX11	Observation	29/05/1997	404409	7529656	RAB /Mud	Montague	Weathered Proterozoic	75	75	50	39-75	1.0	970	22.97	0.69
WEX3	Exploration	6/11/2009	402359	7532951	RAB	Nudrill	Paterson Fm /Proterozoic	126	124	50	28-124	1	4,000	12.02	0.45
CWB11d	Monitoring	12/11/2009	402889	7531975	RAB	Nudrill	Paterson Fm /Coolbro Sst	103	102	100	72-102	0.5	2,100	12.4	-
CWB11s	Monitoring	14/11/2009	402880	7531980	RAB	Nudrill	Paterson Fm /Coolbro Sst	62	61.3	100	25.3-61.3	0.5	5,000	13.02	-
CWB9d	Monitoring	17/11/2009	4054003	7531998	RAB	Nudrill	Paterson Fm /Proterozoic	88	86	100	32-86	2	7,600	14.55	-
North Bore	Production	19/11/2009	400440	7535767	RAB /Mud	Nudrill	Paterson Fm /Coolbro Sst	82	77	200	47-77	3.5	-	16.21	0.86
CWB9s	Monitoring	19/11/2009	404996	7531994	RAB	Nudrill	Paterson Fm /Coolbro Sst	25	25	100	7-25	No flow	16,000	14.19	-
CWB10	Monitoring	20/11/2009	404027	7531977	RAB	Nudrill	Proterozoic	103	100	100	40-100	<0.1	2,100	12.55	-
WEX5d	Exploration	30/11/2009	405007	7532943	Mud	Nudrill	Paterson Fm	133	129.5	100	93.5-129.5	8.50	1,600	15.31	0.45
WEX5s	Exploration	3/12/2009	405005	7532938	Mud	Nudrill	Paterson Fm	38	38	50	20-38	2	2,000	15.69	0.42
CWB8d	Monitoring	6/12/2009	405939	7532011	Mud	Nudrill	Paterson Fm	139	139	100	103-139	12	4,100	18.47	0.53
CWB8s	Monitoring	8/12/2009	405933	7532000	RAB	Nudrill	Paterson Fm	60	60	100	30-60	No flow	2,900	18.59	-
CWB1	Monitoring	10/12/2009	402996	7526995	RAB	Nudrill	Paterson Fm /Proterozoic	86.6	86.6	100	32.6-86.6	<0.2	5,900	16.57	0.66
CWB2d	Monitoring	11/12/2009	402994	7527997	RAB	Nudrill	Paterson Fm /Proterozoic	73	72.7	100	48.7-72.7	No flow	2,000	12.73	-
CWb2s	Monitoring	12/12/2009	403008	7528008	RAB	Nudrill	Paterson Fm /Proterozoic	45	45	100	9-45	No flow	5,300	15.7	0.57
CWB3d	Monitoring	14/12/2009	404005	7527992	RAB	Nudrill	Paterson Fm /Proterozoic	60	60	100	36-60	<1	1,000	11.96	-
CWB3s	Monitoring	16/12/2009	404001	7528004	RAB	Nudrill	Paterson Fm	30	30	100	12-30	No flow	830	12.3	-
CWB6d	Monitoring	8/01/2010	403008	7529986	RAB	Nudrill	Paterson Fm /Coolbro Sst	98	96.5	100	78.5-96.5	0.1	1,800	11.96	-
CWB6s	Monitoring	9/01/2010	402995	7529997	RAB	Nudrill	Paterson Fm	74	73	100	19-73	0.7	820	13.13	-
CWB5d	Monitoring	10/01/2010	403017	7529000	RAB	Nudrill	Paterson Fm	88	86	100	68-86	No flow	4,800	16.61	-

/Proterozoic

Bore ID	Bore Status	Drilled Date	Easting	Northing	Drill Method	Driller	Screened unit	Depth Drilled (m)	Depth cased (m)	Casing i.d. (mm)	Screened Interval (m)	Airlift Yield (L/s)	TDS (mg/L)	SWL (mbgl)	TOC (magl)
CWB4d	Monitoring	12/01/2010	404992	7528495	RAB	Nudrill	Paterson Fm /Proterozoic	80	79	100	61-79	No flow	1,600	12.87	-
CWB5s	Monitoring	12/01/2010	403005	7528996	RAB	Nudrill	Paterson Fm	64	63	100	15-63	No flow	16,000	16.63	-
CWB4s	Monitoring	14/01/2010	405001	7528498	RAB	Nudrill	Paterson Fm	52	51.5	100	15.5-51.5	No flow	7,300	12.87	-
CWB7d	Monitoring	22/01/2010	405960	7530999	RAB /Mud	Nudrill	Paterson Fm /Proterozoic	130	127.5	100	97.5-127.5	3	3,900	18.26	-
CWB7s	Monitoring	28/01/2010	405960	7530999	Mud	Nudrill	Paterson Fm	73	73	100	22.8-73	No flow	2,000	18.1	-
WEX4	Exploration	5/02/2010	403307	7535020	RAB	Nudrill	Paterson Fm	120	118.5	50	28.5-118.5	1.5	540	14.4	0.75
WEX2	Exploration	7/02/2010	401653	7534149	RAB	Nudrill	Paterson Fm /Coolbro Sst	132	128	50	44-128	4	400	12.83	0
WEX1	Exploration	8/02/2010	400994	7534884	RAB	Nudrill	Paterson Fm /Coolbro Sst	90	89	50	29-89	2	250	12	0.5
CWB12	Production	9/10/2010	405951	7530986	Mud	Easternwe ll Minerals	Paterson Fm /Proterozoic	90	90	254	48-90	4	3,200	20.05	0.4
CWB13	Production	1/11/2010	405933	7532064	Mud	Easternwe ll Minerals	Paterson Fm /Proterozoic	159	159	254	111-159	2.5	3,500	23.05	0.41
CWB14	Production	23/11/2010	404989	7532928	Mud	Easternwe ll Minerals	Paterson Fm /Proterozoic	153	152.5	254	98.5-152.5	20	1,400	18.19	0.46
KEB2	Dewatering	5/12/2010	405563	7529499	RAB	Easternwe ll Minerals	Paterson Fm /Proterozoic	150	150	254	42-150	4	2,000	19.56	0.49
CWB15	Production	2/02/2011	401638	7534131	RAB	Easternwe ll Minerals	Paterson Fm /Proterozoic	131	130	254	52-130	4	360	11.92	0.45
CWB16	Production	6/12/2011	406900	7531600	RAB /Mud	Kimberley Water	Paterson Fm /Coolbro Sst	115	105	100	49-105	0.45	-	18.84	0.51
KEB1	Dewatering	19/12/2011	404464	7529613	RAB /Mud	Easternwe ll Minerals	Coolbro Sst	134	125	254	31-125	2	4,800	27.64	0.49
CWB17 (M)	Production	18/02/2012	403313	7535020	RAB	Kimberley Water	Paterson Fm	128	124	254	28-40; 46-124	8-10	-	14.08	0.6
CWB18 (L)	Production	1/03/2012	402761	7534668	RAB	Kimberley Water	Paterson Fm /Quartzite	158.7	157.4	200	31.4-157.4	9-11	-	14.27	0.48
CWB19 (K)	Production	9/03/2012	404293	7534386	RAB	Kimberley Water	Paterson Fm	152	146	200	28-146	12	-	14.74	0.53

Figure 2-2: Heavy foam being ejected from CWB19 during drilling of the surface collar; discharge of cuttings and fluid flowing via a headworks apparatus

3. HYDRAULIC (AQUIFER) TESTING

To develop a thorough appreciation of the hydrogeological system and the likely long-term performance during groundwater abstraction, it is necessary to assess the hydraulic (aquifer) properties of all rock units. In particular, the complex distribution of permeability and groundwater storage capacity are the main input parameters used to develop a numerical groundwater model.

There have been three phases of aquifer testing on the Project:

- Five (5) Constant Rate Tests (CRTs) were undertaken during Dec 1987 (Dames and Moore, 1987);
- Two (2) CRTs were undertaken during June 1997 (Hydro Resources, 1997); and
- Ten (10) CRTs on ten (10) bores were completed by MWH between January 2009 and April 2011 (MWH, 2010; MWH, 2011); and
- Six (6) CRTs were completed by Pennington Scott during April and May 2012.

In each test, a submersible electrical pump was installed and up to five step-drawdown tests were performed. The information from the step-drawdown tests was used to determine the constant discharge rate for the nominal 24, 48, or 72 hour CRT, which was then followed by a period of recovery measurements. Groundwater level measurements were recorded manually and by automated data loggers during the pumping and recovery phases. In some cases, groundwater levels in surrounding observation bores were also monitored throughout the aquifer test.

Figure 3-1 shows a typical hydraulic test set up using a 6 inch Grundfos SP95-8 submersible pump (capable of delivering up to 32 L/s), 75KVA genset; 4 inch inline ultrasonic flow meter with automatic flow actuator valve; backup inline helix flow meter; downhole automated water level metre with backup manual dip tube and dip meter.

Figure 3-1: Hydraulic pump testing being undertaken on a bore at Kintyre

3.1 Step-Drawdown Test Results

Step-drawdown tests were conducted on all production bores and many of the observation bores to determine the well efficiency. The step test protocol was to select a test pump that was capable of producing at least twice the airlift yield. Once the pump was installed, a short open flow pump calibration test is performed to find the maximum system flow. This is then divided into four or five incremental step rates.

Two approaches were used for the step drawdown tests on the Project:

- **Conventional continuous step-rate test**: where each step rate was conducted for a period of 40 to 60 minutes from the lowest to rate. At the end of each step, the rate was increased to the next highest step rate without a break until the final rate was completed. The hole was then left to recover for at least 4 hours and on occasions up to 24 hrs; or
- **Step recovery tests**: the step recovery method is similar to the continuous method except that after each step the pump is turned off and the hole allowed to recover at least the length of time that it had been pumped and until the water level in the bore had recovered at least 95% of the drawdown, before restarting the pump for the next highest step rate.

The results of each step rate are extrapolated either forwards or backwards to obtain the inferred step drawdown at 60 minutes. These results were then use to determine the well efficiency parameters using the Rorabaugh Equation (Table 3-1).

Table 3-1: Summary of Step-Drawdown Test Results

Bore	Date	Pump Setting (mbtoc)	Step Test Rates (kL/day)	Well Efficiency (%)
KEB1	22/04/2011	100	130; 173; 259; 346; 518	80; 74; 66; 59; 49
KEB2	17/04/2011	100	173; 346	19; 11
KEB2 (re-test)	10/03/2012	97.5	92; 180; 270; 359; 448	56; 39; 30; 24; 20
CWB12	27/04/2011	70	86; 173; 259	90; 82; 75
CWB12 (re-test)	05/03/2012	78	43; 86; 130; 173; 216	81; 68; 59; 52; 46
CWB13	16/04/2011	99	173; 346	93; 87
CWB14	21/04/2011	100	864; 1296; 1728	81; 74; 69
CWB15	27/04/2011	57.5	173; 259; 346; 518; 778	59; 49; 42; 32; 24
CWB17	02/05/2012	90	363; 683; 1037; 1382; 1685	73; 59; 48; 41; 36
CWB18	21/04/2012	110	518; 1037; 1598; 2074; 2592	87; 77; 68; 63; 57
CWB19	14/05/2012	97	285; 570; 862; 1150; 1438	95; 91; 87; 84; 81

3.2 Constant Rate Aquifer Test (CRT)

Constant rate pumping tests (CRT) are used to determine near well hydraulic conductivities and likely aquifer boundary and leakage influences. Generally the CRT were conducted for a minimum of 8 hours in 100mm i.d. observation bores; 24 hours in test bores in most aquifer units; and 72 hour in test production water bores in the water supply area.

The CRT test rate was chosen by using the results of the step rate test to extrapolate the rate most likely to achieve 80% of the total available drawdown by the end of the CRT. In the event that a boundary impact causes the bore to dewater before half the planned test duration, the bore is left to recover for at least the same period of time that it was pumped or until it has achieved at least 99% water level recovery. The CRT test is then restarted at 70% of its former CRT rate.

Time-drawdown/recovery plots for all CRT's conducted for Cameco's ERMP are presented in Appendix C and summarised in Table 3-2. These plots generally show an initial high rate of drawdown in the first several minutes due to well loss effects, usually followed by a period of straight-line logarithmic drawdown. The slope of the straight-line response is a function of the abstraction rate and the aquifer transmissivity, which is calculated using methods such as the Cooper-Jacob time-drawdown analysis. The aquifer permeability (hydraulic conductivity) is calculated by dividing the transmissivity by the screened aquifer interval.

Aquifer hydraulic conductivity ranges from 1.1 m/day in the Paterson Formation to 0.03 m/day in bores that are screened in Proterozoic rocks.

3.3 CRT Boundary Effects

In the event that a boundary impact causes the bore to dewater before half the planned test duration, the bore is left to recover for at least the same period of time that it was pumped or until it has achieved at least 99% water level recovery. The CRT test is then restarted at 70% of its former CRT rate. Figure 3-2 shows an example of a CRT completed on CWB18 at an initial CRT rate of 20 L/s, then 17 L/s, then finally completed at 12 L/s. The horizontal axis shows log time projected out to the total life of project (12 years); while the vertical axis shows: (i) drawdown relative to the pump setting; (ii) the base of the screens; and (iii) the designed total available drawdown (assumed as 6 m above the base of the screens).

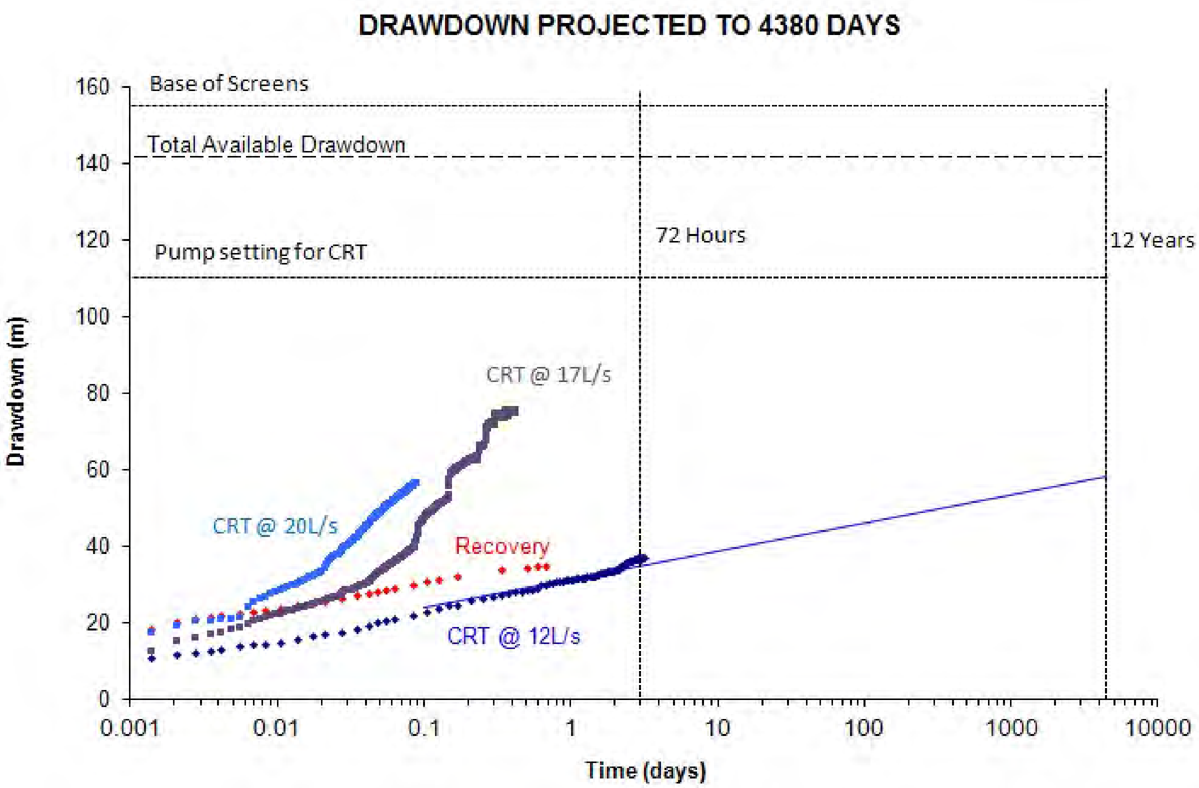

Figure 3-2: Example of boundary conditions encountered during pumping of CWB18

Table 3-2: Summary of CRT Results from ERMP bores

Bore	Date	Constant Test Rate (kL/d)	Duration (mins)	Drawdown at end CRT (m)	Transmissivity m^2/day	Screen length (m)	Hydraulic Conductivity m/day	Aquifer
North Bore	23/10/2009	311	219	18.3	32	30	1.1	Paterson/Coolbro
WEX5s	19/04/2012	39	540	2	12	18	0.6	Paterson
WEX5d	14/12/209	311	360	13.7	15	36	0.42	Paterson
KWP1	26/10/2009	380	25	21.2	7	96	0.07	Coolbro
KEB1	23/04/2011	259	3360	56	3	94	0.03	Coolbro
KEB2 (short)	18/04/2011	259	50	24.7	3	92	0.03	Paterson/Proterozoic
KEB2 (long)	11/03/2012	242	2149	61.2	6	92	0.05	Paterson/Proterozoic
CWB8s	21/04/2012	36	540	2.9	21	30	0.7	Paterson
CWB8d	26/01/2010	389	298	25.9	13	36	0.43	Paterson
CWB12 (short)	28/04/2011	190	120	33	2	42	0.05	Paterson/Proterozoic
CWB12 (long)	22/05/2012	112	1620	55.3	1.8	42	0.04	Paterson/Proterozoic
CWB13	17/04/2011	173	480	59.5	3	48	0.06	Paterson/Proterozoic
CWB14	23/04/2011	1469	720	55.1	14	54	0.26	Paterson/Proterozoic
CWB15	28/05/2011	518	2280	53.7	13	78	0.14	Paterson/Proterozoic
CWB17	03/05/2012	1037	1679	68.9	19	90	0.24	Paterson
CWB18	07/05/2012	1037	4560	37	26	126	0.21	Paterson
CWB19	15/05/2012	950	4324	56.5	26	118	0.22	Paterson

3.4 CRT Storage Parameters

Aquifer storage parameters (storativity and specific yield) can be calculated from analysis of observation bore drawdown during a constant rate test, provided that the aquifer meets the Dupuit assumptions of being infinitely homogeneous and isotropic, and that both the production and observation bores fully penetrate the aquifer. In real life these assumptions are rarely met and thus this analytical approach is subject to large errors. To minimize these errors, the validity of the Dupuit assumptions can be easily tested by comparing the Transmissivity of the observation bore to that of the pumped bore. If the two are more than 10% out; the aquifer is obviously neither homogeneous nor isotropic and therefore the analytical equations should not be used to calculate a storage parameter. Furthermore, the calculated transmissivity from the observation bore should be discarded.

Table 3-3 summarises the aquifer storage determinations from all tests with observation bores conducted for the ERMP, as well as previous investigations conducted by Dames and Moore (1987). Reference to the table shows the observation bore which do not meet the Transmissivity comparison test as appearing in grey.

Table 3-3: Pumping test analyses in the Kintyre area

Bore	Aquifer	Screened Length (m)	Type	Date	Transmissivity (m^2/d)	Radius (m)	Meets Dupuit Assumption (Y/N)	t□	Storativity
1PI	Lower Paterson	6	Pump Bore	6/12/1987	0.7				-
OB1	Lower Paterson	18	Observation		0.7	56.8	Y	0.2	1.1×10^{-4}
TPB1	Lower Paterson	-	Observation		1	20.8	N	-	-
TPB3	Lower Paterson	27.6	Pump Bore	9/12/1987	13.5				-
3PD	Lower Paterson	12	Observation		16.9	44.8	N	-	-
3PI	Lower Paterson	10.4	Observation		14.1	40.1	Y	0.008	1.6×10^{-4}
OB3	Lower Paterson	18	Observation		14.3	7.8	Y	0.001	7.5×10^{-4}
CWB8d	Lower Paterson	36	Pump Bore	25/01/2010	12.9				-
CWB8s	Upper Paterson	30	Pump Bore	21/04/2012	20.9				-
CWB12	Lower Paterson	42	Pump Bore	27/04/2011	2.2				-
CWB7d	Rudall	30	Observation		2.4	23	Y	0.2	1.5×10^{-3}
CWB7s	Upper & Lower Paterson	48	Observation		6.7	25	N	-	-
WEX5d	Lower Paterson	36	Observation		4.1	2180	N	-	-
CWB13	Lower Paterson	48	Pump Bore	16/04/2011	2.8		N		-
CWB8d	Lower Paterson	36	Observation		11.05	56	N	-	-
CWB8s	Upper Paterson	30	Observation		35.2	68	N	-	-
CWB14	Lower Paterson	54.5	Pump Bore	22/04/2011	14				-
CWB13	Lower Paterson	48	Observation		15.6	1279	N	-	-
WEX5D	Lower Paterson	36	Observation		14	20	Y	5.0	2.7×10^{-4}
CWB15	Lower Paterson	78	Pump Bore	27/04/2011	10.8				-
WEX2	Lower Paterson	84	Observation		11.44	23	Y	0.03	1.3×10^{-3}
CWB17	Upper & Lower Paterson	96	Pump Bore	30/05/2012	18.8				-
WEX4D	Upper & Lower Paterson	90	Observation		17.9	8	Y		7.6×10^{-4}
CWB18	Upper & Lower Paterson	126	Pump Bore	7/05/2012	26.2				-
CWB17	Upper & Lower Paterson	96	Observation				No Results		
CWB19	Upper & Lower Paterson	118	P-Drawdown	14/05/2012	26.6				-
CWB17	Upper & Lower Paterson	96	Observation		1486	655	N	-	-
WEX5d	Lower Paterson	36	Pump Bore	14/12/2009	15.2				-
WEX5s	Upper Paterson	18	Observation				No results		
WEX5s	Upper Paterson	18	Pump Bore	18/04/2012	12.0				-

Bore	Aquifer	Screened Length (m)	Type	Date	Transmissivity (m^2/d)	Radius (m)	Meets Dupuit Assumption (Y/N)	t?	Storativity
TPB16	Coolbro Sandstone	25.4	Pump Bore	14/12/1987	65.7				-
OB16	Coolbro Sandstone	24	Observation		69.4	21.5	Y	0.002	5.6×10^{-4}
North Bore	Coolbro Sandstone	30	Pump Bore	23/11/2009	32.1				-
OB16	Coolbro Sandstone	24	Observation		56.9	43	N	-	-
13PI	Coolbro Sandstone	6	Pump Bore	16/12/1987	6.5				-
13PD	Coolbro Sandstone	6	Observation		6.5	25.2	Y	0.1	2.9×10^{-3}
13PS	Coolbro Sandstone	6	Observation		5.3	21.9	N	-	-
M	Coolbro Sandstone		Observation		6.7	40.1	Y	0.04	3.7×10^{-3}
KWP1	Coolbro Sandstone	96	Pump Bore	8/06/1997	19				-
KWX4	Coolbro Sandstone	72	Observation		42	4	N	-	-
KWP1	Coolbro Sandstone	96	Pump Bore	26/10/2009	6.8				-
KWX4	Coolbro Sandstone	72	Observation		35.8	4	N	-	-
KEB1	Coolbro Sandstone	94	Pump Bore	23/04/2011	3.1				-
15PI	Rudall	9	Pump Bore	12/12/1987	6.9				-
15PS	Rudall	6	Observation		12	14.8	N	-	-
15PD	Rudall	12	Observation		10.3	10.1	N	-	-
15PI	Rudall	9	Pump Bore	2/06/1997	34				-
15PS	Rudall	6	Observation		62	5	N	-	-
KEB2	Rudall	108	Pump Bore	17/04/2011	2				-
14PD	Rudall	12	Observation		145.9	221	N	0.06	-
14PI	Rudall	12	Observation				No results		
14PS	Rudall	3	Observation				No results		

Notes: Source D&M – Dames and Moore (1988); H-R – Hydro-Resources (1997); MWH data; PS (MWH) Pennington Scott analysis using MWH data;
Grey line indicates that DuPuit Assumption is not valid as the Transmissivity values are not with 10%

4. WATER QUALITY ANALYSES

Groundwater quality is measured in every groundwater installation following conclusion of bore development and again at the completion of pump testing. Water samples are tested in the field for electrical conductivity (EC), temperature and pH. A water sample is then usually submitted to a NATA-certified laboratory for major component analysis of lab pH, conductivity, TDS, ionic balance, major ions, nutrients and metals.

Apart from the construction water quality, Dames and Moore (1988) also tested groundwater chemistry in many of their holes on a monthly basis from May 1987 until December 1989. Their analytical program included an initial comprehensive analysis of anions and cations, trace metals and radionuclides (monthly, July to October 1988), followed by a revised key element program for standard water analysis, fluoride, silica, ^{226}radium and uranium (monthly, October 1988 onwards) and a revised comprehensive program as for the Key Element Program but including thorium, ^{210}lead and ^{210}polonium (quarterly, October 1988). Summary ranges of the Dames and Moore (1988) groundwater chemistry by aquifer unit are presented in Table 4-1.

Cameco has continued the groundwater chemistry monitoring program for the ERMP between 2009 and 2011; with 54 bores monitored every second month for routine cations and anions, and 33 bores monitored quarterly for isotopes (MWH, 2010).

A final baseline groundwater sampling program was conducted on a wide selection of bores in April 2012, with the sample locations shown in Figure 4-1. During this program each bore purged using a 3 inch submersible pump for a minimum of one hour. A representative natural water sample (no preservatives) was then collected and submitted to a NATA-certified laboratory for major component analysis of pH, conductivity, TDS, ionic balance, major ions, nutrients and metals. The results are summarised in Table 4-2 and included in Appendix D. A Piper diagram of this latest set of chemistry results is presented in Figure 4-2.

Table 4-1: Water quality data for aquifer units, reproduced from Dames & Moore, 1988

Parameter	Unit	Paterson Formation (upper unit)	Paterson Formation (lower unit)	Proterozoic 50–100 m	Proterozoic 100–150 m
Laboratory Parameter					
pH		6.9 – 8.5	7 – 8.5	6 – 12.1	6.4 – 12.5
Conductivity	µS/cm	850 – 18,710	920 – 8,200	215 – 18,000	160 – 21,000
Resistivity	Ohm.m	0.5 – 11.7	1.2 – 1,087	0.5 – 60	0.5 – 7.7
TDS	mg/L	550 –12,270	570 – 5,170	120 – 11,900	930 – 14,260
Major Ions					
Calcium	mg/L	19 – 200	18 – 578	10 – 510	4 – 530
Chlorine	mg/L	102 – 5,370	141 – 1,832	16 – 5,695	12 – 5,245
Magnesium	mg/L	14 – 410	16 – 136	0.1 – 370	<0.1 – 560
Sodium	mg/L	160 – 8,360	210 – 1,510	12 – 3,635	8 – 3,750
Sulphate	mg/L	46 – 2,250	77 – 1,050	7 – 1,965	3 – 3,440
Bicarbonate (HCO_3)	mg/L	77 – 877	44 – 758	1.2 – 661	62 – 792
Hardness (as $CaCO_3$)	mg/L	108 – 2,086	123 – 1,171	45 – 2,795	39 – 3,152
Carbonate Hardness (as $CaCO_3$)	mg/L	70 – 1,890	40 – 572	45 – 1,300	39 – 1,325
Non Carbonate Hardness	mg/L	0 – 1,315	0 – 1,131	0 – 2,552	3 – 2,878
Total Alkalinity (as $CaCO_3$)	mg/L	70 – 798	40 – 670	67 – 1,386	57 – 2,085
Nutrients					
Fluorine	mg/L	<0.01 – 12	<0.1 – 4.5	<0.1 – 15	0.3 – 18
NH_3	mg/L	<0.01 – 0.24	<0.01 – 0.5	<0.01 – 1.5	<0.01 – 2.2
NO_2	mg/L	<0.01	<0.01	<0.01	-
Nitrate as NO_3	mg/L	<0.1 – 24	<0.1 – 22	<0.1 – 43	0 – 9
Phosphate	mg/L	<0.01 – 4	<0.01 – 6.1	<0.01 – 1	<0.01 – 0.97
Potassium	mg/L	16 – 350	7 - 98	4 – 1,071	4 – 320
Metals					
Gold	mg/L	<0.01 – 0.06	0.01 – 0.08	<0.01	<0.01 – 0.05
Aluminium	mg/L	<0.05 – 28	0.5 – 4.5	<0.005 – 4.7	0.1 – 4.4
Arsenic	mg/L	<0.005 – 0.025	<0.002 – 0.11	<0.005 – 0.9	<0.005 – 0.015
Barium	mg/L	<0.02 – 0.04	<0.02 – 0.13	<0.02 – 0.58	<0.02 – 0.16
Cadmium	mg/L	<0.01 – 0.1	<0.01 – 0.01	<0.01 – 0.01	<0.01 – 0.02
Cobalt	mg/L	<0.01 – 0.8	<0.01 – 0.02	<0.01 – 0.02	<0.01 – 0.02
Chromium	mg/L	<0.01 – 0.1	<0.01 – 0.03	<0.01 – 0.71	<0.01 – 0.45
Copper	mg/L	<0.02 – 0.8	<0.02 – 0.44	<0.02 – 0.44	<0.02 – 0.53
Iron	mg/L	<0.03 – 54	<0.03 – 13	<0.03 – 8	<0.03 – 4. 3
Mercury	mg/L	<0.0001 – 0.0003	<0.0001	<0.0001	<0.001 – 0.9
Manganese	mg/L	<0.01 – 14	<0.01 – 1.2	<0.01 – 4.8	<0.01 – 96
Molybdenum	mg/L	<0.01 – 0.02	<0.01 – 0.05	<0.01 – 0.06	<0.01 – 0.02
Nickel	mg/L	<0.02 – 0.2	<0.02 – 0.05	<0.02 – 0.04	<0.02
Lead	mg/L	<0.02 – 0.32	<0.02 – 0.4	<0.02 – 0.15	<0.02 – 0.44
Selenium	mg/L	<0.005 – 0.008	<0.002 – 0.006	<0.002 – 0.01	<0.005 – 0.01
Vanadium	mg/L	<0.01 – 0.15	<0.01 – 0.04	<0.01	<0.01 – 0.49

Zinc	mg/L	<0.02 – 6.7	<0.02 – 4.8	<0.02 – 0.15	<0.02 – 0.33
Boron	mg/L	<0.2 – 5.3	<0.01 – 0.04	<0.01 – 0.99	<0.01 – 2
Silica	mg/L	5 – 59	6 – 50	2 – 80	0.6 – 40
Uranium	µg/L	<1 – 130	<1 – 120	< 1 – 320	<1 – 170
Thorium	µg/L	<1 – 9	<1 – 4	<1 – 3	<1 – 3
Gross Alpha (mBq/L)	mBq/L	<70 – 21,000	<70 – 4,000	<70 – 21,000	70 – 8,800
Gross Beta (mBq/L)	mBq/L	690 – 9,900	590 – 4,600	390 – 200,000	470 – 9,400
Ra^{226} (mBq/L)	mBq/L	6 – 610	11 – 1,200	18 – 180,000	16 – 760
Po^{210}	mBq/L	<7 – 110	<7 – 280	<7 – 17,000	<20 – 100
Pb^{210} (mBq/L)	mBq/L	<15 – 70	<15 – 110	<15 – 3,800	<70 – 970
Th^{230} (mBq/L)	mBq/L	<7 – 1400	<7 – 470	<7 – 170	<7 – 98

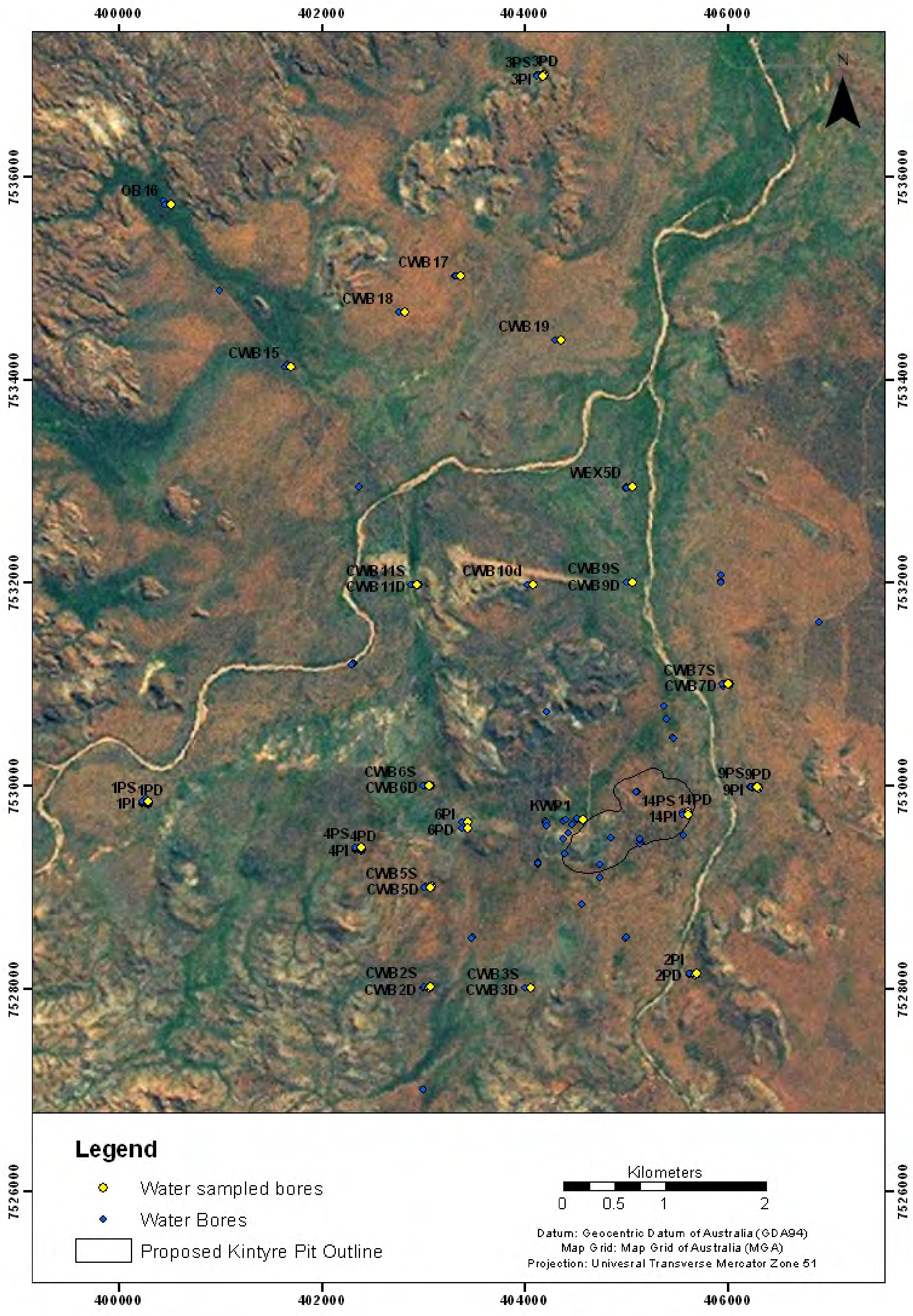

Figure 4-1: Location map showing bores sampled during the 2012 program

Table 4-2: Selected baseline groundwater chemistry April 2012

Parameter	Units	OB16	CWB2D	CWB2S	CWB3D	CWB3S	CWB5D	CWB5S	CWB6D	CWB6S	CWB7D	CWB7S	CWB9D	CWB9S	CWB10D	CWB11D
Laboratory Parameters																
pH	-	6.6	8.3	7.4	7.4	7.6	8	7.2	7.6	7.7	7.7	7.4	7.3	7.4	7.4	7.8
Conductivity at 25° C	µS/cm	800	3,510	10,200	1,880	1,230	6,720	23,900	1,300	2,780	6,760	5,260	10,000	17,200	4,950	1,940
Total Dissolved Solids	mg/L	430	2,120	6,920	1,100	740	4,100	19,600	720	1,620	4,460	3,420	6,420	12,200	3,090	1,090
Ionic Balance	%	94	95	100	93	93	98	102	98	99	98	98	101	95	93	98
Major Ions																
Calcium	mg/L	22	8	110	39	14	24	520	19	42	110	140	79	160	110	22
Chloride	mg/L	140	560	2,300	220	90	1,400	6,000	210	530	1,500	1,200	2,200	4,900	1,100	360
Fluoride	mg/L	0.26	1.4	0.62	1.3	1	0.62	<0.2	0.34	0.65	0.85	0.63	2.2	2.1	1.3	0.56
Magnesium	mg/L	18	31	200	60	21	160	1,100	17	62	160	200	210	490	170	22
Sodium	mg/L	90	720	2,030	270	230	1,300	4,200	210	440	1,100	700	1,900	3,100	650	340
Sulphate	mg/L	65	360	1,700	77	21	190	5,500	120	310	910	770	1,400	2,600	490	190
Bicarbonate as $CaCO_3$	mg/L	91	670	560	650	540	1,400	370	180	280	380	310	740	520	610	220
Carbonate as $CaCO_3$	mg/L	<1	7	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nutrients																
Nitrate as NO_3	mg/L	11	<1	<1	1	2	<1	<1	<1	<1	<1	<1	16	5	4	<1
Potassium	mg/L	15	28	55	30	15	40	78	12	16	49	44	130	290	78	19
Metals																
Aluminium	mg/L	0.015	0.18	0.17	17	7.1	0.16	6.1	0.03	0.08	0.096	0.046	<0.05	36	0.097	0.12
Barium – total	mg/L	0.065	0.084	0.04	0.45	0.18	0.38	0.22	0.12	0.042	0.081	0.022	0.02	0.42	0.16	0.15
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron – total	mg/L	0.2	0.96	1.8	0.6	0.48	1.3	3.5	0.55	0.81	1.4	1.2	2.9	3.3	1.3	0.61
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt – total	mg/L	<0.005	<0.005	<0.005	0.022	0.008	<0.005	<0.005	<0.005	<0.005	0.019	<0.005	<0.005	0.079	0.012	<0.005
Copper	mg/L	<0.005	<0.005	<0.005	0.058	0.009	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.005	0.048	<0.005	<0.005
Iron – total	mg/L	0.087	0.26	1.1	29	13	0.38	13	0.054	0.12	0.56	0.22	<0.005	55	0.76	0.64
Lead	mg/L	<0.001	<0.001	<0.001	0.024	0.005	<0.001	0.009	<0.001	<0.001	0.006	<0.001	<0.001	0.045	<0.001	<0.001
Manganese – total	mg/L	0.014	0.17	0.4	2	0.62	0.37	5.5	0.48	0.23	0.7	0.16	<0.001	3.3	2	1.1
Molybdenum – total	mg/L	<0.005	0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	0.01	0.007	<0.005	<0.005
Nickel – total	mg/L	<0.005	<0.005	<0.005	0.023	0.013	<0.005	0.016	<0.005	<0.005	0.015	<0.005	<0.005	0.096	0.011	0.014
Selenium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tin	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc – total	mg/L	0.012	0.01	0.008	0.091	0.08	0.008	0.049	<0.005	<0.005	0.092	<0.005	<0.005	0.42	0.012	0.039

Table 4-2: Selected baseline groundwater chemistry April 2012 (continued)

Parameter	Units	CWB11S	CWB15	WEX5D	KWP1	1PD	1PI	1PS	2PD	2PI	2PS	3PD	3PI	3PS	4PD	4PI
Laboratory Parameters																
pH	-	7.5	7.9	7.7	7.4	10.9	7.8	7.9	6.3	7.6	6.4	7.7	7.6	8	8	8
Conductivity at 25° C	µS/cm	15,800	1,020	3,700	8,250	1,920	1,270	980	170	420	190	1,470	1,840	1,610	11,100	11,300
Total Dissolved Solids	mg/L	10,600	590	2,250	5,370	1,000	740	590	100	220	110	790	1,050	890	7,360	7,540
Ionic Balance	%	97	90	93	93	93	91	94	104	91	79	90	96	96	105	102
Major Ions																
Calcium	mg/L	150	24	34	110	1	20	19	7	22	6	47	49	37	100	100
Chloride	mg/L	4,600	160	710	2,100	410	190	130	10	20	20	290	400	320	2,700	2,800
Fluoride	mg/L	1.7	0.51	2.6	2.1	0.35	0.85	0.85	0.25	0.48	0.28	0.29	0.27	0.49	0.37	1
Magnesium	mg/L	300	21	53	190	<1	18	15	7	25	7	36	44	38	220	260
Sodium	mg/L	3,000	130	690	1,400	340	210	160	10	20	10	170	230	210	2,200	2,100
Sulphate	mg/L	1,600	74	370	1,100	150	91	52	<5	5	<5	110	120	110	1,500	1,400
Bicarbonate as $CaCO_3$	mg/L	450	200	590	470	<1	300	270	52	200	56	210	170	200	280	490
Carbonate as $CaCO_3$	mg/L	<1	<1	<1	<1	110	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nutrients																
Nitrate as NO_3	mg/L	4	8	3	7	<1	<1	3	5	<1	7	3	6	8	<1	<1
Potassium	mg/L	140	24	37	81	35	16	18	4	8	4	21	22	31	62	110
Metals																
Aluminium	mg/L	6	0.013	0.08	0.016	0.46	0.023	0.72	0.069	0.036	0.34	0.012	0.007	0.22	3.3	0.15
Barium – total	mg/L	0.068	0.065	0.028	0.049	0.047	0.011	0.017	0.11	0.29	0.14	0.017	0.022	0.017	0.051	0.14
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron – total	mg/L	1.7	0.41	1.6	1.7	0.41	0.41	0.3	0.044	0.071	0.047	0.25	0.28	0.29	2.1	1.8
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt – total	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/L	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron – total	mg/L	7.3	0.021	0.018	29	0.68	0.08	0.86	0.21	1.6	0.27	0.052	0.047	0.28	7.7	0.36
Lead	mg/L	0.004	<0.001	<0.001	<0.001	0.017	<0.001	0.009	0.004	0.002	0.002	<0.001	<0.001	0.025	0.022	<0.001
Manganese – total	mg/L	0.74	0.042	0.16	0.22	0.016	0.029	0.4	0.031	0.39	1	0.056	0.13	1.8	1.1	0.083
Molybdenum – total	mg/L	<0.005	<0.005	0.021	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005
Nickel – total	mg/L	0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tin	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.018	<0.01	<0.01
Zinc – total	mg/L	0.042	<0.005	<0.005	0.014	0.036	<0.005	<0.005	0.007	<0.005	0.007	<0.005	<0.005	0.009	0.05	<0.005

Table 4-2: Selected baseline groundwater chemistry April 2012 (continued)

Parameter	Units	4PS	6PD	6PI	9PD	9PI	9PS	14PD	14PI	14PS	CWB8S	WEX5S	CWB12	CWB17	CWB18	CWB19
Laboratory Parameters																
pH	-	7.6	8.3	7.6	8	7.9	7.6	7.5	6.6	7	7.3	7.3	7.5	7.6	7.5	7.4
Conductivity at 25° C	µS/cm	5,950	3,630	470	12,700	14,200	7,510	7,810	4,170	1,850	7,590	6,460	5,430	1,540	980	1,860
Total Dissolved Solids	mg/L	3,100	2,030	240	7,960	9,220	4,550	5,100	2,290	940	4,920	3,070	3,340	890	530	950
Ionic Balance	%	95	90	85	97	99	94	97	88	58	97	95	-	-	-	-
Major Ions																
Calcium	mg/L	60	19	17	87	170	74	240	120	47	290	200	130	20	18	30
Chloride	mg/L	1,100	710	70	3,600	4,200	1,800	2,100	1,100	280	2,100	1,000	1,200	240	140	330
Fluoride	mg/L	<0.2	1.1	0.2	0.37	0.4	2.1	0.64	<0.2	<0.2	0.32	<0.2	0.56	1.3	0.48	0.60
Magnesium	mg/L	39	56	9	210	230	100	170	28	8	300	140	200	23	17	35
Sodium	mg/L	1,100	610	50	2,400	2,600	1,400	1,200	550	130	830	580	750	260	140	260
Sulphate	mg/L	600	190	<5	1,400	1,100	900	780	120	<5	750	660	760	140	80	140
Bicarbonate as $CaCO_3$	mg/L	610	620	130	70	71	490	290	190	380	190	410	300	230	150	190
Carbonate as $CaCO_3$	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nutrients																
Nitrate as NO_3	mg/L	10	22	<1	<1	<1	23	<1	<1	<1	11	<1	<1	8	8	8
Potassium	mg/L	28	35	5	72	60	83	34	18	14	63	27	49	30	23	25
Metals																
Aluminium	mg/L	12	0.059	0.33	0.29	0.13	0.009	38	1	2.7	0.006	<0.005	0.20	0.023	<0.005	0.006
Barium – total	mg/L	0.25	0.22	0.047	0.07	0.05	0.026	0.65	0.73	1.8	0.06	0.027	0.025	0.016	0.006	0.013
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-
Boron – total	mg/L	1.4	0.91	0.07	2.3	1.7	1.7	0.84	0.098	0.034	0.79	0.83	-	-	-	-
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt – total	mg/L	0.014	<0.005	<0.005	<0.005	<0.005	<0.005	0.041	<0.005	0.01	<0.005	0.012	-	-	-	-
Copper	mg/L	0.034	<0.005	<0.005	<0.005	<0.005	<0.005	0.081	<0.005	0.009	<0.005	0.011	-	-	-	-
Iron – total	mg/L	24	0.088	0.79	1	0.71	0.046	110	84	54	0.033	0.045	0.27	0.014	<0.005	0.011
Lead	mg/L	0.072	0.003	<0.001	0.005	0.002	<0.001	0.086	0.005	0.012	<0.001	0.003	-	-	-	-
Manganese – total	mg/L	0.26	0.44	0.26	0.44	0.3	0.21	1.3	9.1	4.4	0.004	0.043	0.25	<0.001	0.016	0.001
Molybdenum – total	mg/L	0.009	0.009	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.005	-	-	-	-
Nickel – total	mg/L	0.023	<0.005	<0.005	<0.005	<0.005	<0.005	0.051	<0.005	<0.005	<0.005	0.007	-	-	-	-
Selenium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-
Tin	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-
Zinc – total	mg/L	0.093	<0.005	<0.005	0.007	0.013	<0.005	0.082	0.025	0.024	0.007	0.027	0.063	0.007	0.013	0.082

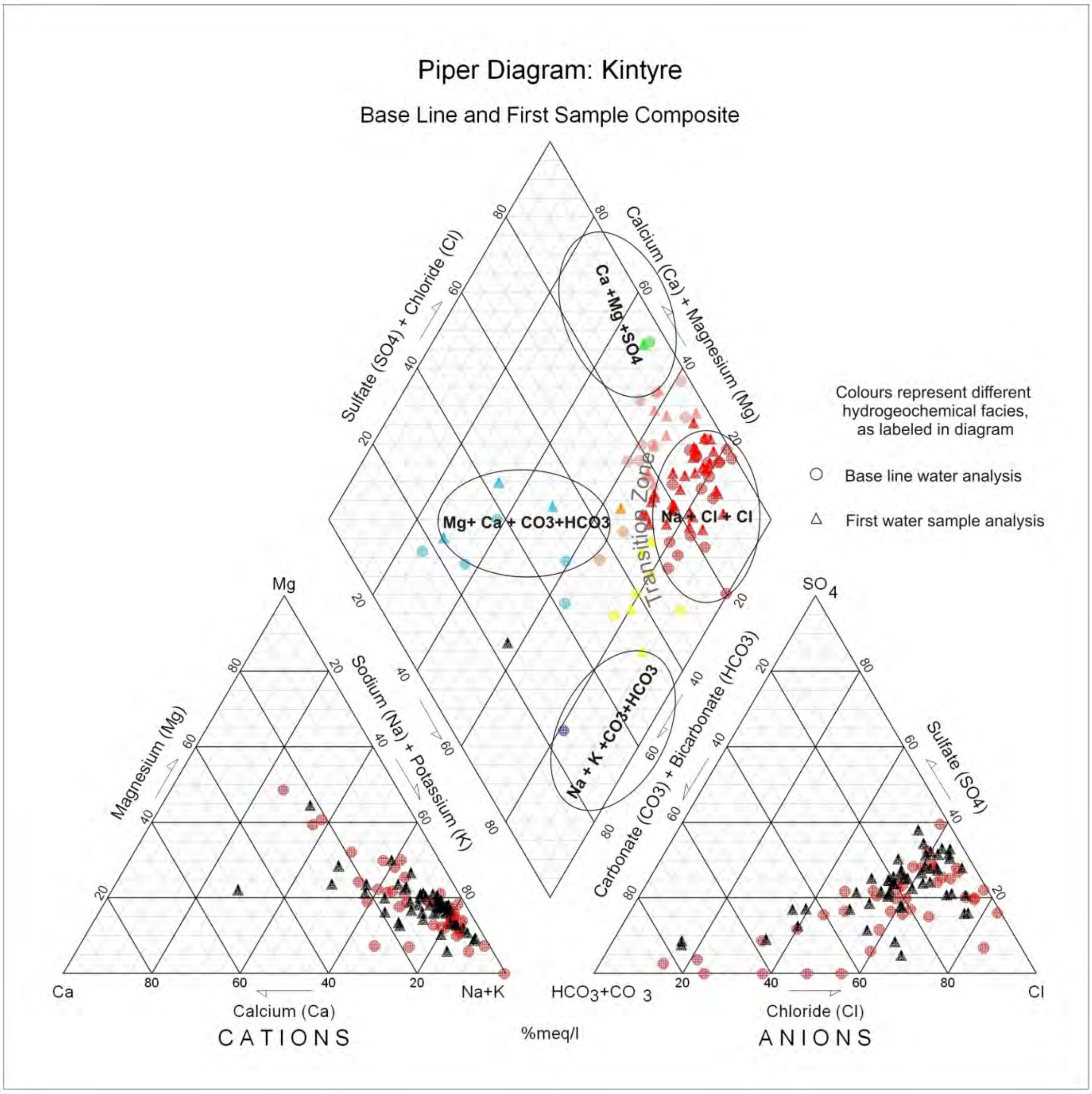

Figure 4-2: Piper diagram of major chemical constituents in groundwater at Kintyre

5. GROUNDWATER LEVEL MONITORING

Table 5-1 summarises Cameco's groundwater water level monitoring program for the ERMP. Static water levels are manually dipped in 74 groundwater installations every two months since October 2009.

In addition to the manual dip measurements, Cameco collected over 24 months of automated water level monitoring at 60 minute intervals in fourteen (14) scattered groundwater locations to assess groundwater response to seasonal rainfall. The hydrographs for these 15 sites are presented in Appendix E along with the daily rainfall records from Telfer for the same period.

The 14 loggers, plus one additional logger, were redistributed between April and May 2012 to monitor drawdown around three production test bores in the water supply area 1 minute intervals. This detailed water level information is used for the transient model calibration of the regional numerical groundwater model (Tetra Tech, 2012b).

Table 5-1 Summary of ERMP groundwater level monitoring

Monitoring interval	Method	Number of stations	Monitor Network	From	To
60 minutes	Automated Troll 500 logger	14	CWB3s, CWB6S, CWB6D, CWB11S, CWB11D, WEX2, 10PD, 10PS, 9PI, 9PS, WEX5D, WEX5S, 1PI, TPB3	2/12/2009	20/05/2012
1 minute	Automated Troll 500 logger	15	3PD, 3PI, 3PS, CWB7D, CWB18, CWB19, WEX1, WEX3, WEX4, CWB6S, CWB6D, CWB11S, CWB11D, TPB3, WEX2	21/04/2012	21/05/2012
Bi-monthly	Manual dip	74	10PD, 10PI, 10PS, 11PD, 14PD, 14PI, 14PS, 16PI, 1PD, 1PI, 1PS, 2PD, 2PI, 2PS, 3PD, 3PDD, 3PI, 3PS, 4PD, 4PI, 4PS, 6PD, 6PI, 9PD, 9PI, 9PS, CWB10D, CWB11D, CWB11S, CWB1D, CWB2D, CWB2S, CWB3D, CWB3S, CWB4D, CWB4S, CWB5D, CWB5S, CWB6D, CWB6S, CWB-7D, CWB7S, CWB8D, CWB8S, CWB9D, CWB9S, KD075, KWP1, KWX11, KWX2, KWX3, KWX4, KWX5, KWX7A, KWX8, KWX9, North Bore, OB1, OB3, Obs16, Temporary P10, TPB3, WEX1, WEX2, WEX3, WEX4, WEX5D, WEX5S, CWB12, CWB13, CWB14, CWB15, KEB1, KEB2	1/10/2009	31/12/2011

Reference to the hydrographs show that the water table in bores CWB3S, CWB6S, CWB6D, CWB11S, TPB3, WEX5C, and WEX5S rose between 0.5 and 1 metres following heavy rainfall during February and March 2011, and from Cyclone Lau on 19 March 2012. Bores 10PS and 10PD, which are screened in Rudall Complex in the middle of the proposed Kintyre pit, show a gradual water fall of 1 m over a two year period between December 2009 and April 2012. Interestingly, these bores did not appear to respond to Cyclone Lau or the high rainfall during early 2011. The response in the latter three bores does not appear to relate to the rainfall pattern in the Telfer data, albeit that the Telfer rain gauge is 60 kilometres north of the Project.

The data loggers in bores 9PI and 9PS are providing pressure readings that are less than atmospheric pressure, which should be reading 10m when the logger is at surface. These loggers will be checked and recalibrated if necessary.

The logger responses in the remaining bores show little discernible response to the seasonal rainfall, but do show sharp local responses to pump tests conducted on nearby production bores.

6. AIRBORNE EXPLORATION METHODS

A rare opportunity to investigate buried palaeovalleys was provided by Geoscience Australia's Onshore Energy Security Program (OESP) that utilised Airborne Electromagnetic (AEM) surveys over the Paterson–Canning Region. The survey was flown using the Fugro TEMPEST AEM system between September 2007 and August 2008 and covered areas of the Paleoproterozoic Rudall Complex and Neoproterozoic Yeneena Basin, as well as the eastern Pilbara Block and parts of the Officer and Canning Basins. A total area of 45,330 km^2 was flown with line spacing of 200 m, 1 km, 2 km and 6 km. Greater discretisation was applied to the Paterson North survey area, particularly around Kintyre.

English (2011) and English et al. (2010) describe this survey and its findings in detail.

6.1 Interpretation

The valley surrounding Kintyre represents a Permian glacial valley that has been mostly filled by predominantly glaciofluvial and glaciolacustrine deposits. Its surface now forms a broad flat valley about 5 km wide through the central and lower reaches, rapidly narrowing to under 2 km in its upper reaches. The extent of the palaeovalley is clearly seen on TDEM sections. Figure 6-1 shows TDEM images at 3 elevation slices. These images reveal an area of predominantly high conductivity, with the main channel about 2 km wide, and areas with relatively low conductivity within the palaeovalley forming a network of channels typically about 400 m wide. The valley flanks against the plateau appear to be very steep and probably hold scree and colluvial deposits form low angle fans. It is clearly seen that the valley contains two branches, referred to as the western and southern branches, which converge north of the Kintyre site.

The survey was used to reveal variations in the conductivity of fluvioglacial sediments and Proterozoic rocks, enabling differentiation of the regional palaeodrainage system from the basement surface. The base of this conductive zone was digitised from Conductivity Depth Image (CDI) slices, which mapped out the contact between Paterson Formation sediments and basement Proterozoic rocks. These digitised surfaces were then mapped into XYZ coordinates and interpolated into a 3D surface, using available bore logs for data control.

To complete the basement surface, a 3D depth to basement model (Woltmann, 2011) was incorporated to provide additional data about hydro-stratigraphy around the Kintyre ore body. A combination of this University of New South Whales (UNSW) geologic block model, interpreted TDEM survey data and drill-hole logs were used to produce the final Paterson Formation basement surface (Figure 6-2).

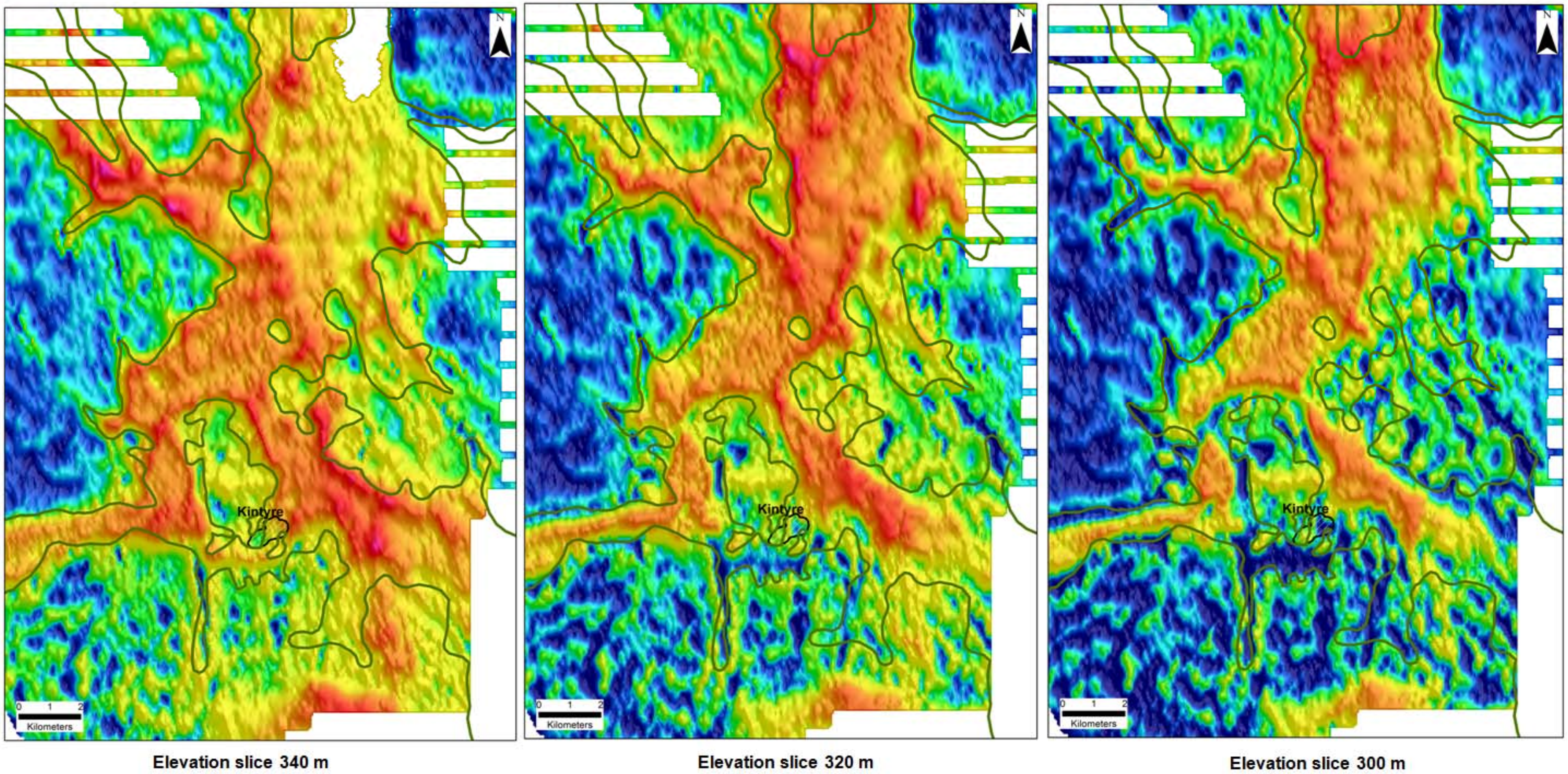

Figure 6-1: TDEM images showing extent of Paterson Formation

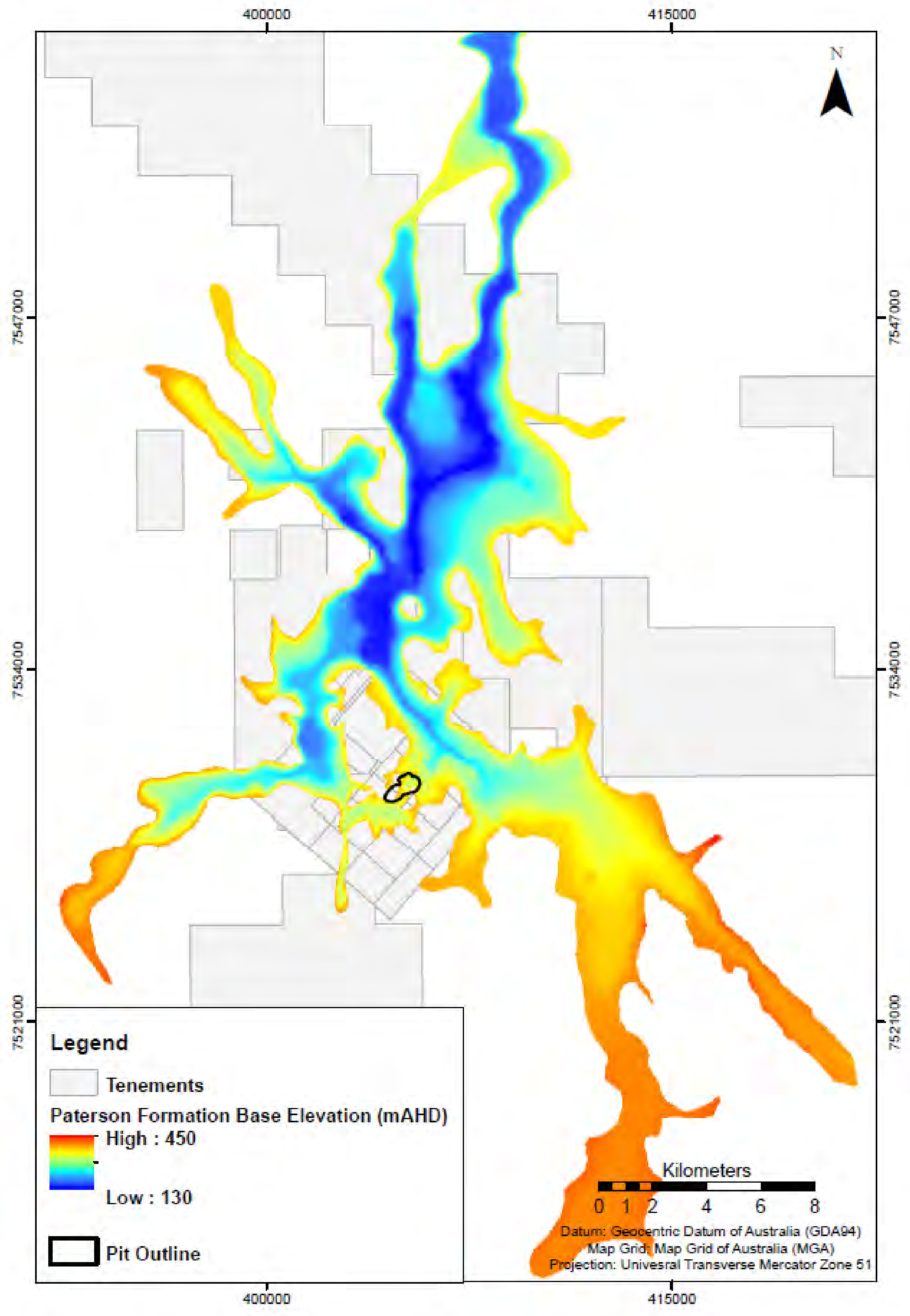

Figure 6-2: Interpreted base elevation of the Paterson Formation

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Appendix A

Licence to Construct a Bore

File No: NWK2288

Government of Western Australia
Department of Water

Instrument No. CAW168652(1)

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Minister under section 26D of the Rights in Water and Irrigation Act 1914

Licensee(s)	Cameco Australia Pty Ltd	
Description of Water Resource	Canning-Kimberley Combined - Fractured Rock West - Fractured Rock	
Location of Well(s)	L45/66, E45/1772, P45/2642	
Authorised Activities	**Activity**	**Location of Activity**
	Construct 2 non-artesian well(s) Alter 2 non-artesian well(s).	L45/66, E45/1772, P45/2642
Duration of Licence	From 17 June 2009 to 16 June 2010	

This Licence is subject to the following terms, conditions and restrictions:

1 That water discharged during the pump test, is to be disposed of in such a manner as to cause no undesirable environmental impact.

2 The well must be constructed by a driller having a current class 1 water well drillers certificate issued by the Western Australian branch of the Australian Drilling Industry Association or other certification approved by the Department of Water as equivalent

3 The licensee is required to provide to the Department of Water a completed ' Particulars of Completed Bore Hole Form ' on completion of the approved drilling programme.

4 That no well shall be sunk within 400 metres of an existing well without the written permission of the owner of that well.

End of terms, conditions and restrictions

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

File No: NWK2288

Government of Western Australia
Department of Water

Instrument No. CAW171498(1)

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Minister under section 26D of the Rights in Water and Irrigation Act 1914

Licensee(s)	Cameco Australia Pty Ltd	
Description of Water Resource	Canning-Kimberley Combined - Fractured Rock West - Alluvium	
Location of Well(s)	P45/2635, P45/2637, P45/2642, P45/2640, P45/2643, P45/2638	
Authorised Activities	**Activity**	**Location of Activity**
	Construct 7 non-artesian well(s).	P45/2635, P45/2637, P45/2642, P45/2640, P45/2643, P45/2638
Duration of Licence	From 10 June 2010 to 9 June 2011	

This Licence is subject to the following terms, conditions and restrictions:

1 The well must be constructed by a driller having a current class 1 water well drillers certificate issued by the Western Australian branch of the Australian Drilling Industry Association or other certification approved by the Department of Water as equivalent.

2 That water discharged during the pump test, is to be disposed of in such a manner as to cause no undesirable environmental impact.

3 That no well shall be sunk within 400 metres of an existing well without the written permission of the owner of that well.

End of terms, conditions and restrictions

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

Appendix B

ERMP Bore Completion Logs

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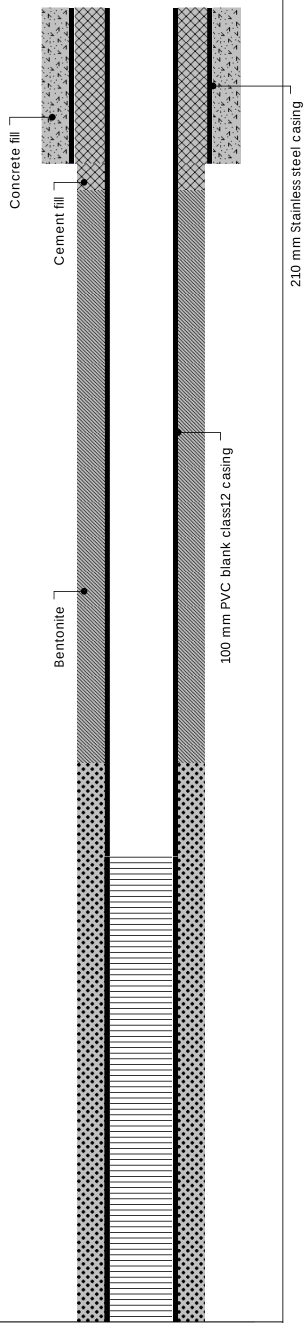
Borehole: CWB1

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 86.6 m
Client: Cameco	Easting: 402996	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7526995	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
			Ground Surface	
0	Alluvial		SW med SAND, loose, dry reddish brown. silty sand (alluvium), fine to medium grained,	
	Upper Paterson Fm		Claystone, brownish grey, Fe staining, dry with fractures	
10				
20			Claystone, grey, weak, poorly consolidated, damp at 26mbgl. Wet at 30mbgl.	
30				
40			Siltstone grey. weathered sandy siltstone with clay, poorly sorted, fine grain sand, less moisture, rare quartz	
50				

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 12/10/2010
Drilling Method: RAB	Compiled: 3/6/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB1

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
			Claystone, grey with moderately consolidated, rare quartz, minor Fe staining, increase in moisture		100 mm PVC slotted class12 screen
60					
			Claystone, dark grey, moderately consolidated, hard, wet, Fe staining. Sandy layer from 66 to 67 mbgl.		
70					Gravel fill
	Lower Paterson Fm		Conglomerate pale grey medium strength. comprising of sandstone, siltstone and quartzite with rare schist. Hard and wet.	0.2 L/s, 8.23, 4.6 mS-cm 25.27 °C.	
80	Saprock		SCHIST dark grey. Hard, wet.	0.2 L/s, 8.27, 4.6 mS-cm 25.27 °C.	Push on cover
90					
100					

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Borehole: CWB2s

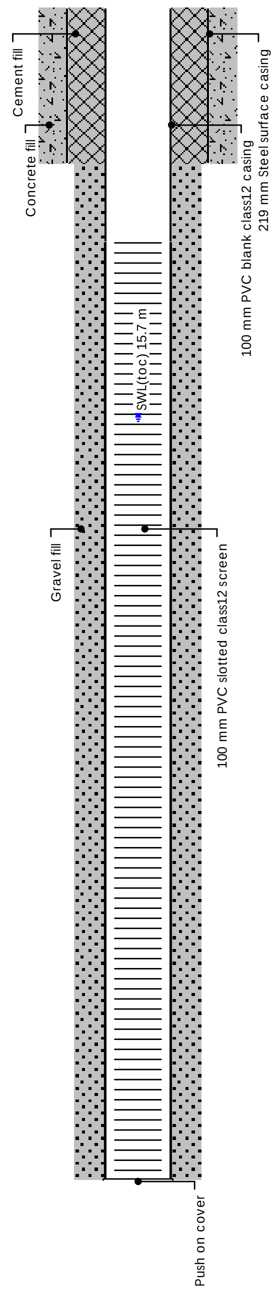
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 45 m
Client: Cameco	Easting: 403008	SWL: 15.7 m (toc) on 12/15/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7528008	Salinity: 6000 mg/L on 12/15/2009	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0–2			SM silty med SAND, loose, qtz reddish brown, Alluvial Deposit.	
2–4			SM silty med SAND, qtz reddish brown. Clayey. Traces of gneiss.	
4–17			Siltstone greyish brown low strength distinctly weathered. Poorly consolidated, traces of clay, dry.	
17–22			Siltstone greyish brown low strength distinctly weathered. Interbedded quartz conglomerate, subrounded, <1cm, dry.	
22–42			Siltstone pale grey high strength slightly weathered. Laminated, traces of quartzite gravel. Moist at 30m.	
42–45			SCHIST grey very high strength. Contains quartzite with grey mica. Moist.	

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill	Started: 12/12/2009
Drilling Equipment:	Completed: 12/12/2009
Drilling Method: RAB	Compiled: 5/8/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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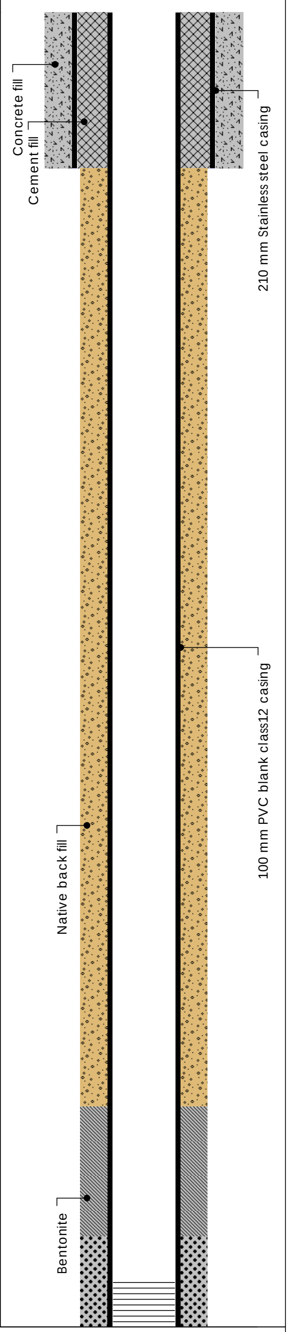
Borehole: CWB2d

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 73 m
Client: Cameco	Easting: 402994	SWL:	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7527997	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology
0			Ground Surface
	Alluvial		SM silty med SAND, loose, dry, qtz reddish brown. minor quartz chips
	Alluvial		SM silty med SAND, loose, dry, qtz reddish brown. some clay with increase in quartz chips
	Upper Paterson Fm		Siltstone granular. Tan, weathered, poorly consolidated, weak with some clay, dry.
10			
	Upper Paterson Fm		Siltstone greyish brown. weathered siltstone and some quartz conglomerate, rounded gravels, dry. Poorly consolidated.
	Upper Paterson Fm		Siltstone pale grey distinctly weathered. with quartz at 21, 25 and 33mbgl. Dry and hard
20			
30			
	Upper Paterson Fm		Claystone, grey,poorly consolidated, soft, dry.
40			
			QUARTZITE pink brown. with schist, minor dark green mica and abundant quartz. Hard, dry.
50			

Bore Construction



Drilling Company: Nudrill
Drilling Equipment: RAB
Drilling Method: RAB

Started:
Completed: 12/11/2009
Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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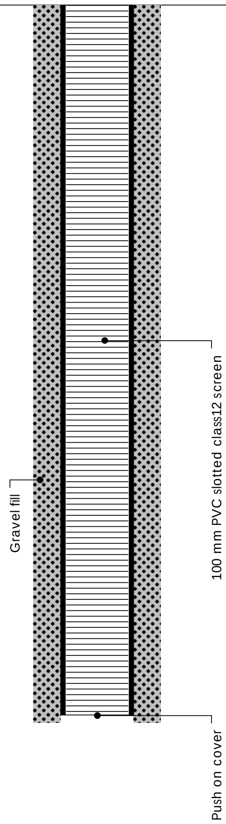
Borehole: CWB2d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Bore Construction
60–72.9	Saprock			

Depth scale: 60, 70, 80, 90, 100



Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB3s

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 30 m
Client: Cameco	Easting: 404001	SWL:	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7528004	Salinity:	Checked By:

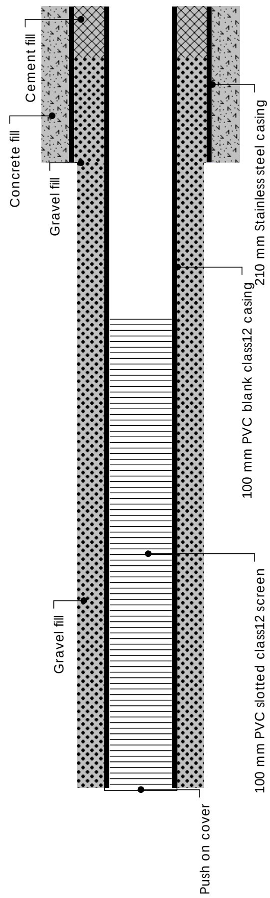
SUBSURFACE PROFILE

Depth (m)	Formation	Lithology
0		Ground Surface
0–1	Alluvial	SM silty med SAND, loose, SA, dry, qtz reddish brown. and gravel, subangular <3cm diameter
1–24	Upper Paterson Fm	GW sandy med GRAVEL, loose, SA, dry, qtz. Tan to brown with minor clay. Abundant schist and siltstone gravels.
24–30	Lower Paterson Fm	Conglomerate. Tan to brown (schist, quartzite, quartz, and siltstone), rounded, loose, damp and moist. Gravel clasts <3cm

Depth scale: 0, 10, 20, 30, 40, 50

Lithology Graphic

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 12/14/2009
Drilling Method: RAB	Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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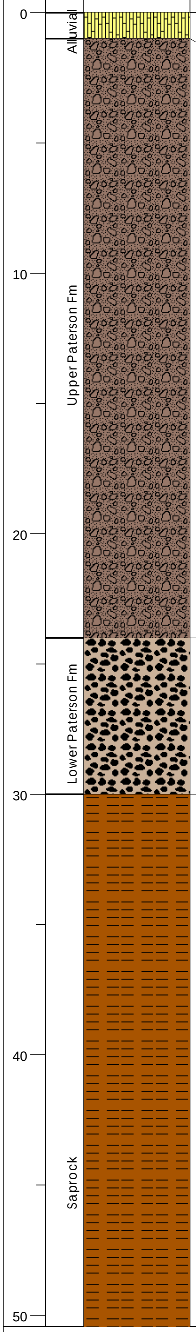
Borehole: CWB3d

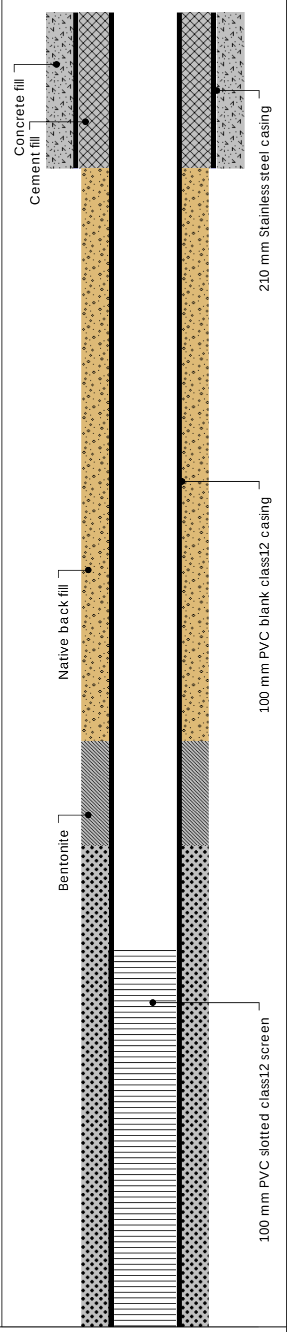
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 60 m
Client: Cameco	Easting: 404005	SWL:	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7527992	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0 – ~1	Alluvial		SM silty fine SAND, dry reddish brown. gravel subangular <3cm diameeter, abundant quartz, loose, dry.	
~1 – ~24	Upper Paterson Fm		GP sandy med GRAVEL poorly graded, loose, SA, qtz. minor clay, dry soft. Adundant schist and siltstone gravels.	
~24 – 30	Lower Paterson Fm		Conglomerate distinctly weathered. Tan to brown, (schist, quartzite, quartz and siltstone), rounded, loose, damp and moist. Gravel clasts >3cm.	
30 – 50	Saprock		SCHIST dark grey. with some quartzite and sandstone, abundant dark grey to green mica, hard, damp to moist. Quartz layer between 44 to 46 mbgl	



Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 12/14/2009
Drilling Method: RAB	Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB3d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
to 60				0.1 L/s, 7.8, 2 mS-cm 26.7 °C.	Gravel fill; Push on cover
60–100					

Depth scale: 60, 70, 80, 90, 100

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB4s

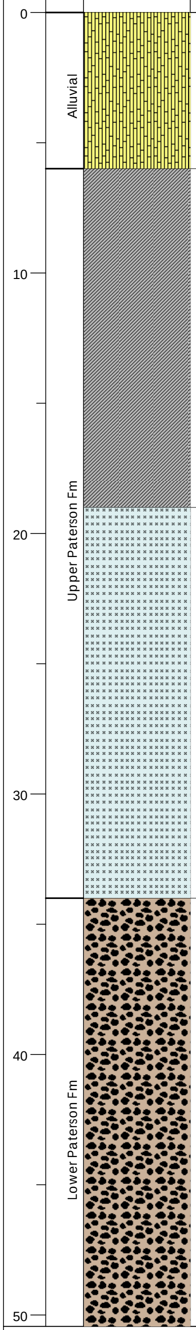
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 52 m
Client: Cameco	Easting: 405001	SWL: 14.32 m (toc) on 1/17/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7528498	Salinity: 7152 mg/L on 1/17/2010	Checked By:

SUBSURFACE PROFILE

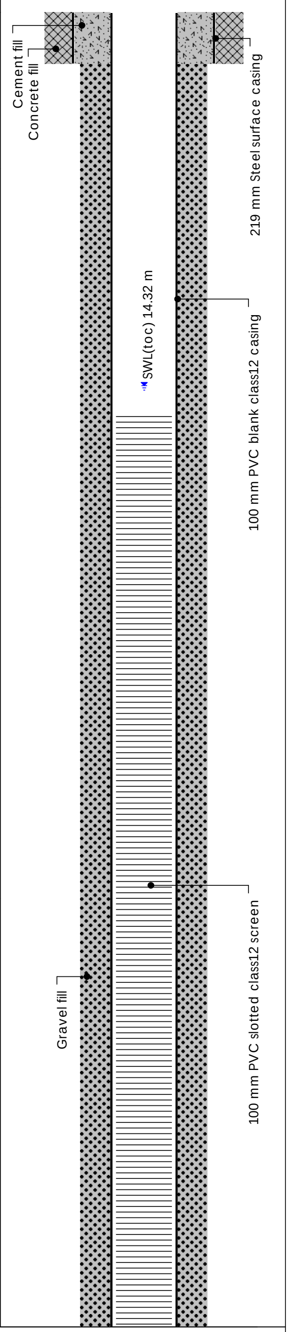
Ground Surface

Depth (m)	Formation	Lithology
0 – ~6	Alluvial	SM silty med SAND, loose, dry reddish brown. with subangular quartz gravel <10mm, poorly sorted
~6 – ~19	Upper Paterson Fm	Claystone with quartz, sandstone and minor schist gravel. Light brown
~19 – ~34	Upper Paterson Fm	Siltstone dark grey. Minor quartz and schist fragments
~34 – 50	Lower Paterson Fm	Conglomerate medium strength. Composed of quartz, schist, quartzite and siltstone with some grey/green mica traces. Subangular to subrounded chips.

Lithology Graphic



Bore Construction



Drilling Company: Nudrill	Started: 1/14/2010
Drilling Equipment:	Completed:
Drilling Method: RAB	Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB4s

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Bore Construction
				Push on cover
60				
70				
80				
90				
100				

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Borehole: CWB4d

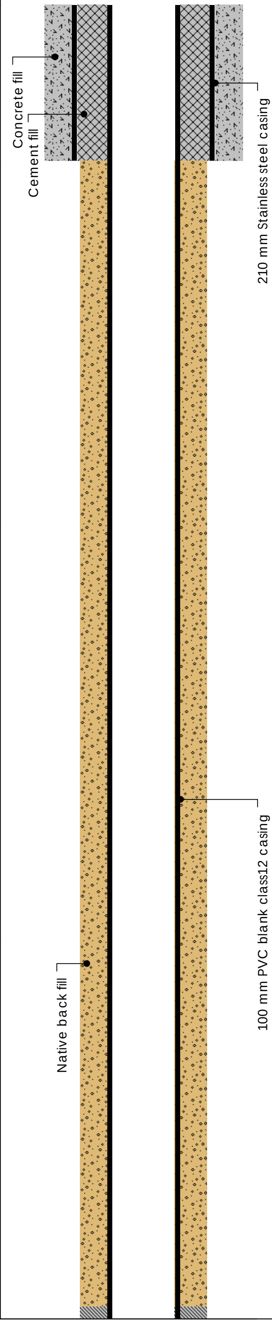
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 80 m
Client: Cameco	Easting: 404992	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7528495	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology
0		Ground Surface
0 – 6	Alluvial	SM silty med SAND, loose, dry reddish brown. with subangular quartz gravel <1cm, poorly sorted.
6 – 20	Upper Paterson Fm	Silty claystone with quartz, sandstone and schist gravel <1cm. Soft, poorly consolidated, plastic. Tan light brown
20 – 36	Upper Paterson Fm	Siltstone dark grey. with minor quartz and schist, subrounded gravel <0.5cm. Moderately hard, dry.
36 – 50	Lower Paterson Fm	Conglomerate grey. composed of siltstone, quartz, schist and quartzite with some grey to green traces of mica. Chips subrounded to subangular, varying in size from 1mm to 1cm. Damp, hard.

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 1/13/2010
Drilling Method: RAB	Compiled: 3/9/2012

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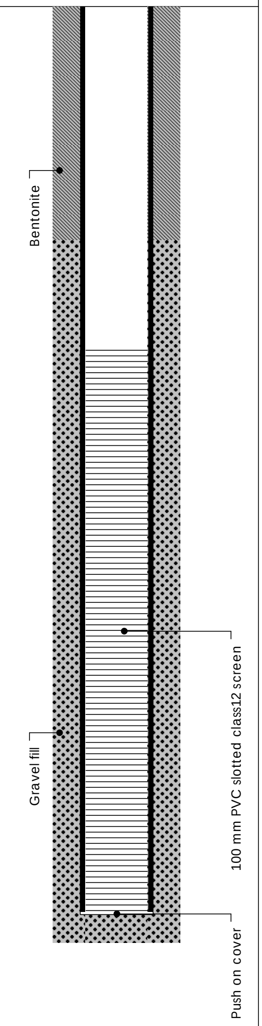
Borehole: CWB4d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology
	Saprock		SCHIST grey high strength fresh rock. with some green grey mica and some quartz and quartzite increasing in content with depth, size <1cm
60			
70			QUARTZITE. White glassy transparent to light grey quartz and quartzite (70%) with grey schist (30%). Fresh, damp, hard
80			
90			
100			

Bore Construction



Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB5s

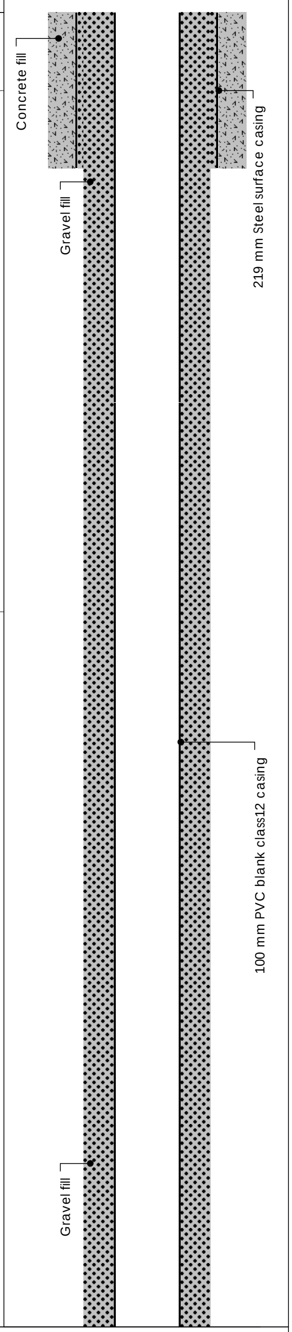
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 64 m
Client: Cameco	Easting: 403005	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7528996	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology
0		Ground Surface
0	Alluvial	SM silty med SAND, loose, dry dark reddish brown. with subangular quartz gravel <1cm. Clayey at base.
	Upper Paterson Fm	Claystone, tan to light brown , silty in parts, soft, poorly consolidated, dry
	Upper Paterson Fm	Siltstone grey dark grey medium strength. with minor schist and sandstone fragments <0.5cm. Becoming harder at 56 mbgl (bigger chips)

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill
Drilling Equipment:
Drilling Method: RAB

Started: 1/12/2010
Completed:
Compiled: 3/9/2012

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Borehole: CWB5s

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Bore Construction
60				
70				Push on cover
80				
90				
100				

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: CWB5d

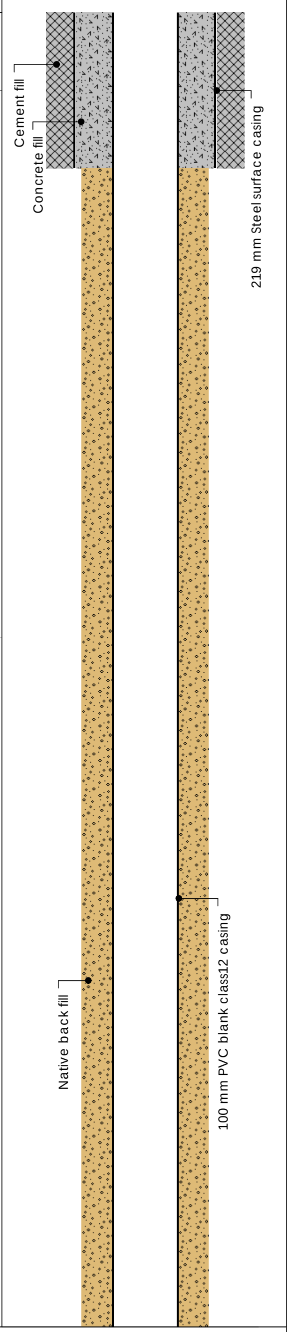
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 88 m
Client: Cameco	Easting: 403017	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7529000	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology
0		Ground Surface
0 – 3	Alluvial	GW fine GRAVEL, loose, SA, qtz dark reddish brown. With silty sand
3 – 24	Upper Paterson Fm	Claystone, pale brown, extremely weathered, traces of quartz and sandstone
24 – 50	Upper Paterson Fm	Siltstone grey dark grey medium strength. minor sandstone and quartz fragments <1cm. Becoming harder between 30 - 33mbgl and 56 - 62mbgl.

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill
Drilling Equipment:
Drilling Method: RAB

Started: 1/10/2010
Completed:
Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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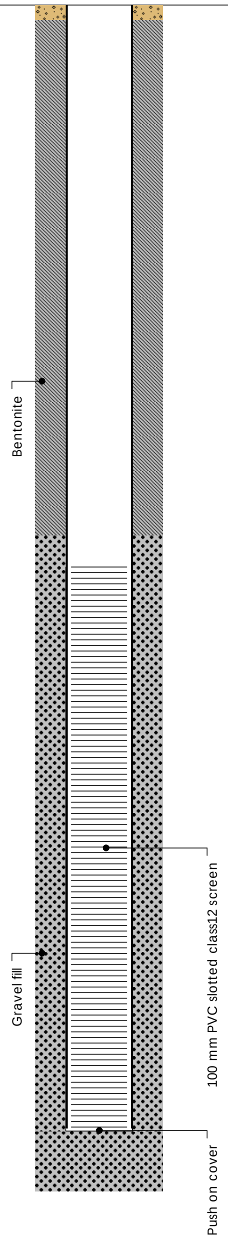
Borehole: CWB5d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology
60			
70	Saprock		QUARTZITE pinkish grey high strength. dry but becoming damp at 80mbgl. Some traces of schist.
80			
			SCHIST grey greenish grey. with grey and green mica,moderately hard, layered.
90			
100			

Bore Construction



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Borehole: CWB6s

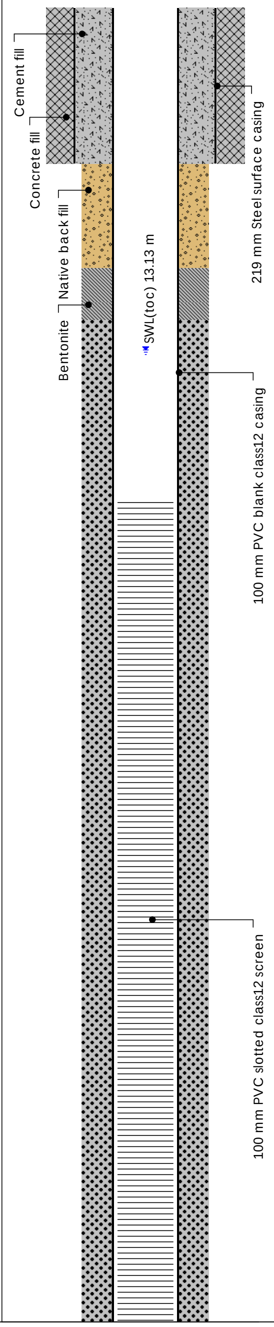
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 74 m
Client: Cameco	Easting: 402995	SWL: 13.13 m (toc) on 1/11/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7529997	Salinity: 0.012 mg/L on 1/11/2010	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
0		Ground Surface	
0–4	Alluvial	GW sandy med GRAVEL, loose, SA, dry, qtz reddish brown. varying in size Gravel comprised primarily of sandstone, quartzite and quartz.	
4–10	Upper Paterson Fm	Siltstone pale grey distinctly weathered. with gravel, friable and weak. Gravel comprised of quartzite, schist and sandstone, subangular to subrounded, size from 0.5cm to 1cm. Some clayey patches at 8 mbgl.	
10–14	Upper Paterson Fm	Conglomerate pale grey. Clayey conglomerate built of quartz, quartzite, sandstone and schist > 0.5cm in diameter, subangular.	Water intercept
14–24	Upper Paterson Fm	MH SILT with clay, medium plasticity pale brown. with gravel comprised of quartzite, schist and sandstone, fairly plastic and consolidated.	
24–35	Upper Paterson Fm	Conglomerate pale grey. composed of quartz, schist, quartzite, sandstone and soft light brown silt with occasional gneiss, mostly subrounded varying in size from 1mm to 1cm.	
35–50	Upper Paterson Fm	Siltstone dark grey medium strength. clayey siltstone, hard parts surrounded by soft, plastic silty/clayey matrix, wet. Some pieces of quartzite schist and sandstone gravel subangular <0.5cm.	0.7 L/s, 8.08, 2.35 mS-cm

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill	Started: 1/9/2010
Drilling Equipment:	Completed:
Drilling Method: RAB	Compiled: 3/9/2012

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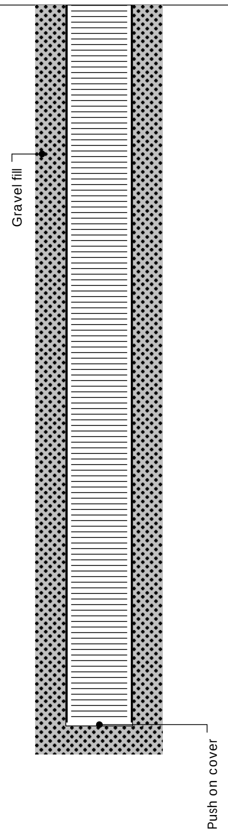
Borehole: CWB6s

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
				0.7 L/s, 8.16, 2.02 mS-cm	
60	Lower Paterson Fm		Conglomerate pale grey. with pinkish pieces, composed of schist, sandstone and some rare gneiss. Varying in shape and size from 0.5cm to 1cm, subangular to subrounded. Some clayey intervals at 68 mbgl.	0.7 L/s, 8.24, 2.97 mS-cm	
70					
80					
90					
100					



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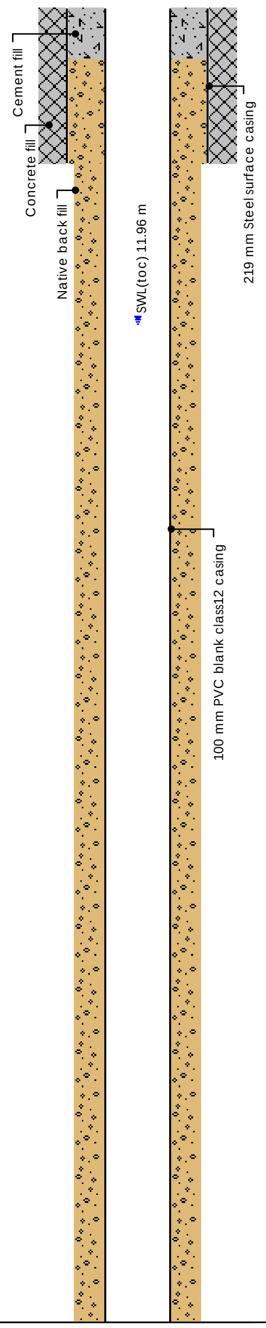
Borehole: CWB6d

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 98 m
Client: Cameco	Easting: 403008	SWL: 11.96 m (toc) on 1/11/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7529986	Salinity: 1824 mg/L on 1/11/2010	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Bore Construction
0			Ground Surface	
			GW sandy med GRAVEL, loose, SR, dry, qtz reddish brown. Gravel comprised primarily of sandstone and quartzite, >1cm diameter.	
			Siltstone pale grey very low strength slightly weathered. Friable. Contains gravel composing quartzite, schist and sandstone, subangular to subrounded, 0.5-1cm diameter. Traces of clay at 8m.	
10			Conglomerate. Clayey. Clasts contain subangular quartz, quartzite, sandstone and schist >0.5cm in diameter.	
			Siltstone pale brown low strength. Clayey with medium plasticity. Traces of gravel comprising quartzite, schist and sandstone.	
20			Conglomerate. Clasts comprise quartz, schist, quartzite, sandstone and soft light brown silt with occassional gneiss. Mostly subrounded, 1mm-1cm in diameter.	
30			Siltstone dark grey medium strength. Clayey, wet. Traces of quartzite schist and sandstone gravel, subangular, <0.5cm in diameter.	
40				
50				



Drilling Company: Nudrill
Drilling Equipment:
Drilling Method: RAB

Started: 7/1/2010
Completed: 8/1/2010
Compiled: 5/8/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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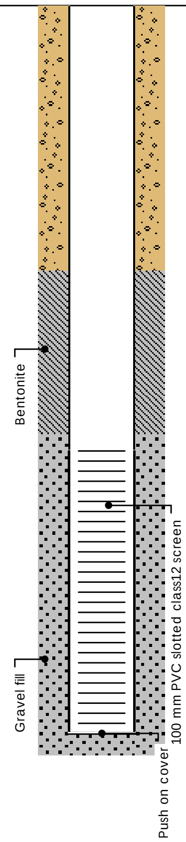
Borehole: CWB6d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology
60			Conglomerate grey speckled pink. Clasts contain schist, sandstone and traces of gneiss, 0.5-1cm in diameter, subangular to subrounded. Some clayey intervals at 68m.
70			
80			Sandstone pale pinkish grey high strength fresh rock. Abundant quarzite and quartz, traces of gneiss and schist.
90			
100			
110			
120			
130			
140			
150			

Bore Construction



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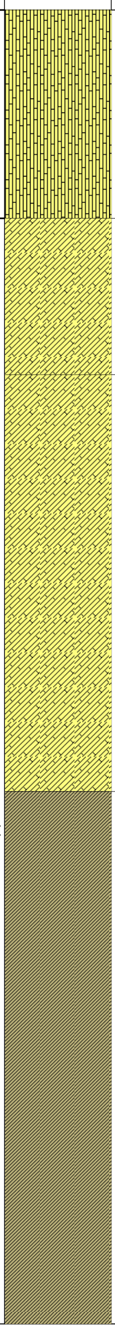
Borehole: CWB7s

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 71 m
Client: Cameco	Easting: 405945	SWL: 18.1 m (toc) on 1/31/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7530999	Salinity:	Checked By:

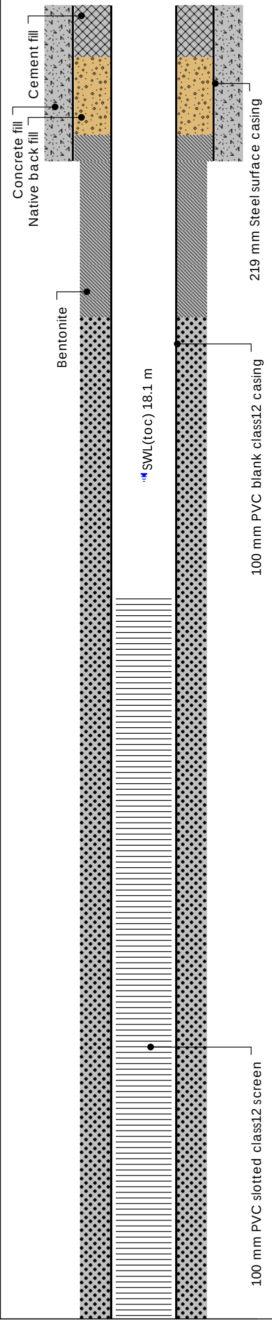
SUBSURFACE PROFILE

Depth (m)	Formation	Lithology
0		Ground Surface
0–8	Alluvial	SM silty med SAND, loose reddish brown. with minor subangular quartz gravel < 1cm, dry
8–14	Upper Paterson Fm	SC clayey med SAND, loose. Tan to brown, with abundant quartz gravel < 3cm diameter, subangular, and some quartzite/sandstone gravel, dry.
14–30	Upper Paterson Fm	SC clayey med SAND pale brown white. with chalk, abundant quartz gravel < 3cm diameter, slightly stiff, plastic.
30–50	Upper Paterson Fm	CH CLAY with med sand, medium plasticity greyish brown. less quartz gravel, minor sandstone/siltstone gravel, stiff, plastic.

Lithology Graphic



Bore Construction



Drilling Company: Nudrill	Started: 1/28/2010
Drilling Equipment: Mud	Completed:
Drilling Method: Mud	Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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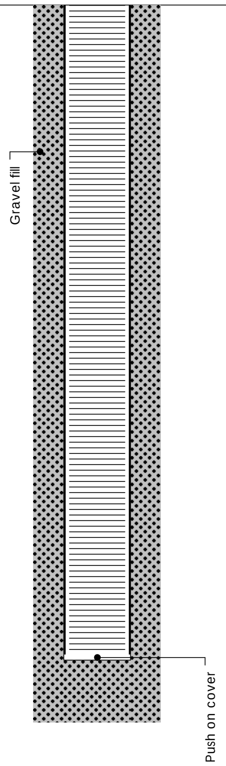
Borehole: CWB7s

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology
	Lower Paterson Fm		Conglomerate greyish brown. with (quartz, siltstone, sandstone, and schist) < 2cm diameter, subrounded to subangular, hard.
60			
70			
80			
90			
100			

Bore Construction



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Borehole: CWB7d

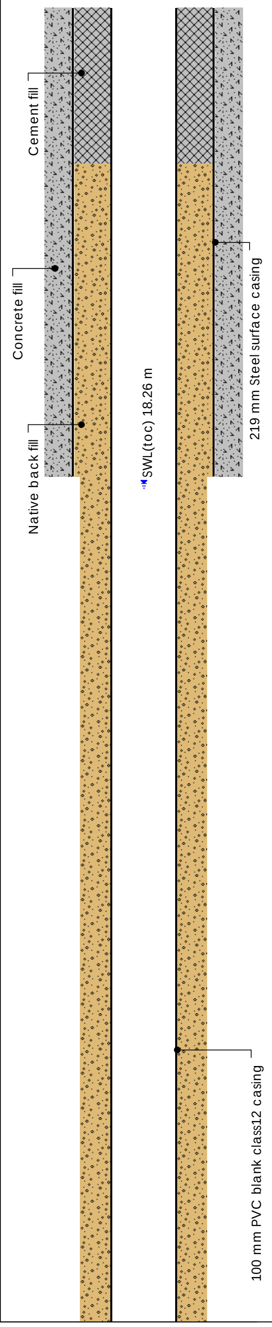
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 74 m
Client: Cameco	Easting: 405960	SWL: 18.26 m (toc) on 1/31/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7530999	Salinity: 3822 mg/L on 1/31/2010	Checked By:

SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0	Alluvial	SM silty med SAND, loose, qtz reddish brown. with minor subangular quartz gravel < 1cm, dry	
	Upper Paterson Fm	SM silty med SAND reddish brown. and gravel with some clay, loose, dry.	
		GW sandy coarse GRAVEL, loose, SA, qtz brown.	
10		CH CLAY, medium plasticity white. Highly weathered with chalk, weak, dry	
		SC clayey med SAND pale brown. rare quartz gravel < 3cm diameter, subrounded, loose, wet.	Water intercept
20			0.5 L/s, 7.71, 6.64 mS-cm 29.5 °C.
30		SC clayey med SAND orange brown. clay slightly stiff, plastic, wet.	
		Siltstone greyish brown. weathered clay and siltstone, moderately stiff, plastic, wet.	
40		Siltstone pale grey distinctly weathered. minor quartz, moderately hard.	
50			

Bore Construction



Drilling Company: Nudrill	Started: 1/21/2010
Drilling Equipment: Mud	Completed:
Drilling Method: Mud	Compiled: 3/9/2012

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Borehole: CWB7d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
60				2 L/s, 7.89, 2.15 mS-cm 28.3 °C.	Native back fill
	Lower Paterson Fm		Conglomerate pale grey distinctly weathered. with quartzite, schist, sandstone, siltstone gravel, subrounded < 2cm diameter, wet.		
70					
			Conglomerate dark grey. increase in quartz and schist, harder.		
80					
			SCHIST dark grey slightly weathered. with siltstone, abundant dark mica, quartz, chalk fragments, hard, wet.		
90					Bentonite
100					

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Borehole: CWB7d

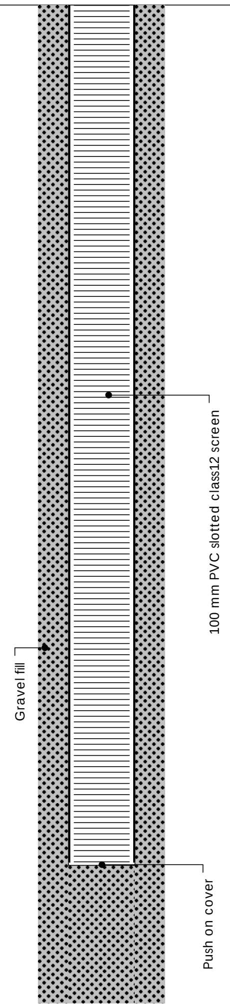
SUBSURFACE PROFILE

Depth (m) | Formation | Lithology Graphic | Lithology | Field Notes | Bore Construction

Formation: Saprock

Depth: 110, 120, 130, 140, 150

Field Notes: 3 L/s, 8, 5.77 mS-cm 29.7 °C.



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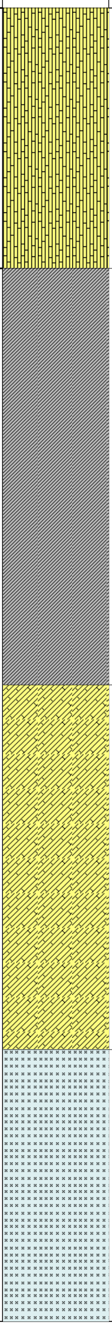
Borehole: CWB8s

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 60 m
Client: Cameco	Easting: 405933	SWL:	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7532000	Salinity:	Checked By:

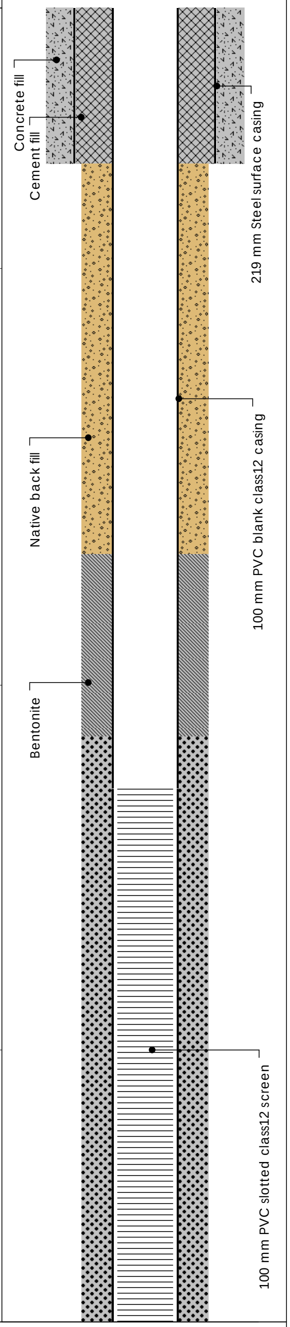
SUBSURFACE PROFILE

Depth (m)	Formation	Lithology
		Ground Surface
0–10	Alluvial	SM silty med SAND, loose, dry reddish brown. with quartz subangular gravel
10–26	Upper Paterson Fm	Claystone. Tan to whitish brown claystone, weak, poorly consolidated, friable, dry to damp.
26–40	Upper Paterson Fm	SC clayey med SAND, loose. Tan, wet at 30 mbgl
40–50	Upper Paterson Fm	Siltstone grey. moderately hard, wet.

Lithology Graphic



Bore Construction



Drilling Company: Nudrill	Started: 12/8/2009
Drilling Equipment:	Completed:
Drilling Method: RAB	Compiled: 3/9/2012

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Borehole: CWB8s

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Bore Construction
60				Gravel fill; Push on cover
70				
80				
90				
100				

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Borehole: CWB8d

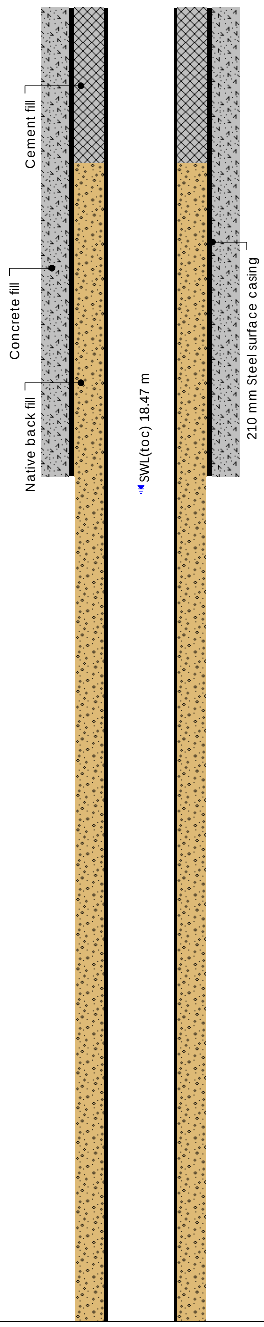
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 139 m
Client: Cameco	Easting: 405939	SWL: 18.47 m (toc) on 12/15/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7532011	Salinity: 3984 mg/L on 12/15/2009	Checked By:

SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0–10	Alluvial	SM silty med SAND, loose, SA, qtz. Tan with some clay. Some gravel, subangular quartz <2cm diam	
10–24		Claystone, tan to yellowish grey, weak, poorly consolidated, some quartz gravel and sand, soft, damp at 24mbgl	Water intercept
24–42		SC clayey med SAND, qtz. Tan with some quartz gravel, loose, poorly sorted, wet at 28mbgl. Increase in clay content from 38mbgl.	
42–50		Siltstone LATERITE GOSSAN pale grey distinctly weathered. with soft tan claystone, minor quartz gravel <1cm, Fe staining, wet	0.75 L/s, 7.67, 5.36 mS-cm 26.6 °C.

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: Mud	Completed: 12/6/2009
Drilling Method: Mud	Compiled: 3/9/2012

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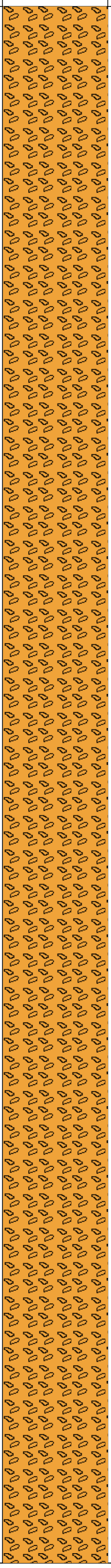
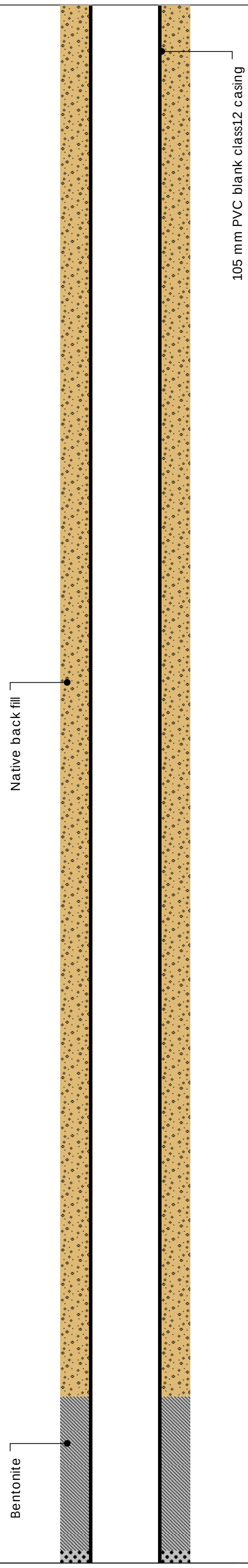
Borehole: CWB8d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
60, 70, 80, 90, 100	Upper Paterson Fm			2 L/s, 7.68, 4.82 mS-cm 25.6 °C. (at 100 m)	

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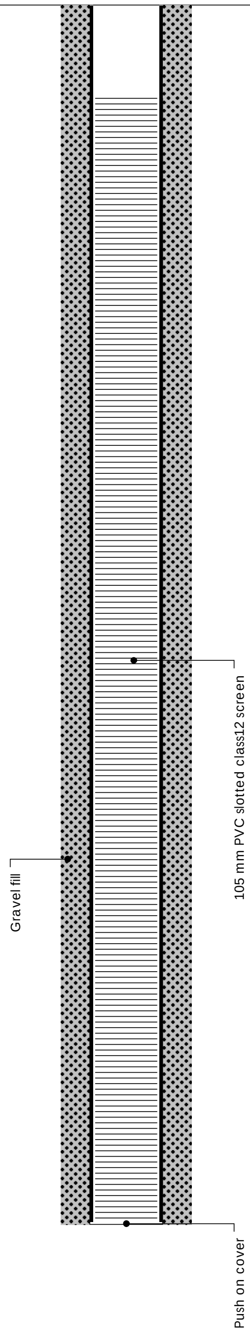
Borehole: CWB8d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
~106–139	Lower Paterson Fm	Conglomerate. Tan to grey clayey sand and gravel. Gravel comprised of sandstone, quartzite, siltstone rounded in shape, loose and wet	7 L/s, 7.64, 6.87 mS-cm 27.3 °C. (~115 m); 12 L/s, 7.79, 6.81 mS-cm 28.1 °C. (~130 m)

Depth scale: 110, 120, 130, 140, 150

Bore Construction



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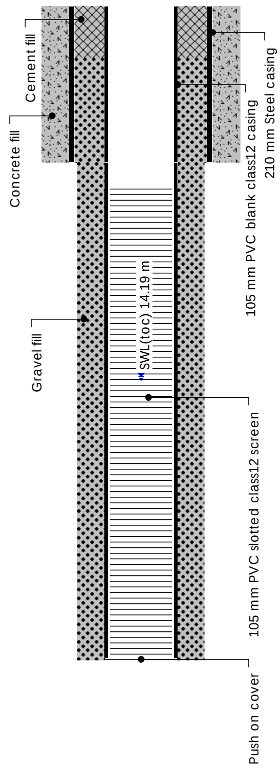
Borehole: CWB9s

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 25 m
Client: Cameco	Easting: 404996	SWL: 14.19 m (toc) on 11/22/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7531994	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Bore Construction
0			Ground Surface	
0	Alluvial		SM silty med SAND, loose, dry. Tan color with quartz gravel <1cm, subangular	
	Upper Paterson Fm		CH CLAY with med sand, medium plasticity, dry. Tan with quartz gravel and layers of poorly consolidated sandstone	
10			CH CLAY with silt, medium plasticity, dry. Tan, poorly consolidated, rare quartz grave	
	Lower Paterson Fm		Sandstone brown low strength. Clayey, poorly consolidated, minor quartz grave <1cm, subangular, damp at 22mbgl.	
20				
30				
40				
50				



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 11/22/2009
Drilling Method: RAB	Compiled: 3/9/2012

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Borehole: CWB9d

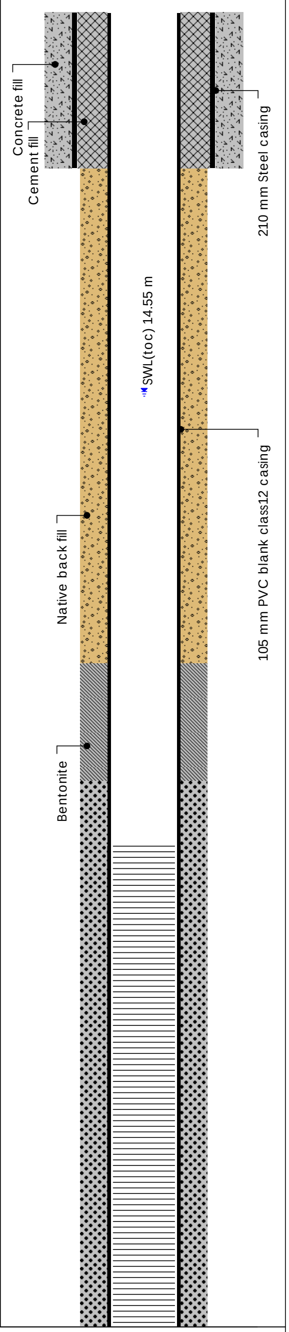
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 88 m
Client: Cameco	Easting: 4054003	SWL: 14.55 m (toc) on 11/22/2011	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7531998	Salinity: 28880 mg/L on 11/22/2011	Checked By:

SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0	Alluvial	SM silty med SAND, loose, dry. Tan to brown with quartz gravel <1cm, subangular .	
	Upper Paterson Fm	Tan with quartz gravel with layers of poorly consolidated sandstone, loose dry	
10			
	Lower Paterson Fm	Sandstone brown, clayey, weak, poorly consolidated, minor quartz gravel, damp	
20			
30			0.5 L/s, 26380 mg/L, 7.25, 13.19 mS-cm 28 °C.
			1 L/s, 16260 mg/L, 7.63, 8.13 mS-cm 27.2 °C.
40			
	Saprolite	QUARTZITE. Tan to grey, some sandstone, hard, with minor quartz gravel, wet	2 L/s, 28020 mg/L, 7.69, 14.01 mS-cm 27.4 °C.
50			2 L/s, 27360 mg/L, 7.6, 13.68 mS-cm 29.1 °C.

Bore Construction



Drilling Company: Nudrill
Drilling Equipment:
Drilling Method: RAB

Started:
Completed: 11/17/2009
Compiled: 3/9/2012

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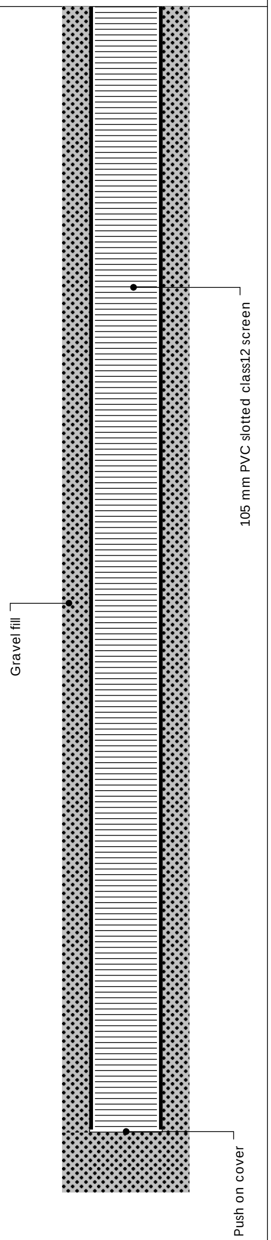
Borehole: CWB9d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
60–80 (to ~88)	Saprock		SCHIST reddish brown. abundant quartz and mica. Wet, moderately hard. Quartz layers 64-66, 70-74, 76-78m BGL	2 L/s, 28580 mg/L, 7.61, 14.29 mS-cm 27.1 °C.
				2 L/s, 24960 mg/L, 7.94, 12.48 mS-cm 26.9 °C.
				2 L/s, 28260 mg/L, 7.87, 14.13 mS-cm 29.1 °C.

Depth scale: 60, 70, 80, 90, 100

Bore Construction



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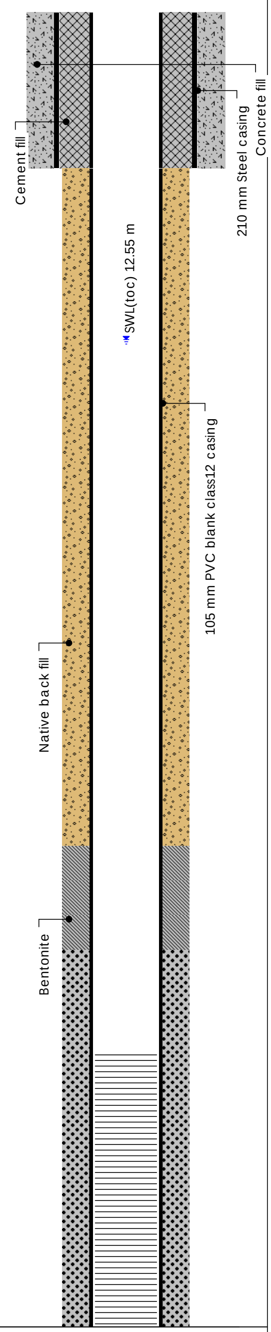
Borehole: CWB10

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 103 m
Client: Cameco	Easting: 404027	SWL: 12.55 m (toc) on 11/22/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7531977	Salinity: 8760 mg/L on 11/22/2009	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
			Ground Surface	
0	Alluvial		SW-SM med SAND with silt, dry, qtz very pale brown. some clay, highly weathered	
			SCHIST brown distinctly weathered. abundant quartz and mica, hard, dry	
10				
20				
30				
40				
50				

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment:	Completed: 11/20/2009
Drilling Method: RAB	Compiled: 3/6/2012

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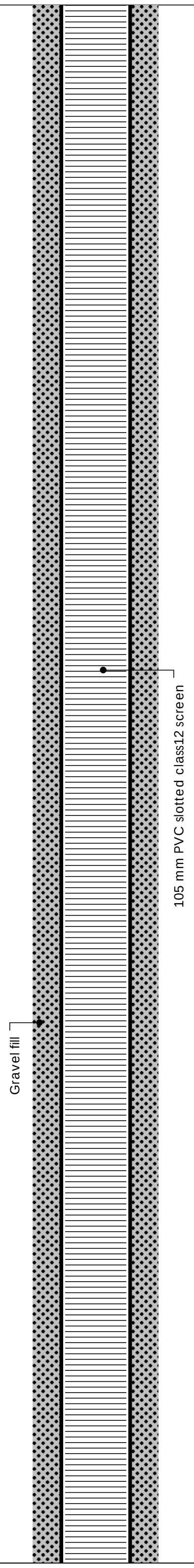
Borehole: CWB10

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
	Saprock			
60				
			SCHIST brownish grey fresh rock. abundant quartz and mica, hard, damp to moist	
70				
80				
90				
				0.1 L/s, 8760 mg/L, 7.31, 4.38 mS-cm
100				

Bore Construction



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Borehole: CWB10

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
					Push on cover
110					
120					
130					
140					
150					

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Borehole: CWB11d

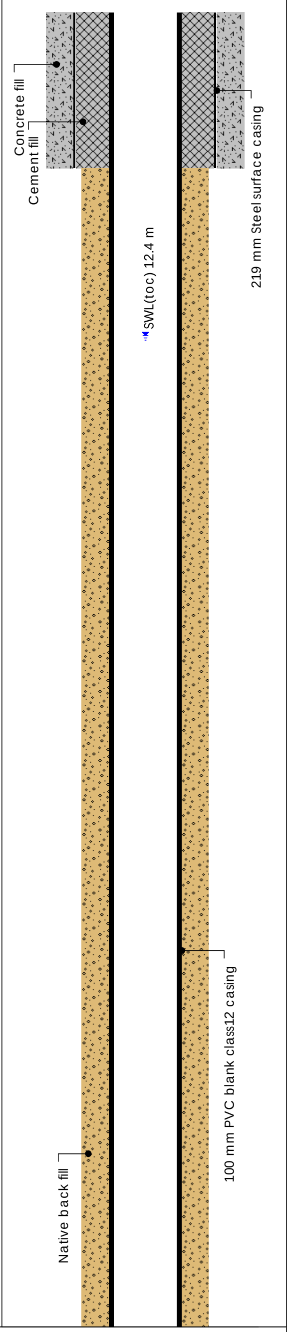
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 103 m
Client: Cameco	Easting: 402889	SWL: 12.4 m (toc) on 11/20/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7531975	Salinity: 6780 mg/L on 11/20/2009	Checked By:

SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0	Alluvial	GW sandy med GRAVEL well graded, loose, SA, dry. Tan to brown with some clay, rare mica	
	Upper Paterson Fm	CLAY AND SAND. Tan sandy clay, poorly sorted with some quartz gravel, subangular <2cm, loose, soft, dry	
10	Upper Paterson Fm	CLAY. Tan clay with minor coarse quartz , sand and gravel <2mm, subangular, moderately plastic, damp at 10mBGL	
20	Upper Paterson Fm	CH CLAY, medium plasticity. CLAY AND SAND. Brownish grey sandy clay with abundant quartz gravel <1cm subangular, loose damp. Traces of poorly consolidated sandstone with minor mica.	
	Upper Paterson Fm	C sandy CLAY bluish grey. with abundant quartz gravel <2cm, angular and some sandstone, poorly consolidated, loose, damp. Siltstone layers from 28mbgl to 32mbgl	
30	Upper Paterson Fm	Siltstone bluish grey high strength. with rare mica, wet.	
	Upper Paterson Fm	CLAY AND SAND. Blue/grey sandy clay with some siltstone layers and angular quartz gravel. Soft, wet.	
40		Sandstone bluish grey. and schist with minor quartz gravel and some clayey matrix. Traces of mica schist. Hard, wet.	0.5 L/s, 10520 mg/L, 8.22, 5.26 mS-cm 30.6 °C.
50			

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment:	Completed: 11/12/2009
Drilling Method: RAB	Compiled: 3/6/2012

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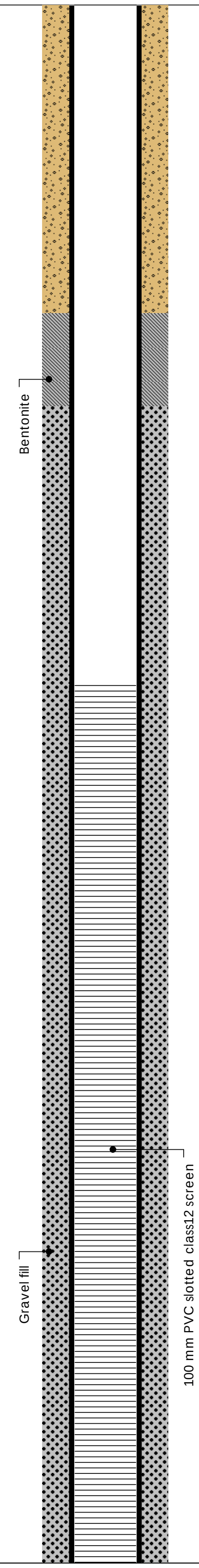
Borehole: CWB11d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
	Lower Paterson Fm		0.5 L/s, 10800 mg/L, 7.97, 5.4 mS-cm 29.4 °C.
60	Lower Paterson Fm	Sandstone dark bluish grey. increase in clay content. Minor schist, softer.	
	Saprock	SCHIST dark bluish grey. less clay and quartz. Hard.	
70			0.5 L/s, 6600 mg/L, 8.06, 3.3 mS-cm 28.2 °C.
80			
90			0.5 L/s, 4140 mg/L, 7.89, 2.07 mS-cm 26.9 °C.
			0.5 L/s, 6780 mg/L, 8.01, 3.39 mS-cm 31.1 °C.
100			

Bore Construction



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Borehole: CWB11d

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110					Push on cover
120					
130					
140					
150					

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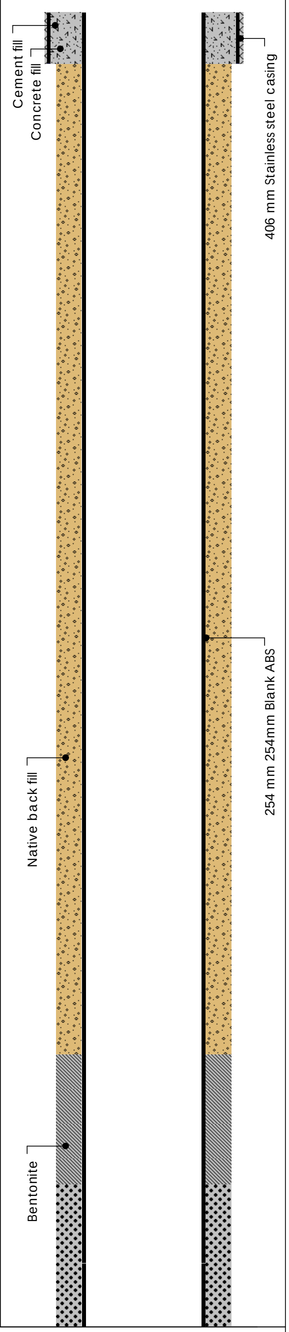
Borehole: CWB12

Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 90 m
Client: Cameco	Easting: 405954	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7530172	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0	Alluvial		SM silty med SAND, loose, qtz reddish brown. minor subangular quartz gravel <1cm, dry	
	Upper Paterson Fm		CH CLAY, medium plasticity white. highly weathered, chalk, weak, dry	
10				
20				
30				
40			Siltstone brownish grey. some clay, moderately stiff, plastic, wet	
50				

Bore Construction



Drilling Company: Easternwell Minerals	Started:
Drilling Equipment: Mud	Completed: 10/1/2010
Drilling Method: Mud	Compiled: 3/9/2012

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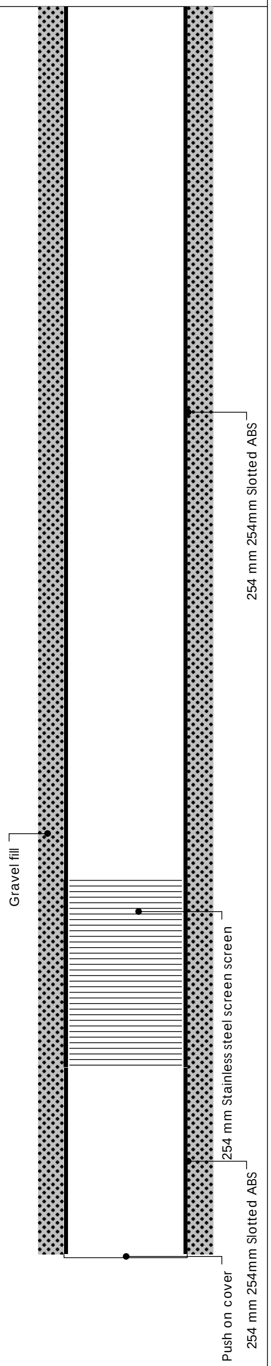
Borehole: CWB12

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
55–57				
57–75	Lower Paterson Fm		Conglomerate dark grey high strength. increase in quartz and schist, harder	
75–90	Lower Saprolite		SCHIST dark grey medium strength slightly weathered. Abundant dark mica, quartz, chalk frags, wet	4 L/s, 8.53, 5480 µS-cm
90–100				

Depth scale: 60, 70, 80, 90, 100

Bore Construction



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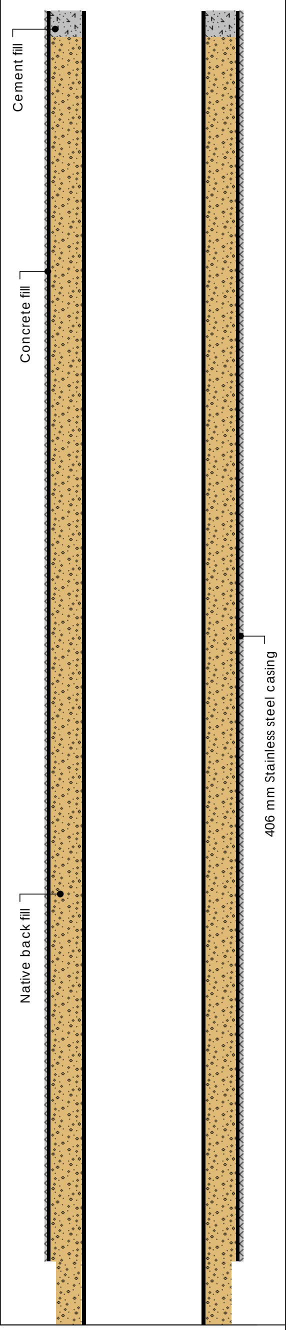
Borehole: CWB13

Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 159 m
Client: Cameco	Easting: 405933	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7532064	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
			Ground Surface	
0	Alluvial		SM silty med SAND, qtz reddish brown. some clay and minor quartz (1-2mm) and claystone (1-2mm)	
10				
			Claystone (2mm) with quartz gravel (3mm) and sand. Increase in size of claystone chips from 20m (4-5mm).	
20				
			SC clayey med SAND. with quartz gravel (3mm) and claystone (2-3mm)	
30				
40			Siltstone grey. with claystone (5mm), quartz (2-3mm)	
50				

Bore Construction



Drilling Company: Easternwell Minerals	Started:
Drilling Equipment: Mud	Completed: 11/1/2010
Drilling Method: Mud	Compiled: 3/9/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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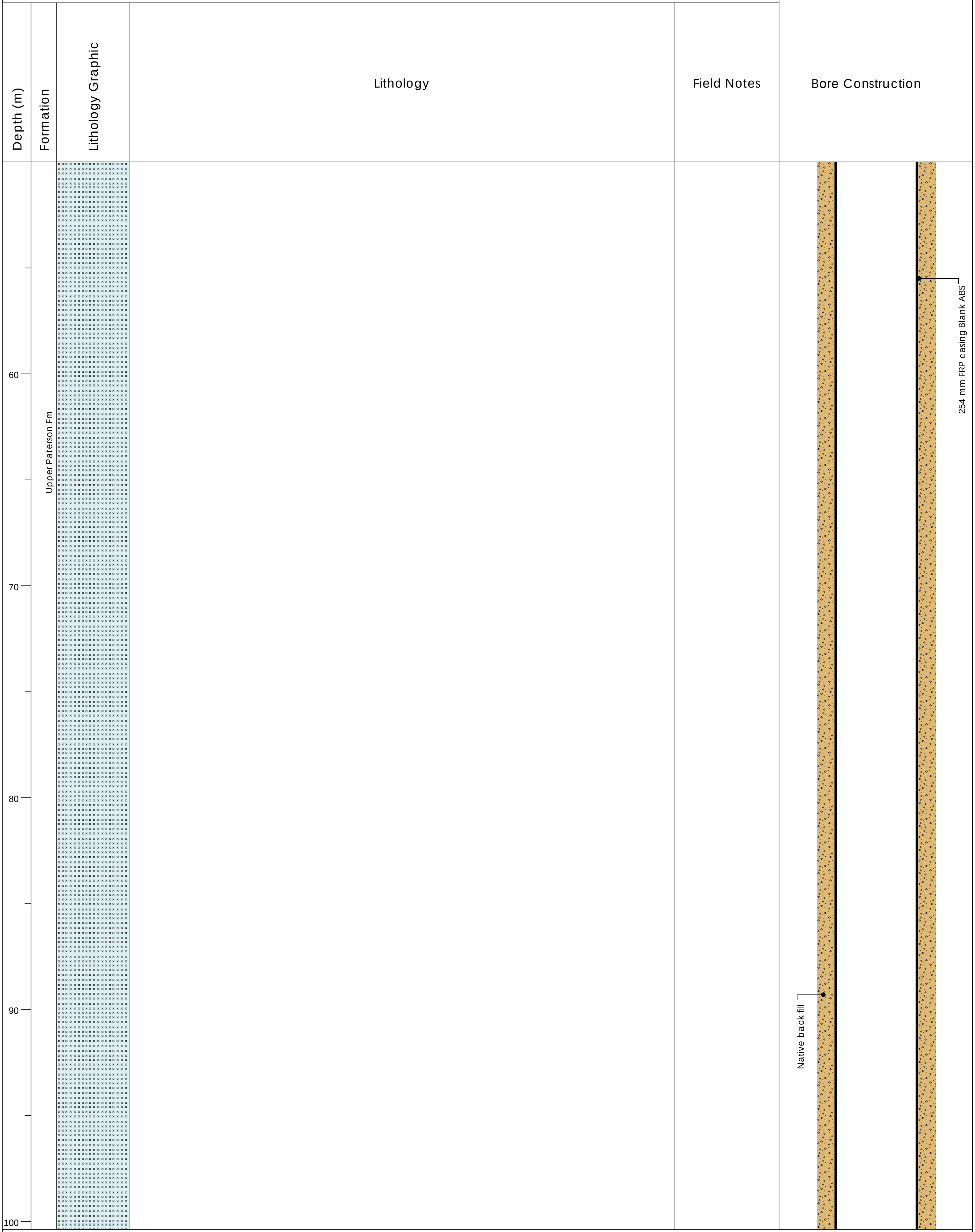
Borehole: CWB13

SUBSURFACE PROFILE



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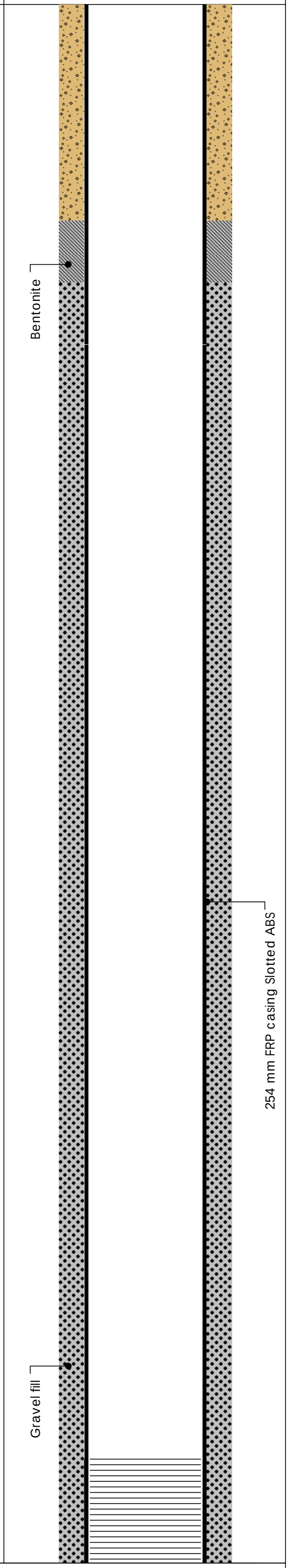
Borehole: CWB13

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
110	Lower Paterson Fm		Conglomerate. comprising sandstone, quartz and siltstone with tan clayey sand	
120				
130				0.5 L/s,
140				
150				2.5 L/s, 8.51, 5470 µS-cm

Bore Construction



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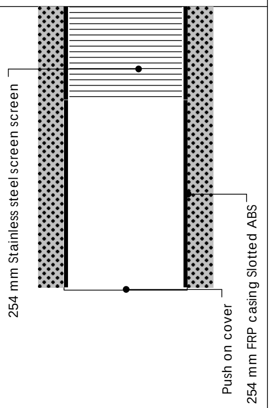
Borehole: CWB13

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
160					
170					
180					
190					
200					



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Borehole: CWB14

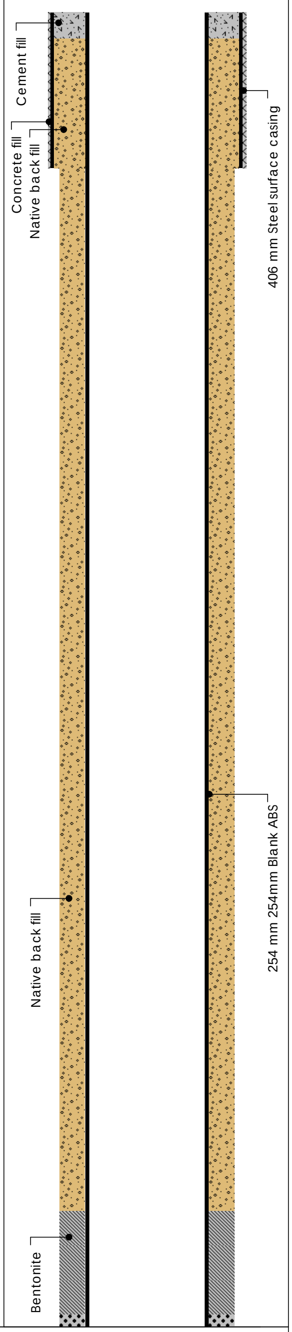
Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 153 m
Client: Cameco	Easting: 404989	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7532928	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0	Alluvial		SM silty med SAND, qtz reddish brown. minor quartz	
14			SC clayey med SAND. Tan color	
42			SC clayey med SAND grey. with moderately weathered siltstone (3-17mm) and minor quartz.	

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Easternwell Minerals
Drilling Equipment: Mud
Drilling Method: Mud

Started:
Completed: 11/8/2010
Compiled: 3/9/2012

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Borehole: CWB14

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
60, 70, 80, 90	Upper Paterson Fm				254 mm 254mm Slotted ABS (from 70)
100			Conglomerate. comprising dark grey schist (4-10mm), quartz (sub angular 4-1-mm), siltstone (hard rounded, 40-10mm) with minor claystone (hard 5mm) and brown sandstone, fe staining from 126m. Sand		

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Borehole: CWB14

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110	Lower Paterson Fm			7.84, 2830 µS-cm	
120					Gravel fill
				7.98, 2880 µS-cm	
130					254 mm Stainless steel screen screen screen Screen
				8.04, 2880 µS-cm	
140					
	Saprock		SCHIST dark grey. (angular) with quartz. Fine cuttings.		254 mm 254mm Slotted ABS
150				8.74, 2980 µS-cm	

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Borehole: CWB14

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
160					Push on cover
170					
180					
190					
200					

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Borehole: CWB15

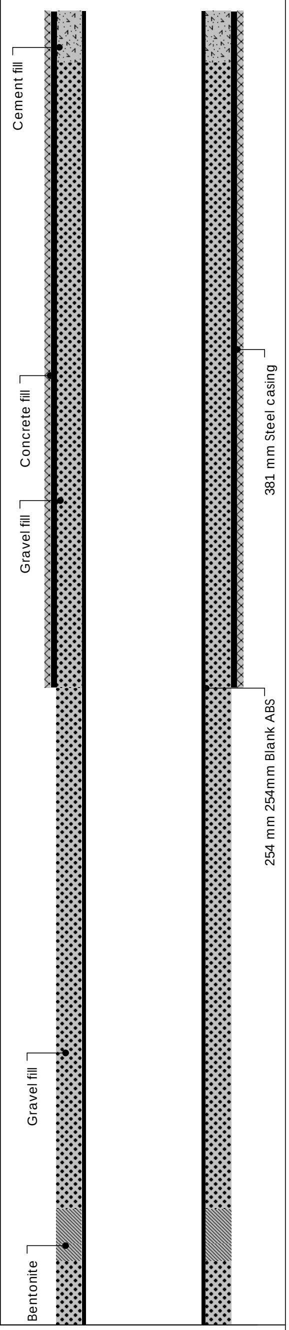
Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 130 m
Client: Cameco	Easting: 401638	SWL:	Logged By: Reproduced from MWH (2011)
Location: Kintyre	Northing: 7534131	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
0		Ground Surface	
0–12	Alluvial	SM silty med SAND, loose, dry reddish brown. Some gravel, mostly quartz <5mm	
12–24	Upper Paterson Fm	SW-SC med SAND with clay. Tan color, some gravel comprised of subrounded sandstone and quartz	
24–42	Upper Paterson Fm	CH CLAY, medium plasticity brown. minor quartz, subangular 2-20mm. Wet at 25m.	
42–50	Upper Paterson Fm	CH CLAY with trace med gravel, medium plasticity grey. with minor quartz gravel(2-15mm) and other various gravel(2-15mm). Wet. Increase in gravel from 44-46m. Dark grey siltstone from 44m (subangular 2-15mm). From 50-52m, claystone (rounded 10-2-mm), sandstone (10-20mm) and larger siltstone (rounded 20-3-mm)	

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Easternwell Minerals	Started:
Drilling Equipment: RAB	Completed: 2/11/2011
Drilling Method: RAB	Compiled: 3/9/2012

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Borehole: CWB15

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Lower Paterson Fm		Conglomerate. comprised of sand(coarse), siltstone (subrounded 10-30mm), sandstone, minor quartz and other various gravel (rounded 2-6mm)		
	Lower Paterson Fm		Conglomerate. comprised of sand (coarse), quartz (subrounded 3-4mm), minor brown stained quartz, siltstone (subronded 10-20), sandstone (rounded 3-6mm), purple quartzite (angular), claystone and other various gravel. From 120m, dark grey/green quartzite (angular 3-15mm) and increase in purple quartzite		
60					
70					
80					254 mm 254mm Slotted ABS
90				3 L/s, 8.18, 878 µS-cm	
100					

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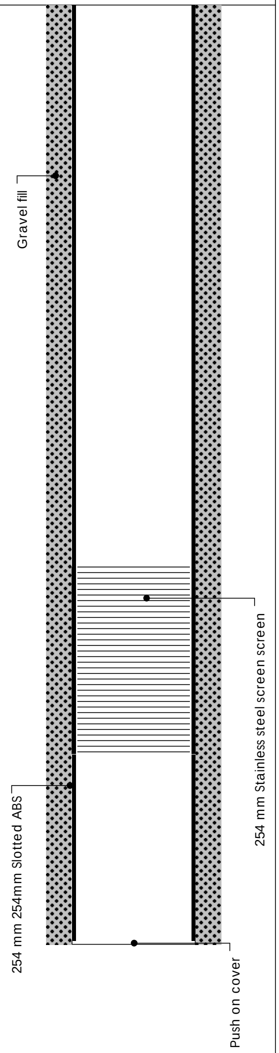
Borehole: CWB15

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
105–110				4 L/s, 8.19, 915 µS-cm
110–120				
120–124				4 L/s, 8.15, 978 µS-cm
124–130	Saprock		QUARTZITE purple high strength fresh rock. (angular 2-30mm), grey/green quartzite (angular 2-30mm), very minor schist (angular 2-10mm), and minor quartz (subangular 2-10mm)	4 L/s, 8.28, 902 µS-cm
130–150				

Depth scale: 110, 120, 130, 140, 150

Bore Construction



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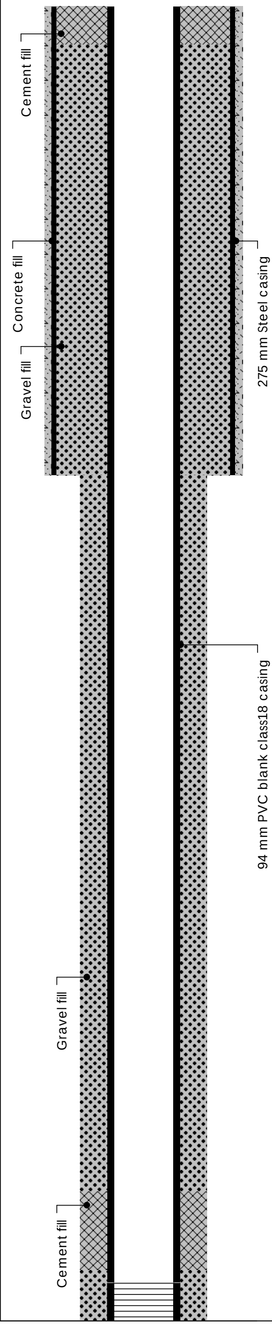
Borehole: CWB16

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 115 m
Client: Cameco	Easting: 406900	SWL:	Logged By: Reproduced from MWH (2011)
Location: Kintyre	Northing: 7531600	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0	Alluvial		Ground Surface SM silty med SAND, dry reddish brown. with gravel-sized, well-rounded, multi-coloured quartz ,clay properties	
			SM silty med SAND reddish brown. with gravel-sized, multi-coloured quartz. Iron oxide on fragments	
10			SM silty med SAND pale grey. with sub-rounded to angular, multi-coloured quartz , poorly cemented, light grey silt and clay particles. Some calcareous particles.	
20			SM silty med SAND, rounded, qtz pale brown. with some iron staining, weakly consolidated silty clays	
30			CH silty CLAY, medium plasticity pale brown. some sand with highly oxidized quartz and some limestone. Low Permability	
40			CH silty CLAY, medium plasticity very pale grey. and some quartz sandstone. Low Permability	
			CH silty CLAY, medium plasticity pale grey. with some siltstone (possbily interbedded layers), and some quartz sand. Low Permability	
50			CH CLAY with silt, medium plasticity pale grey. approximately 25% siltstone (possibly interbedded layers) and some oxidised quartz sand	

Bore Construction



Drilling Company: Kimberly Water	Started:
Drilling Equipment: RAB	Completed:
Drilling Method: RAB	Compiled: 3/9/2012

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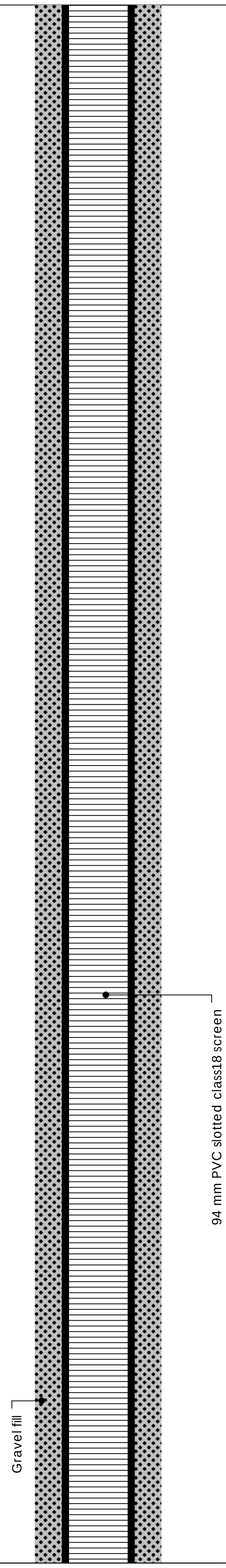
Borehole: CWB16

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
60, 70, 80, 90	Upper Paterson Fm				
90–100			CH silty CLAY, medium plasticity grey. with approximately 50% siltstone (possibly interbedded layers) and some oxidized quartz sand.Low Permability		
100					



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Borehole: CWB16

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110	Saprock		QUARTZITE. BEDROCK. Quartzite, granite	0.5 L/s,	Push on cover
120					
130					
140					
150					

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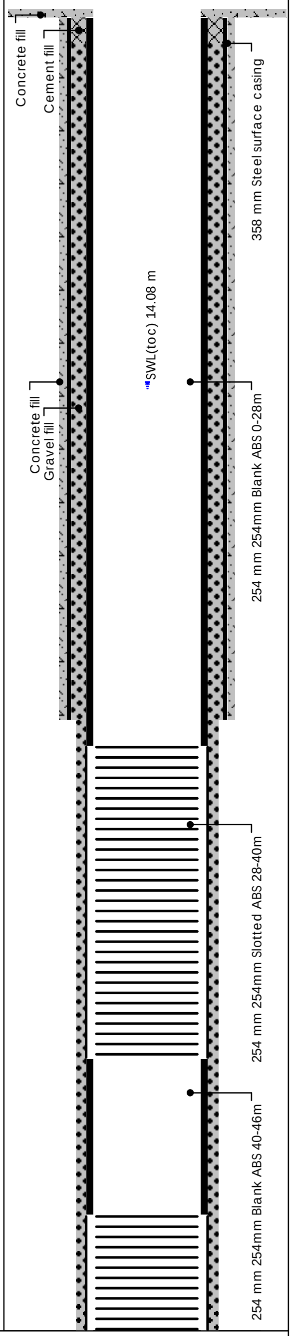
Borehole: CWB17

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: 364 (mAHD)	Total Depth: 128 m
Client: Cameco	Easting: 403307	SWL: 14.08 m (toc) on 2/21/2012	Logged By: D Keating
Location: Kintyre	Northing: 7535020	Salinity: 930 mg/L on 2/21/2012	Checked By: R Taplin

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0	Alluvial		Ground Surface	
	Alluvial		SM silty med SAND poorly graded, loose, rounded, qtz reddish brown. Low permeability, some Qtz gravel. Loosly to well consolidated red siltstone/sandstone and some feldspar	
10	Alluvial		SM silty med SAND poorly graded, loose, rounded, qtz pink brown.	
20			Conglomerate orange red low strength distinctly weathered.	
			Sandstone greenish grey low strength distinctly weathered.	
			Siltstone reddish brown extremely low strength extremly weathered.	
30			Conglomerate medium strength slightly weathered. White, Green/Grey, Red/ Brown	
40			Sandstone extremely low strength extremly weathered. Brownish green, beds of siltstone between 42-46m	
50				

Bore Construction



Drilling Company: Kimberly Water	Started: 12/6/2011
Drilling Equipment: RAB	Completed: 1/3/2012
Drilling Method: RAB	Compiled: 4/11/2012

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Borehole: CWB17

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Upper Paterson Fm				Gravel fill; 254 mm 254mm Slotted ABS 46-124m
			Sample missing		
70			Siltstone grey medium strength slightly weathered. 70-72m increased weathering		
				1240 mg/L, 8.26, 2.48 mS-cm 30.6 °C.	
				1040 mg/L, 7.97, 2.08 mS-cm 32.5 °C.	

Depth scale: 60, 70, 80, 90, 100

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Borehole: CWB17

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
			Sample missing		
110	Lower Paterson Fm		Conglomerate blue green brown with green low strength distinctly weathered. Iron Stained chips 106-108m, Clay and medium sands in the matrix increasing largely in medium sands from 116m		
120			SP med SAND poorly graded, loose, rounded, qtz pale yellowish brown. 5% coarse sands		Native fill; Push on cover
130					
140					
150					

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Borehole: CWB18

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: 370 (mAHD)	Total Depth: 158.7 m
Client: Cameco	Easting: 402761	SWL: 14.27 m (toc) on 3/4/2012	Logged By: K Greenham
Location: Kintyre	Northing: 7534668	Salinity: 600 mg/L on 3/4/2012	Checked By: R Taplin

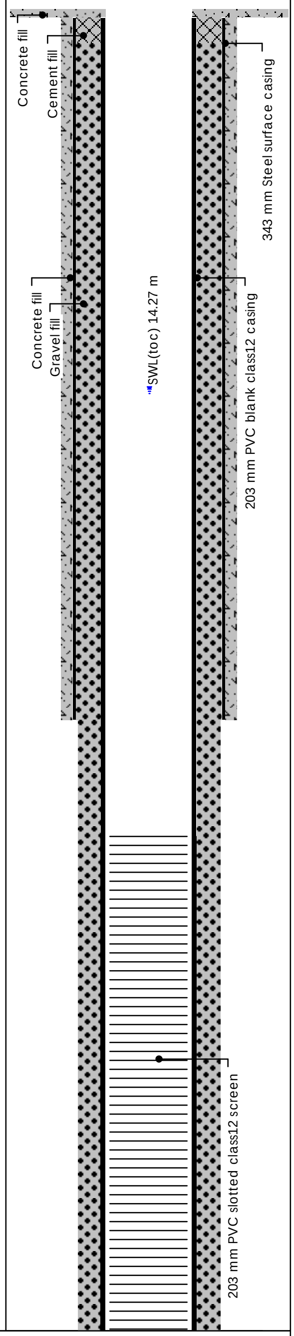
SUBSURFACE PROFILE

Depth (m): 0, 10, 20, 30, 40, 50

Ground Surface

Formation	Lithology	Field Notes
Alluvial	SM silty med SAND poorly graded, loose, rounded, dry, qtz dark reddish brown. Qtz chips of weakly camanted sandstone 9-11m	
Upper Paterson Fm	SM silty coarse SAND well graded, rounded, qtz pale brown. Extremely weathered conglomerate. Minimal Schist and Qtz between 11-21m	
Upper Paterson Fm	Sandstone very low strength extremly weathered. with silt, Orange/Brown to brown	Water intercept 0.3 L/s,
Upper Paterson Fm	Sandstone greenish grey very low strength extremly weathered. Silt present	
Upper Paterson Fm	Sandstone pale brown very low strength extremly weathered. Minor chips of Quartzite and Schist	0.5 L/s,
Upper Paterson Fm	Conglomerate amorphous pale yelllowish brown low strength extremly weathered. Chips of granite, quartz and schist	
Upper Paterson Fm	Sandstone pale yellowish grey low strength extremly weathered. Silty, banded Fe stains, weakely cemented. More clayey 37-39m	
Upper Paterson Fm	Sandstone pale yellowish brown greyish pink very low strength extremly weathered. Mica, clayey 41-43m	

Bore Construction



Drilling Company: Kimberly Water	Started: 2/22/2012
Drilling Equipment: RAB	Completed: 3/1/2012
Drilling Method: RAB	Compiled: 4/11/2012

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Borehole: CWB18

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
			Conglomerate amorphous grey purple high strength slightly weathered. Quartzite <30mm, granite <15mm, sandstone <10mm chips		
60				4.5 L/s,	
			Siltstone grey low strength slightly weathered.		
70					
80					
90					
100					

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Borehole: CWB18

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Lower Paterson Fm				
			Conglomerate amorphous grey medium strength slightly weathered. Quartzite , granite , siltstone, sandstone possibly interbed	10 L/s,	
110					
			Siltstone medium strength slightly weathered. with white felspar	9.3 L/s,	Gravel fill
120					
130				10.1 L/s, 1.07 mS-cm	
			Conglomerate amorphous pale grey pale purple high strength slightly weathered. Pinkish Granite <20mm, purpleish grey quartzite. Iron Staining on fractures		
140					
150					

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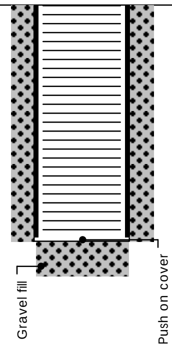
Borehole: CWB18

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Saprock		QUARTZITE granular purple grey high strength slightly weathered. Quartzite <25mm, Schist <30mm	12.1 L/s, 1.16 mS-cm 13 L/s, 1.16 mS-cm	
160					
170					
180					
190					
200					

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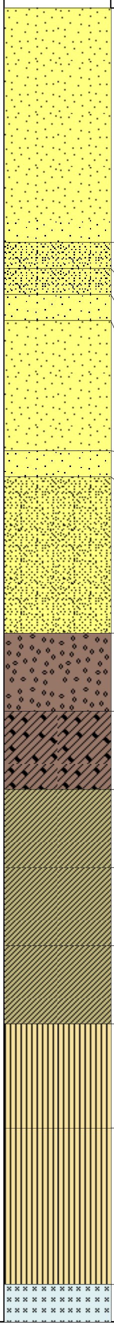
Borehole: CWB19

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: 369 (mAHD)	Total Depth: 152 m
Client: Cameco	Easting: 404293	SWL: 14.72 m (toc) on 3/13/2012	Logged By: R Taplin
Location: Kintyre	Northing: 7534386	Salinity: 1140 mg/L on 3/13/2012	Checked By: R Taplin

SUBSURFACE PROFILE

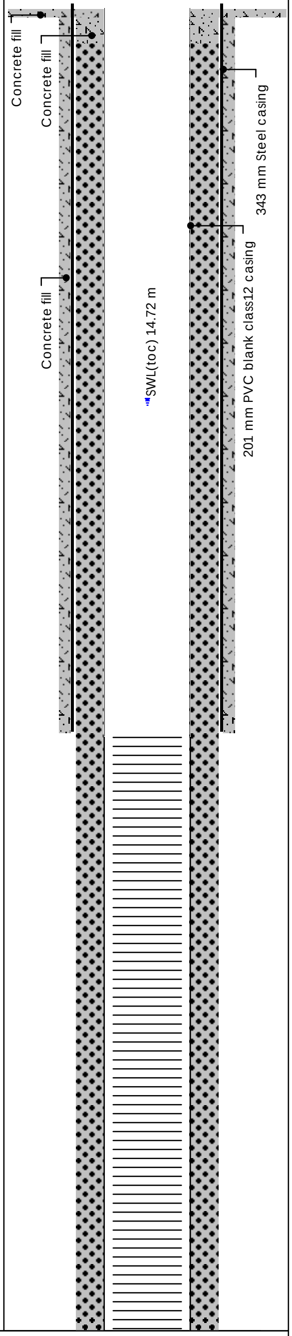
Depth (m) | Formation | Lithology Graphic | Lithology | Field Notes | Bore Construction

Depth scale: 0, 10, 20, 30, 40, 50



Ground Surface

Lithology	Field Notes
SW med SAND with trace fine gravel well graded, loose, SR, dry, qtz reddish brown, Alluvial Deposit. Surficial alluvium/dune sand	
SP med SAND with trace fine gravel poorly graded, loose, SR, dry, qtz pale reddish brown speckled dark brown, LATERITE. Weakly cemented oxidation front. Palaeo-water table, traces of MG. Mineralogy Qtz/Fe, with redox zone Fe cementing.	
SP med SAND uniformly graded, medium dense, SR, dry, qtz pale greyish red, LATERITE. Alluvial/colluvial deposit. Mineralogy Qtz/Fe, with redox zone Fe cementing	
SW gravelly coarse SAND well graded, loose, rounded, dry, qtz pale greyish red, Colluvium. Clasts of quartzite, very minor siliceous overprinting. Colluvial/Fluvial soil origin.	
SW gravelly med SAND well graded, loose, rounded, dry, qtz lithic pale reddish brown, Colluvium. Gravel, up to 20mm - Quartzite, mica-sandstone, banded iron?	
SW fine SAND with trace fine gravel well graded, medium dense, SR, dry, qtz lithic pale greyish brown, Colluvium. Pesoltic FS with traces of polymictic fine gravel	Water intercept
SP fine SAND with trace silt poorly graded, loose, SR, wet, qtz pale yelllowish brown, Colluvium. Clean sands.	
GW-GS fine GRAVEL with fine sand well graded, loose, SR, wet, qtz lithic pale grey speckled white with black, Colluvium. Quartzite, sandstone, micaceous schist, carbonate? Granite. SAMPLES SIEVED FROM 24m ONWARDS	
GC clayey fine GRAVEL well graded, medium dense, SA, wet, lithic pale grey speckled white with black, Colluvium. 10% MS also.	1 L/s,
CL CLAY with trace med sand, stiff, low plasticity, wet dark brown.	
CL CLAY with trace silt, firm, low plasticity, wet dark brown.	0.2 L/s,
CL CLAY with trace med sand, soft, low plasticity, wet greyish red.	
ML SILT with clay, very soft, low plasticity, wet dark grey. Very weakly consolidated	
ML SILT with trace clay, very soft, low plasticity dark grey.	
Siltstone dark grey very low strength fresh rock. Moderately cemented	



Drilling Company: Kimberly Water	Started: 3/3/2012
Drilling Equipment:	Completed: 3/9/2012
Drilling Method: RAB	Compiled: 4/11/2012

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Borehole: CWB19

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
			Siltstone dark grey very low strength slightly weathered. Weakly cemented, 30% clay.		
60			Siltstone dark grey medium strength fresh rock. Consolidated	0.2 L/s,	
70					
80					
90					201 mm PVC slotted class12 screen
			Siltstone dark grey speckled pale brown medium strength slightly weathered. Siltstone with sandstone laminar	0.2 L/s,	
			SW-SG coarse SAND with fine gravel well graded, loose, rounded, wet, qtz lithic dark grey speckled pale grey with pale yellow. Predominantly siltstone and quartzite	5 L/s, 1.7 mS-cm	
100					

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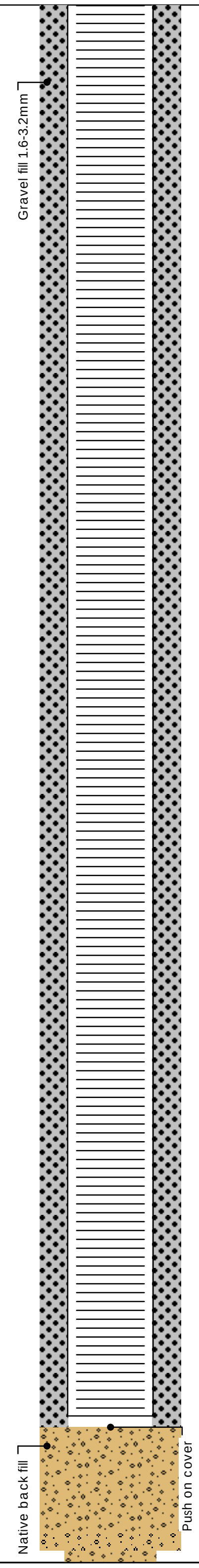
Borehole: CWB19

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
			GW sandy fine GRAVEL well graded, loose, rounded, wet, qtz lithic grey speckled yellowish brown with pink. Clasts up to 20mm, iron staining, granite, sandstone, quartzite, siltstone, schist, talc.	
110			GP fine GRAVEL poorly graded, loose, rounded, wet, qtz lithic pale brownish grey. well rounded platey sandstone pebbles, traces of siltstone and quartzite.	
			SP gravelly coarse SAND poorly graded, loose, SR, wet, qtz lithic pale brownish grey. Gravel consists of granite, sandstone and siltstone. Contamination of red surface sands.	
120			GP fine GRAVEL poorly graded, loose, SR, qtz lithic.	
130			SP coarse SAND with trace med gravel poorly graded, loose, SR, qtz lithic. Clean coarse sand, fining downwards.	8 L/s, 1.9 mS-cm
140				
150				

Bore Construction



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Borehole: CWB19

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
				12 L/s, 1.9 mS-cm	
160					
170					
180					
190					
200					

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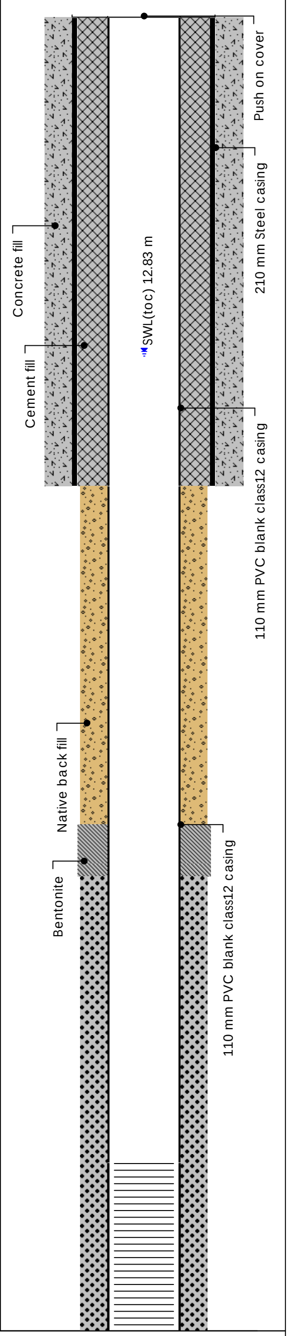
Borehole: WEX2

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 132 m
Client: Cameco	Easting: 401653	SWL: 12.83 m (toc) on 2/9/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7534149	Salinity: 450 mg/L on 2/9/2010	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0	Alluvial		SM silty fine SAND, loose, dry, qtz reddish brown. with gravel. Gravel is mostly quartz, size <5mm but some occasional 2cm diameter pieces	
10				
	Upper Paterson Fm		SC clayey med SAND, loose pale grey. with gravel, wet from 20mbgl, moderately weathered. Gravel comprises subrounded to subangular sandstone, quartzite and quartz <2cm	
20				
			CH CLAY, stiff, high plasticity, wet brown. with some traces of quartz gravel<1cm	
30				0.1 L/s, 720 mg/L, 8.04, 1.44 mS-cm
			CH CLAY, stiff, medium plasticity grey dark grey. hard, wet with some small occasional quartz gravel <5mm	
40				
				0.1 L/s, 215 mg/L, 8.34, 0.43 mS-cm
50				

Bore Construction



Drilling Company: Nudrill	Started: 2/7/2010
Drilling Equipment:	Completed:
Drilling Method: RAB	Compiled: 3/16/2012

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Borehole: WEX2

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Lower Paterson Fm		Conglomerate brownish grey. composed of sand and various gravel. Sand coarse, loose, wet. Gravel subangular, weathered, comprising of <2cm quartzite, sandstone, claystone, quartz and occasinal granitoid and gneiss. At 124mbgl fresh pinkish quartzite appeared	1 L/s, 350 mg/L, 8.28, 0.7 mS-cm	
60				1.5 L/s, 350 mg/L, 8.18, 0.9 mS-cm	
70				2 L/s, 415 mg/L, 8.46, 0.86 mS-cm	
80				2.5 L/s, 345 mg/L, 7.57, 0.69 mS-cm	
90				4 L/s, 455 mg/L, 8.25, 0.91 mS-cm	110 mm PVC slotted class12 screen; Gravel fill
100					

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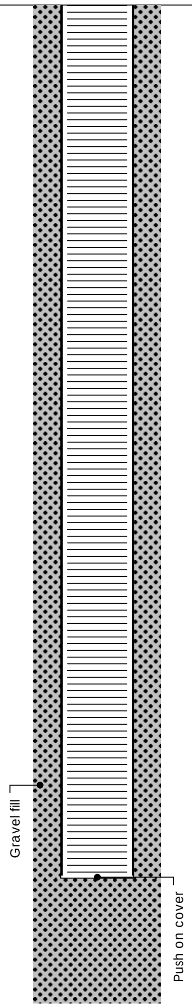
Borehole: WEX2

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
			4.5 L/s, 335 mg/L, 7.62, 0.67 mS-cm
110			
			6.8 L/s, 445 mg/L, 8.2, 0.89 mS-cm
120			
			6 L/s, 445 mg/L, 8.22, 0.89 mS-cm
130	Saprock	QUARTZITE pinkish grey purple fresh rock. hard, wet, subangular with some traces of dark grey schist and white quartz.	
140			
150			

Bore Construction



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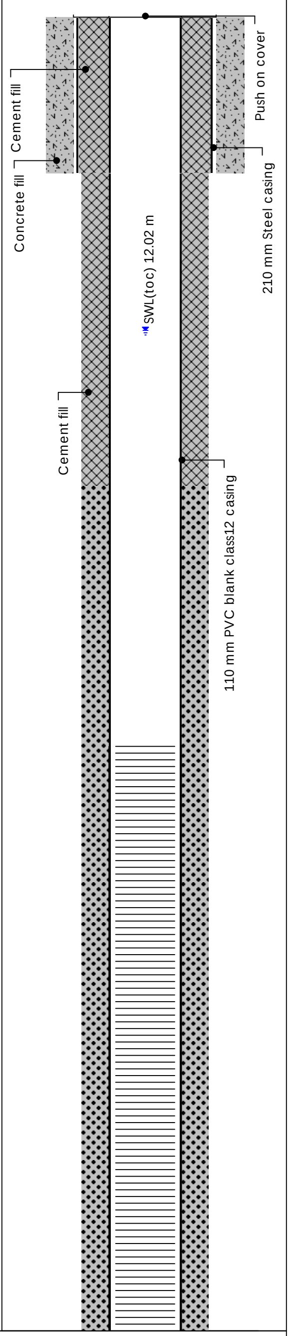
Borehole: WEX3

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 126 m
Client: Cameco	Easting: 402359	SWL: 12.02 m (toc) on 12/12/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7532951	Salinity: 3860 mg/L on 12/12/2009	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0	Alluvial		SW fine SAND, loose, dry reddish brown. with some minor traces of subangular quartz gravel <3mm	
			SW gravelly fine SAND well graded reddish brown. gravel comprised of quartz, quartzite and sandstone varying in size from 1mm to 1cm	
10				
			GW sandy fine GRAVEL well graded grey pale brown. Sand coarse, gravel consisted of pinkish quartzite, white quartz, muscovite schist, sandstone varying in size from 1mm to 1cm	
20			Conglomerate. composed of fine to medium grey grain sand, pinkish, quartzite, quartz, minor sandstone and some minor muscovite schist, subrounded, size from 1mm to 2cm. Occasional trace of granitoid with biotite	
30				Water intercept 5320 mg/L, 7.82, 7.73 mS-cm 31.2 °C.
40				0.5 L/s, 5210 mg/L, 7.93, 7.52 mS-cm 31.3 °C.
50				

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment:	Completed: 11/6/2009
Drilling Method: RAB	Compiled: 3/16/2012

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Borehole: WEX3

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Lower Paterson Fm			0.5 L/s, 4620 mg/L, 8.02, 7.06 mS-cm 32.5 °C.	
60					
				0.5 L/s, 5580 mg/L, 8.24, 8.02 mS-cm 31.6 °C.	
70					
					110 mm PVC slotted class12 screen
				0.3 L/s, 5360 mg/L, 8.07, 7.53 mS-cm 32.5 °C.	
80					
				0.6 L/s, 4590 mg/L, 7.98, 6.78 mS-cm 34.8 °C.	
90					
					Gravel fill
				1.3 L/s, 5340 mg/L, 7.98, 7.62 mS-cm 34.6 °C.	
100					

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Borehole: WEX3

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110					
				1 L/s, 4910 mg/L, 8, 7.72 mS-cm 34.7 °C.	
120					Gravel fill
	Saprock		SCHIST dark grey black. chloride and silicious schist, hard. Some presence of quartzite and quartz.		Push on cover
130					
140					
150					

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Borehole: WEX4

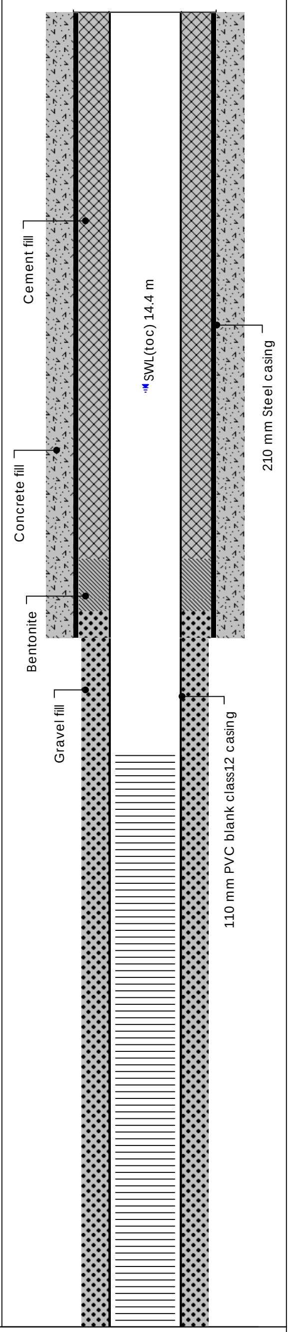
Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 120 m
Client: Cameco	Easting: 403307	SWL: 14.4 m (toc) on 2/9/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7535020	Salinity: 890 mg/L on 2/9/2010	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
0			Ground Surface	
0–6	Alluvial		SW med SAND, loose, dry reddish brown. with minor subrounded quartz gravel <5mm	
6–18			SM silty fine SAND, loose, dry. Light brown to tan with gravel subrounded to subangular <1cm with single quartz pieces of <2cm diameter	
18–30			MH clayey SILT, medium plasticity, wet. Tan with gravel comprises of quartz, sandstone and traces of gneiss, size <3cm diameter	
30–50			SW gravelly coarse SAND. tan to light brown with wet gravel comprises of large pieces of subangular quartz and sandstone <5cm and some smaller pieces of siltstone and gneiss <1cm	0.08 L/s, 470 mg/L, 8.17, 0.95 mS-cm 30.2 °C.

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 2/5/2010
Drilling Method: RAB	Compiled: 3/16/2012

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Borehole: WEX4

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
	Upper Paterson Fm			1.81 L/s, 820 mg/L, 8.27, 1.62 mS-cm 30.2 °C.	
60				3.39 L/s, 880 mg/L, 8.38, 1.78 mS-cm 30 °C.	
			Siltstone grey dark grey. moderately hard, frieable with some minor clay content and fragments of metamorised into quartzite, wet.		
70				3.5 L/s, 880 mg/L, 8.26, 1.77 mS-cm 31.7 °C.	110 mm PVC slotted class12 screen
80				4 L/s, 880 mg/L, 8.08, 1.7 mS-cm 30.9 °C.	
90				4 L/s, 980 mg/L, 8.4, 1.96 mS-cm	Gravel fill
				3 L/s, 935 mg/L, 8.65, 1.87 mS-cm	
100					

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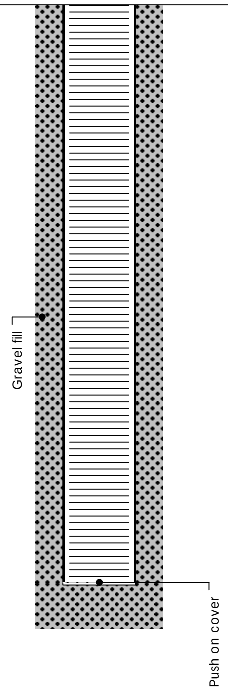
Borehole: WEX4

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
			4 L/s, 895 mg/L, 8.06, 1.79 mS-cm
	Lower Paterson Fm	Conglomerate pale grey. with pink quartzite, grey/green schist, quartz and grey siltstone with trace granite and mica	4 L/s, 885 mg/L, 8.08, 1.77 mS-cm
110			4 L/s, 890 mg/L, 7.84, 1.78 mS-cm
		Conglomerate. Brown sand, coarse with conglomerate gravel <5mm, wet.	
120			
130			
140			
150			

Bore Construction



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Borehole: WEX5D

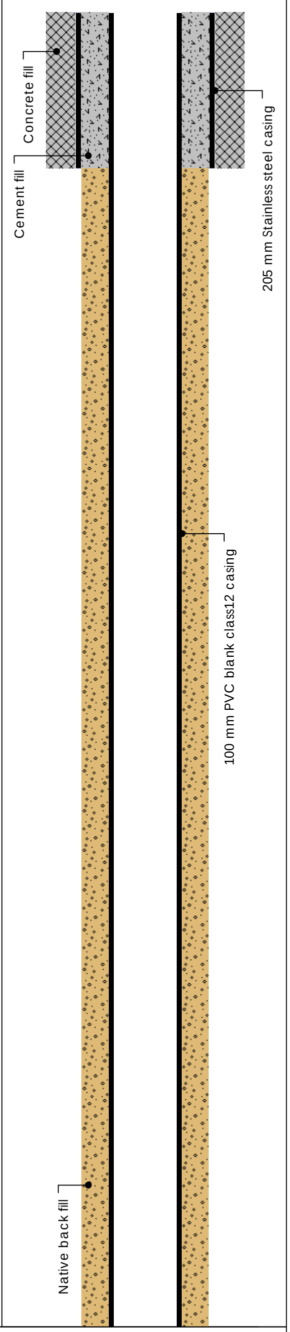
Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 133 m
Client: Cameco	Easting: 405007	SWL:	Logged By: Reproduced from MWH (2009)
Location: Kintyre Uranium Deposit	Northing: 7532943	Salinity:	Checked By:

SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0–12	Alluvial	SM silty fine SAND well graded, loose, SA, qtz reddish brown. with clay and minor Qtz gravel <1cm	
12–18		SC clayey fine SAND. Whitish tan with calcrete and minor qtz gravel	
18–24		SM silty fine SAND well graded, loose brown. some clay and minor calcrete, damp	
24–32		CH sandy CLAY, soft, medium plasticity. Tan to brown with quartz gravel <3mm subrounded, wet at 30mbgl	
32–42		SC clayey med SAND uniformly graded, loose, SR cream. Tan color	0.5 L/s, 7.2, 4.6 29.5 °C.
42–50		CH CLAY, soft, medium plasticity. Grey to light brown with clusters of white friable sand and some traces of red-brown hardstone, wet	0.5 L/s, 7.98, 2.04 27.3 °C.

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: Mud	Completed: 11/30/2009
Drilling Method: Mud	Compiled: 3/16/2012

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Borehole: WEX5D

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
50–60	Upper Paterson Fm			1 L/s, 7.58, 1.87 27 °C.	
60–70					
70–80					
80–90					Bentonite
90–100			Conglomerate dark grey. comprised of abundant dark grey schist, Qtz, brownish sandstone and minor clay and sand. Occasional Fe staining, becoming more sandy from 115mbgl and more muscovite schist from 121mbgl		

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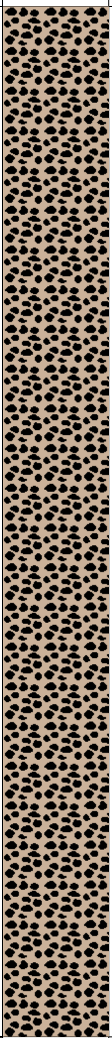
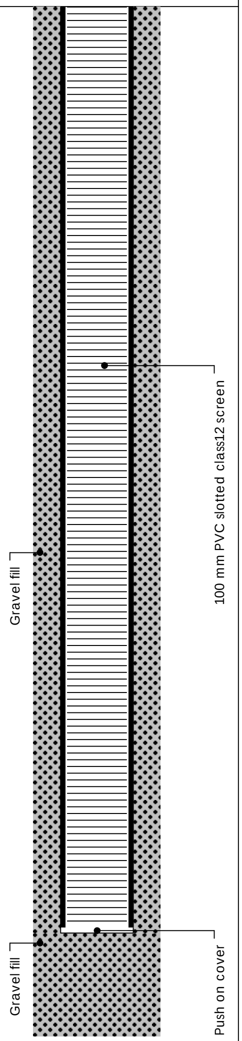
Borehole: WEX5D

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110, 120, 130	Lower Paterson Fm				
140, 150					

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Borehole: WEX5s

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 38 m
Client: Cameco	Easting: 405005	SWL: 15.69 m (toc) on 12/7/2009	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7532938	Salinity:	Checked By:

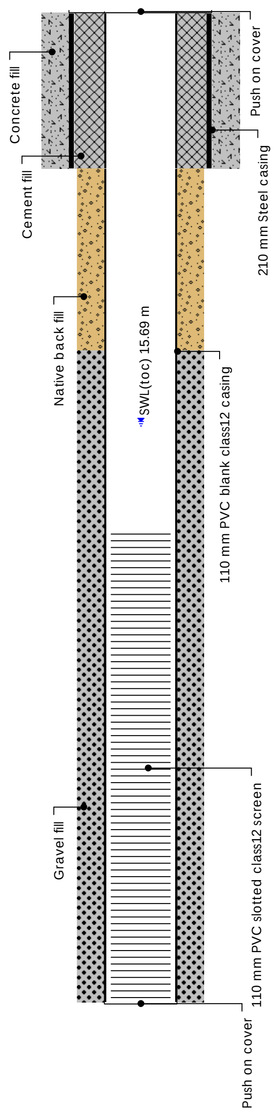
SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0–12	Alluvial	SM silty med SAND well graded, loose, dry reddish brown. and clay with minor subangular quartz gravel <1cm	
12–18	Upper Paterson Fm	SC clayey med SAND. Whitish tan with calcrete and minor quartz gravel	
18–24	Upper Paterson Fm	SM silty med SAND well graded, loose. Tan with clay, minor calcrete, damp.	
24–32	Upper Paterson Fm	SM silty med SAND well graded, loose. Tan with clay, minor calcrete, damp	
32–38	Upper Paterson Fm	SC clayey med SAND, SR, wet. Tan	

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill	Started: 12/3/2009
Drilling Equipment:	Completed:
Drilling Method: RAB	Compiled: 3/16/2012

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Borehole: KEB1

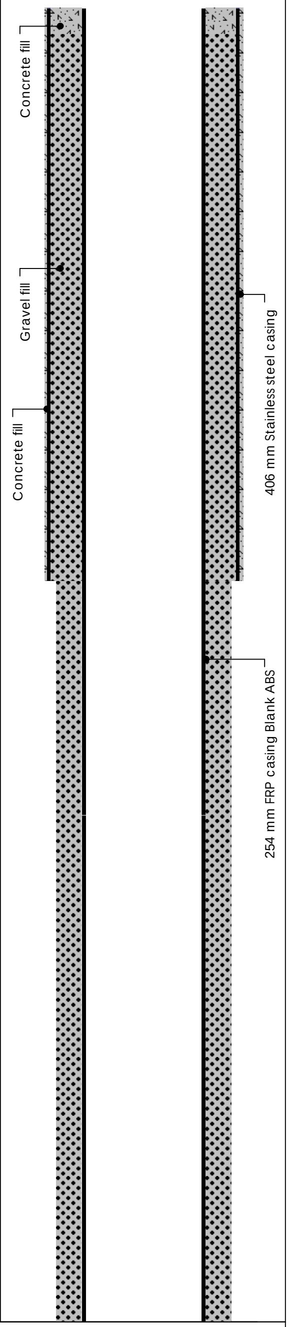
Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 127 m
Client: Cameco	Easting: 404464	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7529613	Salinity:	Checked By:

SUBSURFACE PROFILE

Ground Surface

Depth (m)	Formation	Lithology	Field Notes
0	Alluvial	SM silty med SAND, qtz reddish brown.	
		SW coarse SAND, rounded brown. Green/grey weathered sandstone and chert from 4m	
10			
		SM silty med SAND. Tan/white with green grey weathered sandstone, rounded to subrounded (5-10mm), chert, angular. Larger sized weathered sandstone 910-40mm) from 20m. Less silty sand from 28m.	
20			
30			
		Sandstone greenish grey distinctly weathered. with chert -angular, schist- angular to sub angular (4-15mm), minor brown sandstone.	
40		Sandstone greenish grey. , sub angular to sub rounded (3-20mm, increase in size from 56-74m to 3-60mm), quartz, subangular to subrounded (3-20mm, increase in size from 56-74m to 3-60mm). Minor brown sandstone, 2-7mm, with gravel comprising weathered sandstone and quartz.	
50			

Bore Construction



Drilling Company: Easternwell Minerals	Started:
Drilling Equipment: Mud	Completed: 12/19/2010
Drilling Method: Mud	Compiled: 3/16/2012

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Borehole: KEB1

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
60–74	Lower Paterson Fm			2.1 L/s, 8.81, 8350 µS-cm (70 m)	
74–82			Sandstone grey. 4-30mm, rounded, quartz		254 mm FRP casing Slotted ABS
82–100			Sandstone. Tan/grey fine weathered sandstone, rounded (3-30mm), quartz subangular(3-30mm), dark grey schist (3-20mm), subrounded to subangular. Increase in schist from 92m	2.5 L/s, 8.85, 8350 µS-cm (85 m); 2.1 L/s, 8.72, 8300 µS-cm (100 m)	Gravel fill

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Borehole: KEB1

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110					
			Sandstone distinctly weathered. subrounded to subangular (3-15mm), quartz angular (3-15mm), schist subrounded (2-20mm)	2.5 L/s, 8.83, 8430 µS-cm	
			SM silty med SAND grey. with weathered sandstone (5-15mm), Quartz (5-15mm), and schist (2-10mm). From 132m-134m more sand and less weathered sandstone, quartz and schist.	3 L/s, 8.83, 8530 µS-cm	Native Backfill; Push on cover
120					
130					
140					
150					

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Borehole: KEB2

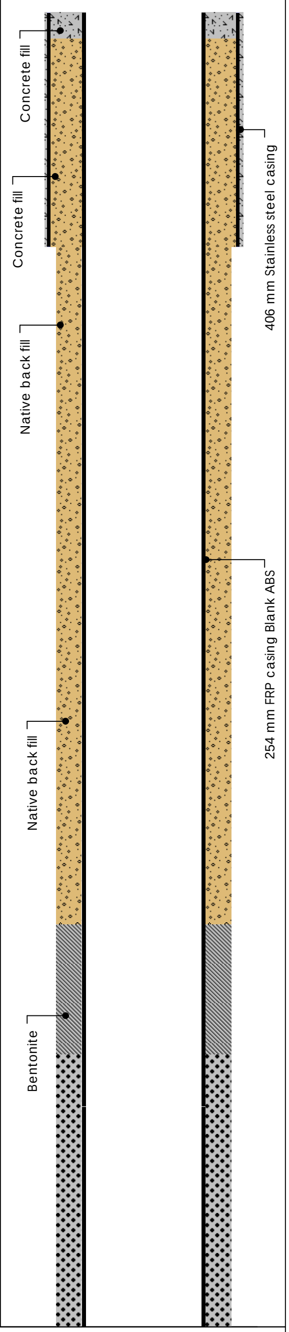
Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 150 m
Client: Cameco	Easting: 405563	SWL:	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7529499	Salinity:	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes
0		Ground Surface	
0 – 6	Alluvial	SM silty med SAND, SA, qtz red brown.	
6 – 8	Alluvial	GW med GRAVEL, SA, qtz brown.	
8 – 10	Alluvial	SM silty med SAND, SA, qtz brown.	
10 – 12	Alluvial	SC clayey med SAND, SA, qtz brown.	
12 – 24	Alluvial	SM silty med SAND brown. with greenish clay lenses and poorly sorted gravel, quartz and sandstone subangular to subrounded (2-15mm). From 14m more greenish grey in color	
24 – 30	Upper Paterson Fm	CH silty CLAY, medium plasticity greenish grey. with dark grey and salmon colour to brown lenses, minor gravel subangular to subrounded (2-5mm)	
30 – 36	Upper Paterson Fm	MH SILT, medium plasticity greenish grey. with chips of schist, mostly up to 10mm but also rare chips up to 20mm subangular to subrounded. Some clay between 30-32	
36 – 48		SCHIST grey. traces of friable brown siltstone and quartz. Water present from 35m. 42m-46m contains more brown fine material, possibly sandstone. Large chips of friable siltstone between 48m-50m	
48 – 50		SCHIST grey. with minor quartz and friable brown siltstone subangular to subrounded (2-10mm)	

Depth scale: 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Easternwell Minerals	Started:
Drilling Equipment: RAB	Completed: 11/30/2010
Drilling Method: RAB	Compiled: 3/16/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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Borehole: KEB2

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology	Field Notes	Bore Construction
		SCHIST brown. quartz and friable grey siltstone subangular to subrounded (2-10mm) also up to 50mm chips of brown sandstone		
60		SCHIST. with grey sandy silt(50%), schist, quartz, subangular to subrounded, mostly (2-5mm) some minor 10mm chips		
		SCHIST. Brown sand (from 64-66m - 50%, 66-68m up to 80%) schist, quartz subangular to subrounded (2-15mm)		
		SCHIST. with some quartz sand (2-5mm) also big chips of quartz (10mm) and purple chert		
70		SCHIST. with 50% brown sand, schist and quartz (2-10mm) subangular to subrounded. Also friable siltstone		
80		SM silty med SAND, qtz brown. with purple and greenish chert, schist. Friable brown siltstone subangular to subrounded (2-10mm)		
		SW med SAND, qtz reddish brown. with schist, red brown sandstone and friable grey brown siltstone (2-20mm) subangular to subrounded. Last few meters big chunks of schist transported to surface (possible washout)		
90		Sandstone. with brown staining. Large chunks of white quartz (up to 25mm),. Crystalline material and smaller pieces of silver sparkling schist		254 mm FRP casing Slotted ABS
100	Saprock	SCHIST bluish grey. with white and pinkish quartz, minor brown friable siltstone subrounded (5-10mm), some siltstone up to 15mm. 108m-110m more siltstone, 110-114 presence of more quartz. Hard drilling	4 L/s, 8.53, 3830 µS-cm	

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Borehole: KEB2

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes	Bore Construction
110				4 L/s, 8.69, 3710 µS-cm	
				4 L/s, 8.61, 3780 µS-cm	
			CH CLAY, medium plasticity green brown. with friable siltstone (5-15mm) subrounded to rounded, minor schist and traces of quartz (possibly fallback)		Gravel fill
			SCHIST bluish grey. minor quartz (5-15mm) subrounded, brown friable siltstone at 123m (up to 50%), 126-128m more quartz		
120					
130				4 L/s, 8.79, 3830 µS-cm	
			SCHIST greenish grey. (small particles with no color, black and greenish grey). Hard drilling. 138m-140m bigger chips (up to 10mm), 148m-150m a bit more quartz (1mm)		
140				4 L/s, 8.81, 3780 µS-cm	
150				4 L/s, 8.87, 3830 µS-cm	Push on cover

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Borehole: North Bore

Project: Cameco Uranium Project	Zone: 51 (GDA 94)	Elevation: (mAHD)	Total Depth: 82 m
Client: Cameco	Easting: 400440	SWL:	Logged By: Reproduced from MWH (2009)
Location: Kintyre	Northing: 7535767	Salinity:	Checked By:

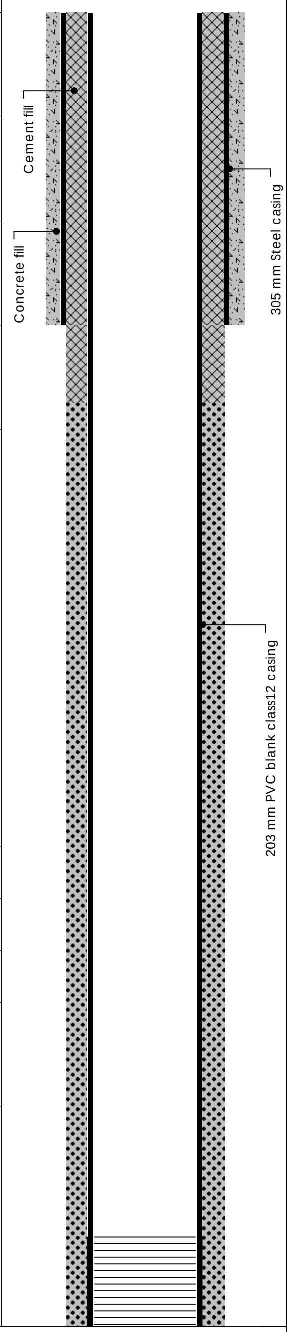
SUBSURFACE PROFILE

Ground Surface

Formation	Lithology
Alluvial	SW fine SAND well graded, loose, dry, qtz reddish brown, Alluvial Deposit.
Alluvial	SM silty fine SAND well graded, loose, dry, qtz reddish brown.
Alluvial	SM silty fine SAND well graded, loose, SA, dry brown.
Alluvial	SW fine SAND well graded, loose, SA, dry, qtz brown.
Upper Paterson Fm	Siltstone pale grey. with minor sandstone lenses. Mod/well indurated, Qtz veins and Fe staining, dry
Lower Paterson Fm	Sandstone pinkish grey high strength slightly weathered. water at 31mbgl, iron staining. Fractured
Lower Paterson Fm	SW fine SAND, loose, wet, qtz greyish brown.
	QUARTZITE granular pinkish grey. Fe staining, wet, gravel 0.5cm subangular
	SW fine SAND, qtz brown. common quartzite gravel, angular 1cm, Fe stained
	QUARTZITE greyish brown slightly weathered. Fe Staining, Fractures (bigger chips) at 46-50m wet.

Depth (m): 0, 10, 20, 30, 40, 50

Bore Construction



Drilling Company: Nudrill	Started:
Drilling Equipment: RAB	Completed: 11/30/2009
Drilling Method: RAB	Compiled: 3/16/2012

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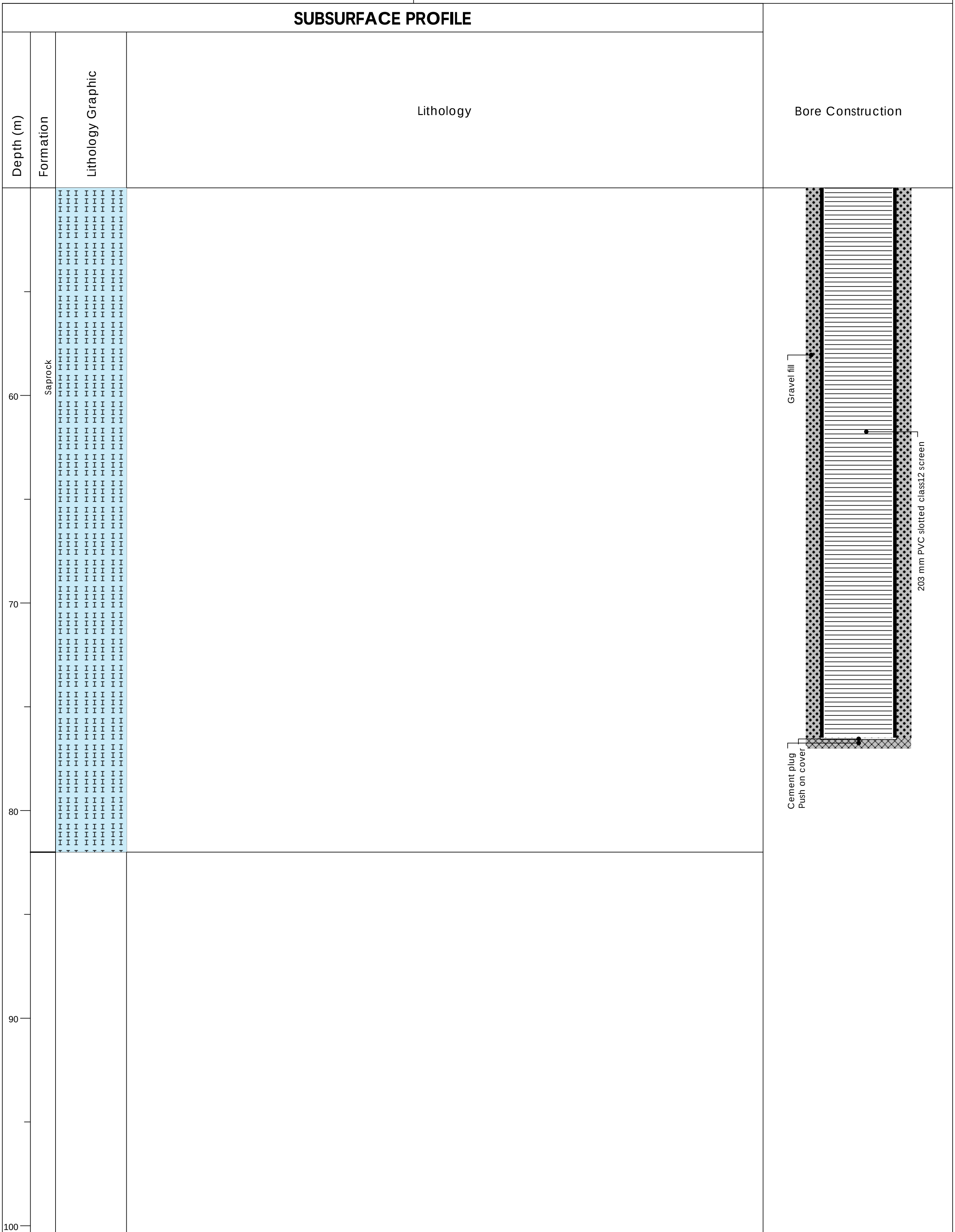
Borehole: North Bore



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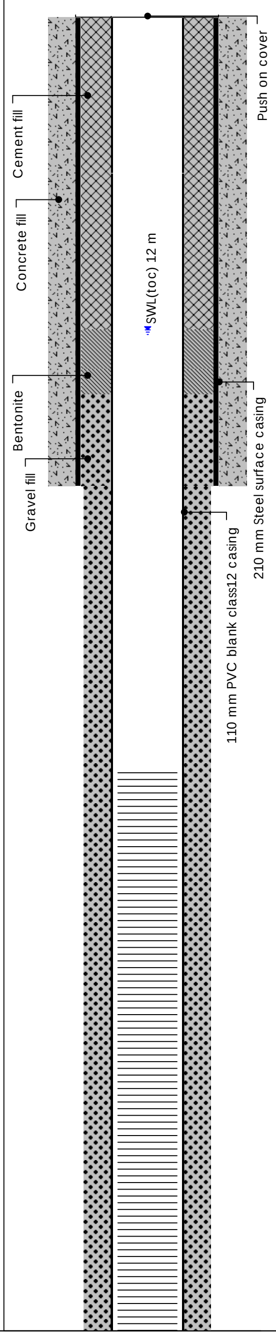
Borehole: WEX1

Project: Cameco Uranium Project	Zone: 51 (GDA94)	Elevation: (mAHD)	Total Depth: 90 m
Client: Cameco	Easting: 400994	SWL: 12 m (toc) on 2/9/2010	Logged By: Reproduced from MWH (2010)
Location: Kintyre	Northing: 7534884	Salinity: 570 mg/L on 2/9/2010	Checked By:

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
			Ground Surface	
0	Alluvial		SM silty med SAND, loose, dry reddish brown. with subrounded quartz gravel <3mm	
10	Upper Paterson Fm		SM silty med SAND poorly graded pale brown. with gravel comprising of weathered subangular sandstone, quartzite and quartz <2cm. Becoming wet at 20m bgl	
20			CH CLAY, high plasticity, wet. Tan with subangular quartzite gravel <1cm diameter	
30			CH CLAY, stiff, high plasticity, wet grey. with subrounded siltstone pieces <1cm.	
40				
50				

Bore Construction



Drilling Company: Nudrill
Drilling Equipment:
Drilling Method: RAB

Started:
Completed: 2/8/2010
Compiled: 3/16/2012

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.

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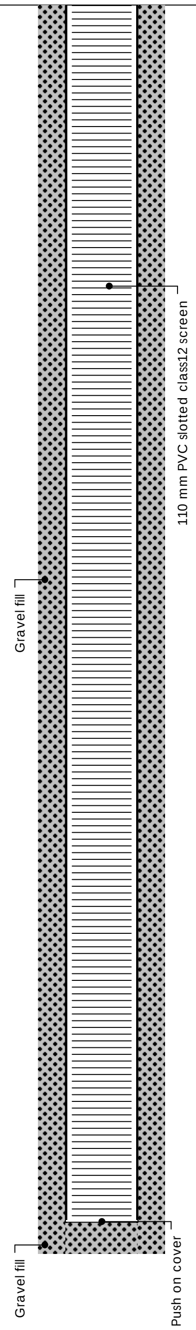
Borehole: WEX1

SUBSURFACE PROFILE

Depth (m)	Formation	Lithology Graphic	Lithology	Field Notes
60, 70			Siltstone dark grey. friable, moderately hard, wet with some clayey matrix and pinkish quartzite gravel, subangular <1cm, hard.	
80, 90	Saprock		QUARTZITE purple pink with grey high strength fresh rock. subrounded <2cm diameter with some races of sandstone, quartz, schist and mica	0.5 L/s, 1330 mg/L, 8.17, 2.66 mS-cm 0.25 L/s, 570 mg/L, 8.59, 1.14 mS-cm
100				

Bore Construction

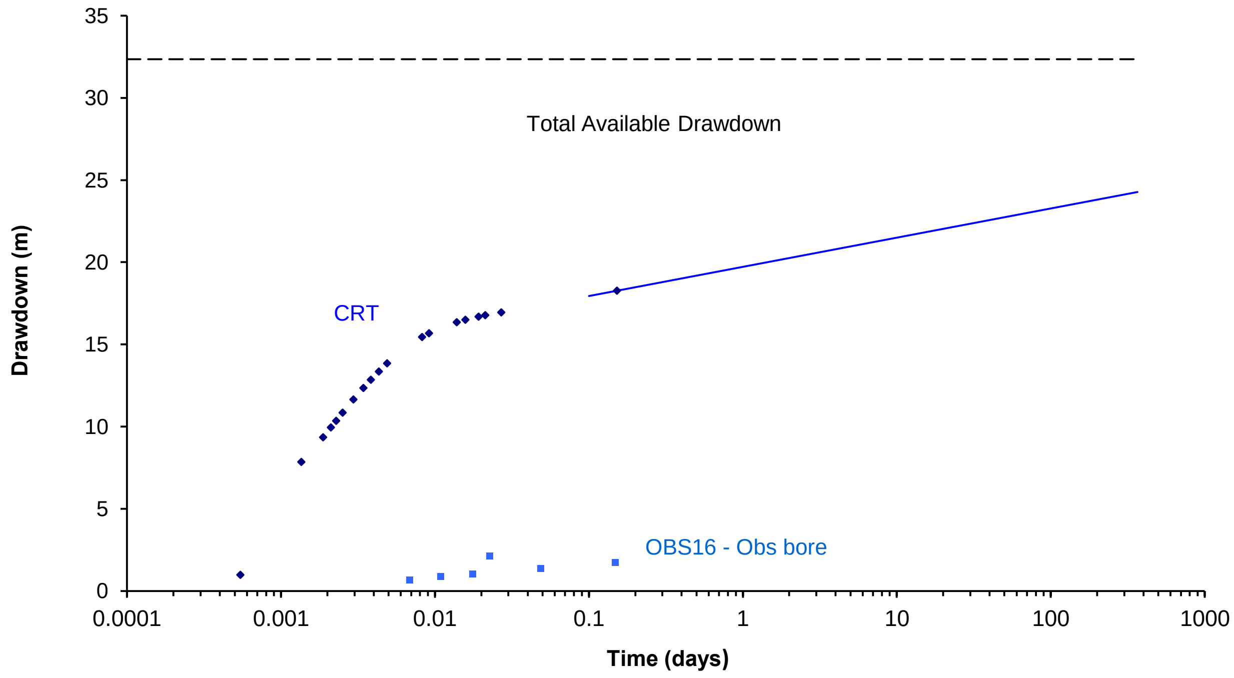


Appendix C

ERMP Hydraulic Test Results

CONSTANT RATE TEST
North Bore

DRAWDOWN PROJECTED TO 365 DAYS



Date of Test	23-Nov-09	
SWL at start	15.7	mBTOC
Pump Setting	48.0	mBTOC
L = Length of Screen =	30	m

Available drawdown above pump setting	32.4	m
Max available drawdown in pump well	61.35	m

$T = 2.3Q/(4\pi\Delta(h_0 - h))$

Q = Test Discharge =	311	kL/day
	3.60	L/s
$\Delta(h_0 - h)$ = Head change per log cycle =	1.77	m
T= Transmissivity =	32.1	m²/day

K = Hydraulic Conductivity = T/L = 1.07 m/day

CONSTANT RATE TEST
WEX5S

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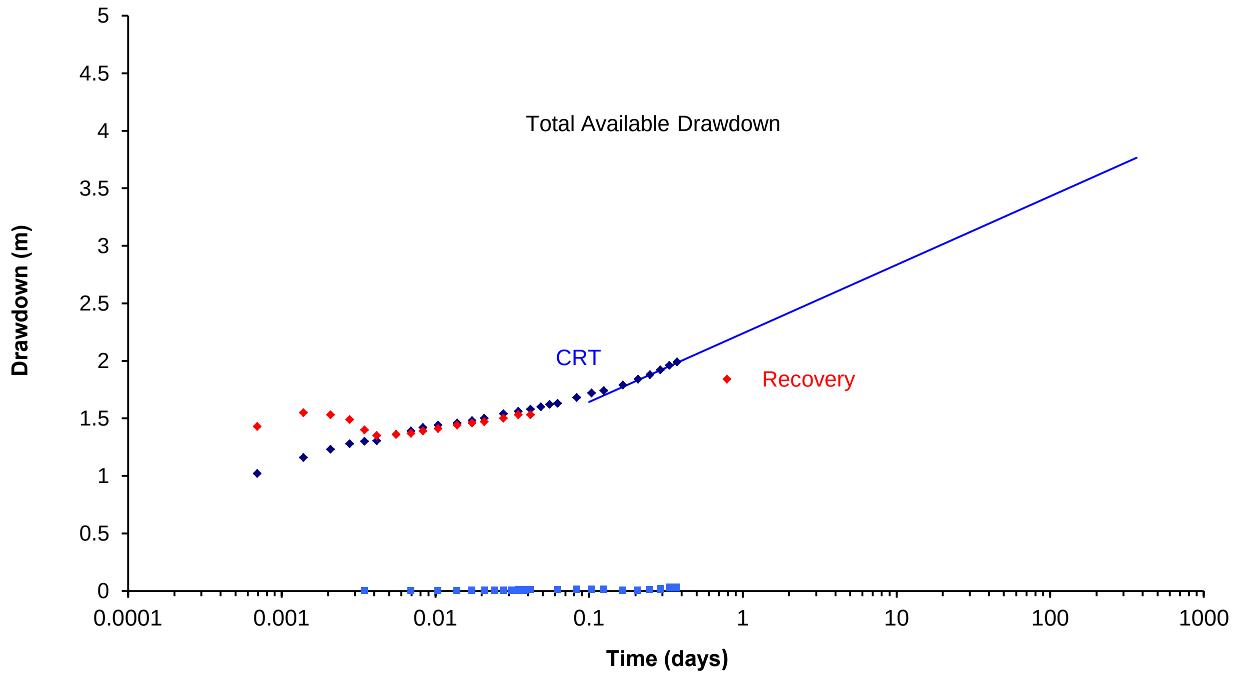
DRAWDOWN PROJECTED TO 365 DAYS



Date of Test	18-Apr-12	
SWL at start	14.9	mBTOC
Pump Setting	35.6	mBTOC
L = Length of Screen =	20	m
Available drawdown above pump setting	20.7	m
Max available drawdown in pump well	23.11	m

$T = 2.3Q/(4\pi\Delta(h_0\text{-}h))$

Q = Test Discharge =	39	kL/day
	0.45	L/s
$\Delta(h_0$-$h)$ = Head change per log cycle =	0.60	m
T= Transmissivity =	12.0	m²/day
K = Hydraulic Conductivity = T/L =	**0.60**	**m/day**

CONSTANT RATE TEST
WEX5d

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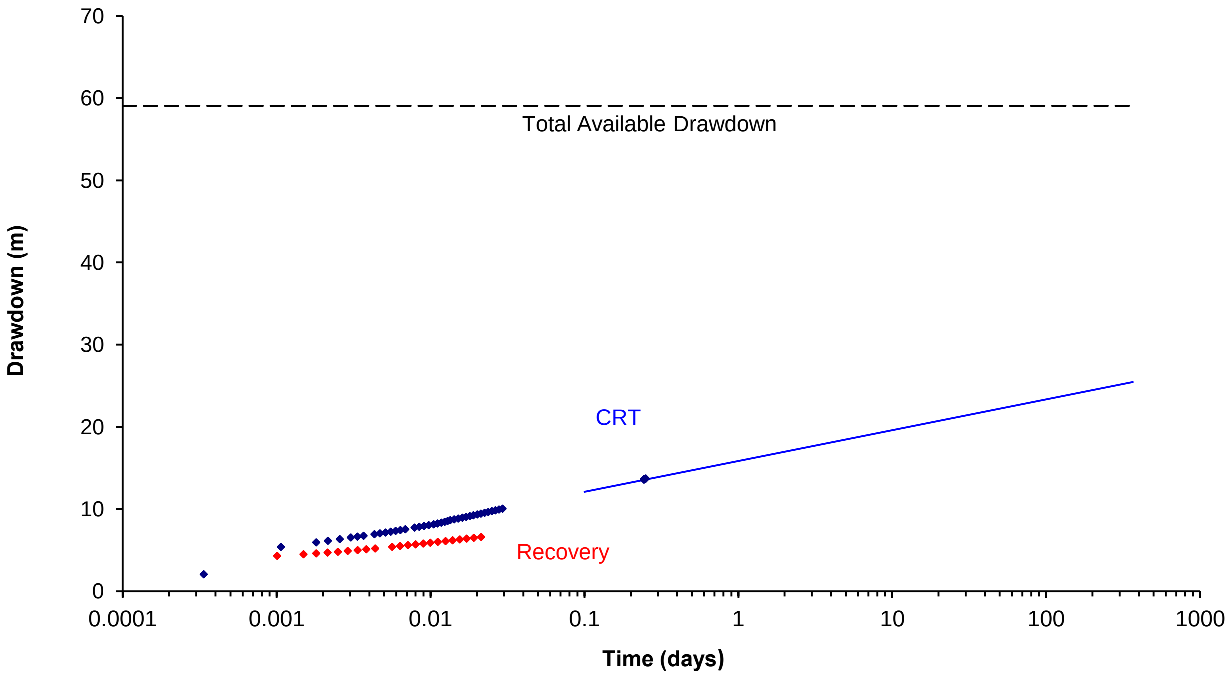
DRAWDOWN PROJECTED TO 365 DAYS



Date of Test	13-Dec-09	
SWL at start	16.0	mBTOC
Pump Setting	75.0	mBTOC
L = Length of Screen =	36	m
Available drawdown above pump setting	59.0	m
Max available drawdown in pump well	114.04	m

$T = 2.3Q/(4\pi\Delta(h_0 - h))$

Q = Test Discharge =	311	kL/day
	3.60	L/s
$\Delta(h_0 - h)$ = Head change per log cycle =	3.75	m
T= Transmissivity =	15.2	m²/day
K = Hydraulic Conductivity = T/L =	**0.42**	**m/day**

CONSTANT RATE TEST

KWP1

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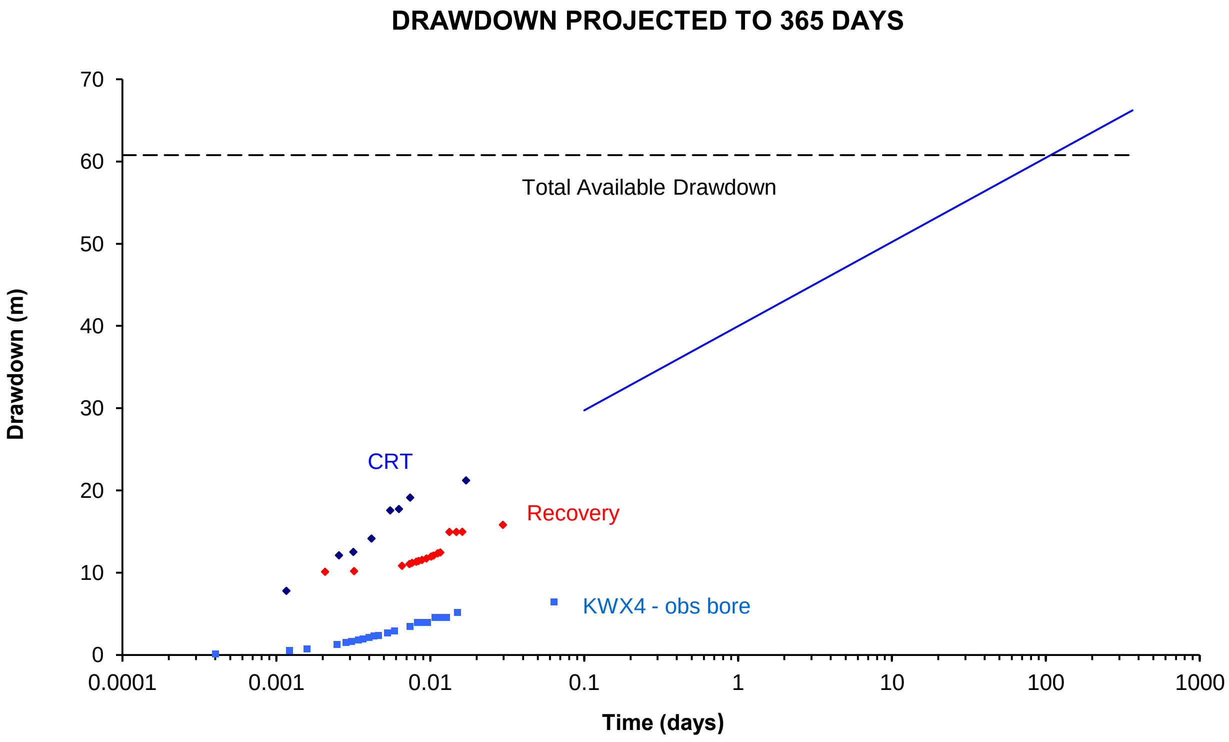
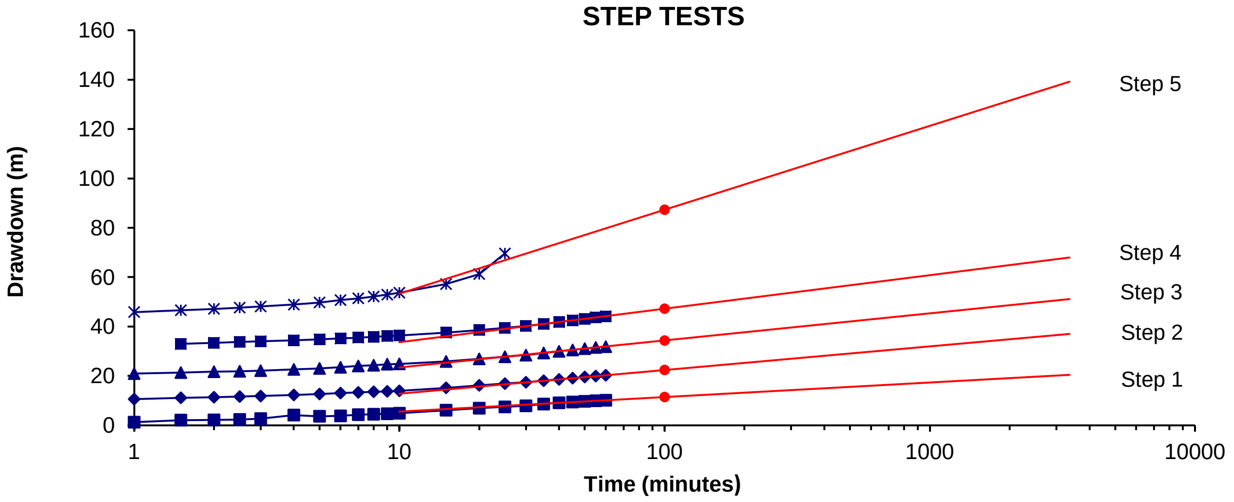


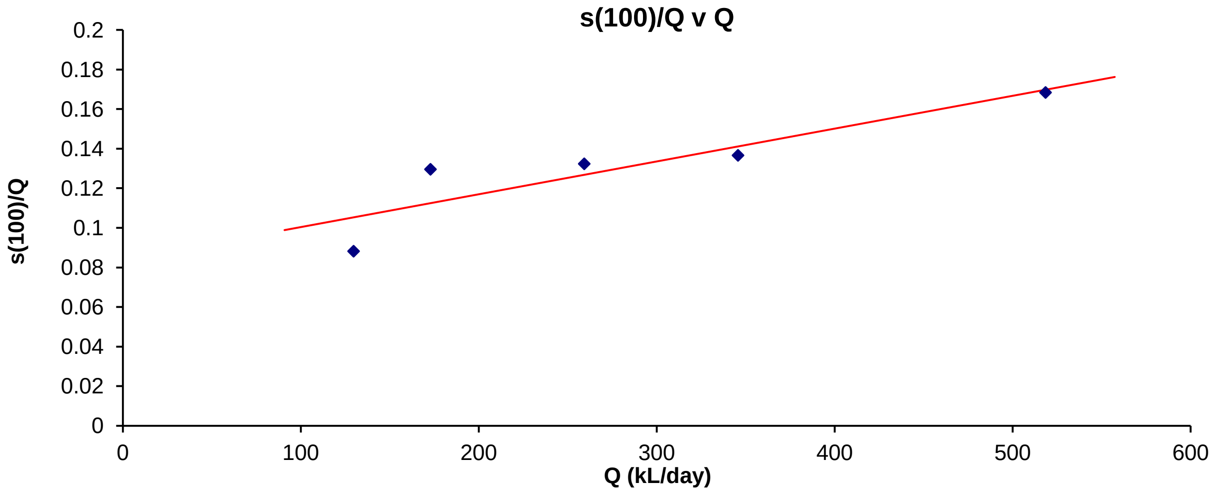
Date of Test	26-Oct-09	
SWL at start	24.2	mBTOC
Pump Setting	85.0	mBTOC
L = Length of Screen =	96.06	m
Available drawdown above pump setting	60.8	m
Max available drawdown in pump well	95.79	m

$T = 2.3Q/(4\pi\Delta(h_0 - h))$

Q = Test Discharge =	380	kL/day
	4.40	L/s
$\Delta(h_0 - h)$ = Head change per log cycle =	10.24	m
T= Transmissivity =	6.8	m²/day
K = Hydraulic Conductivity = T/L =	**0.07**	**m/day**

STEP TEST ANALYSIS
KEB1





s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 8.37E-02

C = gradient = 1.66E-04

S = drawdown in the bore

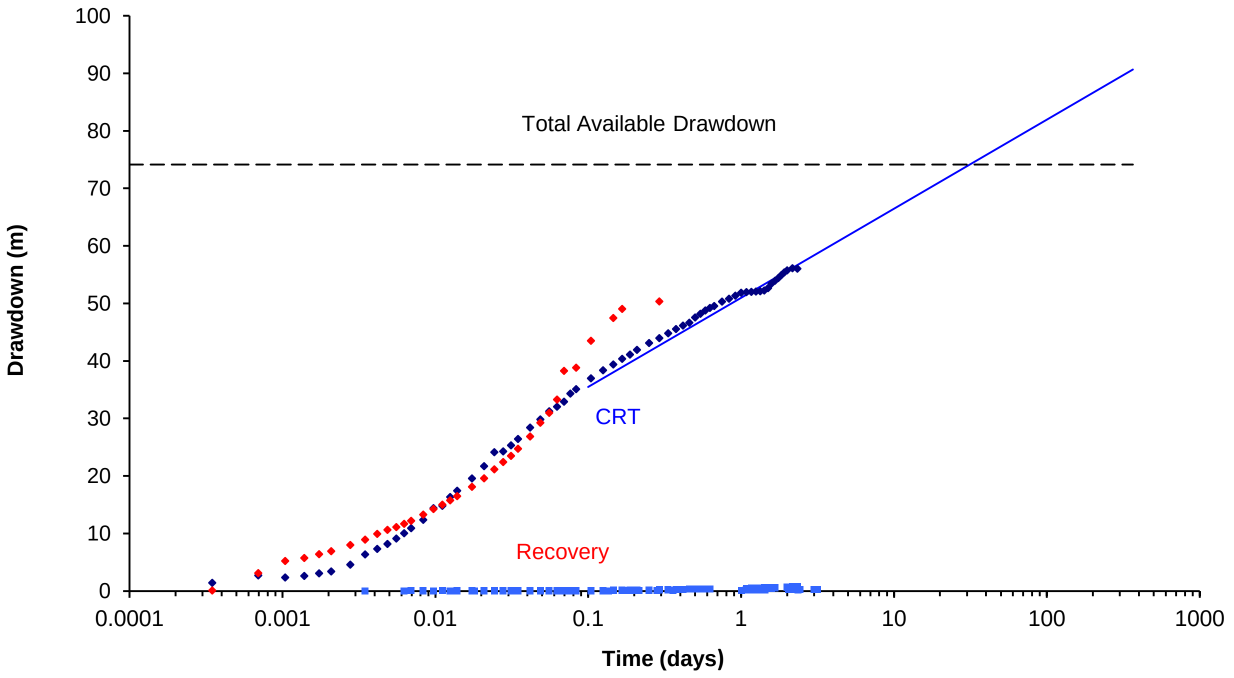
$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	130	10.85	2.79	80
2	173	14.47	4.95	74
3	259	21.71	11.14	66
4	346	28.94	19.81	59
5	518	43.41	44.58	49

CONSTANT RATE TEST

KEB1

DRAWDOWN PROJECTED TO 365 DAYS

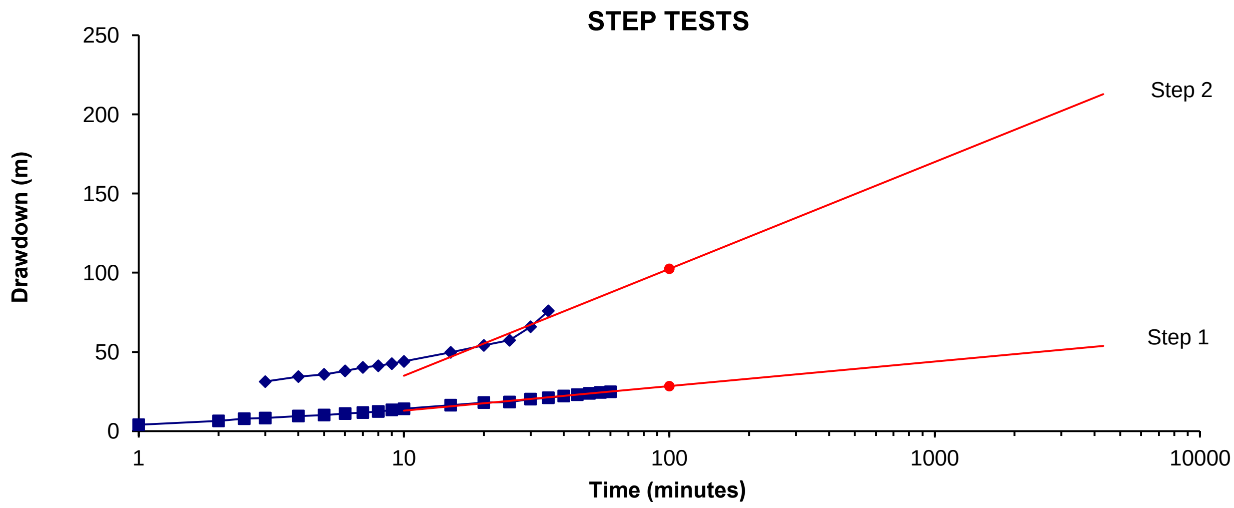


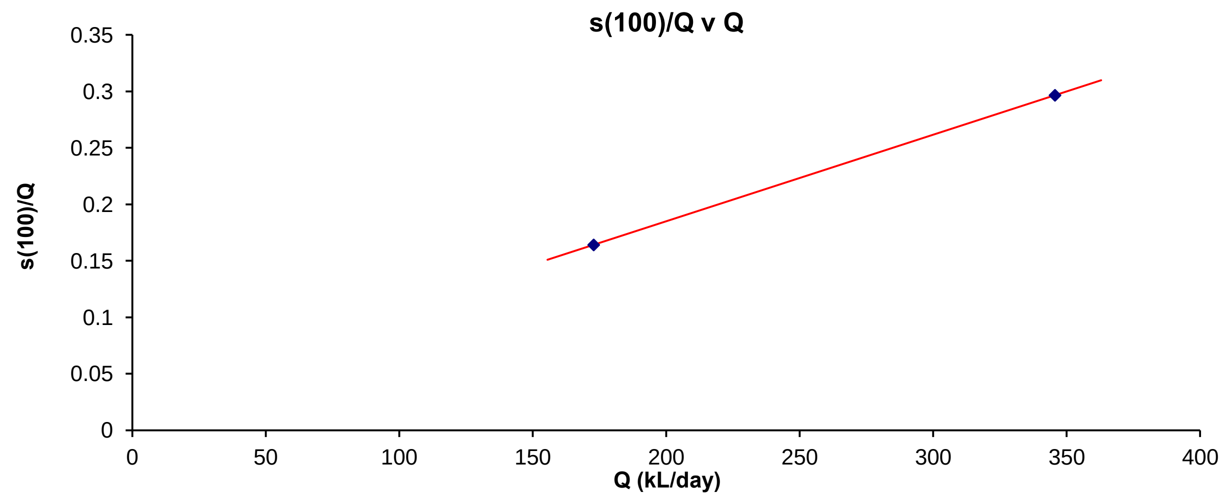
Date of Test	22-Apr-11	
SWL at start	25.9	mBTOC
Pump Setting	100.0	mBTOC
L = Length of Screen =	94	m
Available drawdown above pump setting	74.1	m
Max available drawdown in pump well	99.135	m

$T = 2.3Q/(4\pi\Delta(h_0\text{-}h))$

Q = Test Discharge =	259	kL/day
	3.00	L/s
$\Delta(h_0$-h) = Head change per log cycle =	15.50	m
T= Transmissivity =	3.1	m²/day
K = Hydraulic Conductivity = T/L =	**0.03**	**m/day**

STEP TEST ANALYSIS
KEB2





s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 3.16E-02

C = gradient = 7.67E-04

S = drawdown in the bore

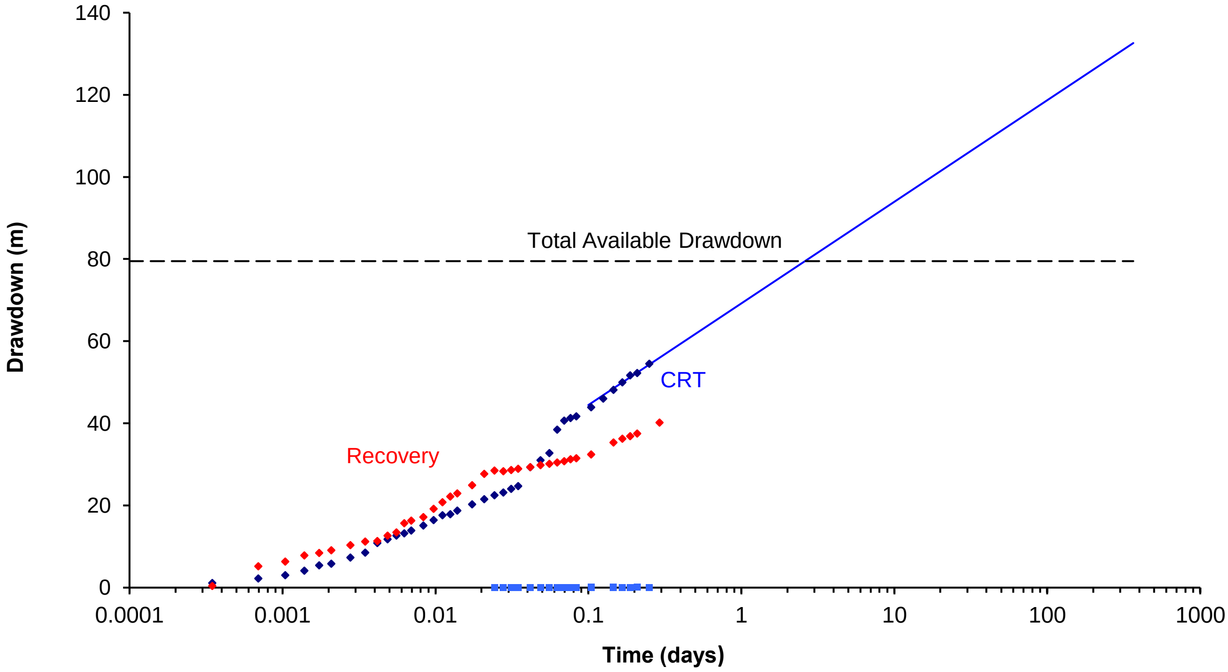
$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	173	5.46	22.89	19
2	346	10.91	91.56	11

CONSTANT RATE TEST

KEB2

DRAWDOWN PROJECTED TO 365 DAYS



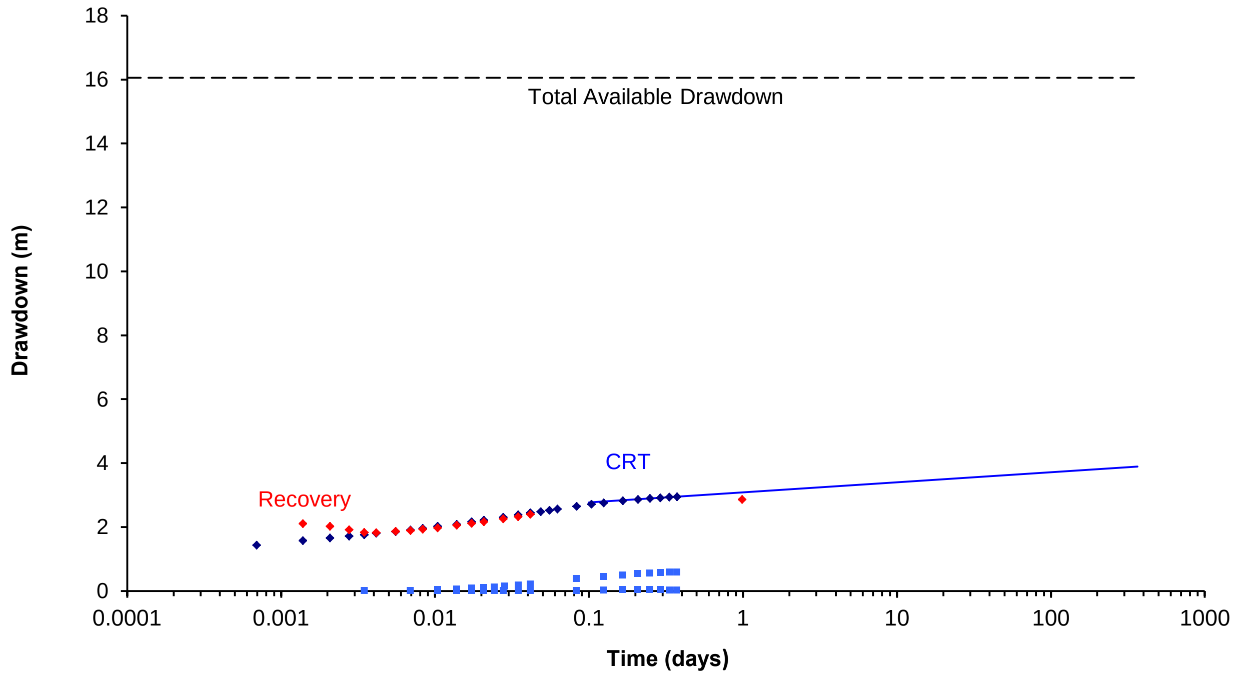
Date of Test	17-Apr-11	
SWL at start	20.5	mBTOC
Pump Setting	100.0	mBTOC
L = Length of Screen =	108	m
Available drawdown above pump setting	79.5	m
Max available drawdown in pump well	129.49	m

$T = 2.3Q/(4\pi\Delta(h^0 - h))$

Q = Test Discharge =	259	kL/day
	3.00	L/s
$\Delta(h^0 - h)$ = Head change per log cycle =	24.75	m
T= Transmissivity =	1.9	m²/day
K = Hydraulic Conductivity = T/L =	**0.02**	**m/day**

CONSTANT RATE TEST
CWB8S

DRAWDOWN PROJECTED TO 365 DAYS



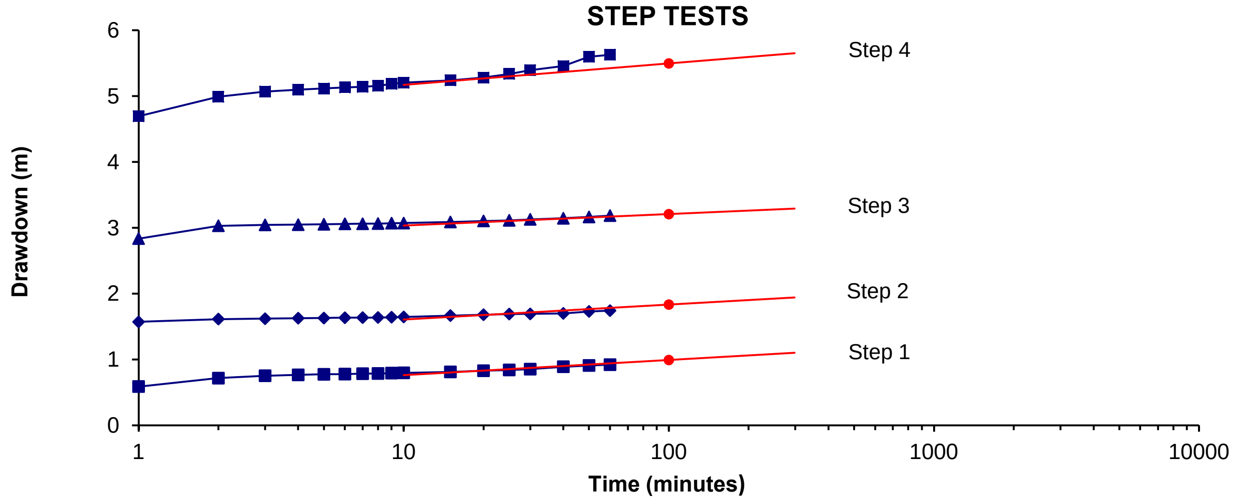
Date of Test	21-Apr-12	
SWL at start	19.1	mBTOC
Pump Setting	35.2	mBTOC
L = Length of Screen =	30	m

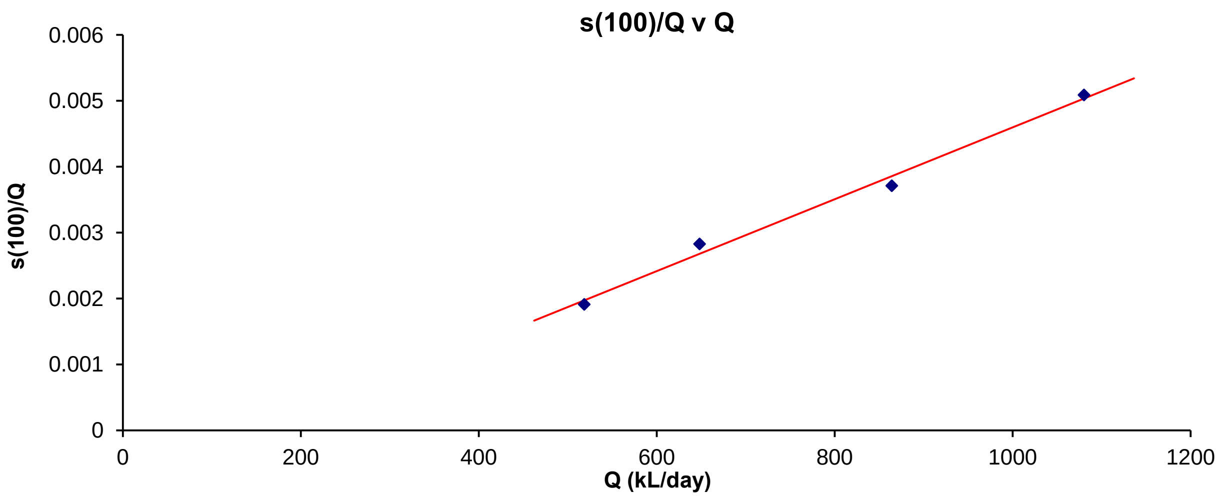
Available drawdown above pump setting	16.1	m
Max available drawdown in pump well	40.9	m

$T = 2.3Q/(4\pi\Delta(h_0\text{-}h))$

Q = Test Discharge =	36	kL/day
	0.42	L/s
$\Delta(h_0$-h) = Head change per log cycle =	0.32	m
T= Transmissivity =	20.9	m²/day
K = Hydraulic Conductivity = T/L =	**0.70**	**m/day**

STEP TEST ANALYSIS
CWB8d





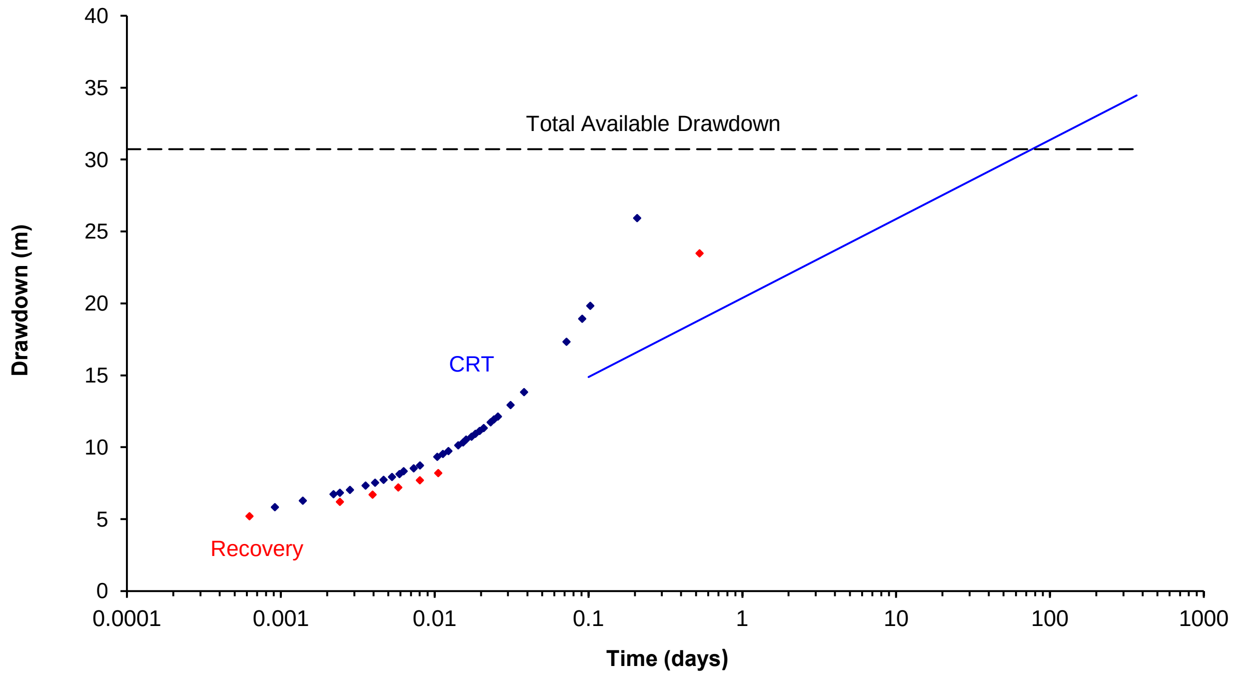
s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

CONSTANT RATE TEST

CWB8d

DRAWDOWN PROJECTED TO 365 DAYS



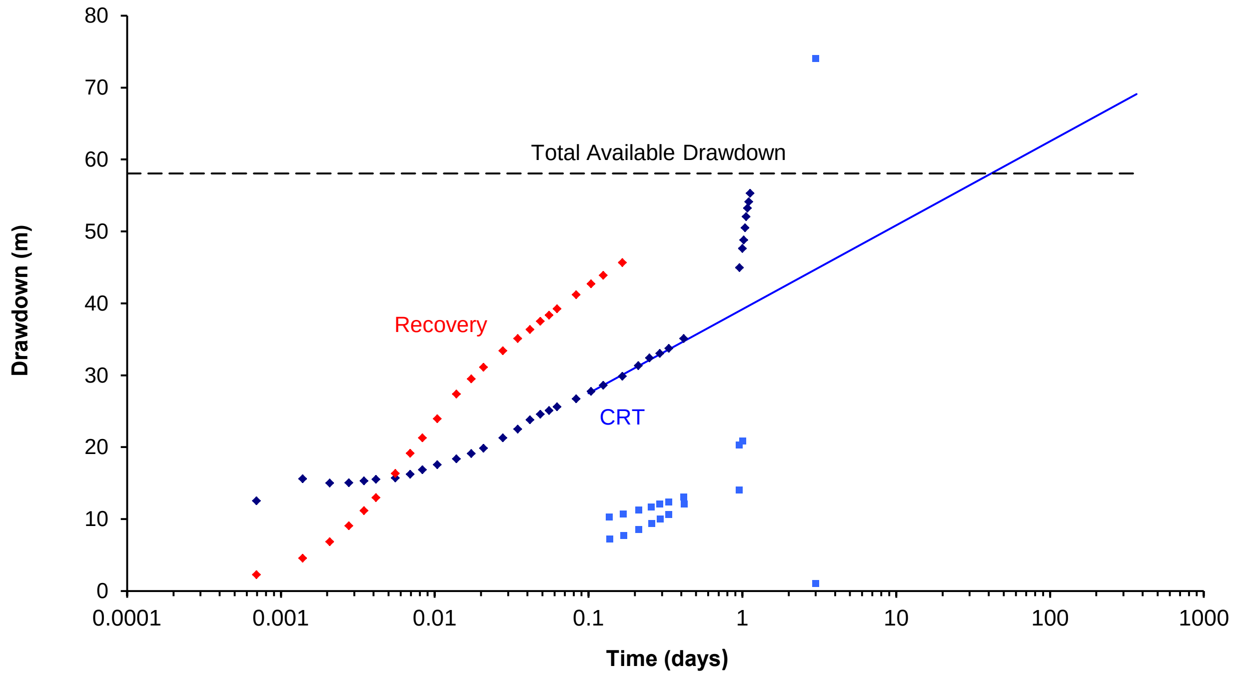
Date of Test	25-Jan-10	
SWL at start	19.3	mBTOC
Pump Setting	50.0	mBTOC
L = Length of Screen =	30	m
Available drawdown above pump setting	30.7	m
Max available drawdown in pump well	119.73	m

$T = 2.3Q/(4\pi\Delta(h_0\text{-}h))$

Q = Test Discharge =	389	kL/day
	4.50	L/s
$\Delta(h_0$-h) = Head change per log cycle =	5.50	m
T= Transmissivity =	12.9	m²/day
K = Hydraulic Conductivity = T/L =	**0.43**	**m/day**

CONSTANT RATE TEST
CWB12

DRAWDOWN PROJECTED TO 365 DAYS

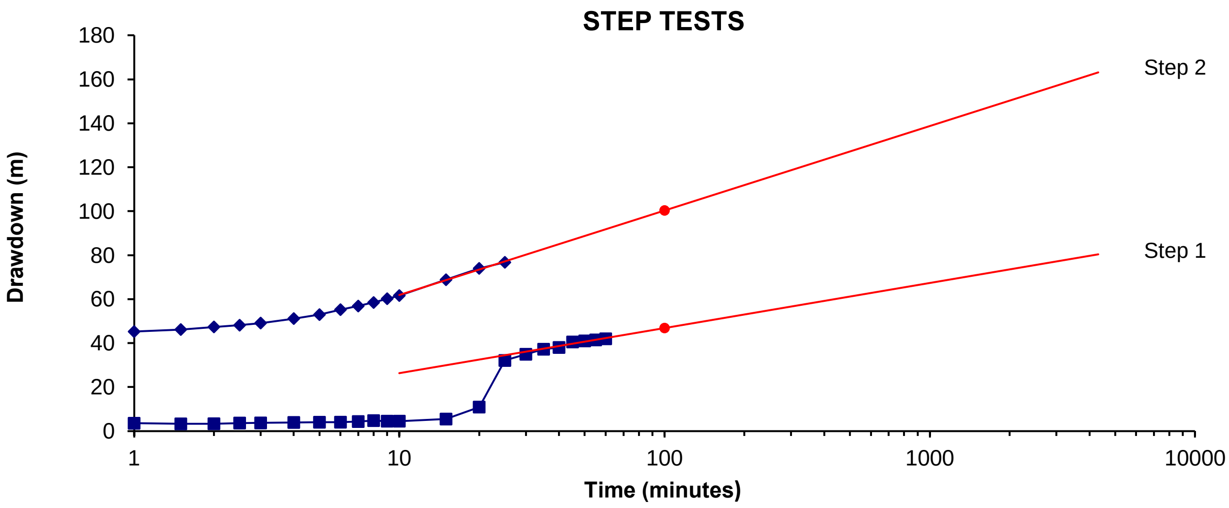


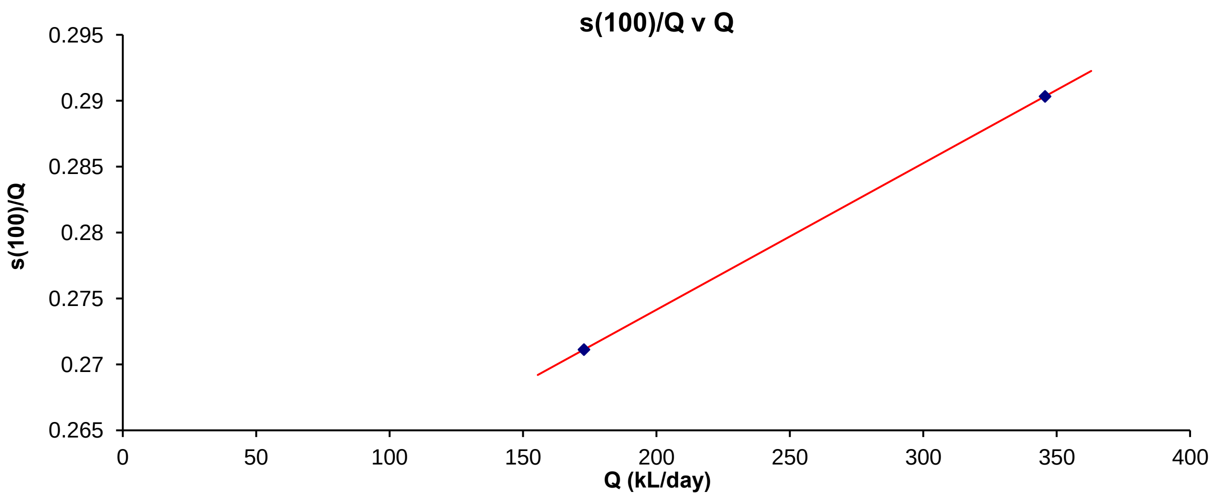
Date of Test	21-May-12	
SWL at start	19.9	mBTOC
Pump Setting	78.0	mBTOC
L = Length of Screen =	45	m
Available drawdown above pump setting	58.1	m
Max available drawdown in pump well	70.07	m

$T = 2.3Q/(4\pi\Delta(h_0-h))$

Q = Test Discharge =	112	kL/day
	1.30	L/s
$\Delta(h_0-h)$ = Head change per log cycle =	11.69	m
T= Transmissivity =	1.8	m²/day
K = Hydraulic Conductivity = T/L =	**0.04**	**m/day**

STEP TEST ANALYSIS
CWB13





s(100) = projected step drawdown at 100 minutes
Q = bore discharge measured in kL/day
Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$
B = y intercept = 2.52E-01
C = gradient = 1.11E-04
S = drawdown in the bore

$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	173	43.53	3.32	93
2	346	87.06	13.28	87

CONSTANT RATE TEST
CWB13

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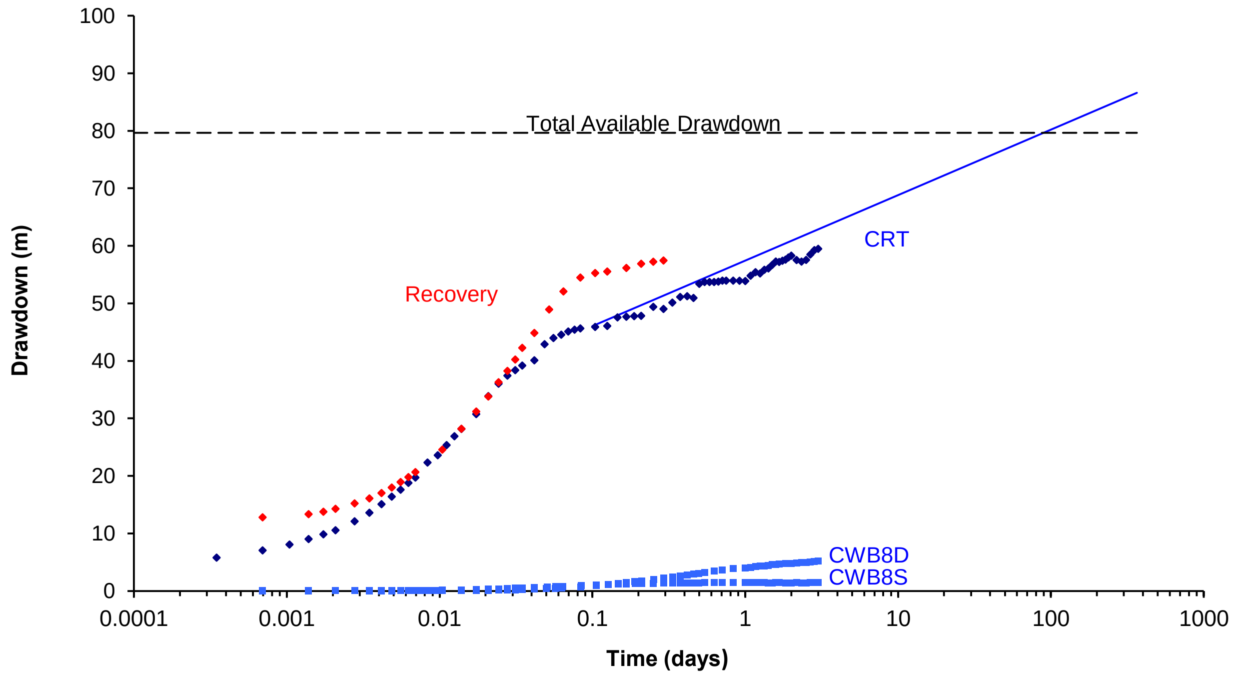
DRAWDOWN PROJECTED TO 365 DAYS



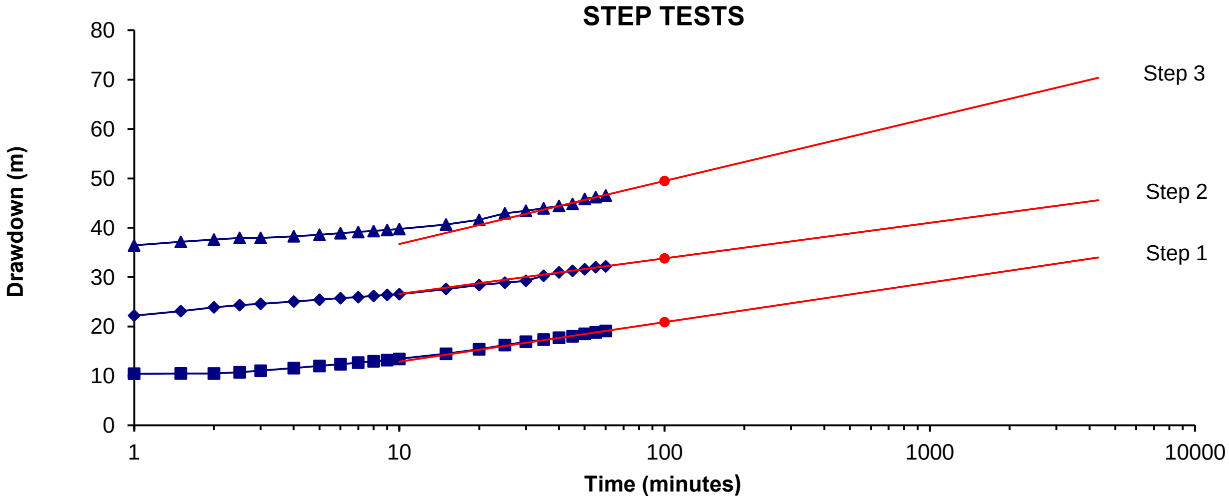
Date of Test	16-Apr-11	
SWL at start	19.4	mBTOC
Pump Setting	99.0	mBTOC
L = Length of Screen =	48	m

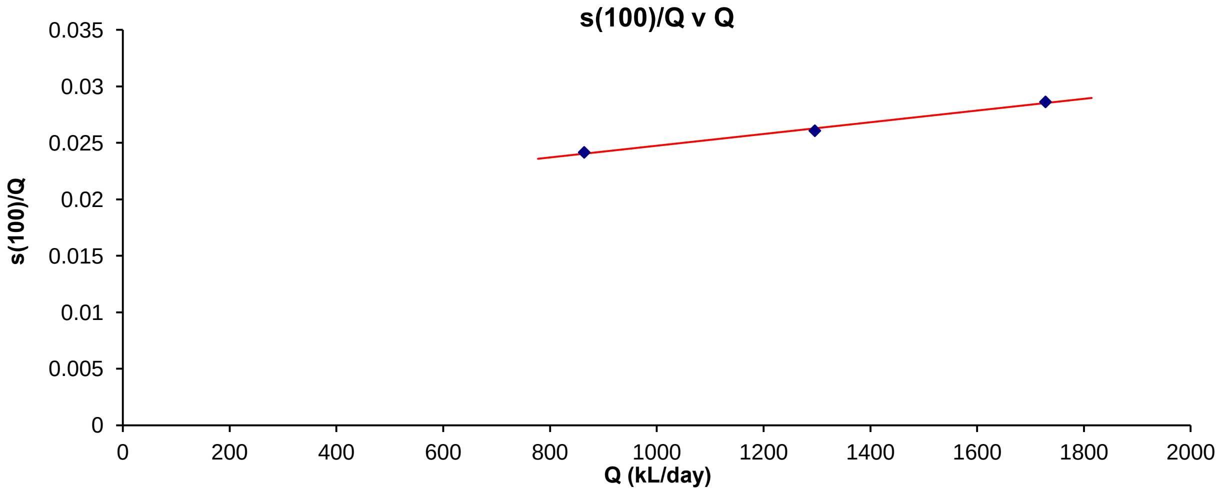
Available drawdown above pump setting	79.6	m
Max available drawdown in pump well	139.615	m

$T = 2.3Q/(4\pi\Delta(h_0 - h))$

Q = Test Discharge =	173	kL/day
	2.00	L/s
$\Delta(h_0 - h)$ = Head change per log cycle =	11.38	m
T= Transmissivity =	2.8	m²/day
K = Hydraulic Conductivity = T/L =	**0.06**	**m/day**

STEP TEST ANALYSIS
CWB14





s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 1.96E-02

C = gradient = 5.17E-06

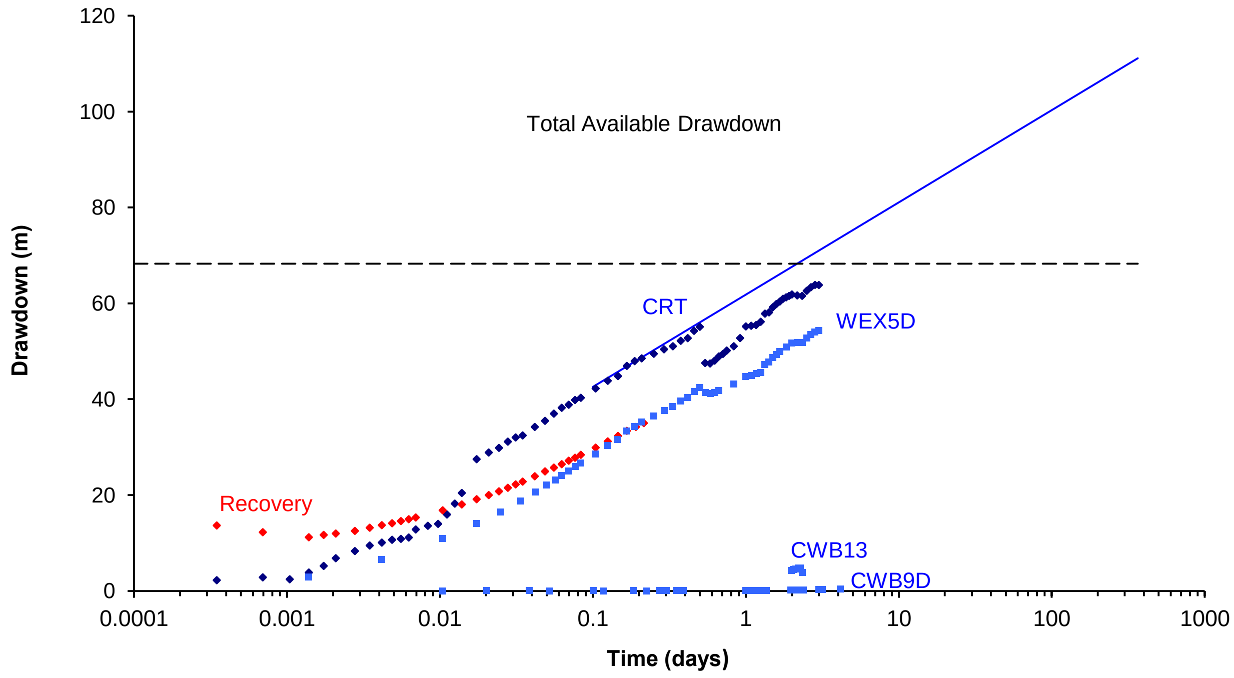
S = drawdown in the bore

$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	864	16.92	3.86	81
2	1296	25.38	8.69	74
3	1728	33.84	15.45	69

CONSTANT RATE TEST
CWB14

DRAWDOWN PROJECTED TO 365 DAYS



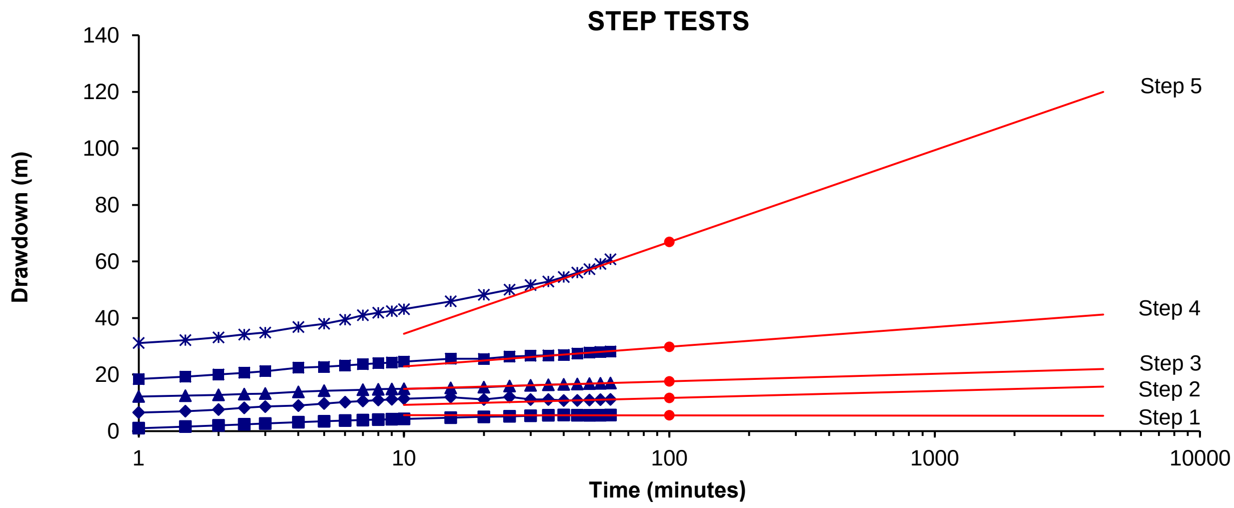
Date of Test	22-Apr-11	
SWL at start	31.8	mBTOC
Pump Setting	100.0	mBTOC
L = Length of Screen =	54	m
Available drawdown above pump setting	68.3	m
Max available drawdown in pump well	120.75	m

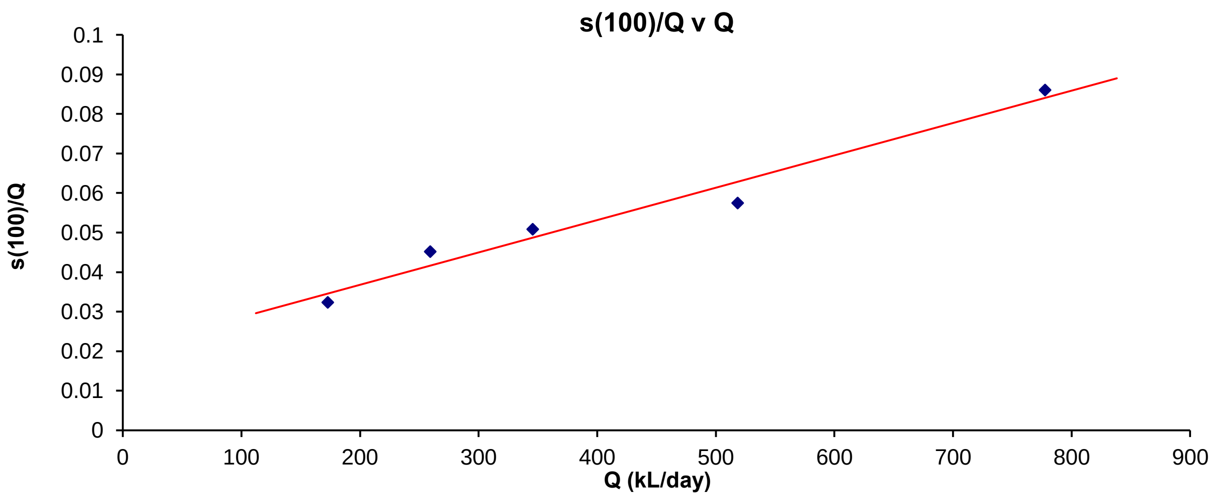
$T = 2.3Q/(4\pi\Delta(h_0 - h))$

Q = Test Discharge =	1469	kL/day
	17.00	L/s
$\Delta(h_0 - h)$ = Head change per log cycle =	19.25	m
T= Transmissivity =	14.0	m²/day
K = Hydraulic Conductivity = T/L =	**0.26**	**m/day**
Radius from pumping bore =	2135.04	m
t_0 =	4.28	minutes
S= Storativity= $(2.25Tt_0)/r^2$ =	**2.08E-08**	

STEP TEST ANALYSIS
CWB15

penningtonscott
securing your water future





s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 2.04E-02

C = gradient = 8.19E-05

S = drawdown in the bore

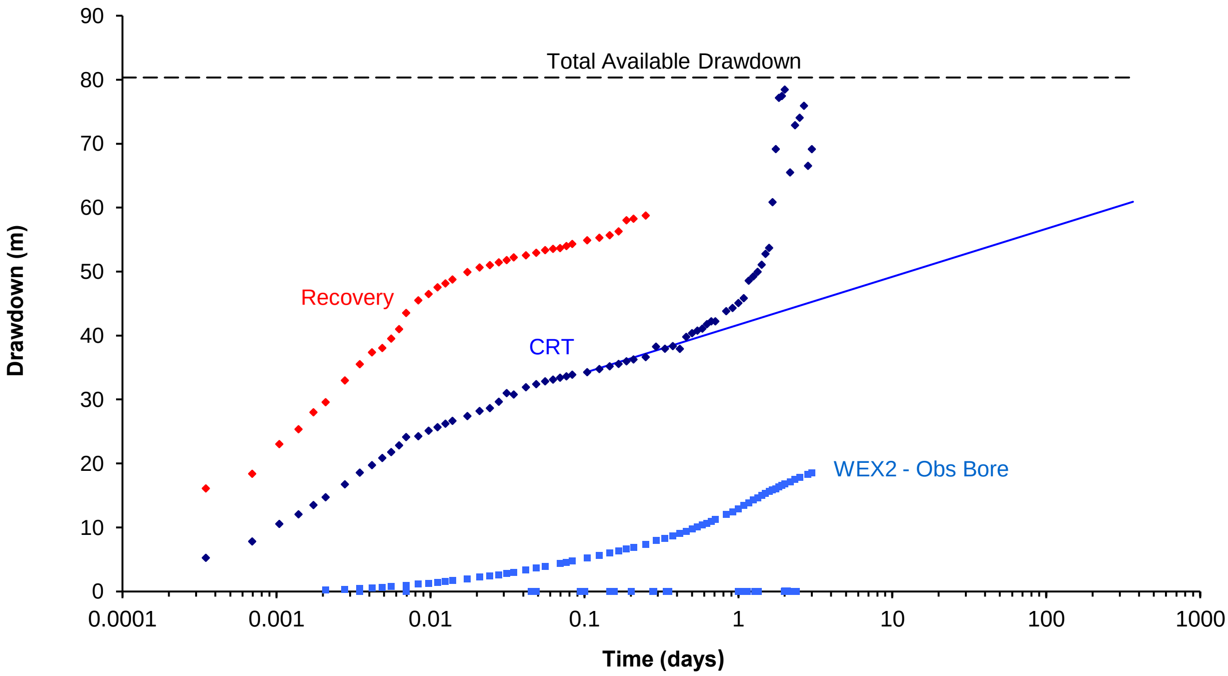
$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	173	3.53	2.44	59
2	259	5.29	5.50	49
3	346	7.06	9.78	42
4	518	10.59	22.00	32
5	778	15.88	49.50	24

CONSTANT RATE TEST
CWB15

pennington**scott**
securing your water future

DRAWDOWN PROJECTED TO 365 DAYS



Date of Test	27-Apr-11	
SWL at start	19.6	mBTOC
Pump Setting	100.0	mBTOC
L = Length of Screen =	78	m

Available drawdown above pump setting	80.4	m
Max available drawdown in pump well	110.36	m

$T = 2.3Q/(4\pi\Delta(h_0 - h))$

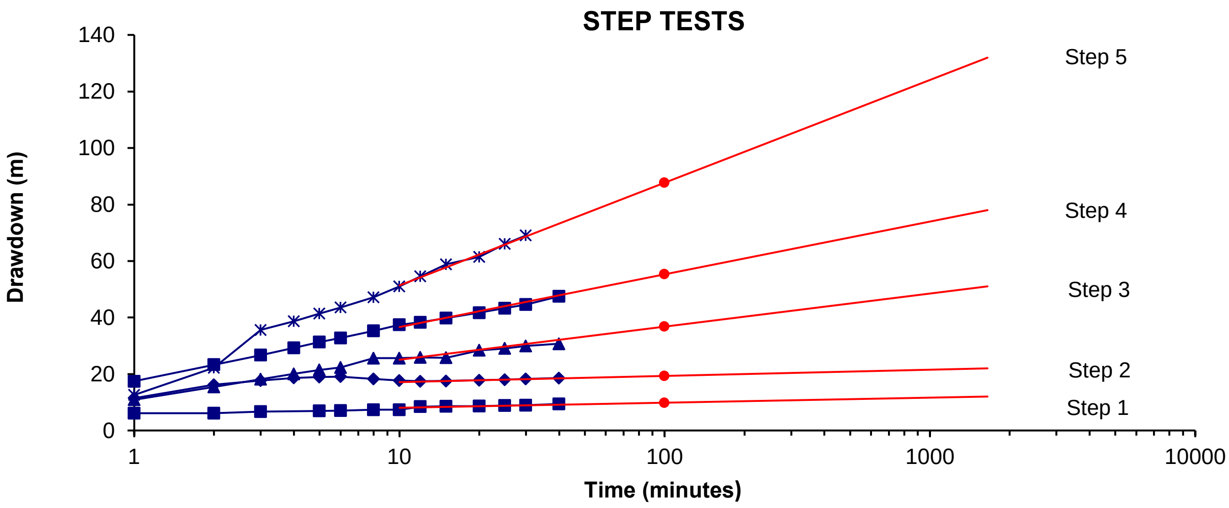
Q = Test Discharge =	518	kL/day
	6.00	L/s
$\Delta(h_0 - h)$ = Head change per log cycle =	7.50	m
T= Transmissivity =	12.7	m²/day

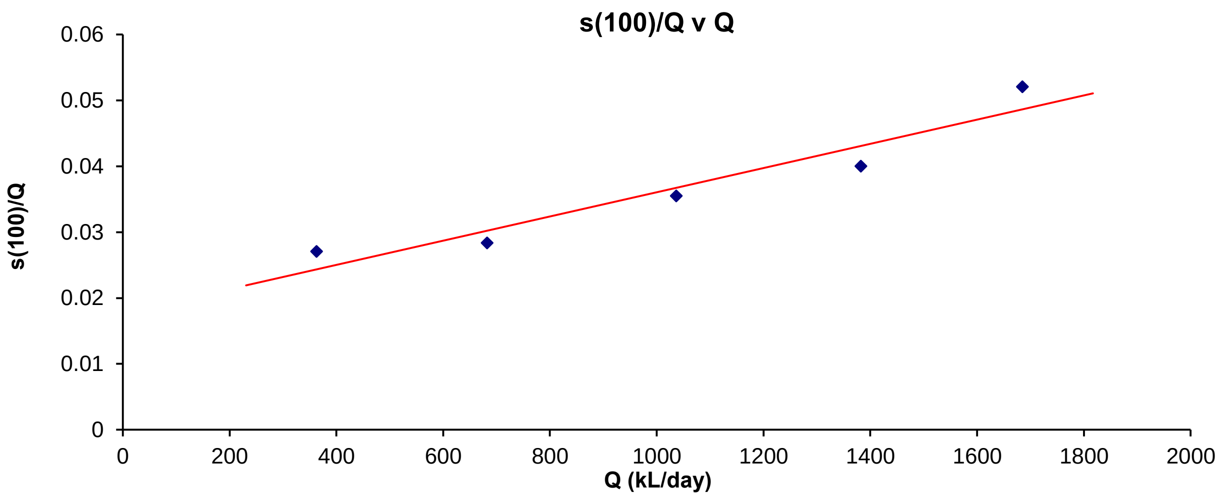
K = Hydraulic Conductivity = T/L = 0.16 m/day

STEP TEST ANALYSIS

CWB17

penningtonscott securing your water future





s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 1.77E-02

C = gradient = 1.84E-05

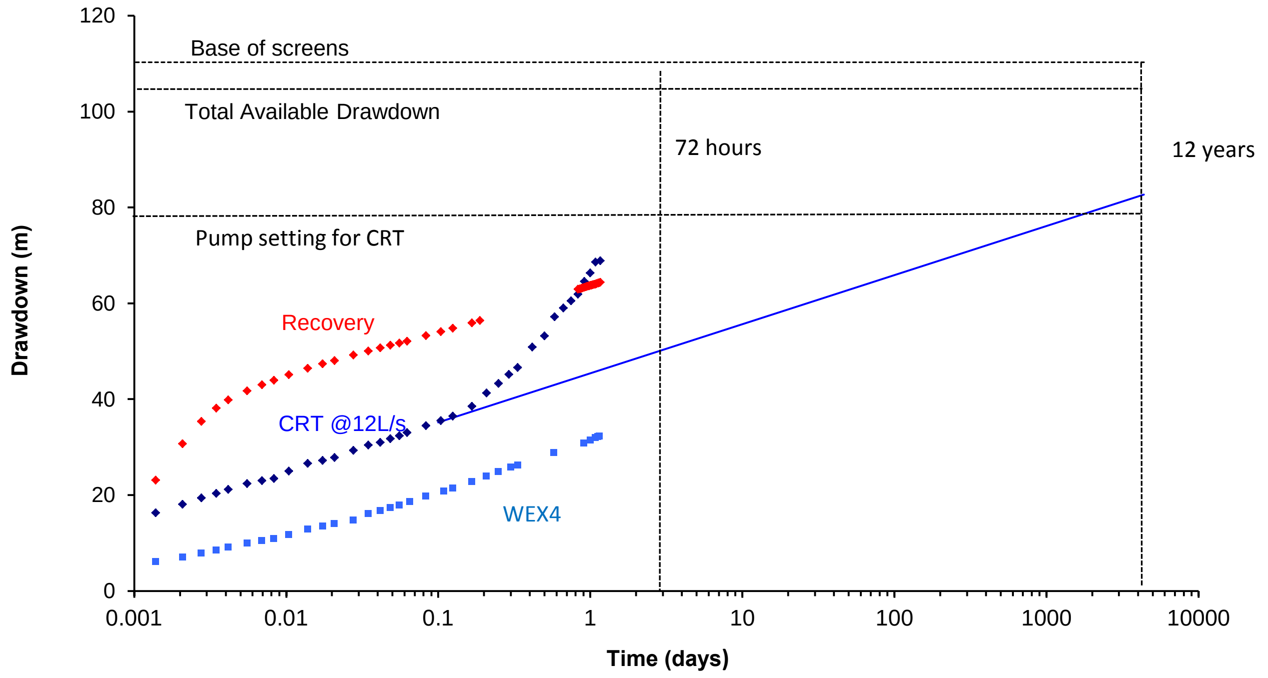
S = drawdown in the bore

$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	363	6.42	2.42	73
2	683	12.07	8.55	59
3	1037	18.34	19.74	48
4	1382	24.45	35.09	41
5	1685	29.80	52.12	36

CONSTANT RATE TEST
CWB17

DRAWDOWN PROJECTED TO 4380 DAYS

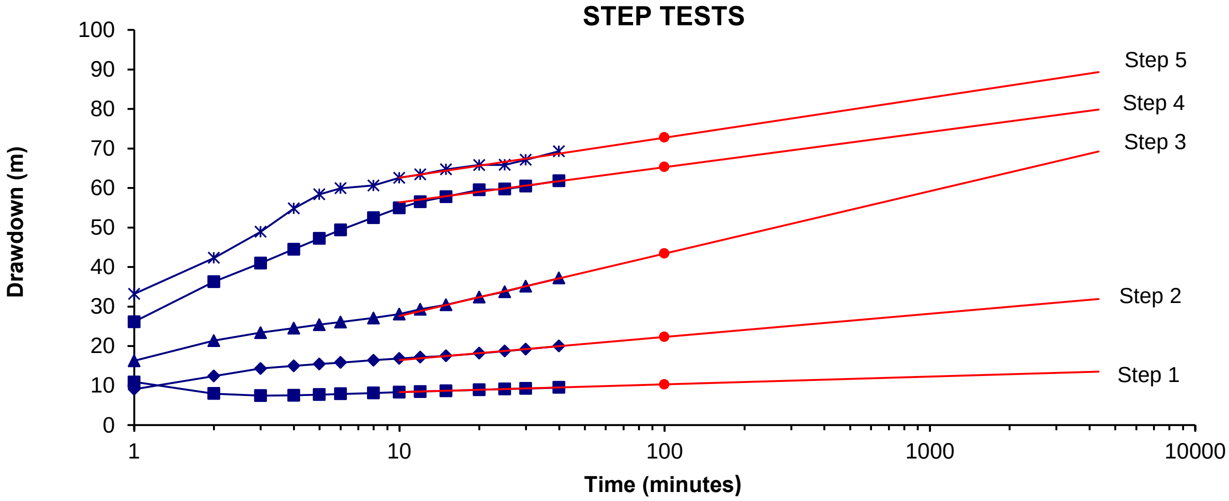


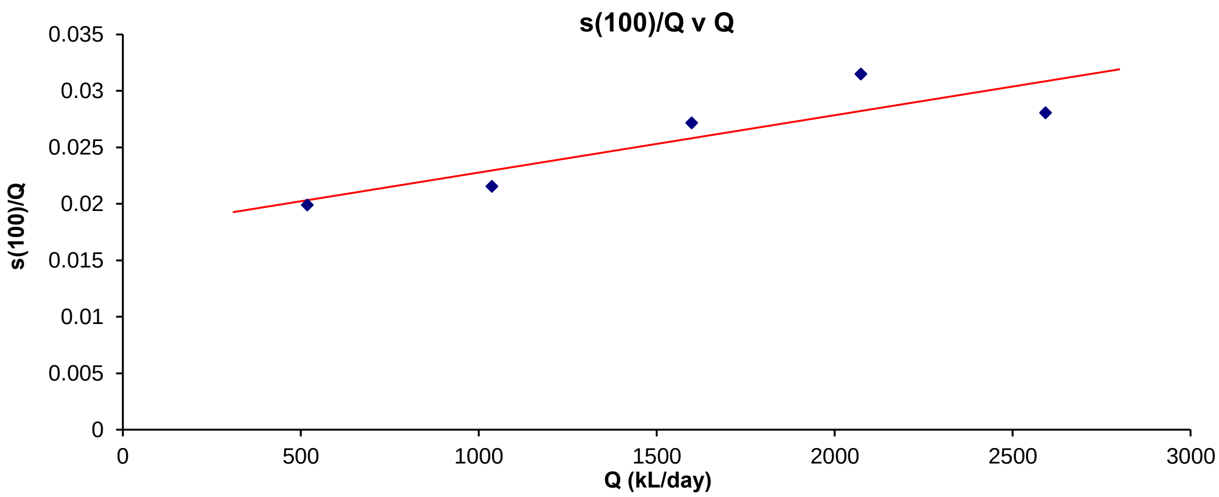
Date of Test	01-May-12	
SWL at start	13.7	mBTOC
Pump Setting	0.0	mBTOC
L = Length of Screen =	78	m
Available drawdown above pump setting		m
Max available drawdown in pump well	110.27	m

$T = 2.3Q/(4\pi\Delta(h_0\text{-}h))$

Q = Test Discharge =	1054	kL/day
	12.20	L/s
$\Delta(h_0\text{-}h)$ = Head change per log cycle =	10.25	m
T= Transmissivity =	18.8	m²/day
K = Hydraulic Conductivity = T/L =	**0.24**	**m/day**

STEP TEST ANALYSIS
CWB18





s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 1.77E-02

C = gradient = 5.09E-06

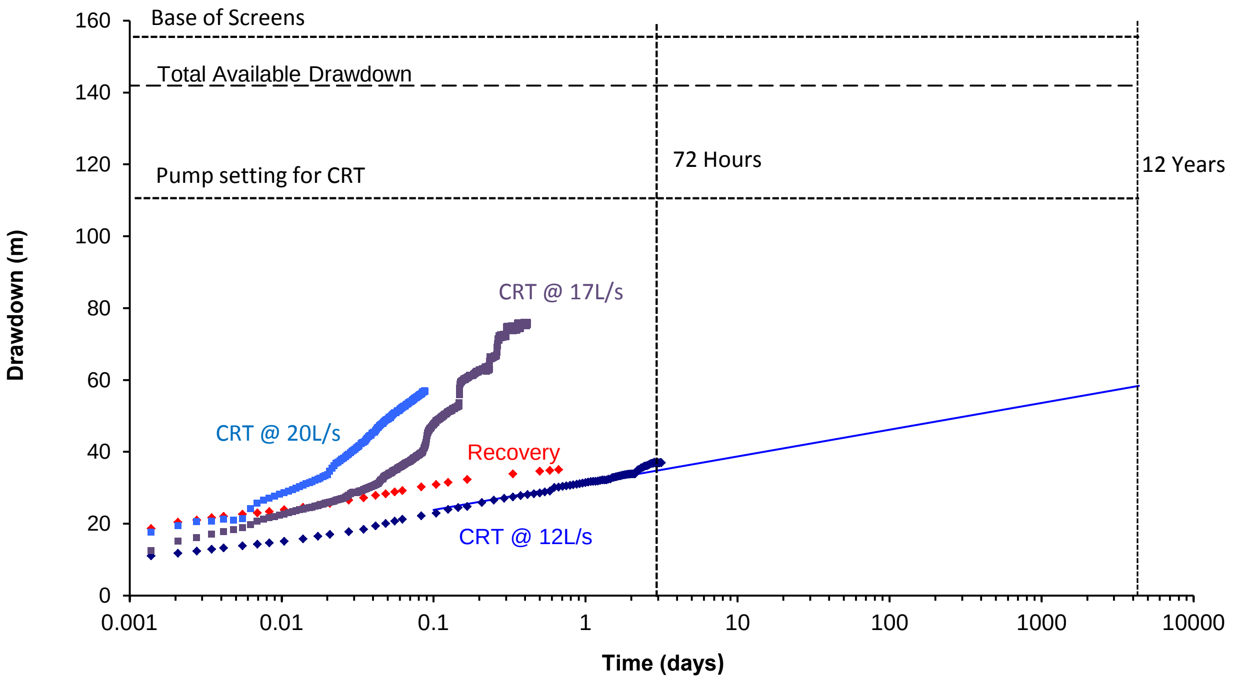
S = drawdown in the bore

$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	518	9.17	1.37	87
2	1037	18.33	5.47	77
3	1598	28.26	13.00	68
4	2074	36.67	21.87	63
5	2592	45.83	34.18	57

CONSTANT RATE TEST
CWB18

DRAWDOWN PROJECTED TO 4380 DAYS



Date of Test	07-May-12	
SWL at start	15.1	mBTOC
Pump Setting	157.0	mBTOC
L = Length of Screen =	126	m
Available drawdown above pump setting	141.9	m
Max available drawdown in pump well	142.38	m

$T = 2.3Q/(4\pi\Delta(h_0-h))$

Q = Test Discharge =	1037	kL/day
	12.00	L/s
$\Delta(h_0$-h) = Head change per log cycle =	7.45	m
T= Transmissivity =	25.5	m²/day
K = Hydraulic Conductivity = T/L =	**0.20**	**m/day**

STEP TEST ANALYSIS
CWB19

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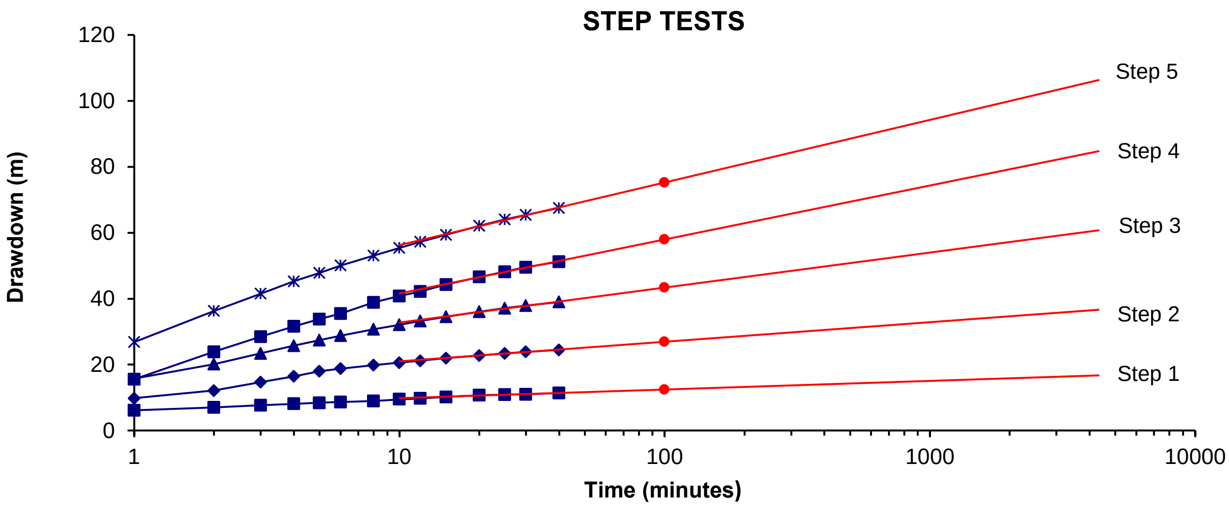
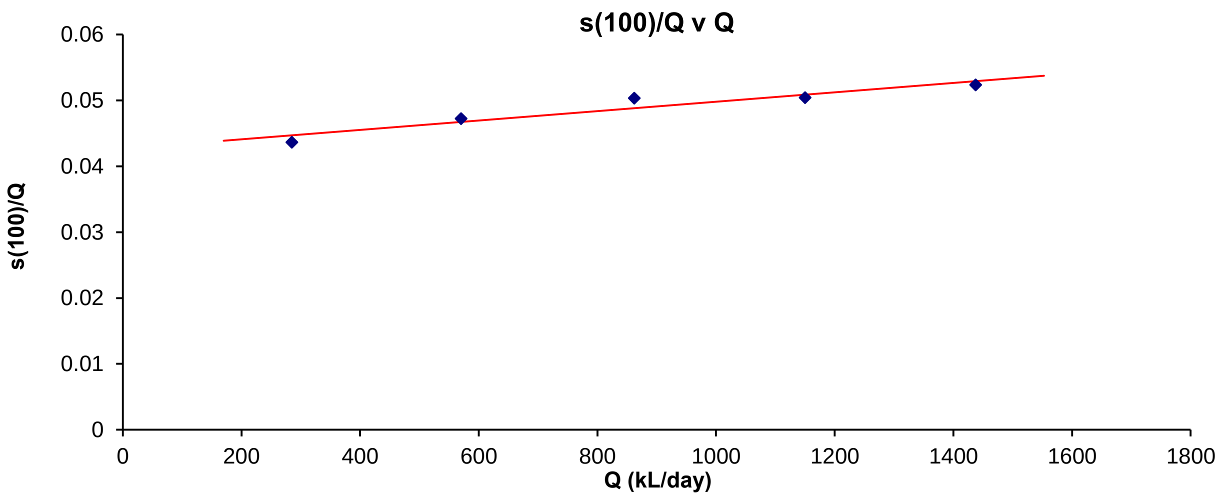




s(100) = projected step drawdown at 100 minutes

Q = bore discharge measured in kL/day

Ew = apparent well efficiency

Calculation of well efficiency using Rorabaugh's Equation

$S = BQ + CQ^2$

B = y intercept = 4.27E-02

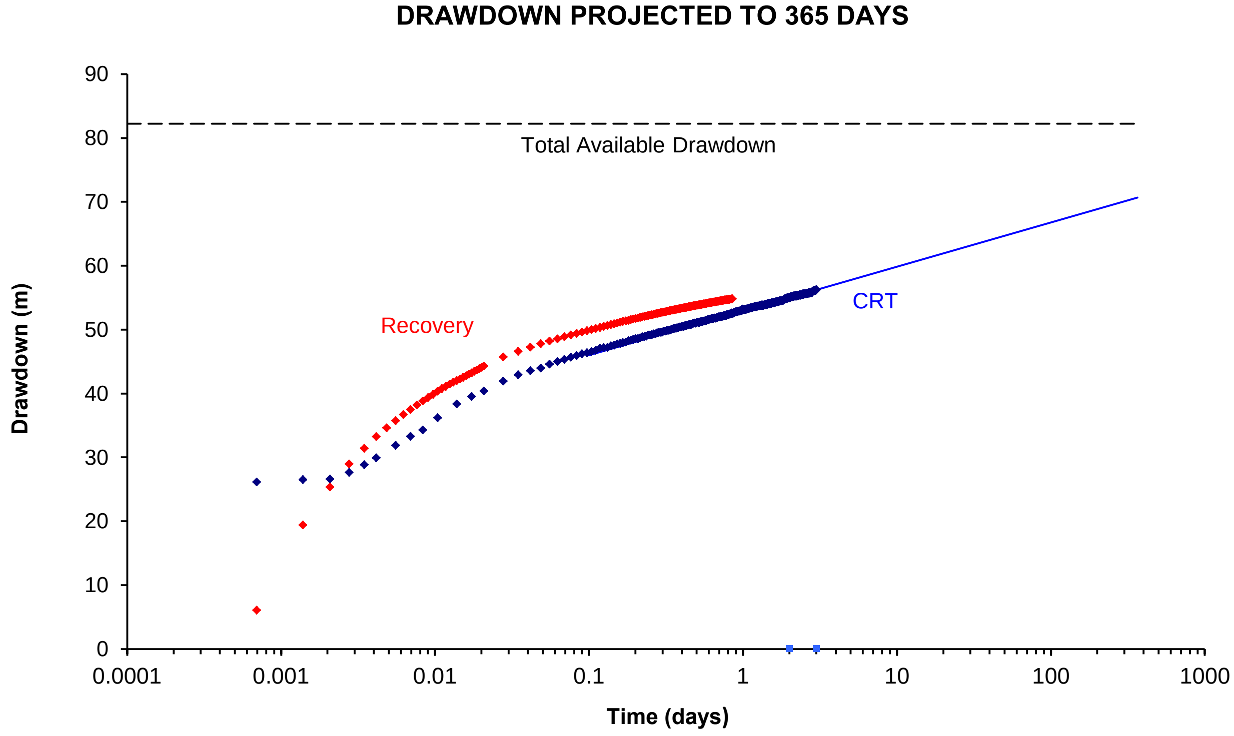
C = gradient = 7.12E-06

S = drawdown in the bore

$Ew = BQ / (BQ + CQ^2) \times 100$

Step	Q (kL/day)	BQ	CQ^2	Ew (%)
1	285	12.16	0.58	95
2	570	24.32	2.32	91
3	862	36.78	5.30	87
4	1150	49.05	9.42	84
5	1438	61.33	14.73	81

CONSTANT RATE TEST
CWB19



Date of Test	14-May-12	
SWL at start	14.8	mBTOC
Pump Setting	97.0	mBTOC
L = Length of Screen =	118	m

Available drawdown above pump setting	82.2	m
Max available drawdown in pump well	131.24	m

$T = 2.3Q/(4\pi\Delta(h_0\text{-}h))$

Q = Test Discharge =	950	kL/day
	11.00	L/s
$\Delta(h_0\text{-}h)$ = Head change per log cycle =	6.94	m
T= Transmissivity =	25.1	m²/day
K = Hydraulic Conductivity = T/L =	**0.21**	**m/day**

Appendix D

April 2012 Laboratory Parameter Analyses

Australian Government
National Measurement Institute

REPORT OF ANALYSIS

Report No. RN921000

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120608
		Quote No.	: QT-01780
		Order No.	:
		Date Sampled	: 4-MAY-2012
		Date Received	: 8-JUN-2012
Attention	: ISAAC ORR	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8400

Lab Reg No.	Sample Ref	Sample Description
W12/008464	CWB 17	WATER 04/05/12
W12/008465	CWB 18	WATER 10/05/12
W12/008466	CWB 12	WATER 23/05/12
W12/008467	CWB 19	WATER 18/05/12

Lab Reg No.		W12/008464	W12/008465	W12/008466	W12/008467	
Sample Reference	Units	CWB 17	CWB 18	CWB 12	CWB 19	Method
Inorganics						
Alkalinity as CaCO3	mg/L	230	150	300	190	WL122
Ammonia as NH3-N	mg/L	< 1	< 1	< 1	< 1	WL132
Bicarbonate as CaCO3	mg/L	230	150	300	190	WL122
Calcium - Filterable	mg/L	20	18	130	30	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	240	140	1200	330	WL119
Conductivity at 25C	uS/cm	1540	980	5430	1860	WL121
Fluoride	mg/L	1.3	0.48	0.56	0.60	WL218
Hardness as CaCO3 (Calc)	mg/L	140	110	1100	220	WL125CALC
Ion Balance		1.04	1.03	1.03	1.01	CALC
Magnesium - Filterable	mg/L	23	17	200	35	WL125
Nitrate as NO3	mg/L	8	8	< 1	8	WL119
ortho-Phosphate as PO4-P	mg/L	0.1	0.1	0.1	< 0.1	WL195
pH		7.6	7.5	7.5	7.4	WL120
Potassium - Filterable	mg/L	30	23	49	25	WL125
Sodium - Filterable	mg/L	260	140	750	260	WL125
Sulfate	mg/L	140	80	760	140	WL119
Total Dissolved Solids (Evap)	mg/L	890	530	3340	950	WL123
Trace Elements						
Aluminium - Total	mg/L	0.023	< 0.005	0.20	0.006	WL272
Arsenic - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Barium - Total	mg/L	0.016	0.006	0.025	0.013	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Chromium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Iron - Total	mg/L	0.014	< 0.005	0.27	0.011	WL272
Manganese - Total	mg/L	< 0.001	0.016	0.25	0.001	WL272
Mercury - Total	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005	WL41
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272

REPORT OF ANALYSIS

Report No. RN921000

Lab Reg No.		W12/008464	W12/008465	W12/008466	W12/008467	
Sample Reference	Units	CWB 17	CWB 18	CWB 12	CWB 19	Method
Trace Elements						
Uranium - Total	mg/L	0.003	<0.002	0.006	0.006	WL272
Zinc - Total	mg/L	0.007	0.013	0.063	0.082	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-JUN-2012

Unless notified to the contrary, the above samples will be disposed of one month from the reporting date.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Accreditated for compliance with ISO/IEC 17025.
This report shall not be reproduced except in full.
Results relate only to the sample(s) tested.

Australian Government

National Measurement Institute

NATA

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT	Job No.	: PENN07_W/120507
	Level 12, 3 Hasler Road	Quote No.	: QT-01898
	HERDSMAN WA 6017	Order No.	:
		Date Sampled	: 24-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name :			
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006711	OB16	WATER 24/04/12
W12/006712	CWB2D	WATER 28/04/12
W12/006713	CWB2S	WATER 28/04/12
W12/006714	CWB3D	WATER 30/04/12

Lab Reg No.		W12/006711	W12/006712	W12/006713	W12/006714	
Sample Reference	Units	OB16	CWB2D	CWB2S	CWB3D	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	91	670	560	650	WL122
Calcium - Filterable	mg/L	22	8	110	39	WL125
Carbonate as CaCO3	mg/L	< 1	7	< 1	< 1	WL122
Chloride	mg/L	140	560	2300	220	WL119
Conductivity at 25C	uS/cm	800	3510	10200	1880	WL121
Fluoride	mg/L	0.26	1.4	0.62	1.3	WL218
Ion Balance		0.94	0.95	1.00	0.93	CALC
Magnesium - Filterable	mg/L	18	31	200	60	WL125
Nitrate as NO3	mg/L	11	< 1	< 1	1	WL119
pH		6.6	8.3	7.4	7.4	WL120
Potassium - Filterable	mg/L	15	28	55	30	WL125
Sodium - Filterable	mg/L	90	720	2030	270	WL125
Sulfate	mg/L	65	360	1700	77	WL119
Trace Elements						
Aluminium - Total	mg/L	0.015	0.18	0.17	17	WL272
Barium - Total	mg/L	0.065	0.084	0.040	0.45	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.20	0.96	1.8	0.60	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	< 0.005	< 0.005	0.022	WL272
Copper - Total	mg/L	< 0.005	< 0.005	< 0.005	0.058	WL272
Iron - Total	mg/L	0.087	0.26	1.1	29	WL272
Lead - Total	mg/L	< 0.001	< 0.001	< 0.001	0.024	WL272
Manganese - Total	mg/L	0.014	0.17	0.40	2.0	WL272
Molybdenum - Total	mg/L	< 0.005	0.015	< 0.005	< 0.005	WL272
Nickel - Total	mg/L	< 0.005	< 0.005	< 0.005	0.023	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006711	W12/006712	W12/006713	W12/006714	
Sample Reference	Units	OB16	CWB2D	CWB2S	CWB3D	Method
Trace Elements						
Tin - Total	mg/L	<0.010	<0.010	<0.010	<0.010	WL272
Zinc - Total	mg/L	0.012	0.010	0.008	0.091	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 30-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006715	CWB3S	WATER 30/04/12
W12/006716	CWB5D	WATER 27/04/12
W12/006717	CWB5S	WATER 27/04/12
W12/006718	CWB6D	WATER 27/04/12

Lab Reg No.		W12/006715	W12/006716	W12/006717	W12/006718	
Sample Reference	Units	CWB3S	CWB5D	CWB5S	CWB6D	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	540	1400	370	180	WL122
Calcium - Filterable	mg/L	14	24	520	19	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	90	1400	6000	210	WL119
Conductivity at 25C	uS/cm	1230	6720	23900	1300	WL121
Fluoride	mg/L	1.0	0.62	< 0.20	0.34	WL218
Ion Balance		0.93	0.98	1.02	0.98	CALC
Magnesium - Filterable	mg/L	21	160	1100	17	WL125
Nitrate as NO3	mg/L	2	< 1	< 1	< 1	WL119
pH		7.6	8.0	7.2	7.6	WL120
Potassium - Filterable	mg/L	15	40	78	12	WL125
Sodium - Filterable	mg/L	230	1300	4200	210	WL125
Sulfate	mg/L	21	190	5500	120	WL119
Trace Elements						
Aluminium - Total	mg/L	7.1	0.16	6.1	0.030	WL272
Barium - Total	mg/L	0.18	0.38	0.22	0.12	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.48	1.3	3.5	0.55	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	0.008	< 0.005	0.008	< 0.005	WL272
Copper - Total	mg/L	0.009	< 0.005	0.010	< 0.005	WL272
Iron - Total	mg/L	13	0.38	13	0.054	WL272
Lead - Total	mg/L	0.005	< 0.001	0.009	< 0.001	WL272
Manganese - Total	mg/L	0.62	0.37	5.5	0.48	WL272
Molybdenum - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Nickel - Total	mg/L	0.013	< 0.005	0.016	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006715	W12/006716	W12/006717	W12/006718	
Sample Reference	Units	CWB3S	CWB5D	CWB5S	CWB6D	Method
Trace Elements						
Tin - Total	mg/L	<0.010	<0.010	<0.010	<0.010	WL272
Zinc - Total	mg/L	0.080	0.008	0.049	<0.005	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 27-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006719	CWB6S	WATER 27/04/12
W12/006720	CWB7D	WATER 30/04/12
W12/006721	CWB7S	WATER 30/04/12
W12/006722	CWB9D	WATER 22/04/12

Lab Reg No.		W12/006719	W12/006720	W12/006721	W12/006722	
Sample Reference	Units	CWB6S	CWB7D	CWB7S	CWB9D	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	280	380	310	740	WL122
Calcium - Filterable	mg/L	42	110	140	79	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	530	1500	1200	2200	WL119
Conductivity at 25C	uS/cm	2780	6760	5260	10000	WL121
Fluoride	mg/L	0.65	0.85	0.63	2.2	WL218
Ion Balance		0.99	0.98	0.98	1.01	CALC
Magnesium - Filterable	mg/L	62	160	200	210	WL125
Nitrate as NO3	mg/L	< 1	< 1	< 1	16	WL119
pH		7.7	7.7	7.4	7.3	WL120
Potassium - Filterable	mg/L	16	49	44	130	WL125
Sodium - Filterable	mg/L	440	1100	700	1900	WL125
Sulfate	mg/L	310	910	770	1400	WL119
Trace Elements						
Aluminium - Total	mg/L	0.008	0.096	0.046	< 0.005	WL272
Barium - Total	mg/L	0.042	0.081	0.022	0.020	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.81	1.4	1.2	2.9	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	0.019	< 0.005	< 0.005	WL272
Copper - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Iron - Total	mg/L	0.012	0.56	0.022	< 0.005	WL272
Lead - Total	mg/L	< 0.001	0.006	< 0.001	< 0.001	WL272
Manganese - Total	mg/L	0.23	0.70	0.16	< 0.001	WL272
Molybdenum - Total	mg/L	< 0.005	0.006	< 0.005	0.010	WL272
Nickel - Total	mg/L	< 0.005	0.015	< 0.005	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006719	W12/006720	W12/006721	W12/006722	
Sample Reference	Units	CWB6S	CWB7D	CWB7S	CWB9D	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	WL272
Zinc - Total	mg/L	< 0.005	0.092	< 0.005	< 0.005	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 22-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006723	CWB9S	WATER 22/04/12
W12/006724	CWB10d	WATER 23/04/12
W12/006725	CWB11D	WATER 23/04/12
W12/006726	CWB11S	WATER 23/04/12

Lab Reg No.		W12/006723	W12/006724	W12/006725	W12/006726	
Sample Reference	Units	CWB9S	CWB10d	CWB11D	CWB11S	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	520	610	220	450	WL122
Calcium - Filterable	mg/L	160	110	22	150	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	4900	1100	360	4600	WL119
Conductivity at 25C	uS/cm	17200	4950	1940	15800	WL121
Fluoride	mg/L	2.1	1.3	0.56	1.7	WL218
Ion Balance		0.95	0.93	0.98	0.97	CALC
Magnesium - Filterable	mg/L	490	170	22	300	WL125
Nitrate as NO3	mg/L	5	4	< 1	4	WL119
pH		7.4	7.4	7.8	7.5	WL120
Potassium - Filterable	mg/L	290	78	19	140	WL125
Sodium - Filterable	mg/L	3100	650	340	3000	WL125
Sulfate	mg/L	2600	490	190	1600	WL119
Trace Elements						
Aluminium - Total	mg/L	36	0.097	0.12	6.0	WL272
Barium - Total	mg/L	0.42	0.16	0.15	0.068	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	3.3	1.3	0.61	1.7	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	0.079	0.012	< 0.005	< 0.005	WL272
Copper - Total	mg/L	0.048	< 0.005	< 0.005	0.011	WL272
Iron - Total	mg/L	55	0.76	0.64	7.3	WL272
Lead - Total	mg/L	0.045	< 0.001	< 0.001	0.004	WL272
Manganese - Total	mg/L	3.3	2.0	1.1	0.74	WL272
Molybdenum - Total	mg/L	0.007	< 0.005	< 0.005	< 0.005	WL272
Nickel - Total	mg/L	0.096	0.011	0.014	0.015	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006723	W12/006724	W12/006725	W12/006726	
Sample Reference	Units	CWB9S	CWB10d	CWB11D	CWB11S	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	WL272
Zinc - Total	mg/L	0.42	0.012	0.039	0.042	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 24-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006727	CWB15	WATER 24/04/12
W12/006728	WEX5D	WATER 22/04/12
W12/006729	KWP1	WATER 25/04/12
W12/006730	1PD	WATER 25/04/12

Lab Reg No.		W12/006727	W12/006728	W12/006729	W12/006730	
Sample Reference	Units	CWB15	WEX5D	KWP1	1PD	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	200	590	470	< 1	WL122
Calcium - Filterable	mg/L	24	34	110	1	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	110	WL122
Chloride	mg/L	160	710	2100	410	WL119
Conductivity at 25C	uS/cm	1020	3700	8250	1920	WL121
Fluoride	mg/L	0.51	2.6	2.1	0.35	WL218
Ion Balance		0.90	0.93	0.93	0.93	CALC
Magnesium - Filterable	mg/L	21	53	190	< 1	WL125
Nitrate as NO3	mg/L	8	3	7	< 1	WL119
pH		7.9	7.7	7.4	10.9	WL120
Potassium - Filterable	mg/L	24	37	81	35	WL125
Sodium - Filterable	mg/L	130	690	1400	340	WL125
Sulfate	mg/L	74	370	1100	150	WL119
Trace Elements						
Aluminium - Total	mg/L	0.013	0.008	0.016	0.46	WL272
Barium - Total	mg/L	0.065	0.028	0.049	0.047	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.41	1.6	1.7	0.41	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Copper - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Iron - Total	mg/L	0.021	0.018	29	0.68	WL272
Lead - Total	mg/L	< 0.001	< 0.001	< 0.001	0.017	WL272
Manganese - Total	mg/L	0.042	0.16	0.22	0.016	WL272
Molybdenum - Total	mg/L	< 0.005	0.021	< 0.005	0.007	WL272
Nickel - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006727	W12/006728	W12/006729	W12/006730	
Sample Reference	Units	CWB15	WEX5D	KWP1	1PD	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	WL272
Zinc - Total	mg/L	< 0.005	< 0.005	0.014	0.036	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 25-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006731	1PI	WATER 25/04/12
W12/006732	1PS	WATER 25/04/12
W12/006733	2PD	WATER 30/04/12
W12/006734	2PI	WATER 30/04/12

Lab Reg No.		W12/006731	W12/006732	W12/006733	W12/006734	
Sample Reference	Units	1PI	1PS	2PD	2PI	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	300	270	52	200	WL122
Calcium - Filterable	mg/L	20	19	7	22	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	190	130	10	20	WL119
Conductivity at 25C	uS/cm	1270	980	170	420	WL121
Fluoride	mg/L	0.85	0.85	0.25	0.48	WL218
Ion Balance		0.91	0.94	1.04	0.91	CALC
Magnesium - Filterable	mg/L	18	15	7	25	WL125
Nitrate as NO3	mg/L	< 1	3	5	< 1	WL119
pH		7.8	7.9	6.3	7.6	WL120
Potassium - Filterable	mg/L	16	18	4	8	WL125
Sodium - Filterable	mg/L	210	160	10	20	WL125
Sulfate	mg/L	91	52	< 5	5	WL119
Trace Elements						
Aluminium - Total	mg/L	0.023	0.72	0.069	0.036	WL272
Barium - Total	mg/L	0.011	0.017	0.11	0.29	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.41	0.30	0.044	0.071	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Copper - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Iron - Total	mg/L	0.080	0.86	0.21	1.6	WL272
Lead - Total	mg/L	< 0.001	0.009	0.004	0.002	WL272
Manganese - Total	mg/L	0.029	0.040	0.049	0.40	WL272
Molybdenum - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Nickel - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006731	W12/006732	W12/006733	W12/006734	
Sample Reference	Units	1PI	1PS	2PD	2PI	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	WL272
Zinc - Total	mg/L	< 0.005	< 0.005	0.007	< 0.005	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 24-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006735	3PD	WATER 24/04/12
W12/006736	3PI	WATER 23/04/12
W12/006737	3PS	WATER 23/04/12
W12/006738	4PD	WATER 26/04/12

Lab Reg No.		W12/006735	W12/006736	W12/006737	W12/006738	
Sample Reference	Units	3PD	3PI	3PS	4PD	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	210	170	200	280	WL122
Calcium - Filterable	mg/L	47	49	37	100	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	290	400	320	2700	WL119
Conductivity at 25C	uS/cm	1470	1840	1610	11100	WL121
Fluoride	mg/L	0.29	0.27	0.49	0.37	WL218
Ion Balance		0.90	0.96	0.96	1.05	CALC
Magnesium - Filterable	mg/L	36	44	38	220	WL125
Nitrate as NO3	mg/L	3	6	8	< 1	WL119
pH		7.7	7.6	8.0	8.0	WL120
Potassium - Filterable	mg/L	21	22	31	62	WL125
Sodium - Filterable	mg/L	170	230	210	2200	WL125
Sulfate	mg/L	110	120	110	1500	WL119
Trace Elements						
Aluminium - Total	mg/L	0.012	0.007	0.22	3.3	WL272
Barium - Total	mg/L	0.017	0.022	0.017	0.051	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.25	0.28	0.29	2.1	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Copper - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Iron - Total	mg/L	0.052	0.047	0.28	7.7	WL272
Lead - Total	mg/L	< 0.001	< 0.001	0.025	0.022	WL272
Manganese - Total	mg/L	0.39	1.0	0.056	0.13	WL272
Molybdenum - Total	mg/L	< 0.005	< 0.005	< 0.005	0.011	WL272
Nickel - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006735	W12/006736	W12/006737	W12/006738	
Sample Reference	Units	3PD	3PI	3PS	4PD	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	< 0.010	0.018	< 0.010	WL272
Zinc - Total	mg/L	< 0.005	< 0.005	0.009	0.050	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 26-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006739	4PI	WATER 26/04/12
W12/006740	4PS	WATER 26/04/12
W12/006741	6PD	WATER 26/04/12
W12/006742	6PI	WATER 27/04/12

Lab Reg No.		W12/006739	W12/006740	W12/006741	W12/006742	
Sample Reference	Units	4PI	4PS	6PD	6PI	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	490	610	620	130	WL122
Calcium - Filterable	mg/L	100	60	19	17	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	2800	1100	710	70	WL119
Conductivity at 25C	uS/cm	11300	5950	3630	470	WL121
Fluoride	mg/L	1.0	< 0.20	1.1	0.20	WL218
Ion Balance		1.02	0.95	0.90	0.85	CALC
Magnesium - Filterable	mg/L	260	39	56	9	WL125
Nitrate as NO3	mg/L	< 1	10	22	< 1	WL119
pH		8.0	7.6	8.3	7.6	WL120
Potassium - Filterable	mg/L	110	28	35	5	WL125
Sodium - Filterable	mg/L	2100	1100	610	50	WL125
Sulfate	mg/L	1400	600	190	< 5	WL119
Trace Elements						
Aluminium - Total	mg/L	0.15	12	0.059	0.33	WL272
Barium - Total	mg/L	0.14	0.25	0.22	0.047	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	1.8	1.4	0.91	0.070	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	0.014	< 0.005	< 0.005	WL272
Copper - Total	mg/L	< 0.005	0.034	< 0.005	< 0.005	WL272
Iron - Total	mg/L	0.36	24	0.088	0.79	WL272
Lead - Total	mg/L	< 0.001	0.072	0.003	< 0.001	WL272
Manganese - Total	mg/L	1.8	1.1	0.083	0.26	WL272
Molybdenum - Total	mg/L	< 0.005	0.009	0.009	< 0.005	WL272
Nickel - Total	mg/L	< 0.005	0.023	< 0.005	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006739	W12/006740	W12/006741	W12/006742	
Sample Reference	Units	4PI	4PS	6PD	6PI	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	< 0.010	< 0.010	< 0.010	WL272
Zinc - Total	mg/L	< 0.005	0.093	< 0.005	< 0.005	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 29-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006743	9PD	WATER 29/04/12
W12/006744	9PI	WATER 29/04/12
W12/006745	9PS	WATER 29/04/12
W12/006746	14PD	WATER 28/04/12

Lab Reg No.		W12/006743	W12/006744	W12/006745	W12/006746	
Sample Reference	Units	9PD	9PI	9PS	14PD	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	70	71	490	290	WL122
Calcium - Filterable	mg/L	87	170	74	240	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	3600	4200	1800	2100	WL119
Conductivity at 25C	uS/cm	12700	14200	7510	7810	WL121
Fluoride	mg/L	0.37	0.40	2.1	0.64	WL218
Ion Balance		0.97	0.99	0.94	0.97	CALC
Magnesium - Filterable	mg/L	210	230	100	170	WL125
Nitrate as NO3	mg/L	< 1	< 1	23	< 1	WL119
pH		8.0	7.9	7.6	7.5	WL120
Potassium - Filterable	mg/L	72	60	83	34	WL125
Sodium - Filterable	mg/L	2400	2600	1400	1200	WL125
Sulfate	mg/L	1400	1100	900	780	WL119
Trace Elements						
Aluminium - Total	mg/L	0.29	0.13	0.009	38	WL272
Barium - Total	mg/L	0.070	0.050	0.026	0.65	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	2.3	1.7	1.7	0.84	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	< 0.005	< 0.005	0.041	WL272
Copper - Total	mg/L	< 0.005	< 0.005	< 0.005	0.081	WL272
Iron - Total	mg/L	1.0	0.71	0.046	110	WL272
Lead - Total	mg/L	0.005	0.002	< 0.001	0.086	WL272
Manganese - Total	mg/L	0.44	0.30	0.21	1.3	WL272
Molybdenum - Total	mg/L	< 0.005	< 0.005	0.010	< 0.005	WL272
Nickel - Total	mg/L	< 0.005	< 0.005	< 0.005	0.051	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.		W12/006743	W12/006744	W12/006745	W12/006746	
Sample Reference	Units	9PD	9PI	9PS	14PD	Method
Trace Elements						
Tin - Total	mg/L	<0.010	<0.010	<0.010	<0.010	WL272
Zinc - Total	mg/L	0.007	0.013	<0.005	0.082	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 28-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006747	14PI	WATER 28/04/12
W12/006748	14PS	WATER 28/04/12
W12/006749	2PS	WATER 21/04/12
W12/006750	CWB8S	WATER 21/04/12

Lab Reg No.		W12/006747	W12/006748	W12/006749	W12/006750	
Sample Reference	Units	14PI	14PS	2PS	CWB8S	Method
Inorganics						
Bicarbonate as CaCO3	mg/L	190	380	56	190	WL122
Calcium - Filterable	mg/L	120	47	6	290	WL125
Carbonate as CaCO3	mg/L	< 1	< 1	< 1	< 1	WL122
Chloride	mg/L	1100	280	20	2100	WL119
Conductivity at 25C	uS/cm	4170	1850	190	7590	WL121
Fluoride	mg/L	< 0.20	< 0.20	0.28	0.32	WL218
Ion Balance		0.88	0.58	0.79	0.97	CALC
Magnesium - Filterable	mg/L	28	8	7	300	WL125
Nitrate as NO3	mg/L	< 1	< 1	7	11	WL119
pH		6.6	7.0	6.4	7.3	WL120
Potassium - Filterable	mg/L	18	14	4	63	WL125
Sodium - Filterable	mg/L	550	130	10	830	WL125
Sulfate	mg/L	120	< 5	< 5	750	WL119
Trace Elements						
Aluminium - Total	mg/L	1.0	2.7	0.34	0.006	WL272
Barium - Total	mg/L	0.73	1.8	0.14	0.060	WL272
Beryllium - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272
Boron - Total	mg/L	0.098	0.034	0.047	0.79	WL272
Cadmium - Total	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	WL272
Cobalt - Total	mg/L	< 0.005	0.010	< 0.005	< 0.005	WL272
Copper - Total	mg/L	< 0.005	0.009	< 0.005	< 0.005	WL272
Iron - Total	mg/L	84	54	0.27	0.033	WL272
Lead - Total	mg/L	0.005	0.012	0.002	< 0.001	WL272
Manganese - Total	mg/L	9.1	4.4	0.031	0.004	WL272
Molybdenum - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Nickel - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Selenium - Total	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	WL272
Silver - Total	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	WL272

REPORT OF ANALYSIS

Lab Reg No.		W12/006747	W12/006748	W12/006749	W12/006750	
Sample Reference	Units	14PI	14PS	2PS	CWB8S	Method
Trace Elements						
Tin - Total	mg/L	< 0.010	0.10	< 0.010	< 0.010	WL272
Zinc - Total	mg/L	0.025	0.024	0.007	0.007	WL272

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

21-MAY-2012

REPORT OF ANALYSIS

Report No. RN915782

Client	: PENNINGTON SCOTT Level 12, 3 Hasler Road HERDSMAN WA 6017	Job No.	: PENN07_W/120507
		Quote No.	: QT-01898
		Order No.	:
		Date Sampled	: 19-APR-2012
		Date Received	: 7-MAY-2012
Attention	: RACHEL TAPLIN	Sampled By	: CLIENT
Project Name	:		
Your Client Services Manager	: DAVID LYNCH	Phone	: (08) 9368 8420

Lab Reg No.	Sample Ref	Sample Description
W12/006751	WEX5S	WATER 19/04/12

Lab Reg No.		W12/006751				
Sample Reference	Units	WEX5S				Method
Inorganics						
Bicarbonate as CaCO3	mg/L	410				WL122
Calcium - Filterable	mg/L	200				WL125
Carbonate as CaCO3	mg/L	< 1				WL122
Chloride	mg/L	1000				WL119
Conductivity at 25C	uS/cm	4640				WL121
Fluoride	mg/L	< 0.20				WL218
Ion Balance		0.95				CALC
Magnesium - Filterable	mg/L	140				WL125
Nitrate as NO3	mg/L	< 1				WL119
pH		7.3				WL120
Potassium - Filterable	mg/L	27				WL125
Sodium - Filterable	mg/L	580				WL125
Sulfate	mg/L	660				WL119
Trace Elements						
Aluminium - Total	mg/L	< 0.005				WL272
Barium - Total	mg/L	0.027				WL272
Beryllium - Total	mg/L	< 0.001				WL272
Boron - Total	mg/L	0.83				WL272
Cadmium - Total	mg/L	< 0.002				WL272
Cobalt - Total	mg/L	0.012				WL272
Copper - Total	mg/L	0.011				WL272
Iron - Total	mg/L	0.045				WL272
Lead - Total	mg/L	0.003				WL272
Manganese - Total	mg/L	0.043				WL272
Molybdenum - Total	mg/L	< 0.005				WL272
Nickel - Total	mg/L	0.007				WL272
Selenium - Total	mg/L	< 0.005				WL272
Silver - Total	mg/L	< 0.001				WL272
Tin - Total	mg/L	< 0.010				WL272
Zinc - Total	mg/L	0.027				WL272

REPORT OF ANALYSIS

Report No. RN915782

Lab Reg No.	Units	W12/006751				Method
Sample Reference		WEX5S				

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Accreditation No. 2474

21-MAY-2012

Unless notified to the contrary, the above samples will be disposed of one month from the reporting date.

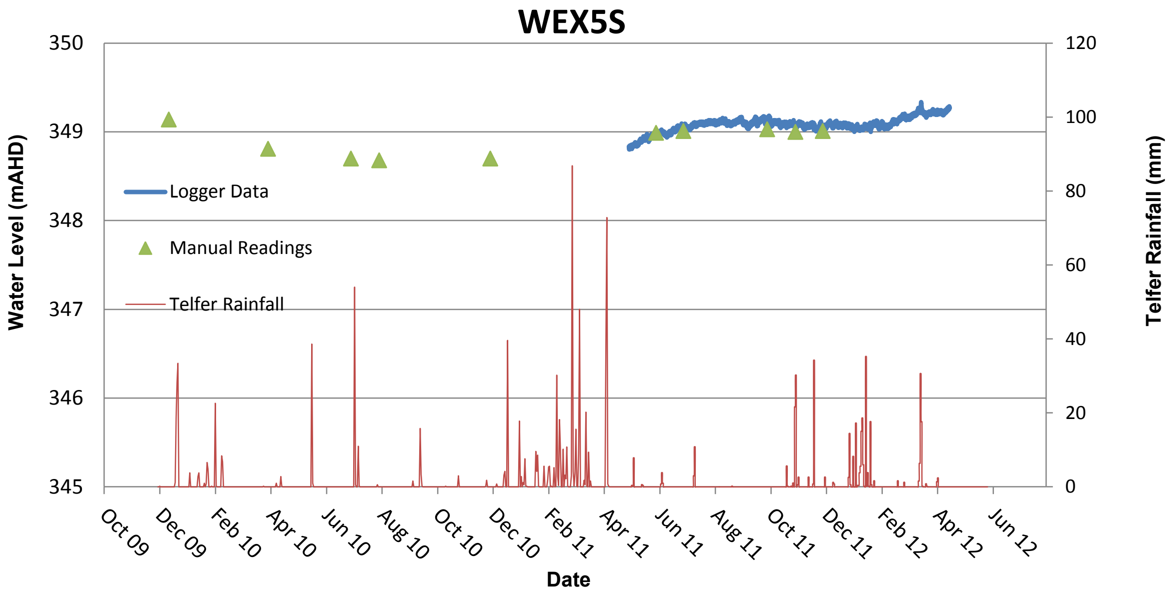
NATA
ACCREDITED FOR TECHNICAL COMPETENCE

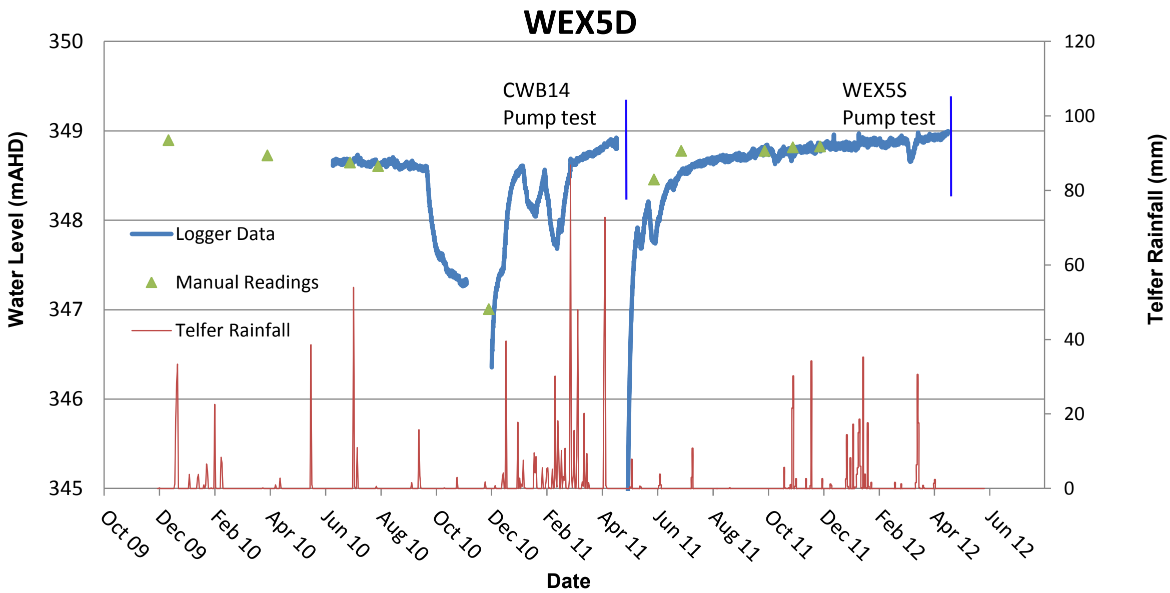
Accreditated for compliance with ISO/IEC 17025.
This report shall not be reproduced except in full.
Results relate only to the sample(s) tested.

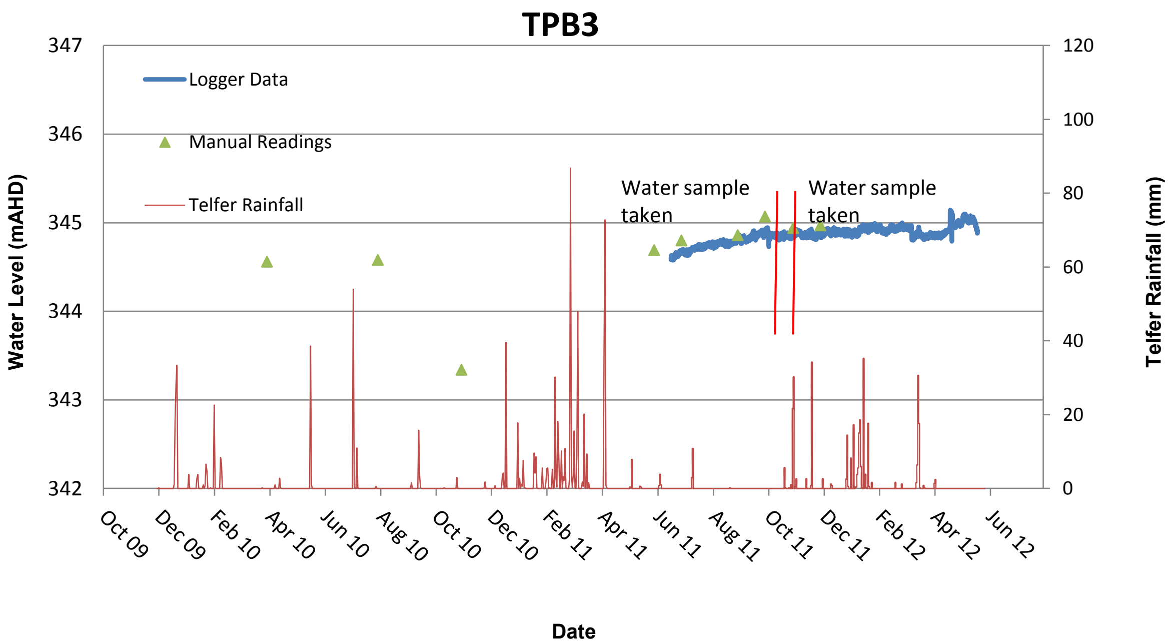
Appendix E

ERMP Groundwater Hydrographs

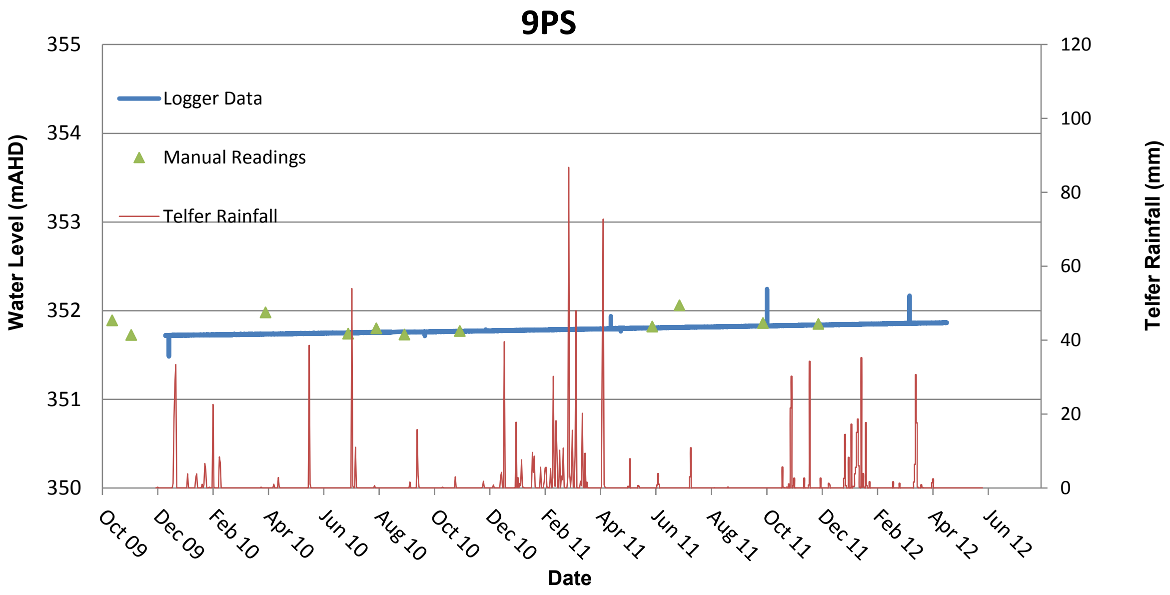
GROUNDWATER HYDROGRAPHS

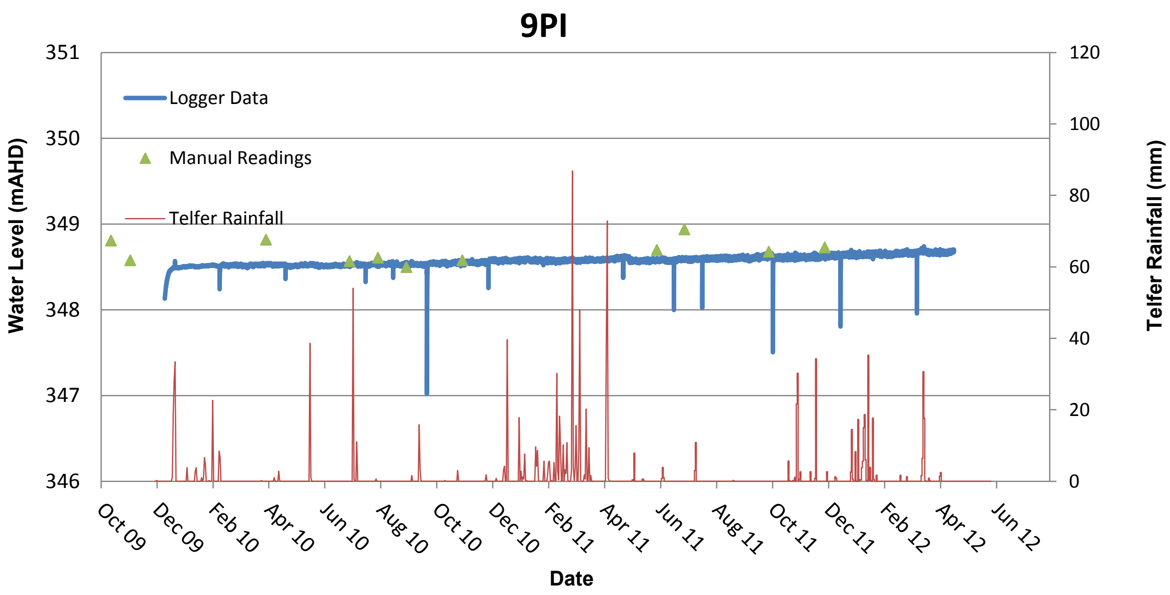


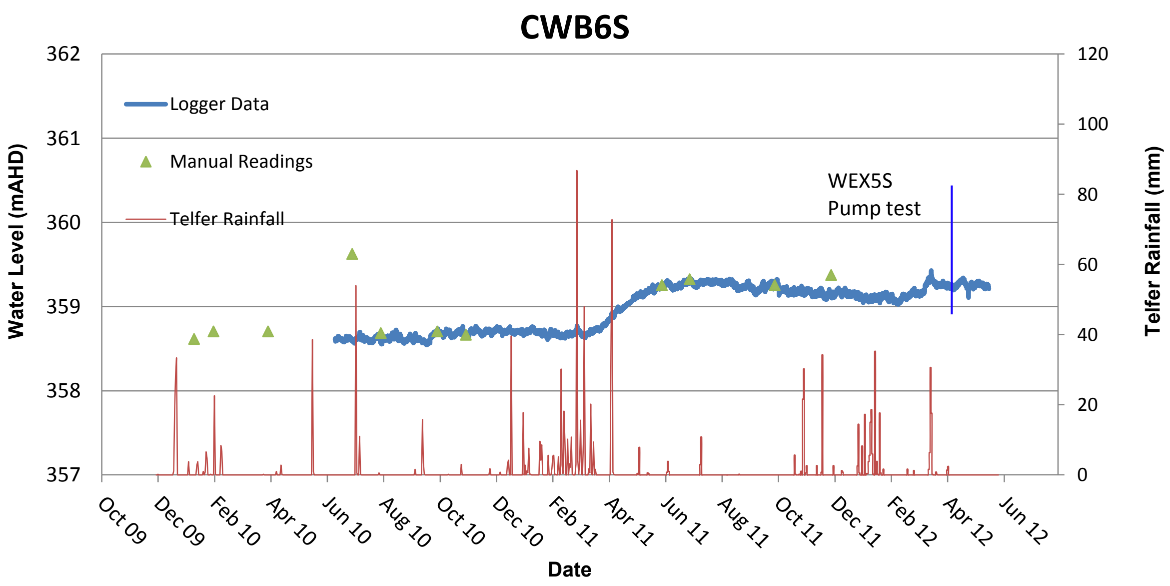




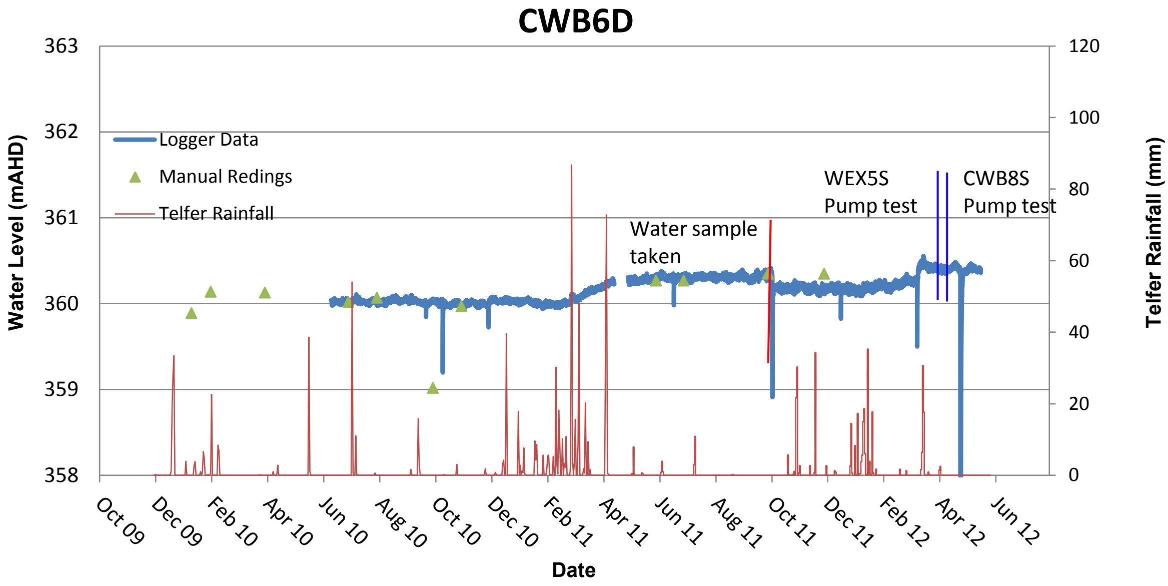
GROUNDWATER HYDROGRAPHS

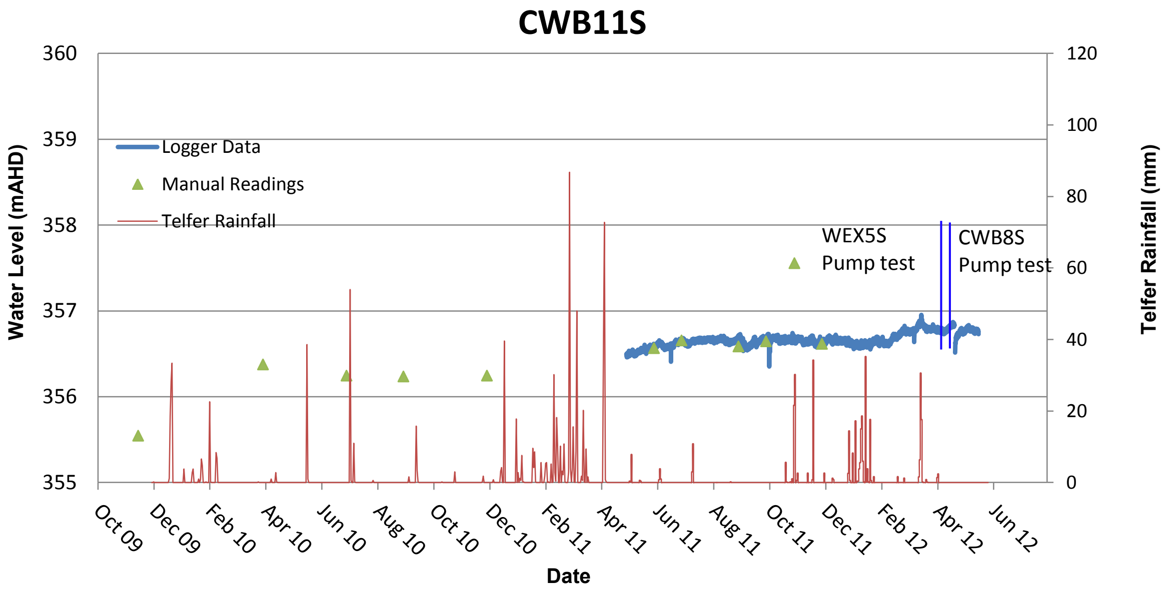


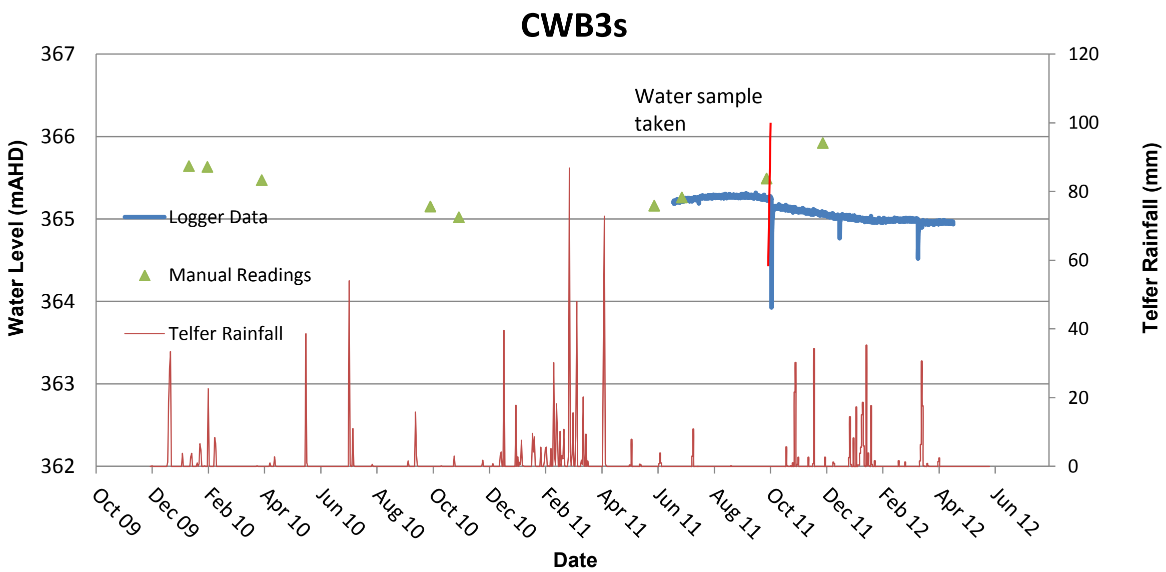




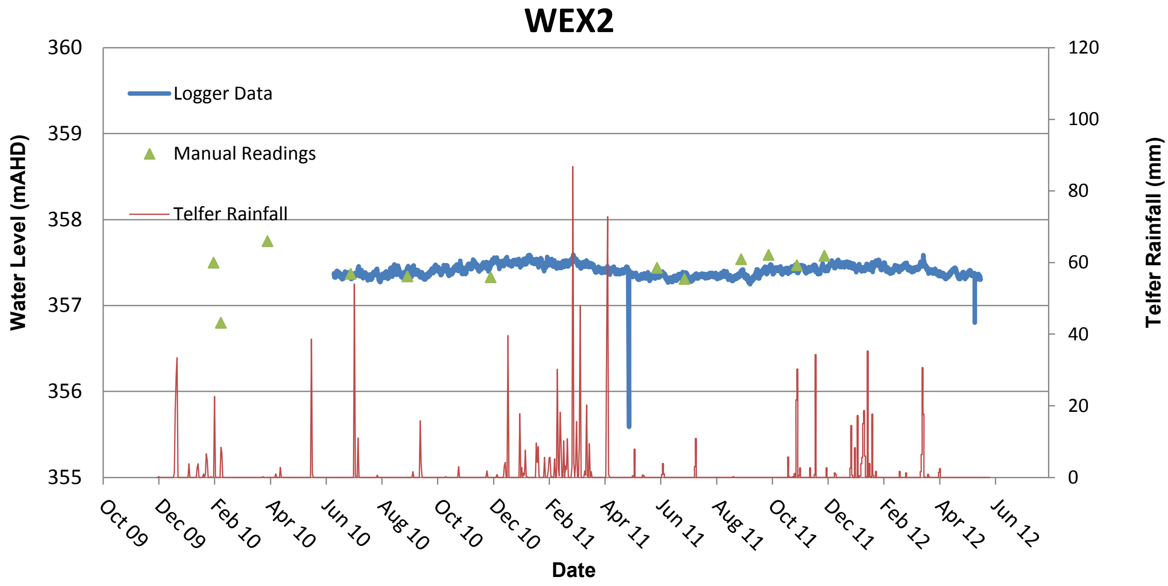
GROUNDWATER HYDROGRAPHS

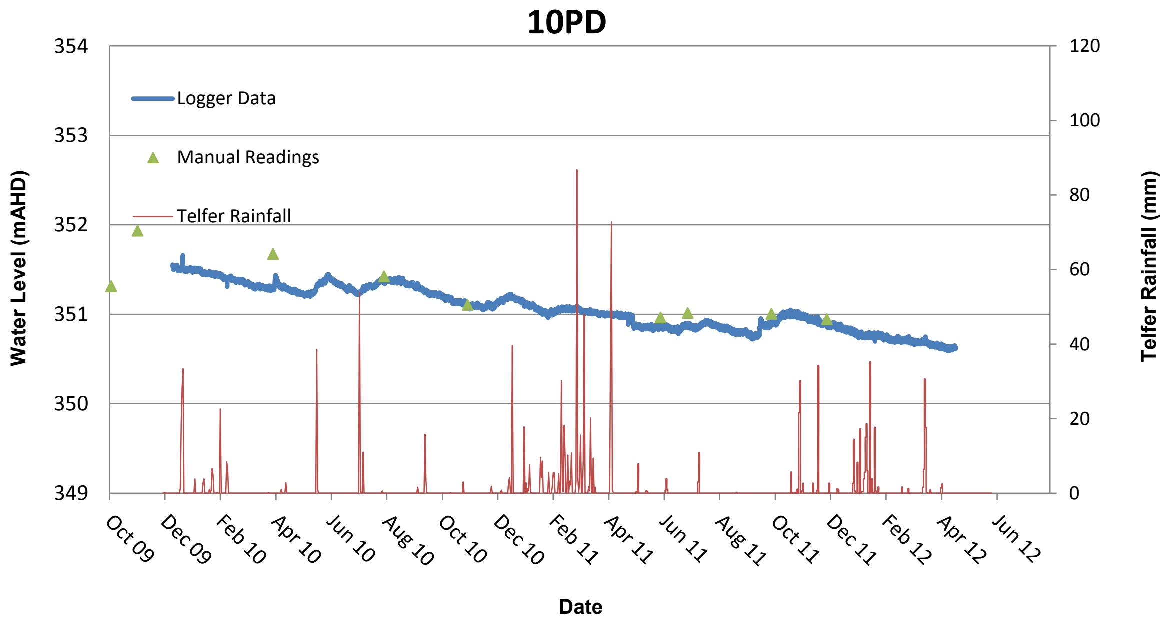


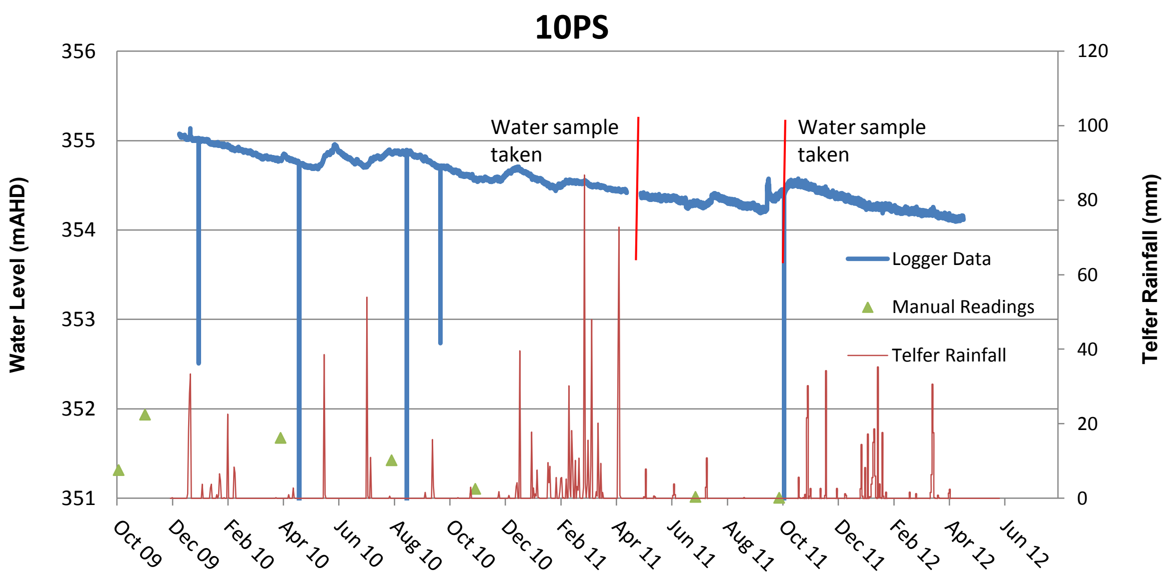




GROUNDWATER HYDROGRAPHS







GROUNDWATER HYDROGRAPHS

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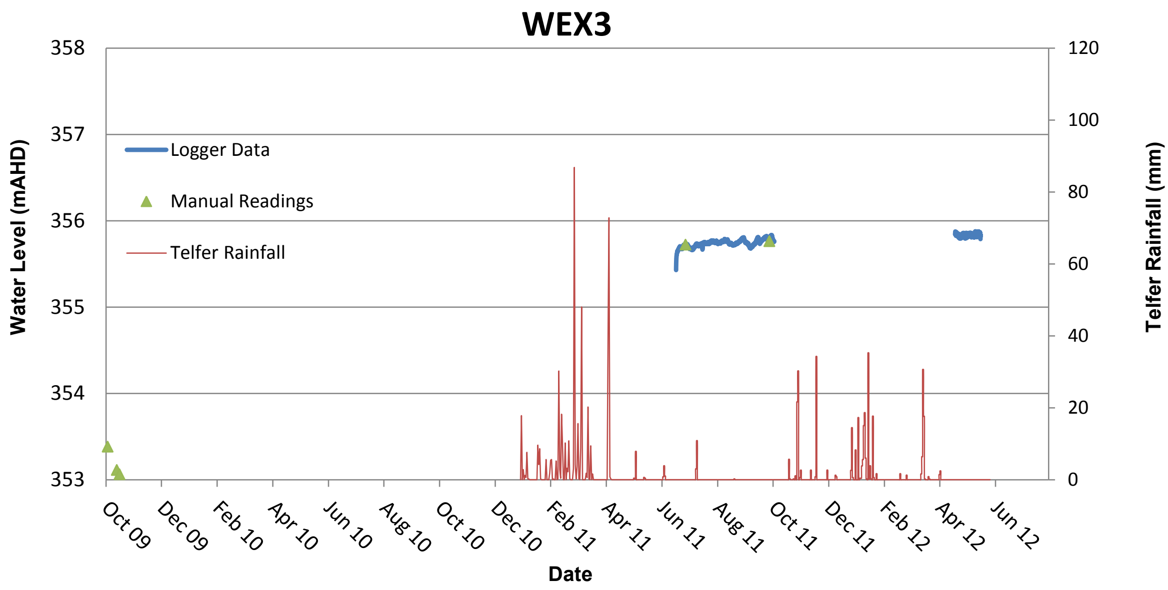

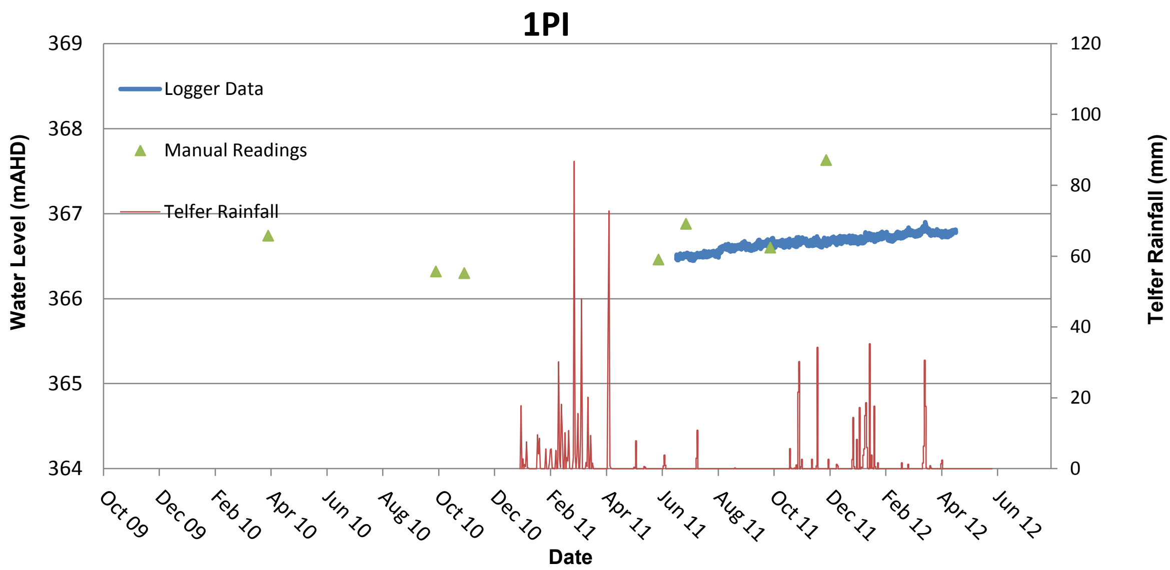

Attachment B

Kintyre ERMP Groundwater Modelling Report

Cameco Australia Pty Ltd

Attachment B – ERMP Groundwater Modelling Report

Kintyre Joint Venture Project

penningtonscott
securing your water future

Kintyre ERMP Groundwater Modelling Report

Western Australia

Prepared for:

Cameco Australia Pty Ltd

Prepared by:

TETRA TECH

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Perth, WA 6000
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July 2012

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1.0 Introduction

The Kintyre Joint Venture (KJV), comprising Cameco Australia Pty Ltd (70%) and Mitsubishi Development Pty Ltd (30%), is developing a 2.7 to 3.6 kTpa uranium project on the western edge of the Great Sandy Desert in the East Pilbara region of Western Australia, referred to as the 'Project'. The Project is located 70 km south of Telfer and 260 km northeast of Newman at the western edge of the Great Sandy Desert. It is immediately north of the Karlamilyi (Rudall River) National Park (Figure C1-1).

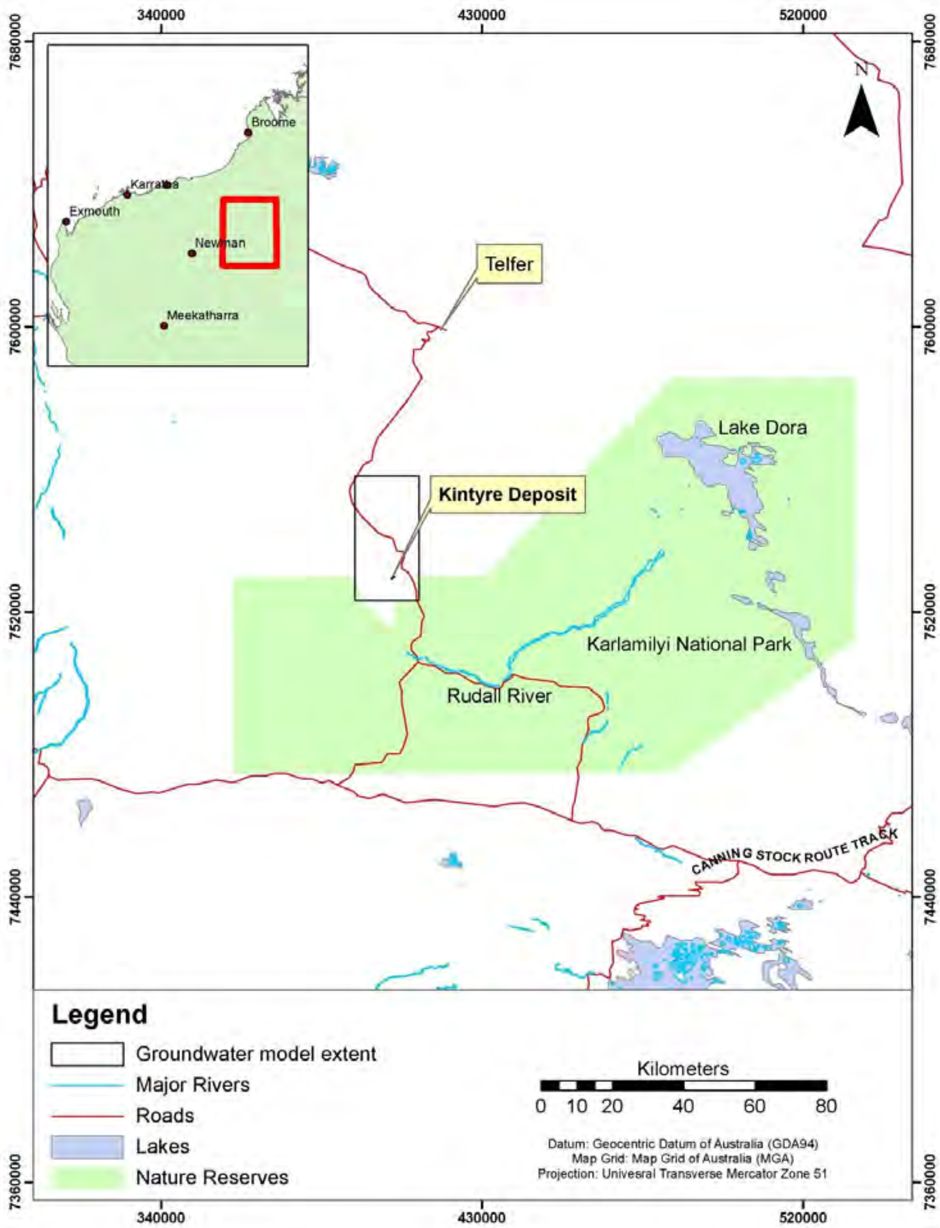


Figure C1-1. Kintyre Location Map

1.1 Modelling Objectives

Groundwater modelling was performed to support the KJV project Environmental Review and Management Program (ERMP) for Cameco Australia Pty Ltd, herein referred to as 'Cameco'. Cameco is proposing to mine the KJV via open cut methods, which will require mining below the water table. This report documents the development and results of a regional numerical groundwater flow model (regional model) constructed to estimate possible impacts to regional and local water resources due to the Kintyre mining operation. A local numerical groundwater flow model (dewatering model) with a more refined grid was used to estimate pit inflows and pit lake characteristics specifically (Section 4.8 of this report). Figure C1-2 shows the boundaries of the regional and local modelled areas. Specific objectives of the modelling effort include estimation of:

- Hydrogeologic conditions associated with pre-mining (steady state), active-mining (mining phase), and post-mining (post-closure) conditions;
- The extent of drawdown associated with water supply pumping;
- The extent of drawdown associated with mining at various stages;
- The rate of groundwater inflow to the open pit;
- Pit infill rates and water-surface elevation after cessation of mining; and
- Particle tracking from the tailings management facility (TMF).

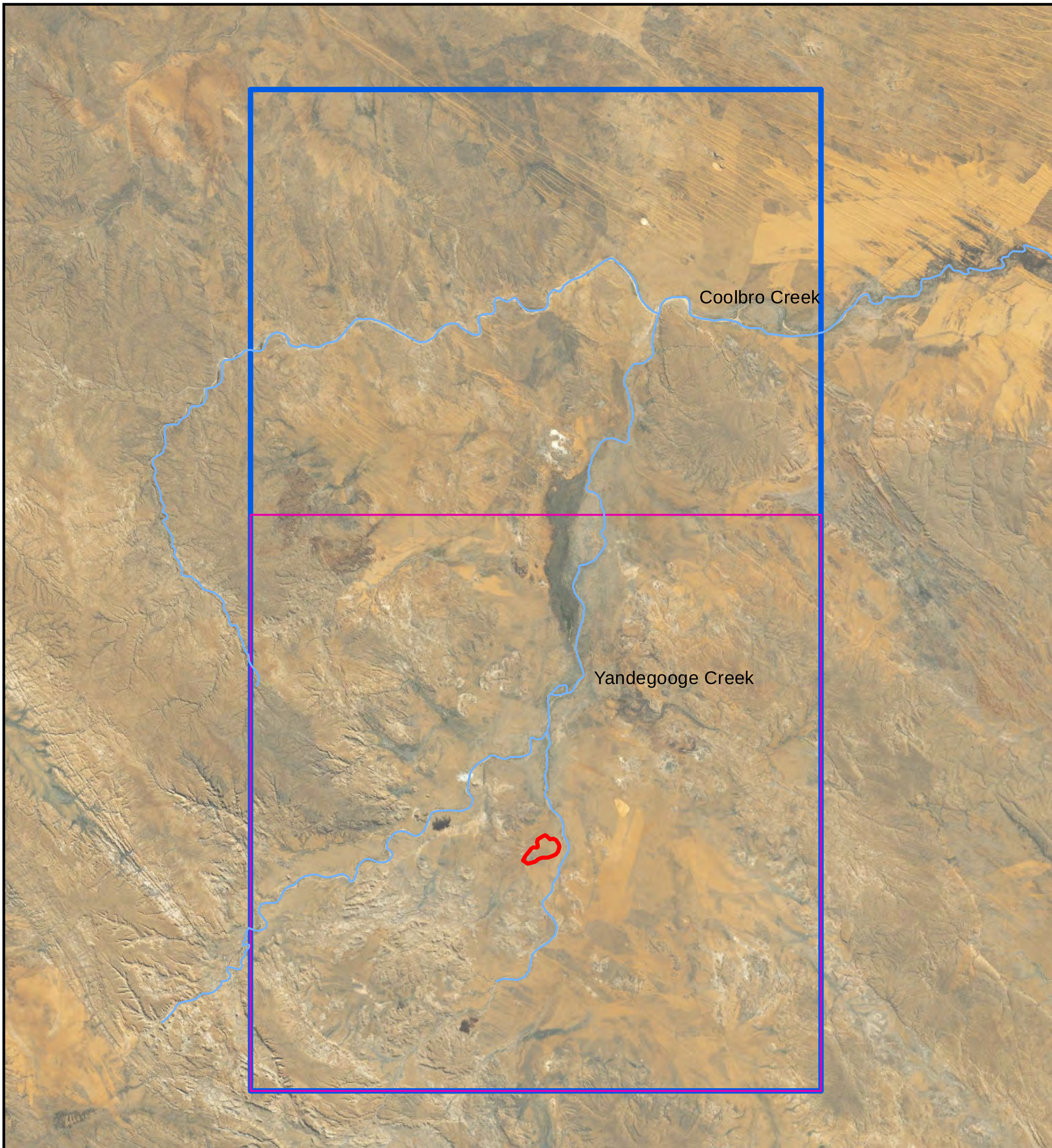
Based on the current Pre-Feasibility Study (PFS) scope of works, a 3.1 ML/day water supply is required over 9.5 years of mining operation. To support security of this water supply and to provide a level of conservatism, a further 40% (additional 1.9 ML/day) water requirement was applied to the model simulations as contingency.

Model results were used to assess potential impacts on groundwater dependent flora and (sub)terranean fauna in the vicinity of the Project site and the proposed water supply borefield to the north of the pit. In addition, the hydrogeologic data generated support design of mine water management systems and will be used to support environmental permitting requirements with the regulatory agencies.

1.2 Approach

Hydrogeologic evaluation of potential impacts to groundwater during Project development, operation, and closure stages involved the following steps:

1. Development of a Conceptual Site Model that considers both regional- and local-scale geologic and hydrogeologic information;
2. Compilation of geologic and hydrogeologic data from published map sources, publicly available borehole log databases, site-specific boreholes, and available geophysical data; and
3. Construction of regional and local groundwater flow models to simulate:
    a. Steady-state, pre-mining conditions;
    b. Transient pumping conditions related to aquifer testing activities;
    c. Transient conditions correlated to the progression of mine development and operation (including water supply borefield development); and
    d. Post-closure to evaluate potential pit lake development and to track the movement of groundwater at and downgradient of the TMF.



Regional Model Extent

Local Model Extent

Proposed pit extent

Creek Locations

0 2,000 4,000 8,000

Met s

N

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ISSUED FOR:

Cameco Australia Pty Ltd

PROJECT NAME:
Kintyre ERMP GW Flow Model

DATE:
July 2, 2012

PROJECT NO.:
117-0532005

TITLE:

Figure C1-2. Model Extents

2.0 Conceptual Site Model

The Hydrogeologic Investigation report (Pennington Scott, 2012) describes the geological and hydrogeological settings, estimated hydraulic parameters, and groundwater dynamics. The following section describes how the information in the main report relates to the conceptual site model used for groundwater modelling. Basically, a conceptual model of groundwater flow consists of the following components:

- The basic shape and composition of the material through which water flows;
- Recharge to and discharge from the groundwater system; and
- The flow paths by which groundwater moves through the subsurface.

2.1 Topography and Geology

The first component of the conceptual site model consists of the topography and geologic setting of the modelled area. Figure 2-2 of Pennington Scott (2012) shows the topographic features surrounding the Project area. As shown on Figure 2-2, the Project area lies on a slight topographic high located between two branches of Yandagooge Creek. Yandagooge Creek flows toward the north-northeast between two mountain ranges, the Throssell Range and the Broadhurst Range. The two mountain ranges are composed of sedimentary Neoproterozoic rocks (Broadhurst Formation and Coolbro Sandstone) and metamorphic Paleoproterozoic rocks (Rudall Complex).

The main report describes in detail how the current Yandagooge Creek channel relates to the underlying Permian glacial valley (palaeochannel). In short, the glacial valleys were mostly filled with glaciofluvial and glaciolacustrine sediments of Permian age (Paterson Formation). The basal Permian is generally tillite, which is overlain by sandstone, siltstone, and claystone. In some locations less-consolidated sand and gravel of Permian age has been noted; however, the distribution of these more permeable materials is poorly understood and appears to be heterogeneous. Coarser-grained Cenozoic sediments overlie the Permian materials in most locations, but are unsaturated in many locations.

Figure C2-1 shows the surficial geology of the model area, with units grouped into the Rudall Complex, Coolbro Sandstone, Broadhurst Formation, Paterson Formation, and Cenozoic materials. The geology on this figure was generalized from the 1:250,000 Rudall geologic map (Bagas et al., 2000). Figure C2-1 indicates there are a number of fold and fault traces present in the area, of which one passes quite close to the proposed Kintyre pit. The rocks in these areas are fairly steeply dipping (up to 80 degrees in many cases), which could impact their hydraulic properties.

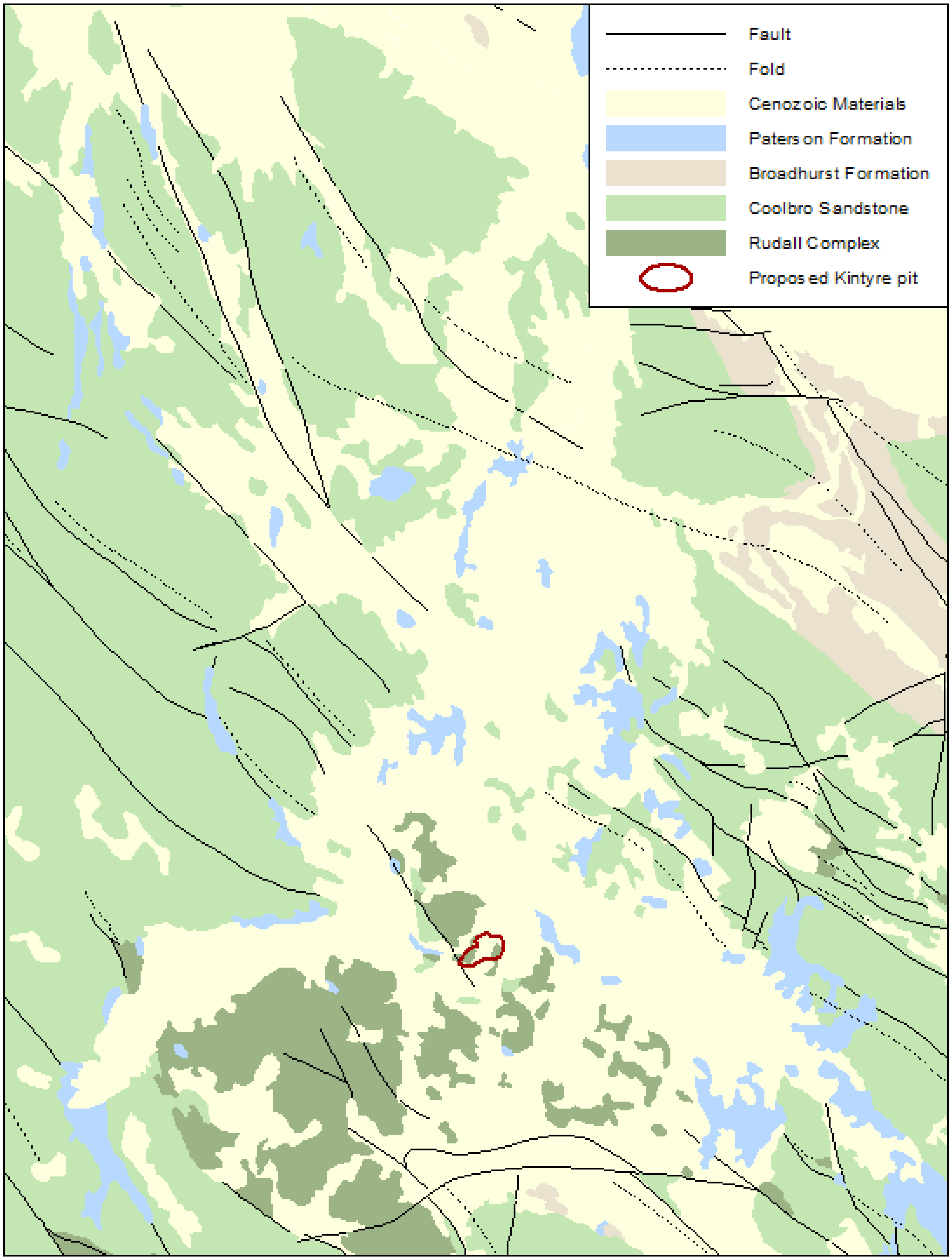


Figure C2-1. Surficial Geology of Modelled Area

2.2 Groundwater Recharge and Discharge

Generally speaking, recharge to groundwater will occur via infiltration of precipitation and infiltration from surface water bodies. Discharge from groundwater could occur due to migration into surface water bodies, via evapotranspiration (vegetation), or by means of pumping.

2.2.1 Recharge

As described in Pennington Scott (2012), chloride data were used to estimate recharge rates for the various formations represented in the model. The following briefly describes the initial estimated recharge rates and rationale provided in the report.

- Rudall Complex (0.35 mm/yr) – High salinity in the Rudall Complex indicates that not much rainfall is able to infiltrate this area.
- Coolbro Sandstone (3.5 mm/yr) – The Coolbro Sandstone outcrops as plateaus with many fractures and drainage lines, allowing significant infiltration as evidenced by low chloride levels.
- Paterson Formation (1.8-2.8 mm/yr) – The valleys initially receive significant infiltration, but the high evapotranspiration rate results in lower overall recharge rates. The chloride distribution in the Paterson Formation also indicates that significant additional recharge occurs as a result of runoff from the Coolbro Sandstone plateaus. Since the Paterson Formation is overlain by the Cenozoic sediments, the recharge actually first infiltrates the Cenozoic sediments and then migrates into the Paterson Formation.

One of the primary drivers of the recharge rate is the topography and degree of incision of the formations. Site-specific data were not available for all areas, but some generalizations can be made for purposes of modelling, based on topography. The Broadhurst Formation is analogous to the Paterson Formation topographically, and so is considered to have similar recharge. The upper, easternmost portion of the Paterson Formation is more incised and therefore likely to be more similar to the Coolbro Sandstone in terms of recharge.

2.2.2 Hydrology

The Project area hydrology is dominated by Yandagooge Creek, as described in Section 2.3 of the main report. However, this creek is typically dry and only flows episodically following heavy rainfall events. Any additional recharge it may provide would be included in the bulk estimate of recharge using the chloride data. Since the creek is dry the vast majority of the time, it is not a primary location of groundwater discharge in the modelled area. Thus, for modelling purposes it was not necessary to represent this creek.

Yandagooge Creek flows into Coolbro Creek approximately 21 kilometres north of the proposed pit. Coolbro Creek dissipates into the desert approximately 17 kilometres east of the confluence with Yandagooge Creek. Coolbro Creek is also seasonal. Coolbro Creek was not represented in the model because it is not clear whether or not Coolbro Creek is actually connected to groundwater or is simply fed by surface water runoff in a similar manner to Yandagooge Creek. The locations of Coolbro Creek and Yandegooge Creek are shown on Figure C1-2.

There are also some ephemeral water pools in the vicinity of the Project area, as illustrated in Figure 2-3 of Pennington Scott (2012). Any recharge they might provide to the groundwater system has to be quite small in order for them to retain water in the absence of additional rainfall.

2.2.3 Evapotranspiration

Most vegetation occurs in association with the Yandagooge Creek and its tributaries. As described in Section 2-4 of Pennington Scott (2012), some tree communities are present along these and other drainage lines.

For modelling purposes, it was not necessary to specifically represent the evapotranspiration rates of vegetation. This is because the recharge estimates using chloride data directly estimate recharge to groundwater after any evapotranspiration has occurred.

2.2.4 Pumped Bores

There are no known water supply bores located in the modelled area. The only other groundwater withdrawals in the modelled area are from Project-related bores. These bores were pumped for short periods of time for aquifer testing purposes and these data are included in the model. Figure C2-2 indicates the locations of the tested bores whose data were used in modelling. These bores are currently not pumped on a regular basis, but some are used occasionally to provide water supply for drilling.

2.3 Hydrogeology

The path groundwater follows through the modelled area is influenced by the regional groundwater gradient and the hydraulic conductivity of the materials in the modelled area. The local flow direction is influenced by differences in recharge, local topography, and local hydraulic conductivity. In addition, any project-related pumping will influence the local flow direction.

2.3.1 Regional Gradient

The regional groundwater gradient in the Kintyre area is toward the north-northeast. As indicated in Figure 2-2 of Pennington Scott (2012), the southern portion of the modelled area is topographically higher than the northern portion. This topographic slope toward the north-northeast corresponds to the underlying geology. The palaeochannel that roughly underlies Yandagooge Creek is ultimately a tributary to a larger palaeochannel north-northeast of the modelled area. Hence, the groundwater gradient in the modelled area follows this topographic slope toward the north-northeast. Figures 4-1 and 4-2 of Pennington Scott (2012) illustrate the groundwater flow direction based on data collected in the modelled area. The vertical gradient varies both with time and with location across the Project area.

2.3.2 Hydraulic Conductivity

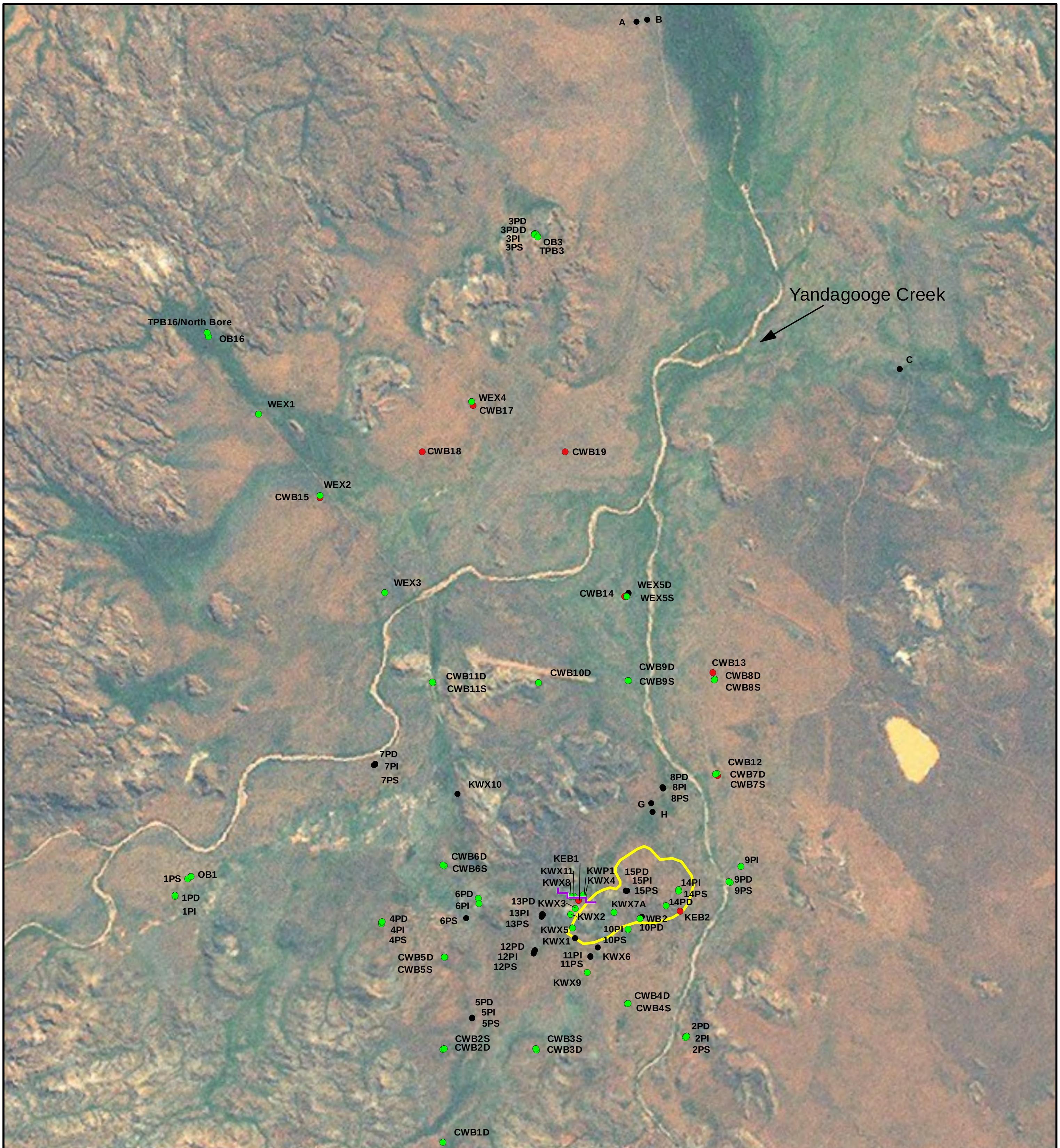
Table 4-2 of Pennington Scott (2012) summarizes the horizontal and vertical hydraulic conductivity (K) ranges for the geologic materials represented in the modelled area. The Cenozoic surficial sediments have the highest horizontal hydraulic conductivity of the modelled geologic units, ranging up to 10 m/d. The Coolbro Sandstone and Paterson Formation have similar horizontal hydraulic conductivity to each other (0.1-1 and 0.01-1 m/d, respectively) but lower than the Cenozoic sediments. The Rudall Formation has the lowest horizontal hydraulic conductivity. Thus, in general, flow is toward the palaeochannels, which are filled with transmissive Cenozoic sediments overlying Paterson formation and therefore represent the path of least resistance to groundwater.

The vertical K of the materials represented in the modelled area varies quite a bit. In general, the vertical K of the Cenozoic and Permian units is two or three orders of magnitude lower than the horizontal K due to interbedded fine grained units and clays. The vertical K of the Coolbro Sandstone and Broadhurst Formations is anticipated to be closer to the horizontal K and will be affected by the dip angle of the bedding planes, if present. The vertical and horizontal K of the Rudall Complex is expected to be heterogeneous due to the variably fractured and deformed nature of the formation; the higher K would be expected to correspond to the dominant fracture sets.

2.3.3 Local Flow Direction

The local groundwater flow mimics the regional groundwater flow direction. Figure C2-2 shows all the bores installed in the Project area over time, and indicates which ones have recent data since April 2011. Figure C2-3 provides recent static groundwater elevation data collected from the bores displayed in Figure C2-2. At the time of model preparation, the most recent data set was primarily composed of March 2012 data, with a few exceptions. Bores CWB8D and North Bore were last measured in April 2011. Bores CWB17, CWB18, and CWB19 were measured in April 2012. Bores OB16 and 2PS were measured in May 2012. Groundwater elevation data before 1994 were omitted from Figure C2-3 due to lower precipitation and groundwater recharge during that time period. It is evident from this figure that in some cases adjacent bores have hydraulic heads that differ from each other by more than 10 metres (i.e., in the area of KEB1: KEB1, KWP1, KWX3, KWX4, KWX8, and KWX11). In part, this is likely due to the fractured and faulted nature of the geologic materials.

A further potential complication to local flow directions is groundwater pumping. Aquifer testing has been performed on many of the bores, and some have also been used for camp and exploratory drilling operations. Furthermore, most of the bores have been subjected to geochemical sampling. Due to the low hydraulic conductivity of the geologic materials, groundwater pumping has been observed to have a long-lasting effect on water levels in some of the bores. Thus, groundwater pumping must be taken into consideration when analysing the water level measurements collected in Project area wells.



9PI Historical Bores (no recent data)

KEB2 Pumped Bores (2011-2012 Aquifer Tests)

10PD Recent Bores

Proposed pit extent

Suspected fault

0 500 1,000 2,000

Met s

N

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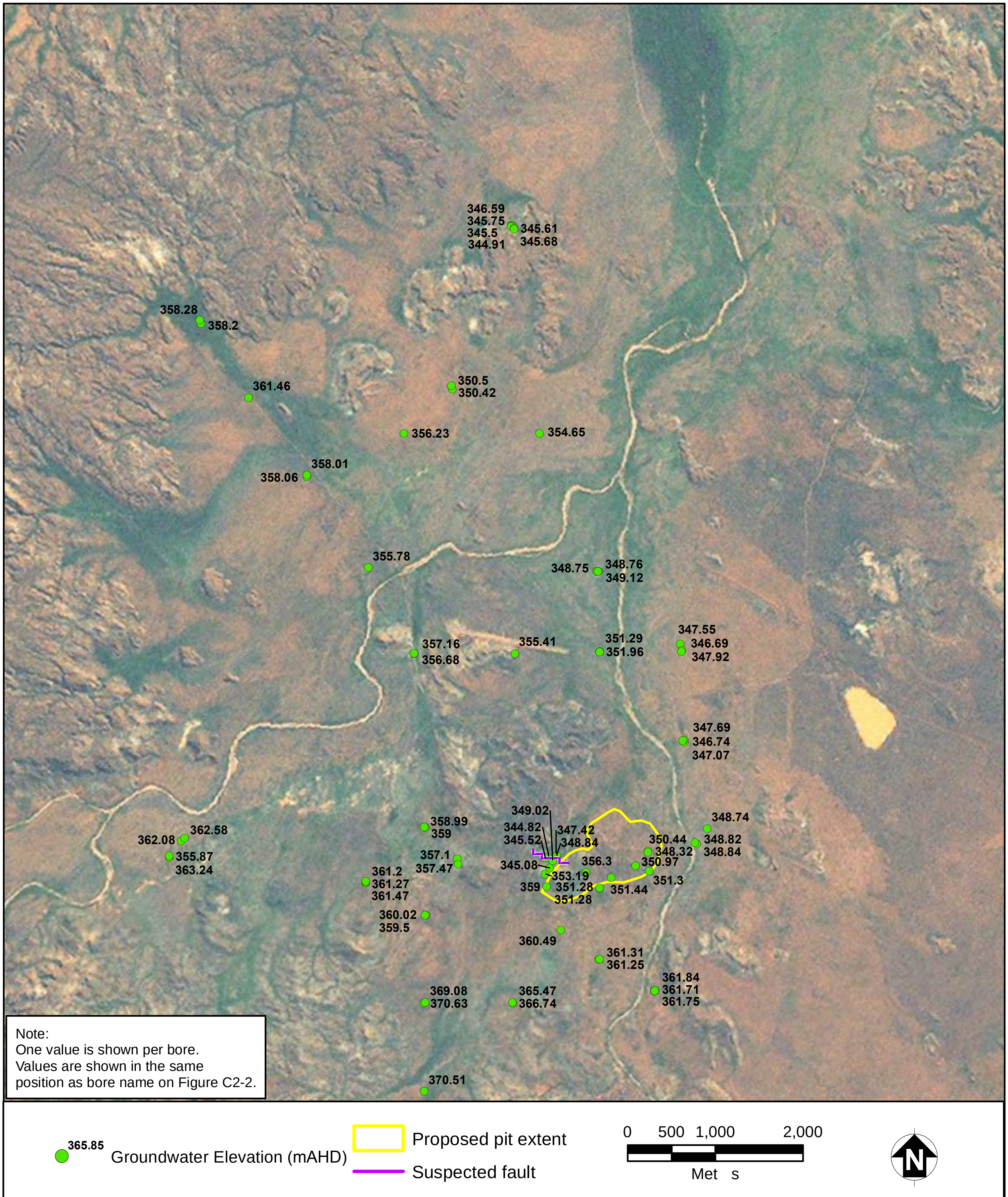
Louisville, Colorado 80027

ISSUED FOR: Cameco Australia Pty Ltd	
PROJECT NAME: Kintyre ERMP GW Flow Model	
DATE: June 26, 2012	PROJECT NO.: 117-0532005

TITLE:

Figure C2-2. Well Location Map



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ISSUED FOR:
Cameco Australia Pty Ltd

PROJECT NAME:
Kintyre ERMP GW Flow Model

DATE:
June 26, 2012

PROJECT NO.:
117-0532005

TITLE:

Figure C2-3. Recent Groundwater Elevation Data

3.0 GEOLOGIC AND HYDROGEOLOGIC EVALUATION

Geologic and hydrogeologic evaluations were performed as part of the groundwater modelling effort. While these evaluations conform in substance to the results described in the main report, somewhat different analyses were required to construct the model. In some cases, generalizations were necessary; in others, additional specifics had to be considered. The following sections describe how the geologic and hydrogeologic data were used to construct the model.

3.1 Geologic Evaluation

A number of data sources were used to complete the geologic evaluation.

- Available surface geologic maps were used to guide initial interpretations of the surficial extent of each unit (Hickman and Clarke, 1994; Bagas et al., 2000).
- The Geoscience Australia (GA) drillhole database (Roach, 2009) provided data regarding thickness of Cenozoic and Permian materials, as well as the nature of and depth to the basement rock (Rudall Complex, Coolbro Sandstone, and Broadhurst Formation).
- Exploration drillholes and water bores at Kintyre (MWH, 2010 and 2011; Pennington Scott, 2012a) were used to specifically identify the subsurface geology, where possible.
- The Geoscience Australia AEM geophysical data (Hutchinson et al, 2010) were used to define the location and depth of palaeochannels in the vicinity of Kintyre.
- The University of New South Wales (UNSW) Kintyre area geologic block model (Woltmann, 2011) was used to define the smaller palaeochannels south of the Kintyre tenement area. The UNSW geologic block model is a 3-D representation of the geology within a 20 km^2 area around Kintyre.

After data from these five sources were imported into an electronic database, the next step was to develop a common geologic nomenclature between the data sets, since each data set used a slightly different nomenclature. Table C3-1 shows the geologic units used to group the data for the Kintyre Area in preparation for geologic surface contouring.

Table C3-1. Geologic Model Units for Geologic Surface Development

Geologic Unit	Abbreviation	Description
Cenozoic (Quaternary and Cenozoic often were not differentiated in logs)	Cg, Cs, Ch	Gravel (Cg), Aeolian sand (Cs), and/or unspecified grain size mixture (Ch)
Permian (Upper)	Pgc	Permian glacial clays and small grain size mixtures
Permian (Basal)	Pgg	Permian basal conglomerate
Proterozoic (Broadhurst)	Pyb	Broadhurst Formation
Proterozoic (Coolbro)	Pyc, Pyg	Coolbro Sandstone (Pyc) and conglomerate (Pyg)
Proterozoic (conductive rock)	-	Fault breccia, banded iron formation, sandstone other than Coolbro, limestone, and saprolite
Proterozoic	Basement	All Proterozoic rock except conductive rock and Coolbro Sandstone

After the data were grouped according to the proposed model units, the process of developing geologic surfaces for import into the model could be initiated.

3.1.1 Geologic Surfaces

Because the palaeochannel is the most prominent hydrogeologic feature of the modelled area, it was mapped first. The palaeochannel is incised into Rudall Complex, Coolbro Sandstone, and Broadhurst Formation rocks, depending on the location. Hence, these three Proterozoic formations grouped together define the Proterozoic basement surface.

Airborne time domain electromagnetics (TDEM) was used to define the main palaeochannel at Kintyre (Figure 3-6; Pennington Scott, 2012). The channel outline on each of the conductivity depth images (CDIs) was digitized and then the XYZ data interpolated into a 3D surface. Channel depths were compared to observed base of Permian conglomerate from the available bore logs and to the layout on the geological maps to ensure consistency.

To complete the Proterozoic basement surface data set and include smaller tributaries to the main palaeochannel, additional data sources were consulted. The UNSW geologic block model was used to define the smaller palaeochannels south of the Kintyre tenement area. For areas of shallow palaeochannel depth, a combination of the TDEM images and available bore log data were used to digitize the depth to the first Proterozoic unit. Finally, a Proterozoic basement surface was generated that combined all data sources.

After defining the Proterozoic basement surface, the next step was to define the infill materials in the palaeochannels. A summary of average unit thicknesses in palaeochannel bores located near the Kintyre deposit is provided in Table 4-1 of (Pennington Scott, 2012). These values (reproduced below) provided initial guidance on the sizing of layers:

- Alluvium/Colluvium – 15 metres;
- Upper Permian – 50 metres; and
- Lower Permian (Basal Conglomerate) – 100 metres.

However, insufficient data existed to define the Permian infill thicknesses. Upon further examination, sufficient bore logs were available to estimate the depth of Cenozoic sediments in most portions of the palaeochannel. Thus, the thickness of the Cenozoic sediments was estimated using available bore log data combined with the edge of the palaeochannels (zero thickness). The Cenozoic thickness was then subtracted from the depth to Proterozoic basement to obtain the Permian unit thickness as a difference.

Once the Proterozoic basement surface, Cenozoic and Permian thicknesses were defined and incorporated into the model. MODFLOW models cannot accommodate layers that pinch out, but the infill sediments pinch out at the edge of the palaeochannels. Hence, a combination of control points and grid bounding (minimum and maximum functions) were used to generate modified thickness maps for the infill units that honoured the infill thickness where present, but also had a thickness (comprised of Proterozoic basement rock) elsewhere.

The Cenozoic materials are represented exclusively in Model Layer 1 with thickness ranging from 0-25 metres, consistent with bore log data. The Permian units varied greatly in thickness, and there were limited data regarding the division between upper

Permian and lower Permian (Basal Conglomerate). Furthermore, in some cases all Permian material was identified as lower Permian (Basal Conglomerate), and in other cases only upper Permian material was identified. Thus, because the average thickness of the upper Permian where identified was about 50 metres, the upper Permian was assigned to Model Layer 2 with a maximum thickness of 50 metres, and all material in the upper 50 metres was assumed to be upper Permian. The remaining Permian material above the Proterozoic basement surface was divided into Model Layers 3 and 4, with uniform thickness of 50 metres each. These layers were assumed to contain only lower Permian (Basal Conglomerate) material.

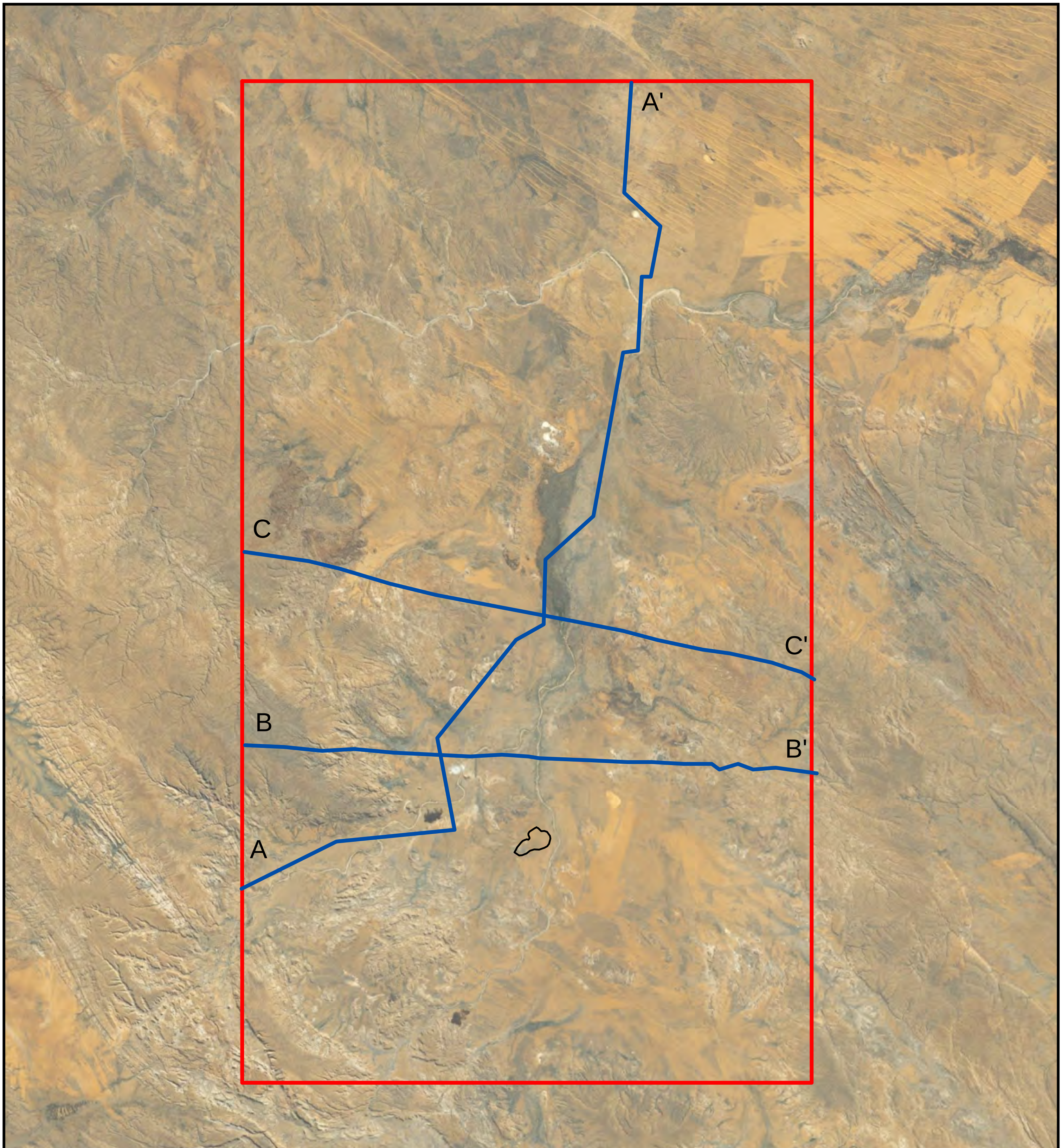
Cross sections were constructed from the model using the model grid to illustrate the vertical distribution of geologic units. Locations of these cross sections are provided in Figure C3-1. Section A-A' is cut along the central palaeochannel axis from southwest to northeast through the pit in the direction of groundwater flow (Figure C3-2). Section B-B' is cut from west to east through both branches of Yandagooge Creek approximately 500 metres north of the pit (Figure C3-3). Section C-C' is also cut from west to east but located approximately 3 km north of the pit through a deeper portion of the central palaeochannel (Figure C3-3).

3.1.2 Site-Specific Geologic Data

Once the geologic surfaces were imported into the model, bore log and surface geology data were used to more specifically identify the lithology at each location. The surface geology maps (Hickman and Clarke, 1994; Bagas et al., 2000) were digitized into Layer 1 of the model. Then, the actual logged lithology from bore logs was used to slightly modify the lithology of Layer 1 as necessary. For example, logged lithology was used to determine the approximate grain size classification of the Cenozoic sediments where possible.

The Permian units were digitized using the calculated extent in each layer generated during the contouring described above. The edges of the Permian zones were modified slightly if needed based on bore log data.

To determine where the various Proterozoic units were located in each model layer, a two-step process was used. First, examination of the published cross-sections on surface geologic maps indicated that the units were all tilted to such an angle that their horizontal extent was fairly consistent with depth. Therefore, the Proterozoic surface geology was assumed to be consistent with depth as a first cut. Next, the bore log data were compared to the layer elevations using a database to determine what the primary lithology was in each layer, and then plotted in GIS. These data points were used to manually digitize the edges of each Proterozoic unit with depth.



Model Domain

Proposed Pit Location

Cross Section

0 2,000 4,000 8,000

Met s

N

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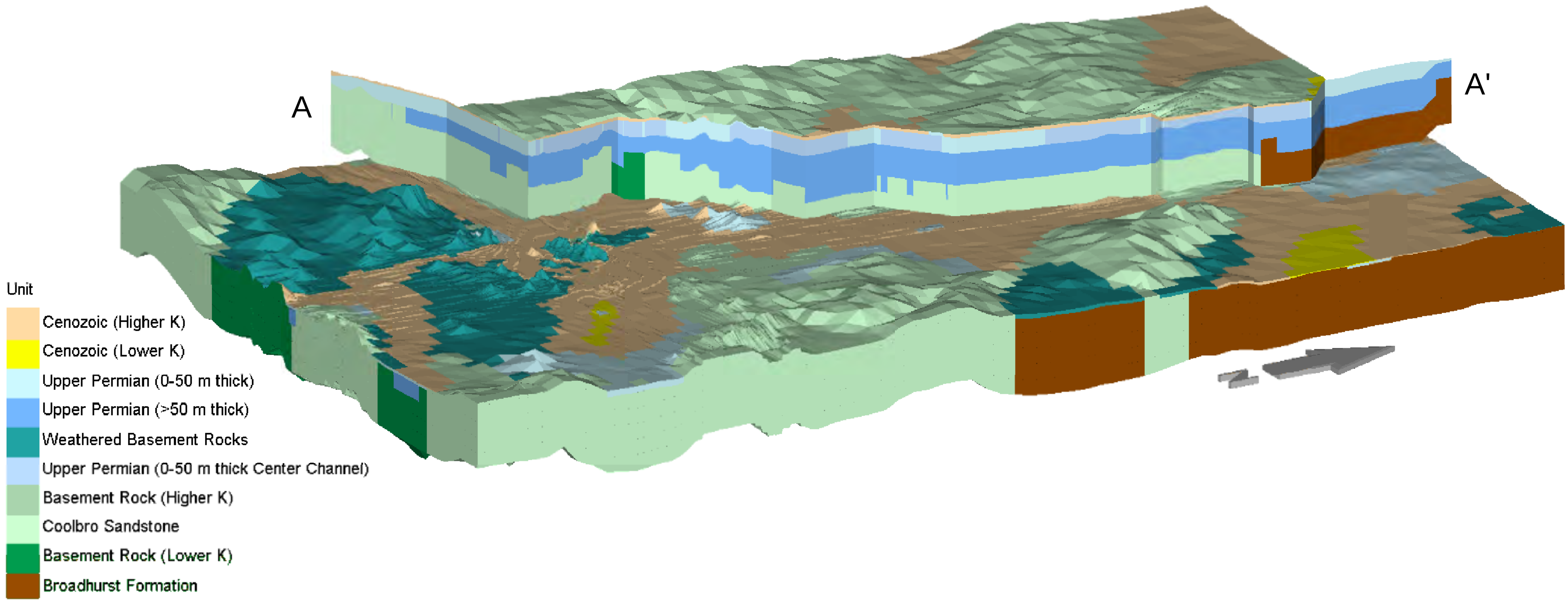
Figure C3-1. Cross-Section Location Map



Note: colored blocks represent model cells in profile

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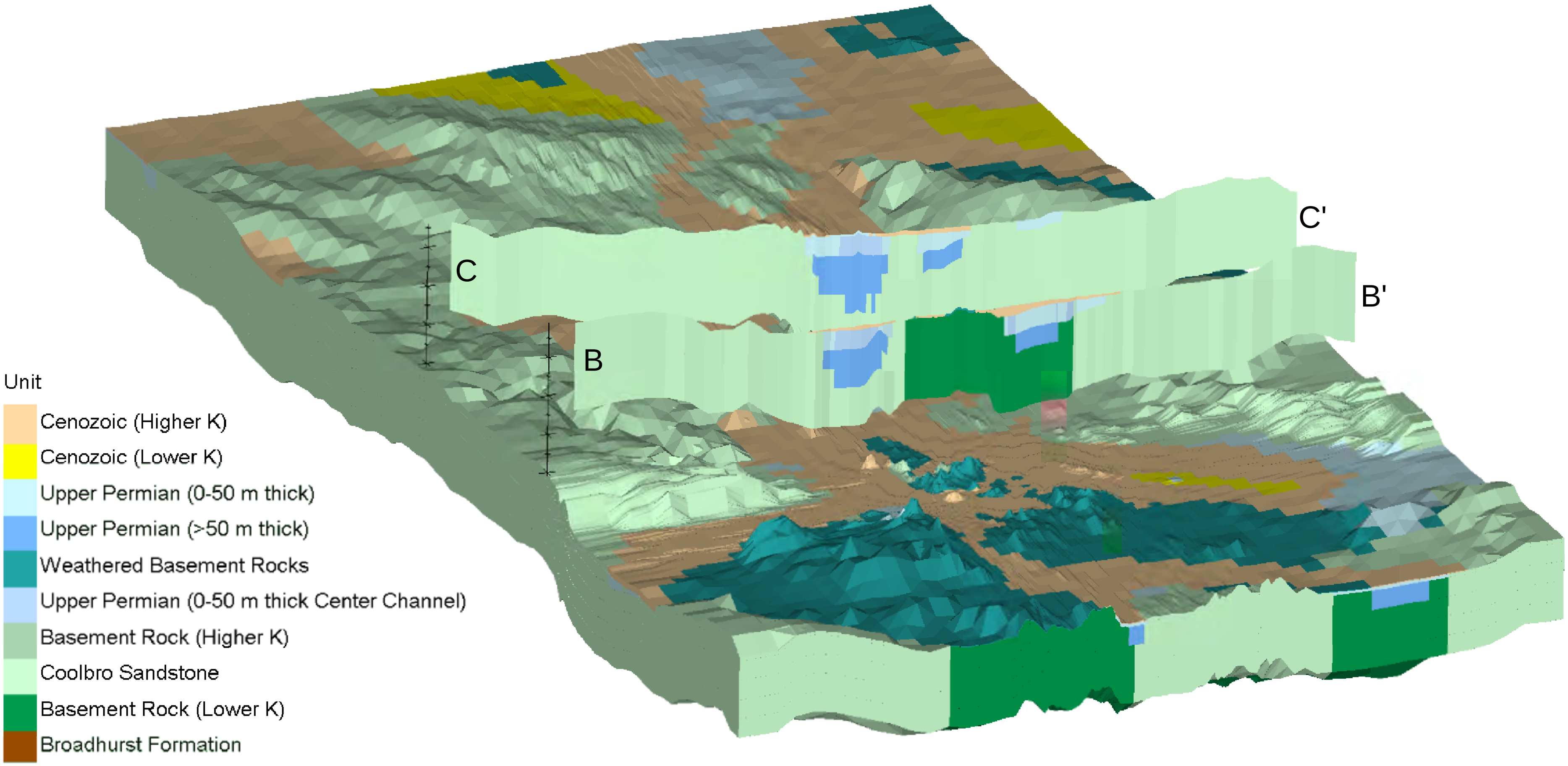

Note: colored blocks represent model cells in profile

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TETRA TECH GEO 363 Centennial Pkwy, Suite 210 Louisville, Colorado 80027	**Cameco Australia Pty Ltd** PROJECT NAME: Kintyre ERMP GW Flow Model DATE: July 2, 2012 PROJECT NO.: 117-0532005	**Figure C3-3. Cross-Sections B-B' and C-C'**

3.2 Hydrogeologic Evaluation

Once the model geology was complete, an evaluation of the available hydrogeologic data was conducted. The purpose of this evaluation was to determine which hydrogeologic data would be used to create a calibration data set for the model. The available data sets were:

- Department of Water's Water Information (WIN) database,
- Manual water levels,
- Aquifer test data, and
- Water level transducer data.

WIN database. This database includes measured water levels from all over Western Australia; it also has limited data near the modelled area. The WIN database proved to be useful in creating initial estimates of boundary conditions for the model.

Manual water levels. Manually measured water levels are available for Project area bores from January 1987 to present. The following ranges are available:

- The 1P, 2P, 3P, 4P, 6PD/I, 9P, 10P clusters –1987 to present.
- The 5P, 7P, 6PS clusters and bores A, B, C, G, and H – 1987 to 1988.
- The 11P, 12P, 13P, 15P clusters – 1987 to 1996.
- The 8P cluster – 1987 to 1997.
- KWP1, KWX2 to KWX5, KWX7A to KWX9, and KWX11 – 1997 to present
- CWB1 to CWB11, WEX5 clusters, and WEX3 – 2009 to present.
- CWB12 to CWB15, WEX1, WEX2, and WEX4 – 2010 to present
- KEB1 and KEB2 – 2011 to present
- CWB16 to CWB19 – 2012 only (these bores were just installed recently).
- OB3, OB16, TPB3, and TPB16 – 1988 to present

There are also a few bores that were only measured once or twice near the time they were installed and therefore are not mentioned above.

Aquifer test data. Various aquifer tests were completed in Project area bores between 1987 and 2012. The initial aquifer test data are not available electronically; the first easily available data set is from 2011. Aquifer testing events included the following.

- November/December 1987 – This event involved constant rate testing of bores 1PI, TPB3, 15PI, TPB16, and 13PI (Dames and Moore, 1987). Falling head tests were performed in a number of other bores.
- June 1997 –Constant rate tests (CRTs) on bores KWP1 and 15PI (Hydro Resources, 1997).
- October 2009 to January 2010 – CRTs on bores KWP1, North Bore, WEX5D, and CWB8D (MWH, 2010).
- April to May 2011 – CRTs were performed on bores KEB1, KEB2, CWB12, CWB13, CWB14, and CWB15 (MWH, 2011). These tests generally lasted three days, followed by about three days of recovery.

- April to May 2012 – CRTs were completed on bores CWB8S, CWB17, CWB18, CWB19, KEB2, and WEX5S (Pennington Scott, 2012a). The tests in bores CWB8S and WEX5S were 9 hours long and intended to briefly assess the upper Paterson hydraulic conductivity. The other tests ranged in length up to three days. Recovery measurements were taken until at least 90% recovery was observed after the three-day tests.

Water level transducer data. Transducer data sets are available electronically for a number of wells. Long-term transducer data were collected from the following bores:

- 1PI – starting in May 2011
- 9PS, 9PI – starting in December 2009
- 10PS, 10PD – starting in December 2009
- CWB3S – starting in May 2011
- CWB6S, CWB6D – starting in June 2010
- CWB11S, CWB11D – starting in May 2011
- TPB3 – starting in June 2010
- WEX2 – starting in June 2010
- WEX3 – starting in May 2011
- WEX5S, WEX5D – starting in June 2010

Transducer data were also collected from many of the pumping and monitoring bores Cameco used during the aquifer testing events (MWH, 2010; MWH, 2011; Pennington Scott, 2012a).

From the available hydrogeologic data sets described in this section, both steady state and transient calibration data sets were selected.

3.2.1 Steady State Data Set

An evaluation of the manual water level data was performed to determine the best way to construct a steady state calibration data set. Initially it appeared that the system should have been at steady state throughout the time of measurement, since no pumping bores were in operation nearby. In that situation, one reasonable method to assemble a steady state calibration data set would be to average the groundwater elevations measured at each bore over time to obtain a single value for each bore.

However, as noted in Section 4.3.1 of Pennington Scott (2012), the area has experienced an increase in recharge beginning in 1994. The water levels measured in Project area bores have increased by about 4 metres from the 1980's to present which appears to be a result of the increased recharge. This clearly presents a problem if the averaging method were to be followed to obtain a steady state calibration data set.

Therefore, the most recent groundwater elevation data set was used as the calibration data set. This is a reasonable approach because the current precipitation regime has been in place for a number of years at this point. At the time of model preparation, the most recent data set was primarily composed of March 2012 data, with a few exceptions. CWB8D and North Bore were last measured in April 2011. Bores CWB17, CWB18, and CWB19 were measured in April 2012. Bores OB16 and 2PS were measured in May 2012. This steady state calibration data set is the data set shown on Figure C2-3.

3.2.2 Transient Pumping Data Sets

The two most recent aquifer testing events were selected for transient model calibration. These two data sets included the KEB1, KEB2, CWB12, CWB13, CWB14, and CWB15 testing completed in 2011, and the CWB17, CWB18, and CWB19 testing performed in 2012. Each data set had interesting features discussed below.

The 2011 testing was performed in a very compressed time frame, with multiple bores tested simultaneously. Each pumped bore was subjected to step testing at various rates before the CRT began. As a result of the compressed time frame, some of the bores did not fully recover from the step testing before the CRT began. In addition, in some cases multiple CRTs and step tests had to be performed because the initially selected rate proved too high to sustain over the planned 3-day test. However, data were collected meticulously with nearly 3,000 manual water level measurements over the course of the testing. Hence, the entire set of manual water level measurements was used as the calibration data set for the 2011 aquifer testing event. Figure C3-4 illustrates the raw data generated by the 2011 aquifer testing event.

Aquifer testing in 2012 was undertaken over a longer time frame to allow adequate recovery time between step tests and CRTs, and between testing at the different bores. However, there were very few monitoring bores that responded to testing, so the primary response was in the pumped bore. In addition, due to the large distances between bores and due to other field activities that had to be performed while testing, a fairly limited set of manual water levels was collected. One benefit of the less-aggressive schedule was that the step tests did not have to be represented in the model, since full recovery was experienced by each bore prior to the CRT. Figure C3-5 illustrates the raw data generated by the 2012 aquifer testing event.

Figure C3-4. Measured Drawdown – 2011 Aquifer Testing Event

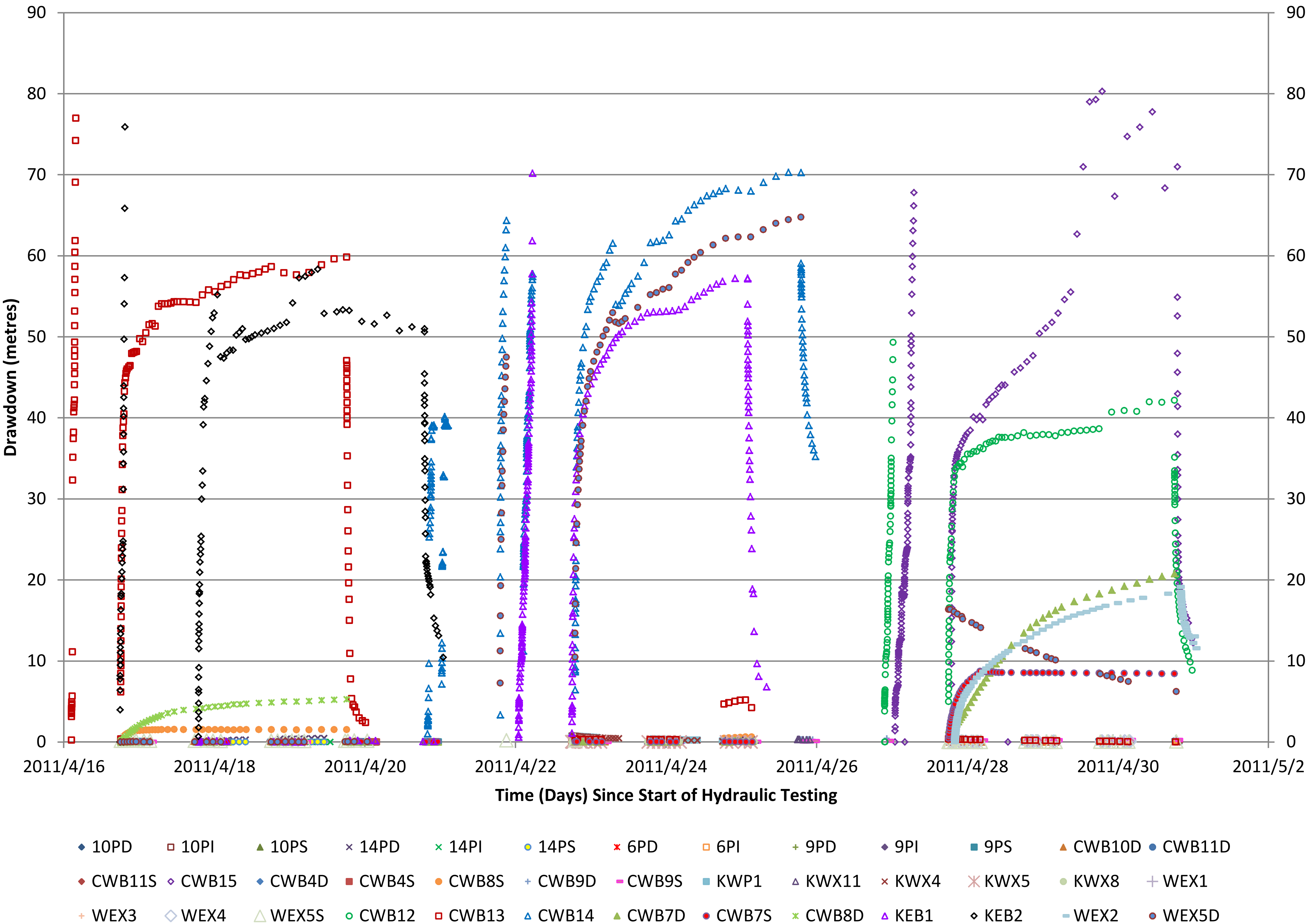
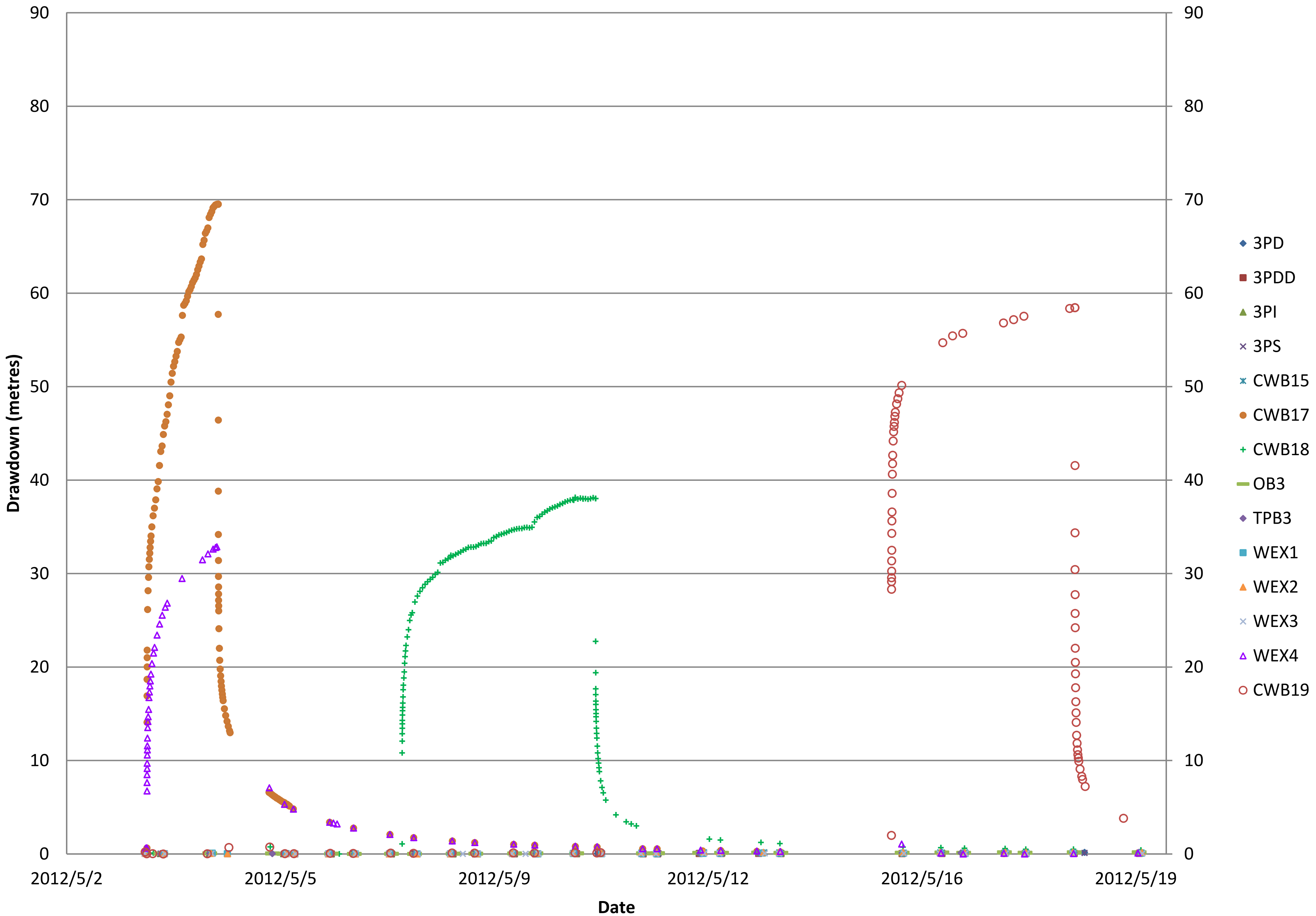


Figure C3-5. Measured Drawdown – 2012 Aquifer Testing Event



4.0 Numerical Groundwater Flow Model

The Kintyre area numerical flow model was constructed in several stages. First, a model was constructed to match the steady state and transient calibration data set. Next, the calibrated model was refined to a local scale in order to better simulate pit dewatering and pit lake formation. Third, the regional model was used to simulate both the pit dewatering and the regional water supply pumping. Finally, the regional and local models were run for 1,000 years to simulate post-mining conditions and development of a pit lake. The following simulations document the numerical model construction, calibration, and predictive simulations.

4.1 Numerical Code Selection

MODFLOW-SURFACT (HydroGeoLogic, 2010) was selected for use over the traditional MODFLOW model code due to the following capabilities: 1) the code allows modelling of free movement of the water table in unconfined layers (while satisfying flow-continuity requirements), which is important for modelling a steep water table in multiple layers, such as in a pit dewatering simulation; 2) improved and faster solvers (Pre-Conditioned Conjugate Gradient (PCG) solvers PCG4 and PCG5); and 3) adaptive time-stepping and output control package (ATO4) that reduces simulation time and makes it possible to achieve convergence in complex transient simulations, such as this project. The Newton formulation of MODFLOW-2005, MODFLOW-NWT (Niswonger et al., 2011), was selected initially for this project due to its capability to solve problems involving drying and rewetting nonlinearities of the unconfined groundwater-flow equation. However, due to the complex pumping schedule for the transient modelling simulation (see Section 3.5.3.1), convergence was not possible without using the ATO4 package available in MODFLOW-SURFACT.

4.2 Regional Model Grid Domain

The regional model domain encompasses an 806 square kilometre area (Figure C1-2). The selected northern, eastern, western, and southern model boundaries are located far enough away from the Kintyre pit to minimize potential boundary effects in the mining-phase and post-closure simulations.

The regional model domain was selected to evaluate water supply alternatives from the proposed borefield to the north of the Kintyre deposit (Figure C4-1).

A telescoping horizontal regional model grid was used to increase the simulation resolution in the pit area, while maintaining a manageable number of cells in the entire model domain. The model grid cell width was selected as 500 metres at the model domain edges, decreasing to a cell width of 50 metres in the vicinity of the Kintyre pit (Figure C4-1). The model grid was also aligned north-south and east-west since groundwater predominantly flows from south to north.

The vertical regional groundwater flow model grid was constructed using 11 model layers with constant thicknesses except for Model Layers 1, 2, and 7 (Table C4-1). The top of Model Layer 1 was generated from ground surface elevation data. Model Layers 1 and 2 have variable thickness to simulate the change in thickness of the Cenozoic sediments and upper Permian sediments, respectively (see Section 3.1.1 for more details). Model Layer 7 has variable thickness to create horizontal model layers from Layers 8 through 11, which were added to accurately simulate drawdown from the water supply bores north of the site. Figures C4-2, C4-3, and C4-4 illustrate the modelled top of Layer 1 (ground surface), bottom of Layer 1, and bottom of Layer 2. As noted in the previous section, Figures C3-1, C3-2 and C3-3 provide a cross-section location map and cross-sections through the model domain in a north-south and east-west direction, respectively.

Table C4-1. Model Layer Elevations and Thicknesses

Model Layer	Top Elevation (m)	Layer Thickness (m)
1	506	2 to 25
2	504	0.6 to 50
3	496	50
4	446	50
5	396	50
6	346	50
7	296	25 to 246
8	50	200
9	-150	350
10	-500	700
11	-1,200	1,050

4.3 Model Recharge Distribution

As described in Section 2.2.1, several recharge zones were implemented across the model domain. Figure C4-5 shows the model recharge distribution and final calibrated values. The final values were:

- Rudall Complex – 0.44 mm/yr;
- Paterson Formation (also includes Broadhurst Formation) – 1.35 mm/yr;
- Coolbro Sandstone – 4.4 mm/yr; and
- Paterson Formation (incised portion in easternmost part of modelled area) – 3.5 mm/yr.

The recharge values include the effects of evapotranspiration (ET). In the groundwater flow model, recharge was applied to the uppermost active model cell within the entire model domain. The Evapotranspiration Package is not being utilized for this model, since the recharge based on chloride data already incorporates the effects of evapotranspiration.

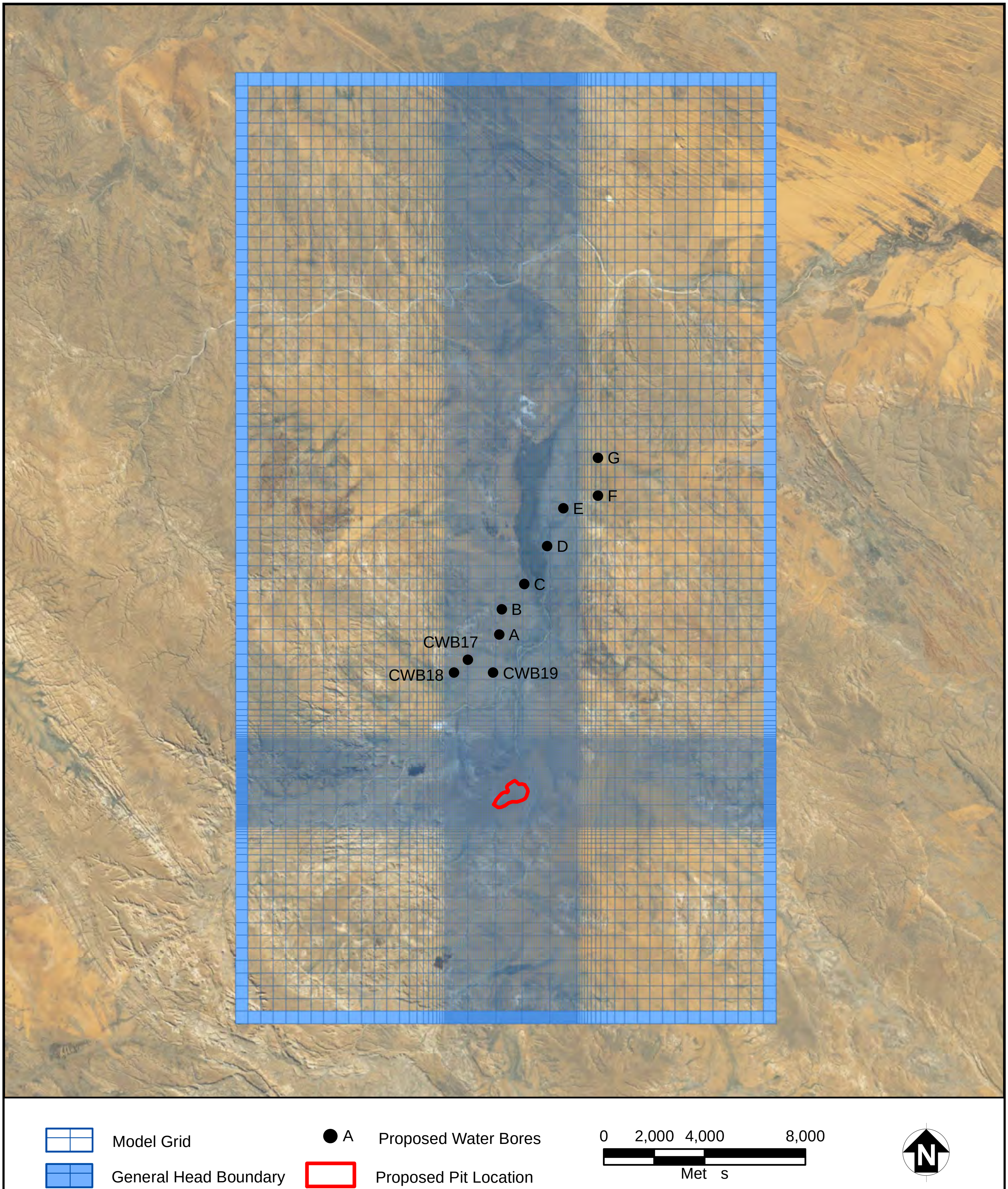


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Figure C4-1. Regional Model Features

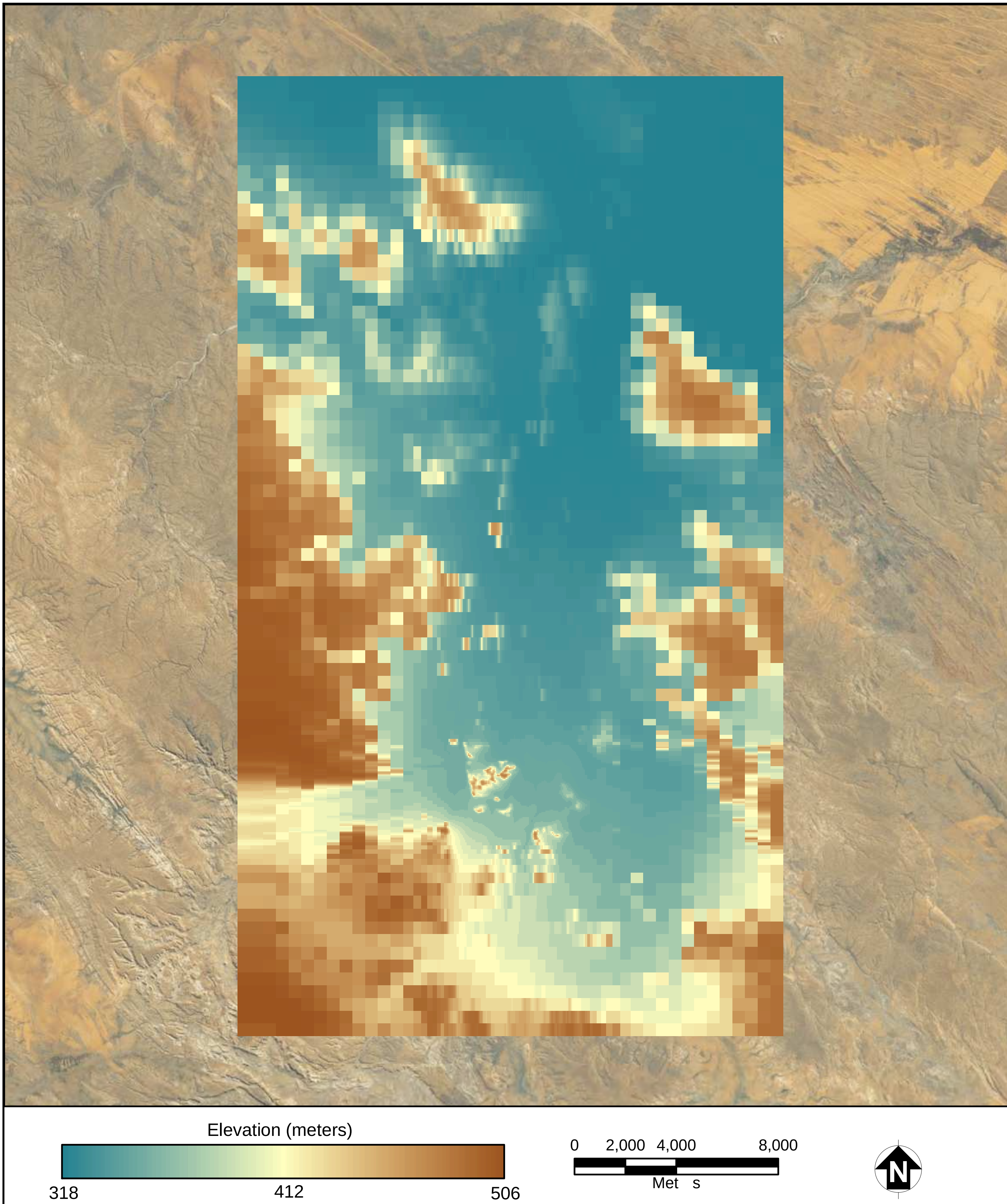

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Figure C4-2. Top Elevation of Layer 1

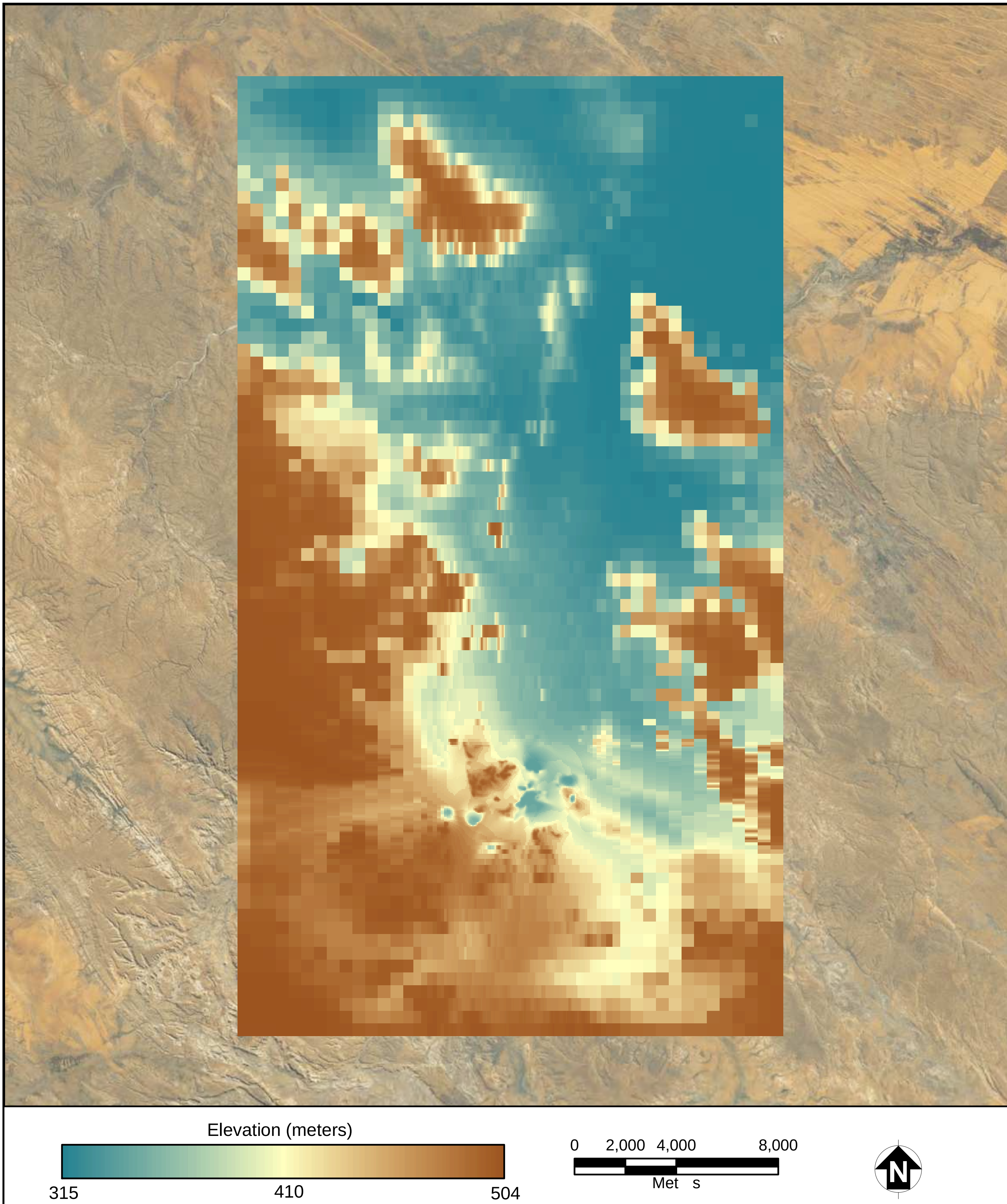

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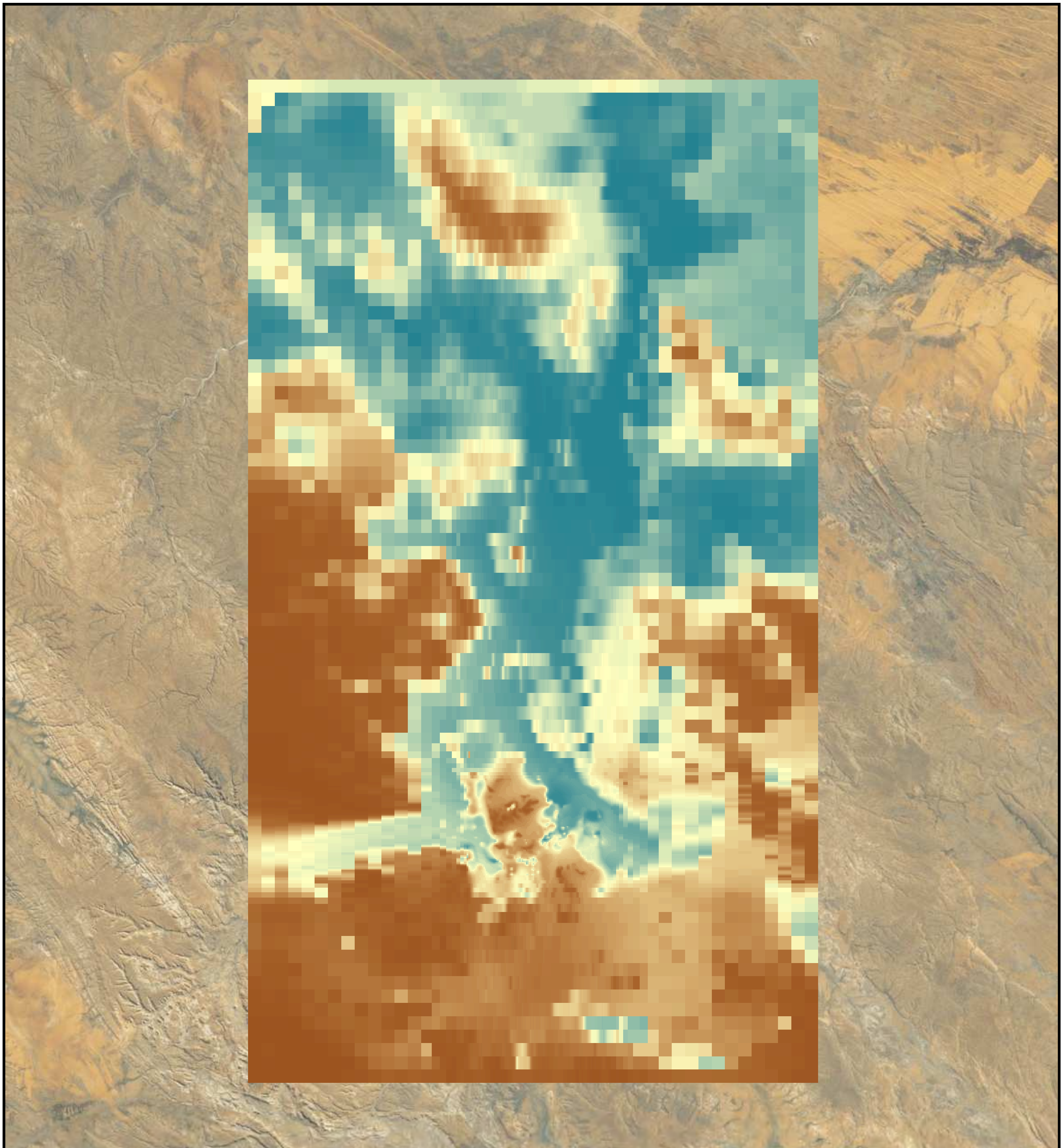
Figure C4-3. Bottom Elevation of Layer 1



Elevation (meters)

274 385 496

0 2,000 4,000 8,000

Met s

N

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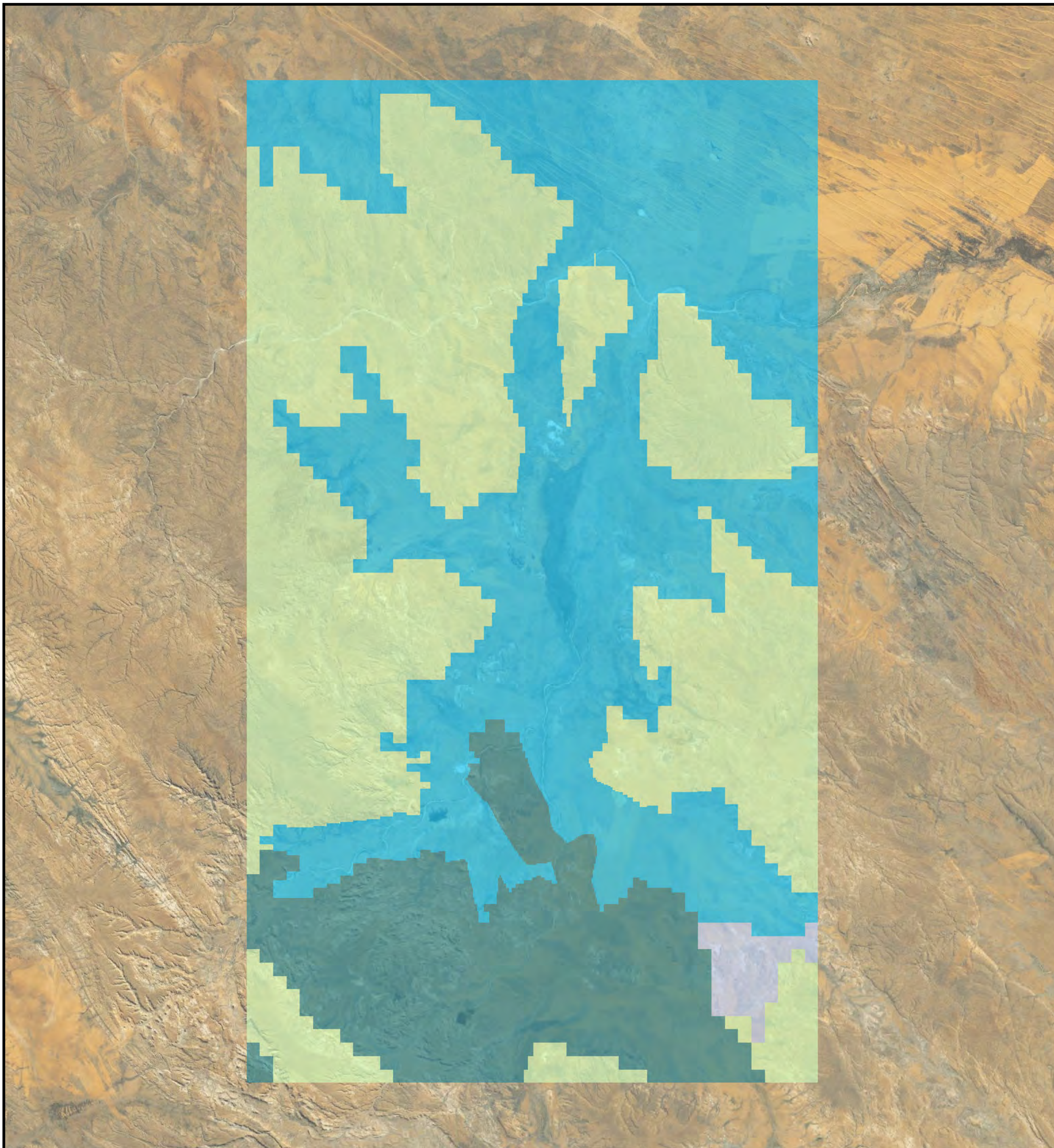
Figure C4-4. Bottom Elevation of Layer 2



Rudall Complex, 0.44 mm/yr	Paterson (incised portion), 3.5 mm/yr
Paterson and Broadhurst, 1.35 mm/yr	Coolbro Sandstone, 4.4 mm/yr

0 2,000 4,000 8,000
Met s

N

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Figure C4-5. Recharge Distribution

4.4 Model Boundary Conditions

Model boundary conditions in the Kintyre model consist of general head boundaries, groundwater pumping, and one small horizontal flow barrier representing a fault (discussed in section 4.4.3). Drains and lake cells were employed in the predictive modelling but not during calibration; hence, these are discussed in the mining and post-mining sections of this report.

4.4.1 General Head Boundaries

The external model boundaries were modelled using General Head Boundaries (GHB) in MODFLOW-SURFACT. This approach was adopted due to the lack of information about water levels and hydrogeologic divides in the vicinity of the Kintyre deposit and the fractured nature of the Proterozoic bedrock. An initial attempt to represent GHBs at the average measured depth to water resulted in heads above land surface in the centre of the model. Hence, hydraulic heads in the GHB cells were initially based on contoured regional groundwater elevation data extracted from the Department of Water's WIN database, which resulted in a more reasonable water table. Figure C4-6 shows the location of the GHBs and their final calibrated hydraulic head values. These heads were slightly modified during calibration to achieve a better match to site data. The vertical gradient at the model boundaries is not known, and the measured vertical gradient at the site is not consistent over time or between bore clusters. Therefore, no vertical gradient between model layers was imposed using the GHBs. Topography indicates that groundwater generally flows from south to north toward the discharge location at Lake Waukarlykarly.

4.4.2 Groundwater Pumping

As stated earlier, because Kintyre is located in a remote area not developed for pastoral use, there are no stock bores in the area and water level data are limited mainly to mining investigations. Therefore, there are no long-term stresses applied to the groundwater system or the numerical model. However, there were short-term stresses (i.e., 1-3 days) from aquifer testing conducted by previous investigations near Kintyre [e.g., MWH (2011), Pennington Scott (2012)]. Drawdown data from these aquifer tests were used during transient model calibration.

4.4.3 Horizontal Flow Barrier

Regional geologic maps from Czarnota et al. (2009) and Hickman and Clarke (1994) show northwest/southeast trending faults, folds, and shear zones throughout the Kintyre area in the basement rocks. Faults acting as barriers to groundwater flow in MODFLOW-SURFACT are typically specified using the Horizontal Flow Barrier (HFB) package; while faults or shear zones acting as conduits would be represented using increased hydraulic conductivity zones. Initially, no faults were included in the numerical groundwater flow model, since the hydraulic properties of the faults shown on Figure C2-1 are not known. However, during calibration it was ultimately necessary to represent one small fault near KEB1; the rationale and basis for this fault are discussed in Section 4.6. This small fault is shown on Figure C4-6.

Elevation (meters)

285.8 338 389.5

Proposed pit extent

N

0 2,000 4,000 8,000

Met s

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Figure C4-6. Calibrated General Head Boundary Values

4.5 Model Hydraulic Conductivity Distribution

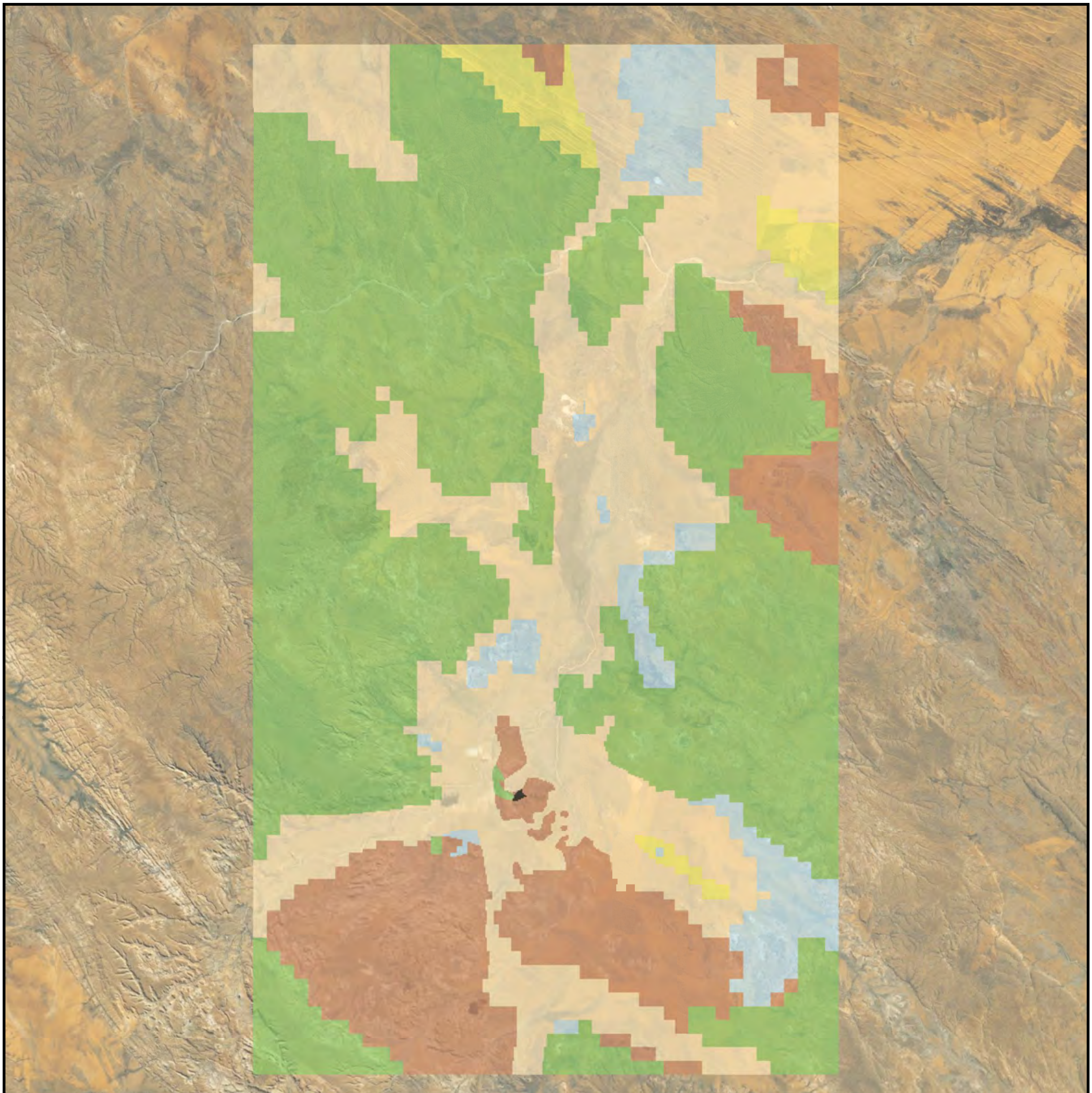
The model hydraulic conductivity (K) distribution was based on the regional and local geology. The basic units represented using hydraulic conductivity zones are the Cenozoic Sediments, the Permian units (Paterson Formation), and the Proterozoic units (Broadhurst Formation, Coolbro Sandstone, and Basement Rock). Table 4-2 in Pennington Scott (2012) summarises available information regarding horizontal and vertical hydraulic conductivity (Kh and Kv) and storage parameters based on:

- the values determined in previous investigations;
- interpretation of aquifer tests; and
- empirical values used elsewhere in WA.

Figures C4-7 to C4-12 present the hydraulic conductivity zones in Model Layers 1 through 6. The hydraulic conductivity zones are described in more detail below. The calibrated hydraulic conductivity and storage coefficient values are presented in Table C4-2. These zone values are briefly discussed below, and their effects on calibration are discussed in more detail in Section 4.6.

Table C4-2. Calibrated Hydraulic Conductivity and Storage Coefficient Values

Hydraulic Conductivity (K) Zone	Horizontal Hydraulic Conductivity (metres/day)	Vertical Hydraulic Conductivity (metres/day)	Specific Storage (1/metre); Specific Yield
Cenozoic (higher K)	9.5	0.021	Sy = 0.03
Cenozoic (lower K)	0.026	0.0017	Sy = 0.03
Upper Permian (0-50 metres thick)	0.36	0.050	5.00E-07; Sy = 0.03
Upper Permian (central channel)	0.097	0.050	5.00E-07; Sy = 0.03
Lower Permian (>50 metres thick)	0.067	0.0021	5.00E-07; Sy = 0.005
Weathered Basement	0.01	0.01	5.00E-07; Sy = 0.0001
Broadhurst Formation	0.001	0.005	1.00E-06; Sy = 0.01
Coolbro Sandstone	0.40	0.0001	1.00E-07; Sy = 0.01
Basement Rock (higher K)	0.080	0.067	5.00E-07; Sy = 0.0001
Basement Rock (lower K)	0.007	0.26	1.00E-07; Sy = 0.0001



Cenozoic (higher k)
Cenozoic (lower k)
Upper Permian (0-50m thick)
Upper Permian (center channel)
Lower Permian (>50m thick)
Weathered Basement Rock
Broadhurst Formation
Coolbro Sandstone
Basement Rock (higher k)
Basement Rock (lower k)

N

0 2,000 4,000 8,000
Met s

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Figure C4-7. Hydraulic Conductivity Zones - Model Layer 1

Cenozoic (higher k)	Weathered Basement Rock
Cenozoic (lower k)	Broadhurst Formation
Upper Permian (0-50m thick)	Coolbro Sandstone
Upper Permian (center channel)	Basement Rock (higher k)
Lower Permian (>50m thick)	Basement Rock (lower k)

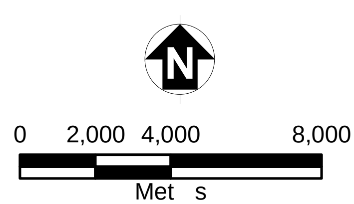

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Figure C4-8. Hydraulic Conductivity Zones - Model Layer 2

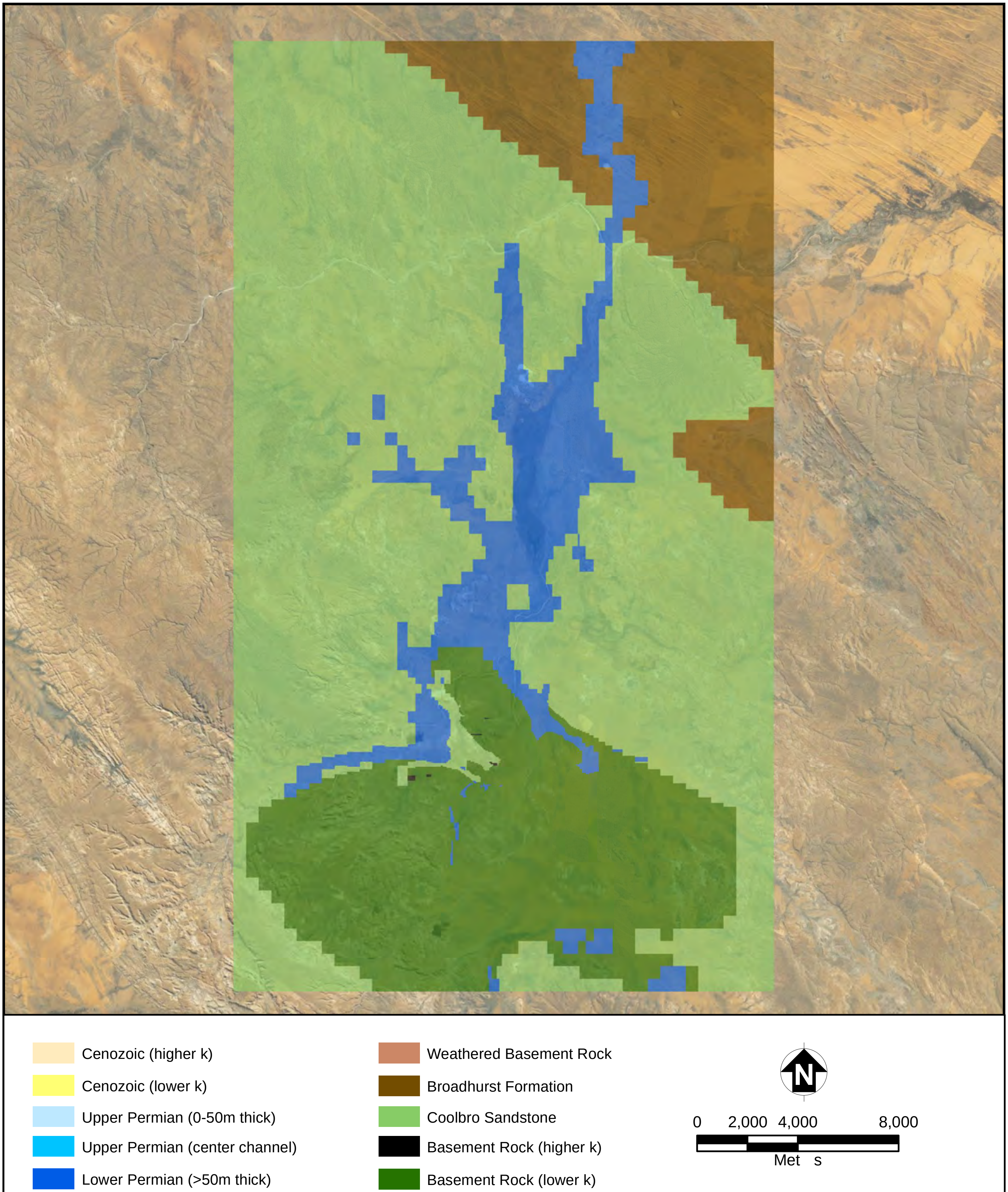

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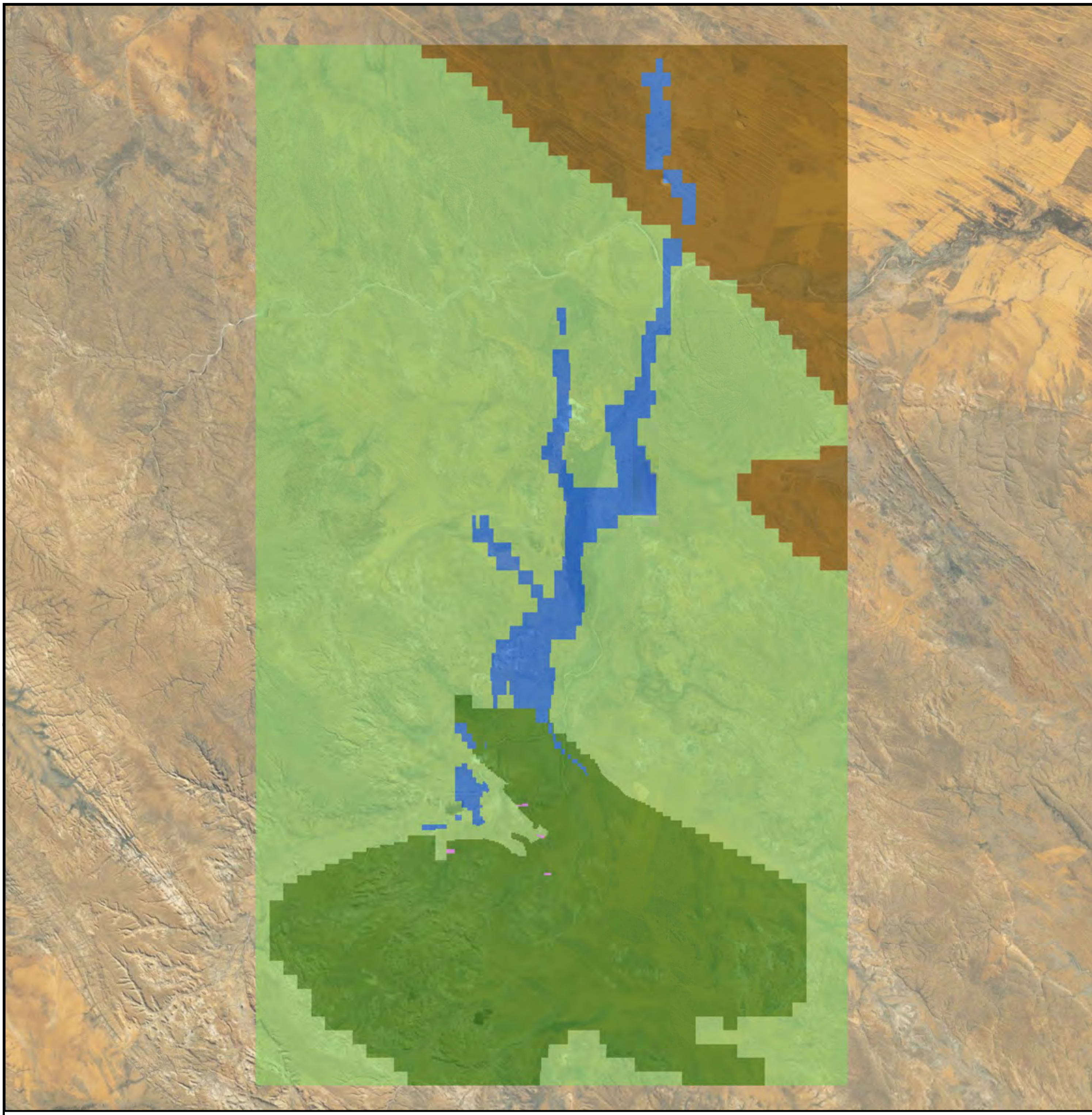
Figure C4-9. Hydraulic Conductivity Zones - Model Layer 3



Cenozoic (higher k)	Weathered Basement Rock
Cenozoic (lower k)	Broadhurst Formation
Upper Permian (0-50m thick)	Coolbro Sandstone
Upper Permian (center channel)	Basement Rock (higher k)
Lower Permian (>50m thick)	Basement Rock (lower k)

N

0 2,000 4,000 8,000
Met s

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Figure C4-10. Hydraulic Conductivity Zones - Model Layer 4

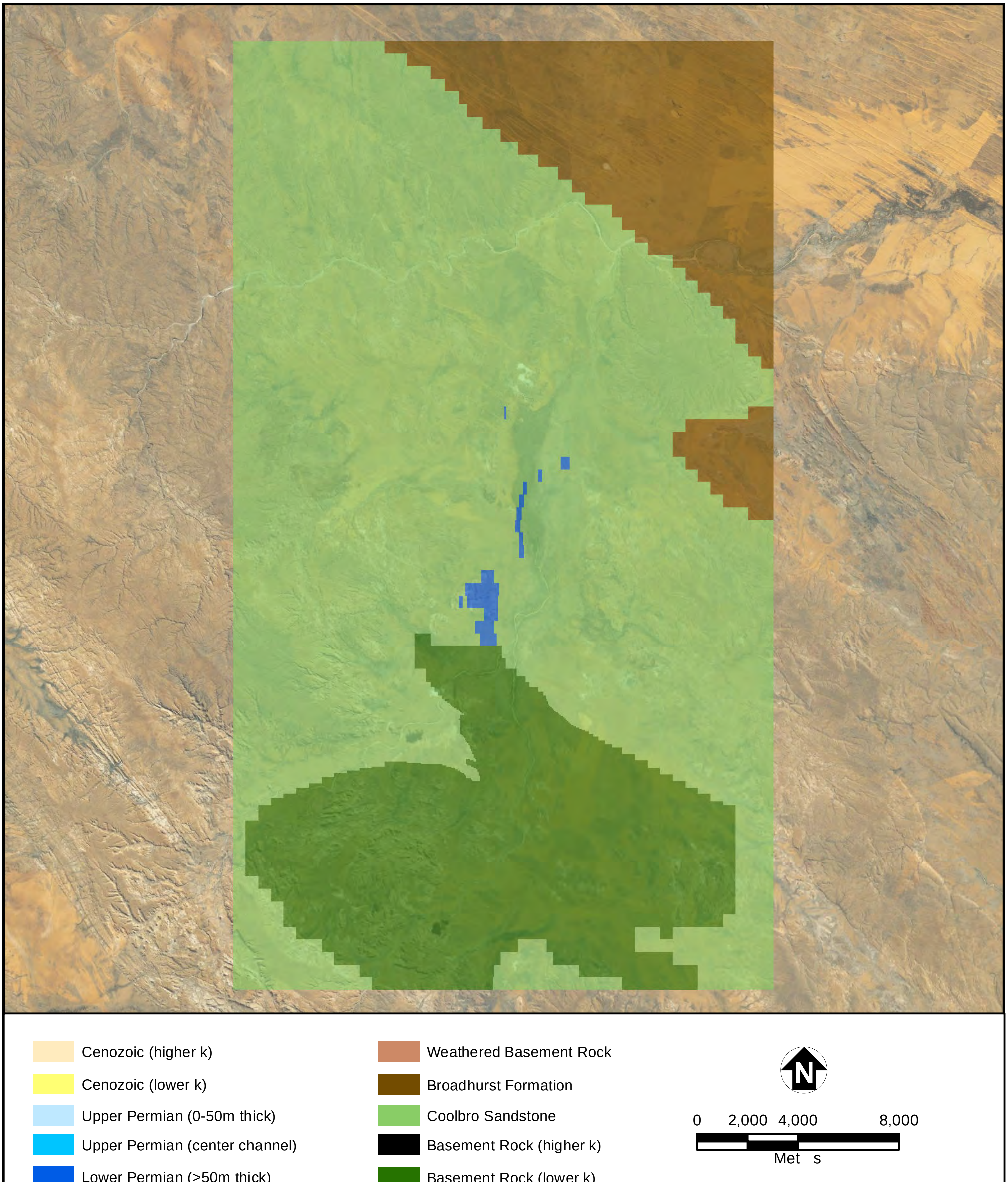

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Figure C4-11. Hydraulic Conductivity Zones - Model Layer 5

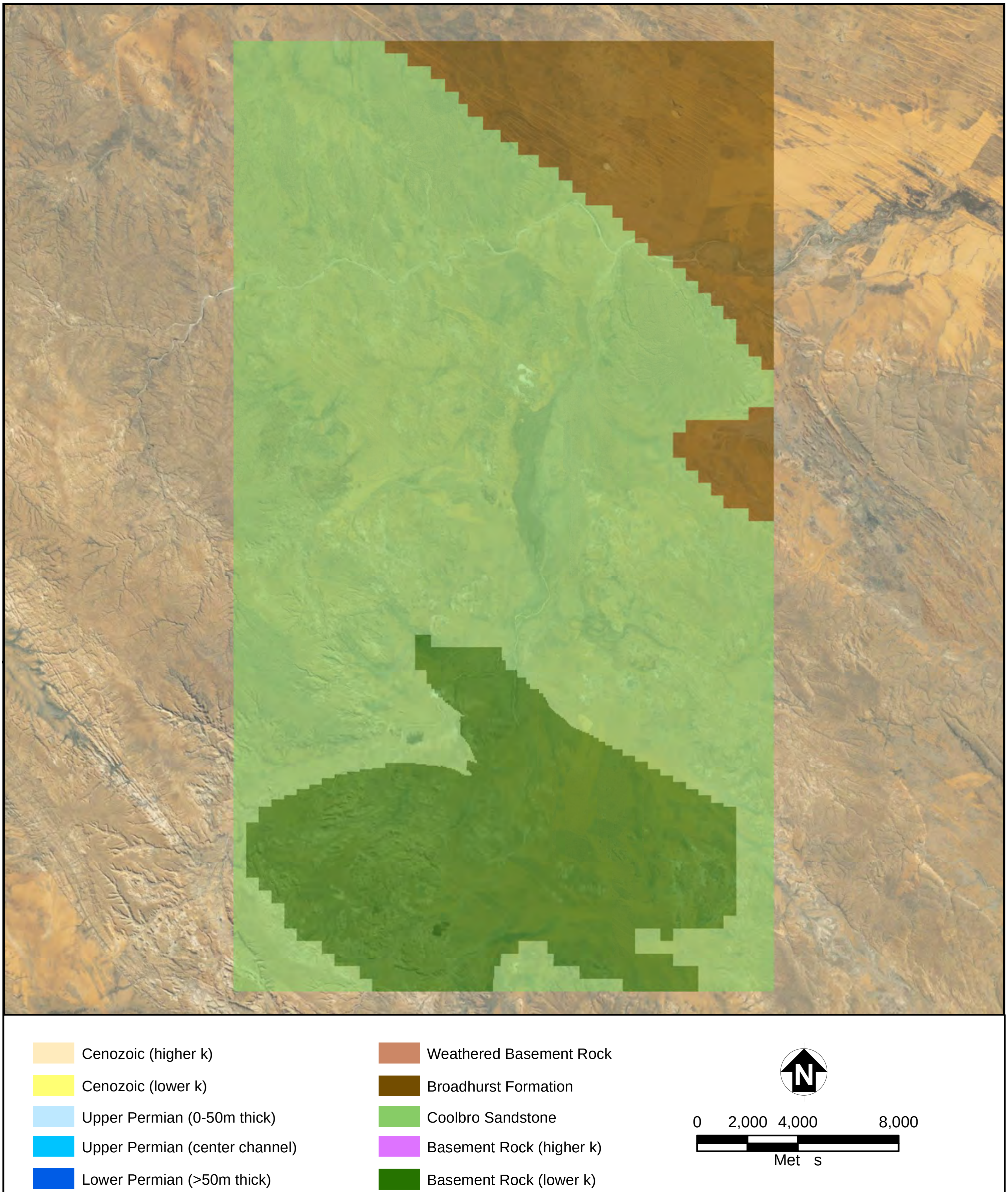

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Figure C4-12. Hydraulic Conductivity Zones - Model Layer 6

4.5.1 Cenozoic Sediments

The Cenozoic sediments are basically unconsolidated alluvial, fluvial, and/or Aeolian sediments. Since many borehole logs did not identify whether the sediments were Palaeogene, Neogene, or Quaternary in age, all three Cenozoic periods were grouped together for modelling purposes.

The upper unconsolidated Cenozoic (including Quaternary) alluvium appears to be mostly unsaturated in the Kintyre area. In areas where they are saturated, these alluvial deposits usually contain brackish to saline water. These are represented in the model entirely in Layer 1 (see Figure C4-7).

The model uses two hydraulic conductivity zones to represent the Cenozoic sediments: higher conductivity (sands and gravels) and lower conductivity (finer grained sediments). The higher K zone has a calibrated hydraulic conductivity of 9.5 m/day. This is in keeping with the estimates provided in Table 4-2 of Pennington Scott (2012), and with the visual observation that the sediments are composed of sand, gravel, and often large cobbles due to cyclone-related flooding events in the channel. The ratio of vertical K (Kv) to horizontal K (Kh) is about 1:500; this is reasonable in light of the likely stratification of very high K cobbles and gravel to low-K silts often deposited during flood events. The lower K zone has a calibrated hydraulic conductivity of 0.026 m/day, which is in keeping with the logged clayey lithology of these lenses. The Kv:Kh ratio of the lower K zone is about 1:15, which is reasonable (for stratified, but potentially more uniform, silty to clayey sediments.

A specific yield of 3% was used based conservatively on the low end of the range presented in Pennington Scott (2012).

4.5.2 Permian Units

The Permian units represented in the model are identified with the Paterson formation shown on the Broadhurst geologic map (Hickman and Clarke, 1994). For purposes of modelling, the Permian units were subdivided into two zones: upper Permian and lower Permian.

4.5.2.1 Upper Permian

The model is sensitive to the vertical anisotropy of the upper Permian, particularly when the bores are only screened in the Basal conglomerate and bentonite grouted through the upper Permian. Existing geologic logs indicate that fine grained layers exist within the upper Permian; as a result strong vertical anisotropy would be expected.

As described in Section 3.1.1, the upper Permian represents the upper 50 metres of the Permian Unit in the model. Hence, in some cases where the entire Permian Unit is less than 50 m thick, this model unit would include both upper and lower Permian. Furthermore, where detailed lithology was available, the upper Permian materials are not as fine grained as initially thought and include sandstones, conglomerates, and unconsolidated sands and gravels in places. In some cases the bore logs do not indicate the presence of a basal conglomerate; in other cases conglomerate extends over the entire Permian interval. Finally, many of the older electronic borehole logs do not indicate the grain size of the Permian material, but only that the Permian or Paterson Formation is present. Hence for the purposes of modelling, the Permian Unit was subdivided based on thickness rather than lithology.

One further subdivision of the upper Permian was made. Based on analysis of existing geophysical and borehole log data, a difference in hydraulic conductivity was apparent between the central and marginal portions of the palaeochannel in the upper Permian (Pennington Scott 2012),. Figure C4-8 indicates the placement of this channel.

The calibrated hydraulic conductivity estimates were similar between the two upper Permian zones. The main upper Permian zone had a calibrated Kh of 0.36 m/day, and the central channel had a calibrated Kh of 0.097 m/day. These values are well within the estimated K values shown in Table 4-2 of the main report. Both upper Permian zones had a Kv of 0.05 m/day, which represents anisotropy ratios of about 7 and 2, respectively. The calibrated specific storage and Sy values of 5e-7 per metre and 0.005, respectively, are within the expected range for fractured consolidated rock.

4.5.2.2 Basal Conglomerate (lower Permian)

The basal conglomerate is a conglomerate that is generally present at the bottom of the Permian Unit in palaeochannels near Kintyre. At other sites in WA, comparable basal conglomerate units are observed to have relatively high hydraulic conductivity and produce significant water. It was initially thought that the basal conglomerate near Kintyre would be similar; however, tested values for hydraulic conductivity were found to be significantly lower.

The calibrated Kh of the lower Permian was 0.067 m/day, and the Kv was 0.0021 m/day. Both these values are in keeping with the range of the values presented in Table 4-2 Pennington Scott (2012). The Kv:Kh ratio of approximately 1:30 seems reasonable, since the lower Permian is composed of a conglomerate which is essentially cobbles and gravel embedded in a matrix of low-permeability material that would be expected to hinder downward flow.

4.5.3 Proterozoic Units

The Proterozoic units in the Kintyre area are represented in the model using various hydraulic conductivity zones: Broadhurst Formation, Coolbro Sandstone, and Basement Rock. These categories are described in more detail below.

4.5.3.1 Broadhurst Formation

The Broadhurst Formation is part of the Yeneena Group, and is present only in the northeastern portion of the model area. It is comprised of thinly laminated sandstones, siltstones, and shales with some carbonate (Czarnota et al, 2009). The Broadhurst Formation has little impact on the model calibration overall, but was represented for completeness. The uppermost, weathered portion of this unit was represented in Layer 1 using the weathered basement hydraulic conductivity zone. In addition, the Broadhurst Formation was subject to uplift and erosion, and the portions underlying the palaeochannel were replaced by Permian and/or Cenozoic units (see Figures C4-7 to C4-12). Where not replaced by palaeochannel infill, the extent of Broadhurst Formation was assumed to remain constant with depth through Layer 6.

The Kv and Kh values of the Broadhurst Formation were not a sensitive model parameter, so their final values are not well constrained. The final Kh and Kv values were set to be low (0.001 and 0.005 m/day), consistent with the rest of the relatively unweathered basement rock. The storage and Sy values were also not sensitive, and were set to be consistent with the other consolidated basement rock units.

4.5.3.2 Coolbro Sandstone

The Coolbro Sandstone, and Broadhurst Formation are part of the Yeneena Supergroup; the Coolbro Sandstone occupies the basal portion of the group, conformably underlying the Broadhurst Formation. The Coolbro Sandstone is a regionally extensive sandstone up to 2.5 km thick with minor shale interbeds (Czarnota et al, 2009). In the Kintyre area, the Broadhurst geologic map (Hickman and Clarke, 1994) indicates that the Coolbro Sandstone is extensively folded and faulted with dip and dip direction varying widely. The Coolbro Sandstone is a potentially productive water-bearing unit.

The Coolbro Sandstone is represented in the model from Layers 1 through 6. In the absence of a detailed structural analysis and borehole log data, the extent of the Coolbro Sandstone outside of the immediate Kintyre vicinity was assumed to remain constant with depth through Layer 6.

The calibrated hydraulic conductivity values of the Coolbro Sandstone were fairly well constrained in the model. The Kh of 0.40 m/day is within the range of what one would expect for sandstone and within the range identified in Table 4-2 of Pennington Scott (2012). The Kv of 0.0001 m/day is lower than expected. The role of the Coolbro Sandstone Kv in the transmission of recharge and steady state model calibration is discussed in more detail in Section 4.7, Sensitivity Analysis. The specific storage (1e-7 1/m) and Sy (0.01) were conservatively set at the low end of what would be expected for sandstone, since there is very little information regarding these values in the Project area.

4.5.3.3 Basement Rock

Basement rock in the model generally represents the Rudall Complex. The Rudall Complex is older than the Yeneena Group, but within the Rudall Complex the stratigraphic succession has not been determined (Hickman and Clarke, 1994). For the most part, the basement rock in the model area is comprised of metamorphic rocks. In the Kintyre area, these rocks have little to no intergranular permeability, with groundwater yields and aquifer characteristics dependant on secondary structures, such as fault and shear zones. The most dominant of these structures are believed to be a series of northwest trending folds, faults and shear zones.

Four hydraulic conductivity zones were used to represent the basement rock in the model:

- Weathered basement – this is the uppermost, weathered clayey portion of the basement rock in Layer 1. It includes both weathered Rudall Complex and weathered Broadhurst Formation. The hydraulic conductivity of the weathered basement rock is represented as 0.01 m/day, both horizontally and vertically.
- Basement rock (higher K) – Rudall Complex banded iron formations, sandstones, calcrete, identified fault and shear zone materials, quartzite, and limestones were identified as potentially more conductive units. These units are not very extensive. In addition, a small portion of the Coolbro Sandstone near KEB1 is represented by this zone, since it appears to have a higher K than the basement rock as a whole, but a far lower K than most of the Coolbro Sandstone. Hence the unit designation was changed to match its apparent hydraulic properties. The calibrated Kh and Kv are 0.08 and 0.067 m/day. The similarity in Kh and Kv values is plausible because the rock types represented by this unit are highly

fractured, and in most cases have permeability related to primary porosity as well as secondary porosity (fractures and faults).

- Basement rock (lower K) – this zone represents the less-conductive Rudall Complex in model Layers 2 through 6. The calibrated Kh and Kv are 0.0078 and 0.26 m/day, respectively. Both were fairly well constrained in the model. The higher Kv seems reasonable because the main permeability pathways in the Rudall Complex are steeply dipping faults and fracture sets. The original rock type is schist, with very little primary permeability.
- Basement rock (undifferentiated) – below model Layer 6, no data were available regarding the type or properties of the basement rock. Further, Layer 6 ends at about 200 metres below ground level. The basement rock below this level was assumed to have minimal open fractures and to be generally nonconductive in nature. It was assigned a hydraulic conductivity of 0.001 m/d in both horizontal and vertical directions.

As indicated by Table 4-2 in Pennington Scott (2012), the basement rock has, in general, low storage capacity. The modelled values for specific storage (1e-7 to 5e-7) are at the low end of the possible range of values that occur in nature, but these values resulted in a good fit to the shape of the drawdown curves. The low Sy (0.0001) would also be expected from fractured metamorphic rock units.

4.6 Calibration

The objectives of the model calibration were to: 1) obtain appropriate model parameters that were representative of the hydrogeologic conditions; and 2) simulate current, observed water levels and drawdown from a series of aquifer tests conducted by MWH (2011) and Pennington Scott (2012). The magnitude of the difference (called the residual) between observed and measured water levels and drawdowns was used as a measure of the flow model accuracy and representativeness. A good model fit is generally able to reduce the water-level and drawdown residuals to within 5-15% of the measured values.

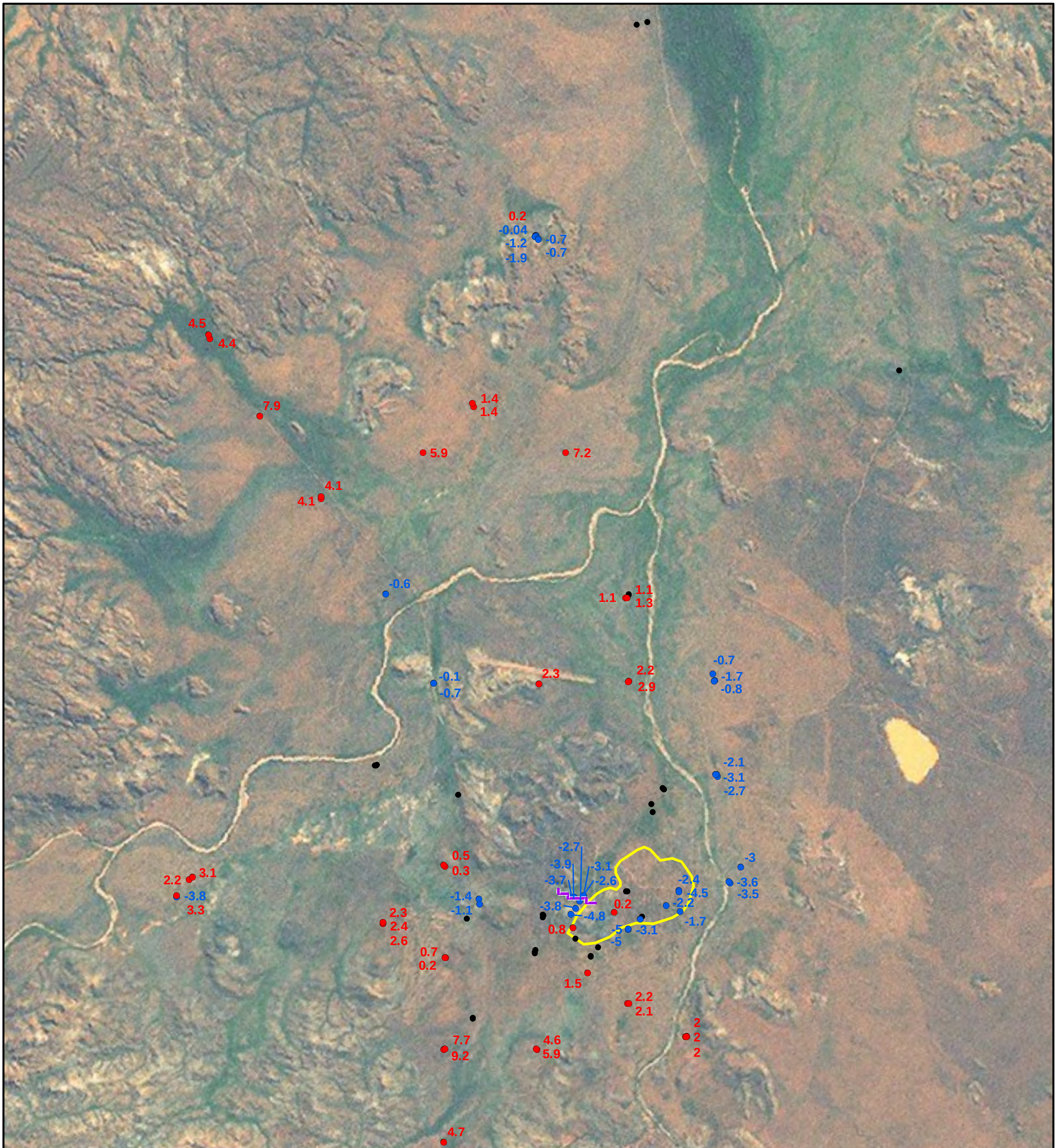
The calibration approach consisted of iteratively using automated parameter estimation (PEST) methods (Doherty, 2010) and manual calibration to achieve the calibration objectives and the best possible model fit. The hydraulic head and drawdown measurements (calibration targets) were used to minimize the objective function in PEST to calibrate the steady-state and transient models, respectively. In other words, adjustments to model input parameters were made sequentially in order to produce a close match between model-calculated and measured steady-state potentiometric surface data and transient drawdown data.

4.6.1 Steady State Calibration

Given the lack of groundwater pumping within the model domain, the groundwater system can be assumed to be at steady state over the near term. However, as mentioned in Section 4.3.2 of Pennington Scott (2012), there has been a slow, long-term rise in water level since the 1980's due to increased precipitation beginning in 1994. Many of the bores were installed in the 1980's or 1990's, and so their early measurements would represent a significantly lower groundwater elevation. Wells with multiple measurements over the past few years have shown very consistent hydraulic head data. Therefore, only wells with recent water level measurements were used for steady-state calibration targets.

The most recent water levels were generally collected in spring 2012, but in a few cases the last measurement was in 2011. As mentioned earlier, Figure C2-2 indicates which bores had recent measurements, and which ones did not and were therefore not included in calibration. Seventy-three (73) bores were used as steady-state model calibration targets (see Figure C2-3 for the actual steady state target values). Calibration targets were generally set in the model layer that contained the midpoint of the screen interval in each bore. Figure C4-13 shows the steady state hydraulic head residuals, with the residual plotted spatially in the same location and orientation as the bore name on Figure C2-2 and its corresponding groundwater elevation on Figure C2-3. Water level data are not available outside a 7.5 km radius of the site. Water levels outside this radius were constrained by land surface and hydraulic heads set at the external model boundaries (GHBs).

Several statistical measures were calculated to assess the quality of the steady-state model calibration. A selection of these calibration statistics are summarized in Table C4-3. Statistics allow a standardized assessment of the model fit to all water-level targets. In general, lower values of absolute mean residual and root mean square (RMS) represent a better fit to the observed conditions. In the case of mean residual, the ideal value would be zero, since that would indicate that residuals were equally distributed between positive (i.e., simulated value is lower than measured value) and negative (i.e., simulated value is higher than measured value). The scaled RMS, root mean fraction square, and absolute residual mean over range (also called the scaled mean sum of residuals) should be low; generally between 5-10% is considered acceptable.



Historical Locations (no recent data)

-0.7 Negative residual at bore (m)

0.7 Positive residual at bore (m)

Proposed pit extent

Suspected fault

0 500 1,000 2,000

Met s

N

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Figure C4-13. Steady-State Model Residuals

Table C4-3. Steady-State Model Calibration Statistics

Statistic	Value (Unweighted)	Value (Weighted)
Residual Mean (m)	-0.18	0.45
Absolute Residual Mean (m)	3.32	2.69
Root-Mean-Square (RMS) (m)	4.51	3.33
Minimum Residual (m)	-12.94	-5.02
Maximum Residual (m)	9.22	9.22
Range of Observations (m)	25.80	25.80
Scaled RMS (%)	17.5	12.9
Root-Mean-Fraction-Square (%)	1.28	0.93
Abs. Res. Mean/Range (%)	12.9	10.4

Most simulated values are fairly close to the measured value except for six bores located in and around KEB1: KEB1, KWP1, KWX3, KWX4, KWX8, and KWP1. Actual measured heads in these bores were about 10 metres lower than the measured heads in nearby bores. These bores are also located in proximity to the Kintyre Shear Zone, as described in Section 3.2 and Figure 3-17 of Pennington Scott (2012). It appears that this area has significant uncharacterized geologic complexity which was also evident in the transient data from KEB1, as described further in Section 4.6.2 below. Detailed geologic and hydrogeologic characterisation of this area is beyond the scope of this model and would require additional field work. In the absence of additional data, these heads were weighted at 30%. The unweighted and weighted residual statistics are both shown in Table C4-3.

The weighted residual mean for the model calibration was slightly positive (0.45 m), indicating a slight model bias toward under predicting water levels. The difference between observed and simulated water levels was expected to be larger in a regional-scale model than in a site-scale model. The calibration statistics for the groundwater flow model indicated an acceptable model fit at this regional scale. For example, the scaled mean sum of residuals is 10%, and the scaled root mean square is 13%.

An analysis of the spatial patterns in residuals shows evidence of the complex and fractured nature of the groundwater system. Overall, however, the model is under-predicting heads (red coloured residuals in Figure C4-13) in the south and northwest and over-predicting heads in the far north and east (blue coloured residuals in Figure C4-13). Thus, the model has a somewhat lower hydraulic gradient than is observed in collected data. This is probably due to a lack of information regarding the correct hydraulic head values for the GHBs, a lack of information regarding the nature of faulting in the area, and possibly other factors. For example, if the actual hydraulic heads in the southwest are significantly higher than represented by the GHBs on the model boundary, and the heads in the northeast significantly lower, that would steepen the gradient. Another example could be if a large number of the northwest-southeast trending faults in the Coolbro Sandstone and Rudall Complex represent barriers to flow, this would cause the water to “stack up” in the southwest, steepening the gradient. A third possibility is that the hydraulic conductivity of the Rudall Complex is different in the southwest area than it is near the pit. Overall, however, the hydraulic gradient is adequately represented for the purposes of this regional water supply and dewatering model.

The comparison between observed and simulated water-level elevations for the steady-state model is shown on Figure C4-14. A perfect model fit would have all of the data plotting on the 1:1 line. A good model fit was indicated by the data points being well distributed above and below the 1:1 line. For illustrative purposes, the unweighted residuals are plotted, and the cluster of six bores with unusually low heads (KEB1, KWP1, KWX3, KWX4, KWX8, and KWP1) is circled.

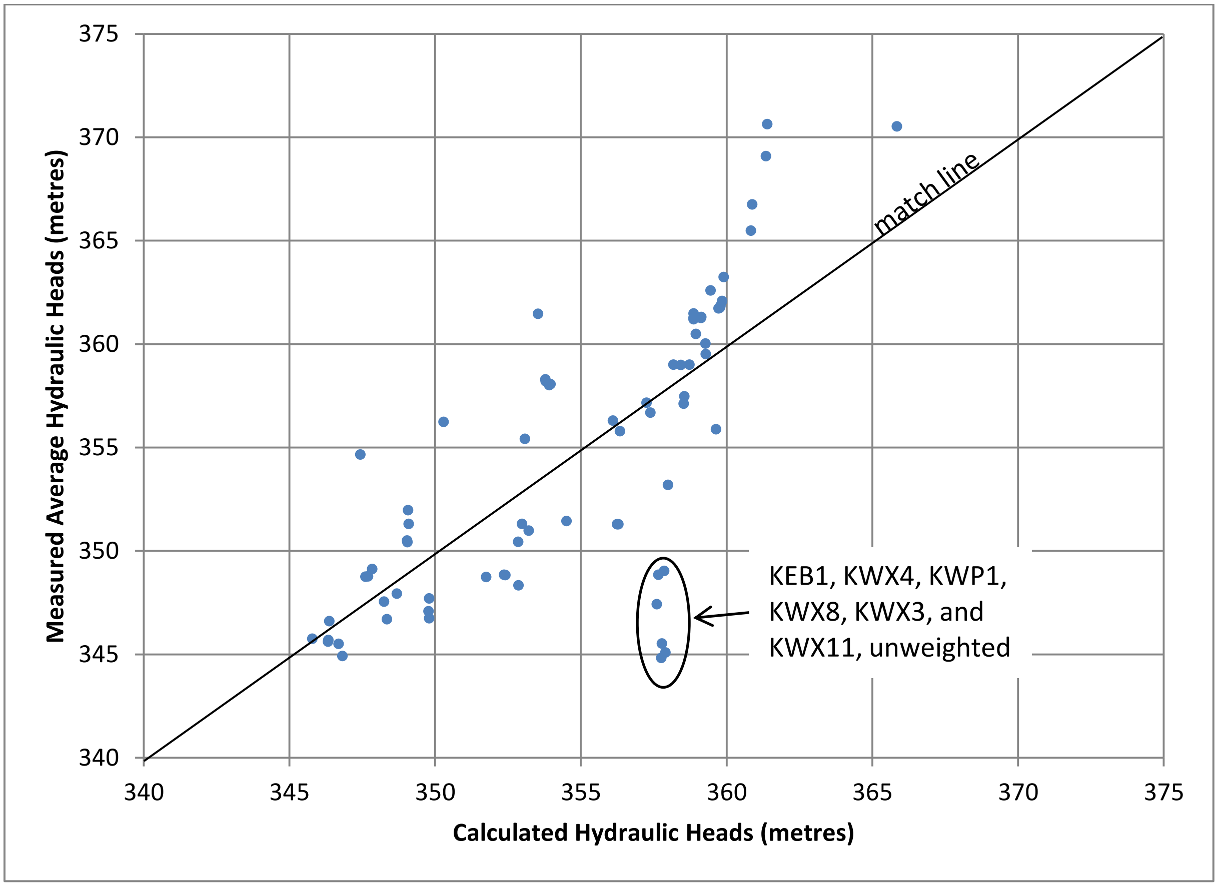

Figure C4-14. Measured vs. Modelled Hydraulic Heads

4.6.2 Aboriginal Water Hole Observations

The steady state model was used to estimate depth to water at five water holes near the proposed Kintyre pit (discussed in section 2.3, Pennington Scott, 2012). The resultant depth-to-water estimates ranged from 13.5 to 28.6 metres below land surface. This would appear to indicate that the water holes are perched rather than groundwater fed. Figure C4-15 shows the water hole locations and estimated depth to groundwater from the model at those locations.

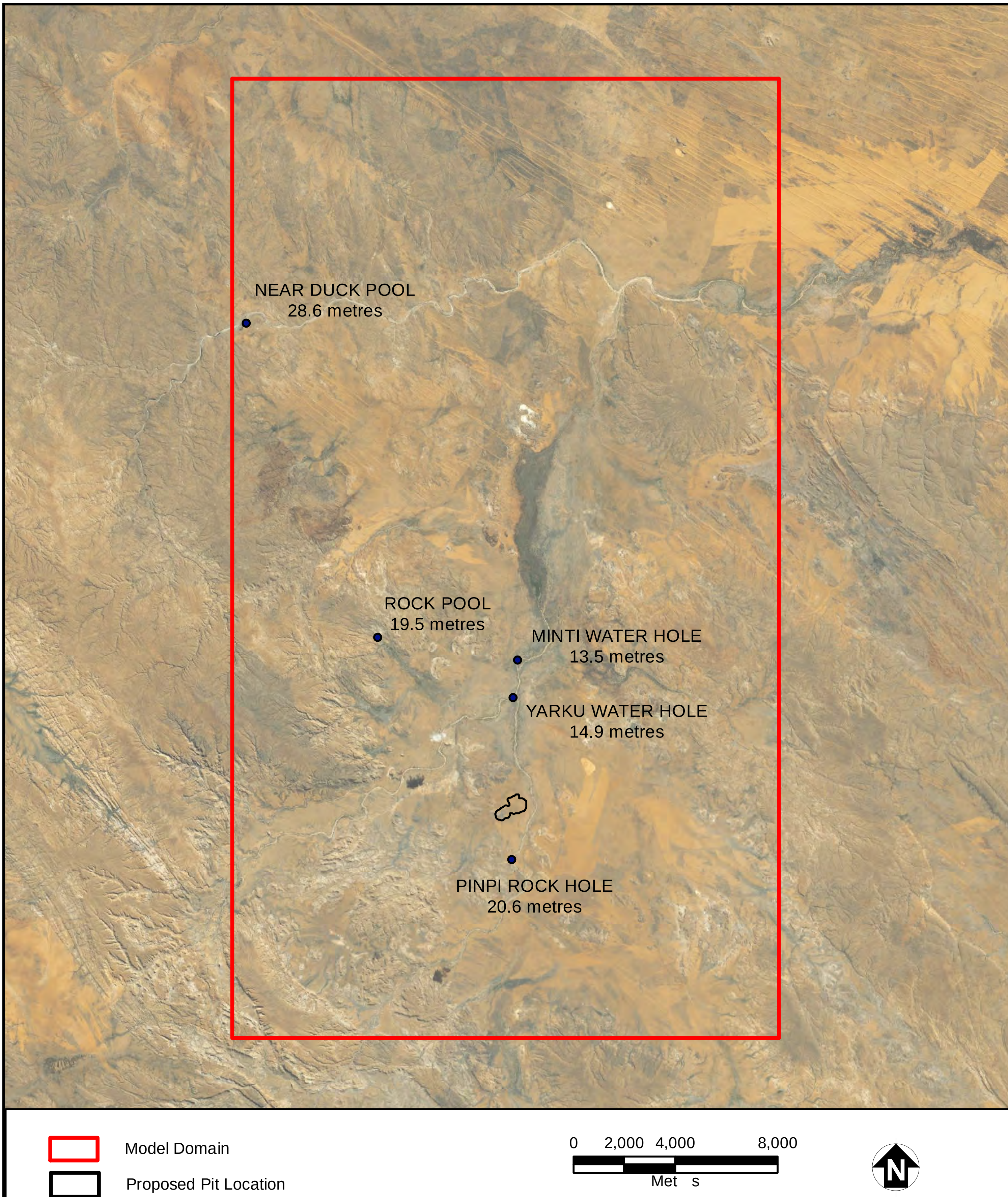

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Figure C4-15. Estimated Depth to Groundwater at Aboriginal Water Holes

4.6.3 Steady State Mass Balance

A summary of the steady-state model mass balance is presented in Table C4-4. Due to the low permeability rocks that exist in the model domain, the PCG4/5 solver (HydroGeoLogic, 2010) was critical in obtaining a stable solution that converged with a very small percent discrepancy between inflows and outflows. Given the lack of internal boundary conditions, approximately 60-percent of the water budget was from groundwater flow in and out of the model through the external model boundaries simulated as general head boundaries. The remaining 40-percent was composed of groundwater recharge (Table C4-4).

Table C4-4. Steady-State Model Mass Balance

Cumulative	Rate (m^3/d)
IN	9,295.2
Recharge	5,485.7
General Head	3,809.5
OUT	9,285.0
General Head	9,285.0
IN - OUT	10.2
PERCENT DISCREPANCY	0.11%

4.6.4 Transient Calibration

Simulating groundwater system changes over time with a predictive model requires aquifer-storage parameters. It is common practice to estimate the storage and hydraulic conductivity parameters from hydraulic tests. These parameter estimates are then adjusted in the groundwater flow model to match observed changes in water-level and flow observations over time. This process is called a “transient calibration.”

Time-varying water-level, spring flow, and/or stream flow observations based on a known groundwater system stress, such as pumping, recharge changes, ET changes, etc., are also needed for a transient calibration. It is fairly common for groundwater levels to have declining and rising trends due to variations in long-term pumping and climatic conditions. Spring flows and stream flows can also have fluctuations correlated to pumping and climatic conditions. When available, these data types are used as transient model target observations in the same manner that water-level targets are used in steady-state model calibration. The time-varying pumping is simulated and the hydraulic properties are adjusted until the model adequately reproduces the observed water-level and flow fluctuations.

Long-term water-level and flow fluctuations due to pumping have not been observed within the model domain. This is largely due to the limited groundwater development in region. Long-term water-level rises due to an increased precipitation trend have been observed. However, data regarding spring flow, stream flow, and stream connectivity to groundwater would be important to a transient calibration using this type of data set, and such data are not available. In addition, the main goal of the transient calibration is to assess the system’s response to dewatering due to mining and water supply bores. A groundwater pumping data set is therefore more appropriate to use for calibration purposes in this case.

The short-term hydraulic tests conducted as part of the hydrogeologic characterisation program ((MWH, 2011) and Pennington Scott (2012)) provide a transient water-level data set. Given the lack of major or long-term pumping stresses on the groundwater system over time, a transient calibration was performed on these short-term hydraulic tests.

4.6.4.1 Hydraulic Testing Pumping Schedule

Figure C4-16 shows the pumping schedule and rates for the step and constant rate tests conducted in bores CWB12, CWB13, CWB14, CWB15, KEB1, and KEB2 in 2011 (MWH, 2011). As Figure C4-16 clearly shows, multiple tests were running concurrently at the site. Also, some of the constant rate tests had difficulty maintaining a constant rate, such as CWB-14. Given this timing complexity, the variable rates on some of the tests, and the potential interference between aquifer tests, a numerical model is the best method to simulate these tests. The transient flow model was set up with 48 stress periods to model the changes in pumping rate from these tests. Transient stress period lengths in the model varied from 5 minutes to 3 days. Unfortunately, due to the complex pumping regime, it was not possible to represent the small-scale changes to pumping rates during the constant rate tests over time. Hence, the average pumping rate was used for constant rate tests.

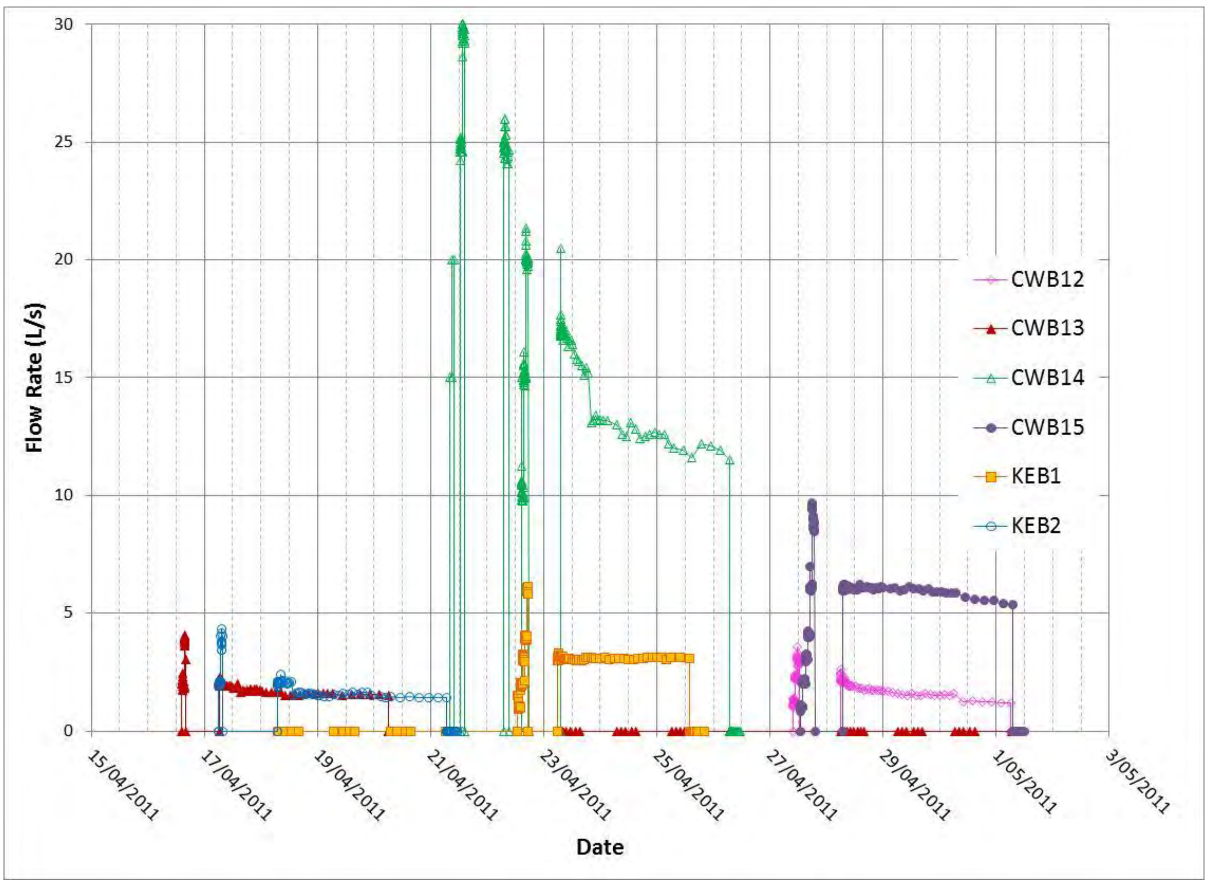


Figure C4-16. Aquifer Testing Flow Rates and Schedule – 2011 Event.

The aquifer tests performed in bores CWB17, CWB18, and CWB19 (Pennington Scott, 2012) were also used for calibration. These aquifer tests maintained a constant rate and the bores were allowed to fully recover between tests, so implementing the tests in the model was far simpler. The 2011 groundwater abstraction regime shown in Figure C4-16 was implemented using the abstraction schedule shown in Table C4-5.

Table C4-5. Model Abstraction Schedule – 2011 Aquifer Testing Event

Stress Period	Sequential Time (days)	Stress Period Length (minutes)	Pumping Bore	Activity	Average Rate (L/s)
1	0	0.1	All	Steady State	-
2	0.0001	60	CWB13	Step 1	2.0
3	0.042	29	CWB13	Step 2	3.8
4	0.062	841	CWB13	Off	0
5	0.6458	15	KEB2	Step 1	2.0
6	0.6563	45	CWB13	Constant Rate	1.8
7	0.6875	35	KEB2	Step 2	3.8
8	0.7118	1,405	KEB2	Off	0
9	1.6875	2,835	KEB2	Constant Rate	1.8
10	3.6563	1,485	CWB13	Off	0
11	4.6875	60	KEB2	Off	0
12	4.7292	60	CWB14	Step 1a	15
13	4.7712	59	CWB14	Step 2a	20
14	4.8125	150	CWB14	Off	0
15	4.9167	60	CWB14	Step 1b	24.8
16	4.9587	59	CWB14	Step 2b	29.7
17	5	1,000	CWB14	Off	0
18	5.6944	120	CWB14	Constant Rate	24.9
19	5.7778	230	CWB14	Off	0
20	5.9375	60	KEB1	Step 1	1.1
21	5.9792	30	KEB1	Step 2	2.0
22	6	30	CWB14	Step 1c	10.4
23	6.0208	30	KEB1	Step 3	3.1
24	6.0417	30	CWB14	Step 2c	15.2
25	6.0625	30	KEB1	Step 4	4.0
26	6.0833	30	CWB14	Step 3c	20.2
27	6.1042	25	KEB1	Step 5	6.0
28	6.1215	5	KEB1	Off	0
29	6.125	750	CWB14	Off	0
30	6.6458	60	KEB1	Constant Rate	3.1
31	6.6878	3,300	CWB14	Constant Rate	15.2
32	8.9792	1,020	KEB1	Off	0
33	9.6878	1,600	CWB14	Off	0
34	10.7986	60	CWB12	Step 1	1.2
35	10.8406	60	CWB12	Step 2	2.3
36	10.8823	49	CWB12	Step 3	3.0
37	10.916	31	CWB12	Off	0
38	10.9375	60	CWB15	Step 1	1.0
39	10.9792	60	CWB15	Step 2	2.1
40	11.0208	60	CWB15	Step 3	3.1
41	11.0628	60	CWB15	Step 4	4.1
42	11.1042	60	CWB15	Step 5	6.1
43	11.1458	60	CWB15	Step 6	9.1
44	11.1875	665	CWB15	Off	0
45	11.6493	55	CWB12	Constant Rate	1.9
46	11.6875	4,265	CWB15	Constant Rate	6.0
47	14.6493	55	CWB12	Off	0
48	14.6875	14,400	CWB15	Off	0

The 2012 aquifer testing event was implemented by allowing the system to recover for ten days (see stress period 48 in Table C4-5), then sequentially pumping and shutting off CWB17, CWB18, and CWB19. The six stress periods added to the model to represent the 2012 aquifer testing event are shown in Table C4-6.

Table C4-6. Model Abstraction Schedule – 2012 Aquifer Testing Event

Stress Period	Sequential Time (days)	Stress Period Length (minutes)	Pumping Bore	Activity	Average Rate (L/s)
49	24.6876	1,679	CWB17	Constant Rate	12.2
50	25.8536	4,117	CWB17	Off	0
51	28.7126	4,780	CWB18	Constant Rate	12
52	32.032	6,971	CWB18	Off	0
53	36.873	4,324	CWB19	Constant Rate	11
54	39.8758	14,400	CWB19	Off	0

During the calibration process, it is common for changes to be made in the transient model that in-turn require edits to the steady state model, so that the hydraulic properties are identical between data sets. To simplify this process, the model was constructed with the first stress period being steady state. Thus, whatever property changes were made to the transient model were automatically implemented in the steady state model, allowing simultaneous calibration.

The transient calibration process made use of 2,852 manual water level data points collected during the 2011 aquifer testing event, and an additional 677 manual water level data points collected during the 2012 aquifer testing event. The actual measured data points are graphed on Figures C3-4 and C3-5, as previously discussed. As approximately half of the data points were collected in bores which were pumping, the data would be expected to reflect additional drawdown due to bore loss and bore efficiency issues. It was therefore necessary to correct the drawdown values measured in the pumped bores for bore efficiency.

Step tests performed in 2011 and 2012 were used to estimate bore efficiency. The basis for the estimates is provided in Appendix A, Section 4.1 of Pennington Scott (2012). Figures C4-17 and C4-18 show the drawdown data, adjusted for bore efficiency.

Table C4-7. Estimated Bore Efficiencies

Bore	Rate (L/s)	Rate (KL/d)	Efficiency	Note
CWB12	1.2-2	103-173	59%	
CWB13	1.65	143	93%	
CWB14	11.5-17.7	993-1531	95%	Had to use a higher efficiency because WEX5D showed 92% of the observed drawdown at CWB14.
CWB15	6	519	32%	
KEB1	3	259	66%	
KEB2	1.4	121	50%	Linear interpolation between step test rates
CWB17	12.2	1054	48%	
CWB18	12	1037	47%	
CWB19	11	950	86%	Linear interpolation between step test rates

Figure C4-17. Transient Calibration Data Set - 2011 Aquifer Testing Event

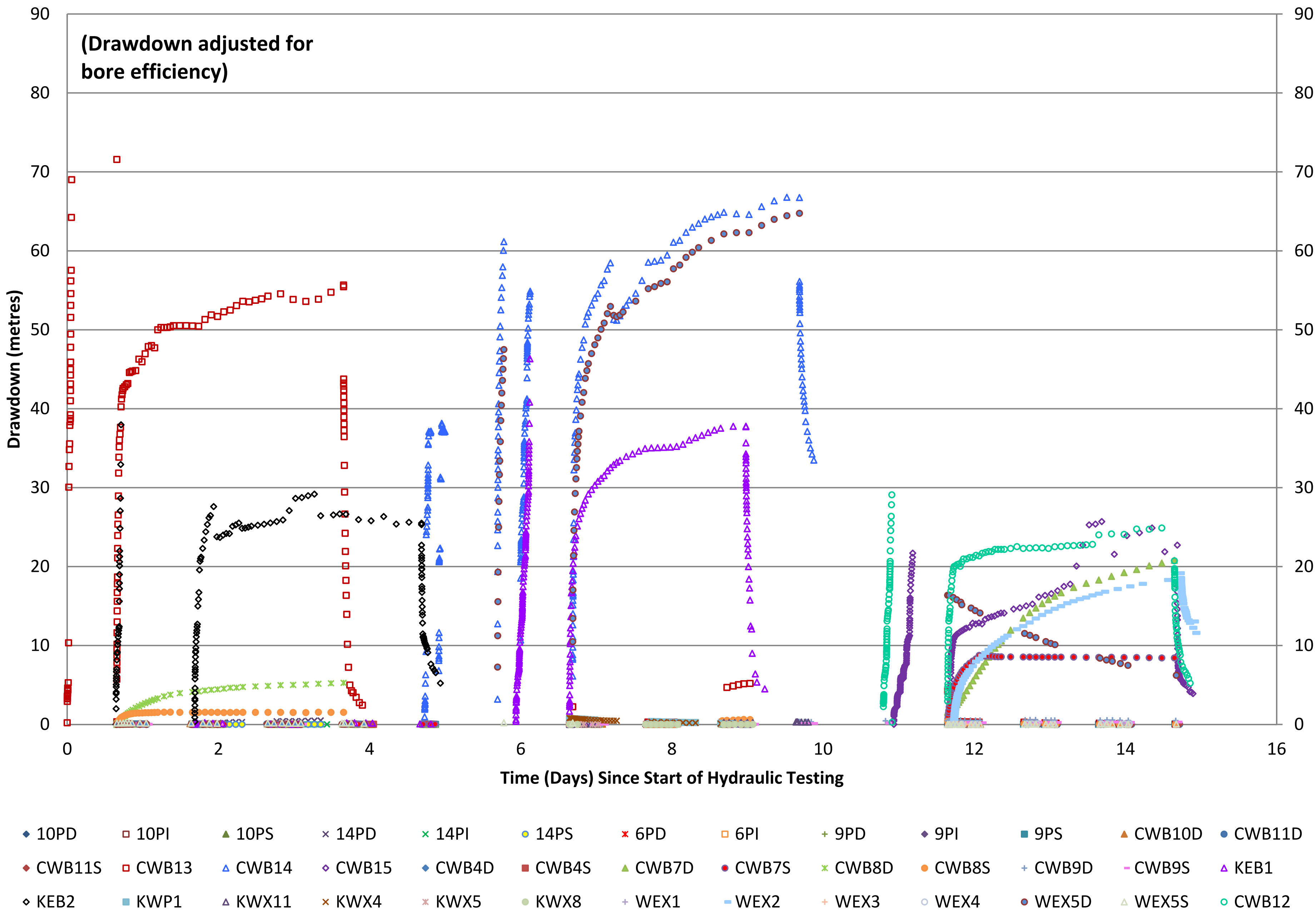
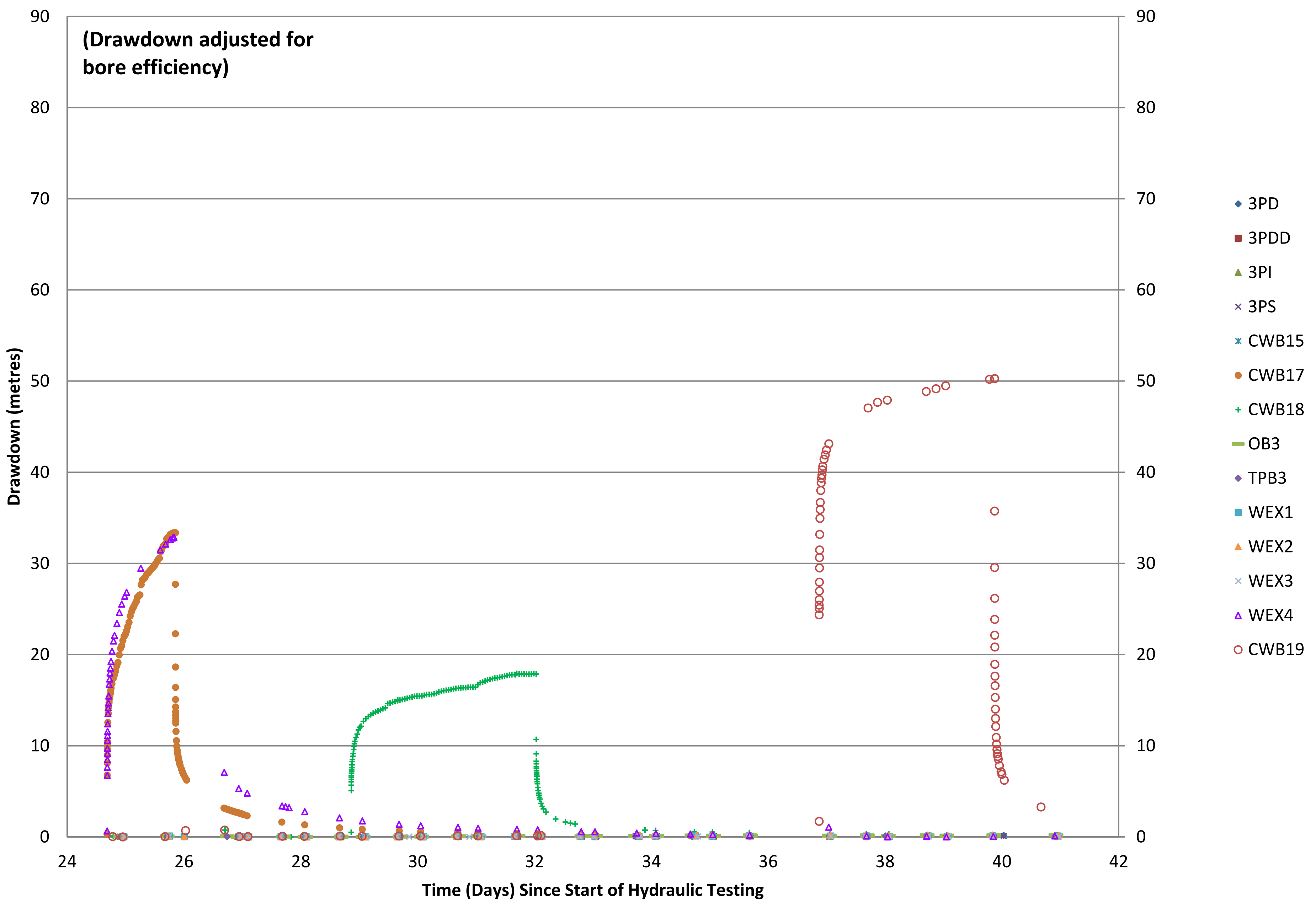


Figure C4-18. Transient Calibration Data Set - 2012 Aquifer Testing Event



An additional complication inherent in using pumping bore drawdown data is that MODFLOW cannot accurately estimate the quick steepening of the water table that occurs very near the pumped bore. Generally, a telescoped grid near each pumping location is used in an attempt to overcome this problem. However, in this regional model, further telescoping was not feasible due to the already-large number of active model cells. As a result, it was expected that the MODFLOW-calculated drawdown estimates for the pumped bores would be underestimated.

4.6.4.2 Calibration Results

The final calibration statistics are shown below in Table C4-8. Figures C4-19 and C4-20 show the simulated drawdowns (adjusted for pumping bore efficiency) for the 2011 and 2012 aquifer testing events.

Table C4-8. Transient Model Calibration Statistics

Statistic	Value
Residual Mean (m)	1.19
Absolute Residual Mean (m)	4.16
Root-Mean-Square (RMS) (m)	7.46
Minimum Residual (m)	-23.3
Maximum Residual (m)	43.9
Range of Observations (m)	71.6
Scaled RMS (%)	10.4
Abs. Res. Mean/Range (%)	5.8

In general, a well-calibrated model should be able to simulate drawdowns to within 5-15% of measured data (i.e., Scaled RMS). In this case, the simulated drawdowns are overall within 6% of the measured data.

As expected, simulation of drawdown measured in the pumped bores proved to be somewhat problematic. Typically, pumping bore drawdowns are not used during calibration for the reasons listed above. However, it was felt that they would help guide the calibration of the pumping tests given the fact that several of the tests did not have a measured response in the observation bores. In order to achieve a reasonable match to pumping bore data, the drawdown in nearby monitoring bores was generally overestimated. This overestimation of drawdown should lead to a conservative model in terms of estimating water supply for Kintyre.

Figure C4-19. Modelled Drawdown - 2011 Aquifer Testing Event

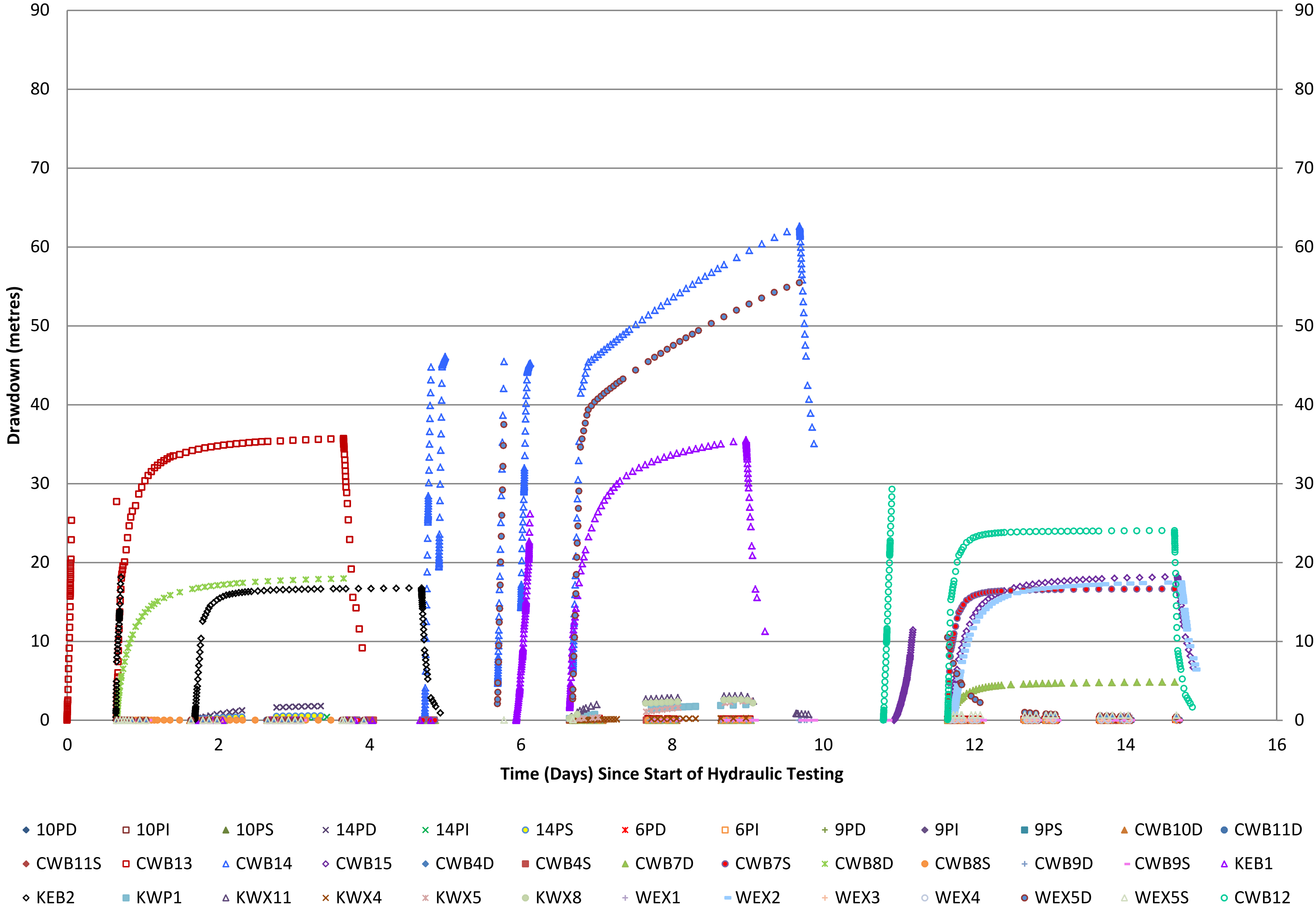
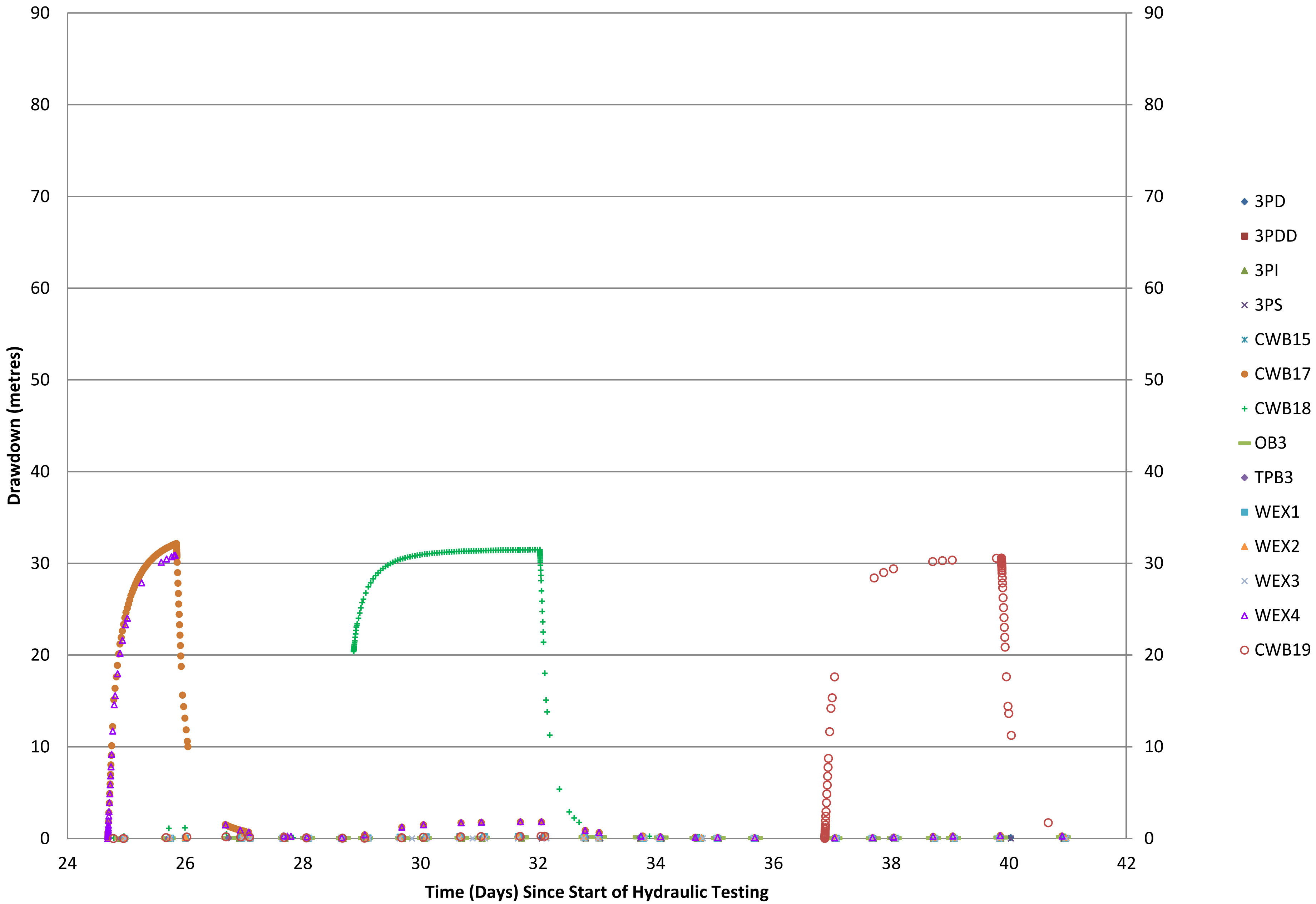


Figure C4-20. Modelled Drawdown - 2012 Aquifer Testing Event



Overall, a comparison of Figures C4-17 and C4-19 and Figures C4-18 and C4-20 reveals the matches to the observed drawdown are relatively good in the model. However, the final calibrated matches to several test data sets merit further explanation (see below), either because of a visually poor fit or because of the assumptions necessary to achieve a match.

4.6.4.3 KEB1 Test

During hydrogeologic evaluation, it was discovered that, during the KEB1 constant rate pumping test, nearby monitoring points KPW1, KWX4, and KWX8 did not respond, and that KWX11 responded very minimally (~0.3 m). Due to the close proximity of these points to KEB1, (less than 100 metres); they would be expected to respond strongly to KEB1 pumping. In fact, the model originally simulated approximately 20 metres of response, but only 0-0.3 metres of response actually occurred. This indicated a barrier feature of some sort was present between the pumping and observation bores. Examination of the Broadhurst regional geologic map and recent aerial photography revealed that a regional fault may be present at this location. Hence, an approximate 400 m long HFB boundary condition was inserted between the monitoring locations and the pumping bore. This HFB reduced the drawdown by about half, but was not sufficient to eliminate all drawdown because the radius of the drawdown cone was larger than the extent of the HFB feature.

Furthermore, a comparison of calculated hydraulic conductivity values from aquifer tests conducted in other Coolbro Sandstone bores revealed that the hydraulic conductivity near bore KEB1 is significantly lower than nearby monitoring bores (see Table 3.3 in Appendix A). In fact, the K of this small portion of the Coolbro Sandstone near KEB1 seemed more representative of the “conductive Proterozoic basement rock” hydraulic conductivity zone. This small area of Coolbro Sandstone appears to have a higher K than the basement rock as a whole, but a far lower K than that tested for the bulk Coolbro Sandstone unit; furthermore, it is located in what appears to be a fault or shear zone. Hence the unit designation in the model was changed to match its apparent hydraulic properties.

While the method employed to achieve calibration for this data set is reasonable in light of the limited available data, further investigation would be required if more certainty in the representation of this area was desired. Further field investigation and structural evaluation would be needed to determine the location, extent, and nature of the geologic complexity in this area.

4.6.4.4 CWB13, CWB18, and CWB19 Tests

In all three of these tests, the pumped well responded with visibly more or less drawdown than expected for the Permian Formation in which it was screened. Each of these situations could relate to the calculated well efficiency.

- CWB13 was calculated to be 93% efficient, meaning that its drawdown calibration targets were nearly equal to the actual measured drawdown in the bore. However, the model predicted that far less drawdown would occur, suggesting that the well may be less efficient than estimated.
- CWB18 was calculated to be 47% efficient, meaning that its drawdown was cut in half from what was measured. The model estimated the drawdown to be approximately as much as the actual measured value, suggesting that the well could potentially be more efficient than estimated.

- CWB19 was calculated to be 86% efficient, but the model under-predicted drawdown at this well by about 40%. This suggests that the efficiency might be somewhat lower than estimated.

An alternate explanation could be variations in the hydraulic conductivity of the Permian units screened by these wells. Such variation would be both normal and expected. However, the generalizations made for purposes of modelling meant that the Permian units were represented as fairly homogeneous. Since, overall, the calibration to the transient data set held relatively high confidence, these discrepancies are not of particular concern.

4.7 Calibration Sensitivity Analysis

PEST was used to perform a sensitivity evaluation of each model parameter. PEST successively changed each parameter slightly and then determined the effect on the residuals. Based on the PEST results, the following parameters were comparatively the most influential:

Steady State Model:

1. Recharge to the Coolbro Sandstone.
2. Recharge to the Paterson Formation.
3. Recharge to the Rudall Complex.
4. Vertical K of the Coolbro Sandstone.
5. Horizontal K of the Coolbro Sandstone.

Transient Model:

1. Specific storage in the lower Permian.
2. Vertical K of the lower Permian.
3. Horizontal K of the lower Permian.
4. Horizontal K of the Rudall Complex.
5. Specific yield of the lower Permian.

The results of the PEST sensitivity evaluation are very instructive in understanding the groundwater system as a whole in the regional model. After identifying the most sensitive model parameters, changes were made to each of those parameters and the model re-run to determine the actual effect on calibration. Table C4-9 shows the changes in two major calibration statistics when each of the parameters above was increased and decreased by a factor of two.

Table C4-9. Sensitivity of Calibration to Key Model Parameter Changes.

Parameter name	Change	New Value	Scaled RMS (%)		Absolute Residual Mean/Range (%)		Notes
			Steady State	Transient	Steady State	Transient	
Calibrated Statistics (weighted)			12.9	10.4	10.4	5.8	
Recharge - Coolbro Sandstone (m/day)	Calibrated	1.20E-05					
	Double	2.40E-05	16.3	10.4	14.0	5.8	Severe flooding in North third of model
	Half	5.99E-06	16.1	10.4	13.0	5.8	
Recharge - Paterson Formation (m/day)	Calibrated	3.70E-06					
	Double	7.39E-06	13.5	10.4	11.1	5.8	Flooding in North part of channel
	Half	1.85E-06	14.0	10.4	11.2	5.8	
Recharge - Rudall Complex (m/day)	Calibrated	1.20E-06					
	Double	2.40E-06	***12.6***	10.4	***10.1***	5.8	More than 25% above recharge based on chloride data
	Half	5.99E-07	13.3	10.4	10.7	5.8	
Kv - Coolbro Sandstone (m/day)	Calibrated	0.0001					
	Double	2.00E-04	13.3	10.4	10.7	5.8	
	Half	5.00E-05	***12.5***	10.5	***10.2***	5.8	Ratio Kv/Kh even lower; seems unreasonable
Kx - Coolbro Sandstone (m/day)	Calibrated	0.40					
	Double	0.80	17.4	***10.2***	14.2	***5.7***	Transient is slightly better, but steady state significantly worse.
	Half	0.20	17.7	10.8	15.1	5.9	
Specific Storage - lower Permian (1/m)	Calibrated	5.00E-07					
	Double	1.00E-06	12.9	10.9	10.4	6.1	
	Half	2.50E-07	12.9	***10.2***	10.4	***5.7***	Flattens drawdown curves.
Kv - lower Permian (m/day)	Calibrated	0.0021					
	Double	0.0043	12.9	10.4	10.5	5.8	
	Half	0.0011	***12.8***	11.4	10.4	6.4	Steady state slightly better, transient somewhat worse.
Kh - lower Permian (m/day)	Calibrated	0.067					
	Double	0.134	13.1	11.3	10.6	6.3	
	Half	0.033	***12.7***	13.4	***10.3***	7.6	Steady state slightly better, transient significantly worse.
Kh - Rudall Complex (m/day)	Calibrated	0.0078					
	Double	0.016	13.3	11.1	10.8	6.2	
	Half	0.0039	***12.6***	***10.3***	***10.0***	***5.7***	Helps in some places but makes others worse.
Specific Yield - lower Permian	Calibrated	0.005					
	Double	0.010	12.9	10.5	10.4	5.9	
	Half	0.0025	12.9	10.5	10.4	5.8	

4.7.1 Steady State Model Sensitivities

The steady state simulation is most sensitive to recharge to the three major units represented in the model. Often, recharge is somewhat arbitrary in a model given its difficultly in estimation and is used as a calibration parameter. However, in this model, recharge was not allowed to vary by more than 25% in either direction, since the actual recharge values to the main modelled geologic units were reliably estimated using chloride data (see Section 4.3.1 of Pennington Scott, 2012). Hence, the final modelled values are known with a fair degree of certainty. Table C4-9 indicates that, for the Coolbro and Paterson, changing the recharge by a significant amount from the calibrated value results in a worse model fit, and also resulted in unrealistic flooding of some regions of the model. For the Rudall Complex, a slightly better fit would be possible with a higher value of recharge. However, the recharge to the Rudall Complex would then be significantly higher than values calculated using observed water quality data with the chloride mass balance method (Pennington Scott, 2012).

The next most influential parameters are the Kv and Kh for the unit receiving the most recharge – the Coolbro Sandstone. The Kv of the Coolbro Sandstone was estimated to be very low compared to Kh. The function of the low Kv in the model is to prevent the recharge from infiltrating right away, causing it to flow along the uppermost portion of the Coolbro Sandstone and toward the edge of the palaeochannel. If the Kv of the Coolbro is increased significantly, the heads in the Permian palaeochannel units decrease substantially. Decreasing the Kv even further results in a slightly better match to steady-state heads as shown in Table C4-9; however, a value of 0.0001 is really the lowermost bound of what could be considered a reasonable Kv. A low Kv in the Coolbro Sandstone is in keeping with the measured hydraulic head distribution and the chloride data evaluation, which indicates that seepage of runoff from the adjacent Coolbro Sandstone plateau appears to be an important source of recharge water to the aquifer, contributing low salinity groundwater over the western portion of the palaeochannel (Pennington Scott, 2012). The Kh of the Coolbro Sandstone governs the horizontal transport of recharge. Table C4-9 shows that any significant change up or down of the Coolbro Sandstone Kh results in a significantly worse steady state model fit.

4.7.2 Transient Model Sensitivities

The transient model is very sensitive to the properties of the lower Permian zone. The modelled lower Permian zone is, for the most part, comprised of the Paterson Formation basal conglomerate. Most of the palaeochannel production bores (in which the transient calibration aquifer tests were performed) are screened primarily in this zone. Hence, it is reasonable that the transient model would be most sensitive to the hydraulic properties of the Lower Permian.

The storage parameters of the lower Permian were both highly sensitive. Increasing the specific storage of the lower Permian noticeably degraded the transient calibration. Decreasing the specific storage of the lower Permian zone creates a slight numerical improvement in the model fit, but results in drawdown curves that are significantly flatter than actually observed. Part of the visual fit to the calibration data is matching the slope of the drawdown curves, since the storage coefficients greatly influence the slope of the drawdown curve. Therefore, the decision was made during calibration to allow a numerically poorer fit, which in return allowed a better match to the slope of the drawdown curve. The specific yield of the lower Permian was well constrained by the model in the sense that any significant change resulted in a poorer fit to the transient calibration data set.

The hydraulic conductivity of the lower Permian was also a very sensitive parameter. Decreasing the Kv or the Kh of the lower Permian resulted in a slight improvement to the steady state model fit, but visibly and significantly degraded the transient calibration. In deciding whether to make this type of change, more weight was given to improving the transient calibration, since the main goal of the model is really to predict transient pumping and dewatering responses.

The transient calibration was also sensitive to the Kh of the Rudall Complex. In fact, it was observed that decreasing the Kh of the Rudall Complex resulted in numerical improvement to both the steady state and transient calibrations. However, visual inspection of the transient fit to data indicated that decreasing the Kh of the Rudall Complex resulted in an improvement of fit for several bores (mainly pumped bores), but degraded the fit for other bores.

4.7.3 Sensitivity Scenarios for Predictive Modelling

Based on the sensitivity analysis above, two scenarios were selected for predictive modelling:

- Increased recharge – Rudall Complex. This scenario resulted in benefits to the steady state calibration and had no impact on the transient calibration. Further, it did not result in the significant and widespread flooding of model cells that was observed after increasing other recharge zones. The only disadvantage is that the increased recharge is higher than estimated from the chloride data.
- Decreased Kh – Rudall Complex. This scenario benefitted both the steady state and transient calibration. It resulted in degradation of the fit of some monitoring bores, but helped the fit for other bores (mainly pumped bores).

The two selected scenarios resulted in improved calibration with minimal drawbacks. These two scenarios were also carried through to illustrate variability in the predicted pit inflows and lake development associated with reasonable alternative model parameters (see Section 4.11).

4.8 Predictive Simulation – Mining Phase

Mine operation and dewatering was simulated using both a regional and a local model. The regional model was used to predict the response to simultaneous mine dewatering and water supply pumping from the proposed bore field. The local model was used to provide a more-refined picture of the pit dewatering.

The hydrologic stresses associated with mine dewatering activities were modelled to predict groundwater inflow rates to the mine and related water-level changes in the area.

4.8.1 Water Supply Pumping Simulation Methods

The water supply borefield was simulated using several basic steps. First, the 10 proposed water supply bores were inserted into the regional model using the MODFLOW-SURFACT fracture well (FWL) package. This package allows dynamic reallocation of pumping to lower layers if a layer goes dry during the simulation, which allows more realistic simulation of multi-layer aquifer dewatering.

The water supply bore locations are shown on Figure 5-3 of Pennington Scott (2012), including existing and proposed production bore sites. The bores were simulated as installed for CWB17, CWB18, and CWB19. In the model, these bores partially penetrate Layer 2 but fully penetrate Layers 3 and 4, so they were simulated as being screened in Layers 3 and 4. Bores A through G were simulated as specified in Section 5.2.2 (Pennington Scott, 2012), meaning that they would fully penetrate the entire Permian aquifer and also extend into the Coolbro Sandstone. These wells were therefore simulated with screens in Layers 2 through 5.

Based on the current mining plan, 3.1 ML/day water supply is required for 9.5 active mining years. For security of water supply and to assess the maximum potential aquifer impact, the borefield was modelled to operate at full capacity with all 10 bores operating at once (at 0.5 ML/day each or 5 ML/day total).

4.8.2 Dewatering Simulation Methods

Wellbores, horizontal drains and/or sumps will be used to maintain dry working conditions in the mine (described in section 5.1, Pennington Scott, 2012). Dewatering of the mine was simulated in the mining-phase model using MODFLOW's drain boundary condition. Drain boundaries are useful for simulating the effects of mine dewatering because they remove water from the groundwater system only when heads in the adjoining cells are greater than the elevations of the heads specified for the drain cells. The configuration of the drain cells within the model can be adjusted through time as the mine configuration changes, thereby enabling accurate simulation of the mine progression.

4.8.3 Stress Period Set-up

Mining is anticipated to last for approximately 9.5 years. The local dewatering model was divided into 31 stress periods. The first stress period simulates steady-state conditions with only natural inputs to and outflow from the groundwater system and is included to assure that the model is equilibrated at the start of the mining simulation. Two stress periods of one year each were inserted after the steady-state stress period to simulate the peak water demands during the first two years of mining. Thirty stress periods of 90 to 91 days simulate the subsequent period of mining. In the case of the regional water supply model, the same stress periods were used to simulate pit dewatering.

The local model required further discretization to allow more accurate simulation of the pit dewatering and lake infilling scenarios. Each model cell was split in two vertically, so that each layer in the regional became two layers in the local model. Next, the telescoping grid was further telescoped down to 25x25 metres in the immediate vicinity of the proposed pit.

4.8.4 Dewatering Drains

Drains were assigned to each layer based on the layout of the mine. Drain cells were assigned to all model cells that would be occupied by the mine pit. The increase in the depth of the pit over time is simulated by sequentially activating the drain cells in deeper layers of the model and lowering the drain elevations over time. A total of 6,316 drain cells were used to simulate the mine dewatering in the local dewatering model. The regional model used only 829 drain cells due to the coarser discretization.

The local model's simulation of the mine pit by drain cells is illustrated in Figure C4-21, which includes both plan and cross-sectional views of the drain cell layout in the model.

The plan view shows the mine pit perimeter and drain cell layout in model layer 1, and the cross-sectional view shows a slice through model row 91. To increase clarity, the cross section extends down only through layer model layer 16.

Achieving full dewatering of the Kintyre mine required drains throughout the entire mine pit volume. The low hydraulic conductivity of the bedrock within the mine area created instances in which the water was not completely draining from some model cells. The rocks within the mine will be physically removed by mining and the mined area will have essentially infinite hydraulic conductivity. Because the model becomes mathematically unstable when extremely large hydraulic conductivity values are used as input, the horizontal and vertical hydraulic conductivity of the mined cells was increased to 5.0 m/d, which facilitated dewatering of the mine cells. The results indicate that the mine cells dewater in an appropriate manner.

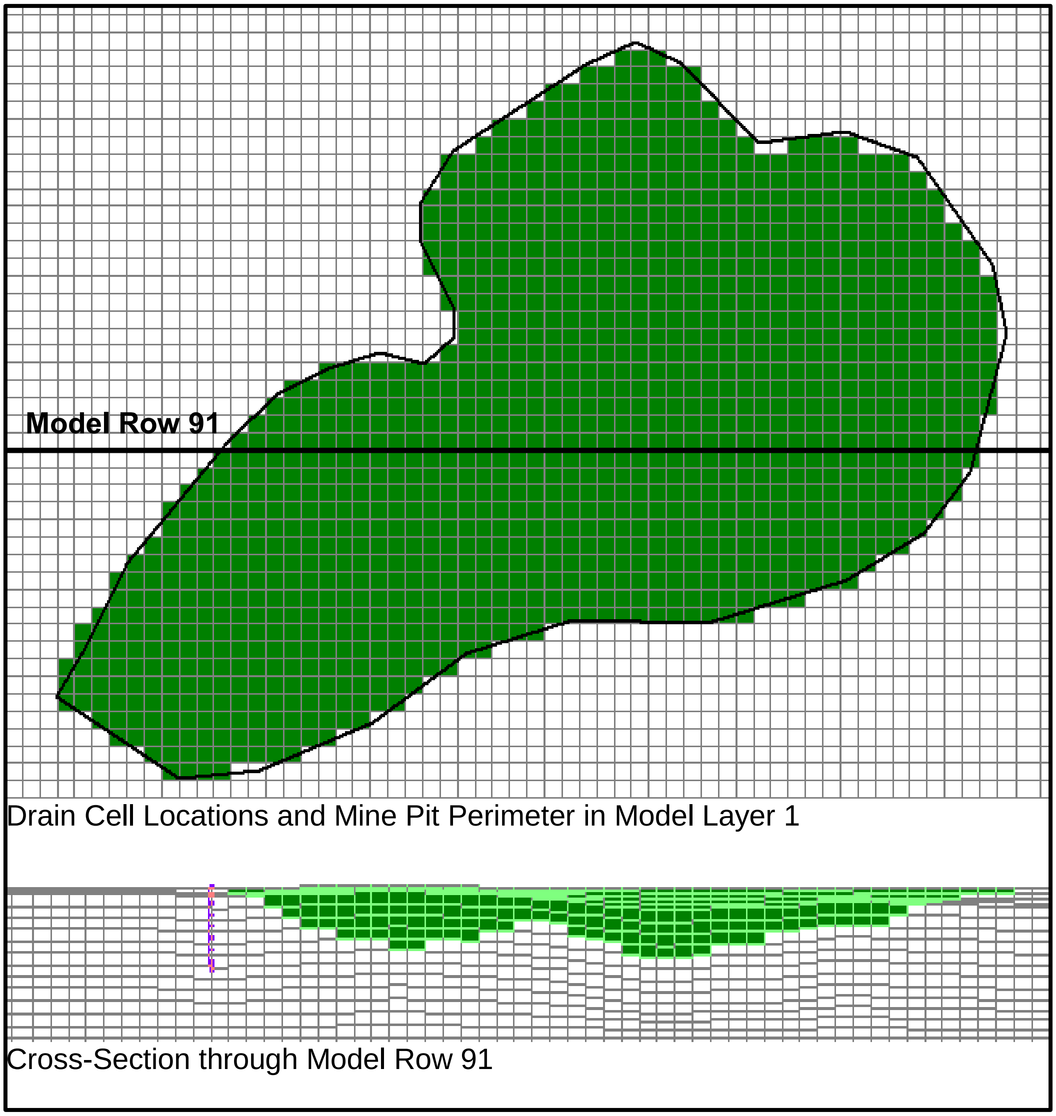


Figure C4-21. Simulation of Mine Pits in Local Dewatering Model

4.8.6 Mining-Phase Simulation Results

The mining-phase simulation provided estimates of the model-predicted groundwater inflow to the mine pit during the mining phase and water-level drawdown related to the mine dewatering.

4.8.6.1 Uncertainty in Estimation of Mine Inflows and Mining-Related Water-Level Changes

The simulation results depicted in the figures and tables that follow are based on the model described herein, which was developed using currently-available information on the geologic and hydrogeologic conditions at the project site and in the region. It is possible that as-yet-unidentified conditions, such as other faults, zones of intense fracturing or of low-permeability materials, could be encountered during mining operations. Such conditions could result in mine inflows and mining-related water-level changes that differ from those predicted by the model.

Because mining has not yet begun, no field data yet exist against which the model results can be compared and the model thus verified. In cases where appropriate field data such as measured mine inflow rates and water-level changes in monitoring wells are available, the results from the calibrated model can be verified against observed data and the model can be adjusted accordingly, thereby reducing uncertainty inherent in predictions made based on the model.

4.8.6.2 Mine Inflow Predictions

Estimated groundwater inflow rates during mining are shown graphically in Figure C4-22 for both the regional and local models. Short-term variability of inflows calculated by the models has been smoothed but not eliminated by averaging the flows over periods of approximately 90 days. The short-term variability in the model results is caused by the activation of new sets of lower-elevation drain cells at the start of particular stress periods. The activation causes an initial sharp increase in predicted inflows, followed by a gradual decrease through the remainder of the stress period. The variability in predicted inflows is caused by the vertical layering and time-stepping in the model simulations and would not occur during development of the mine. Rather, changes of the actual inflows to the mine would occur gradually as mining progresses and the mine pit deepens.

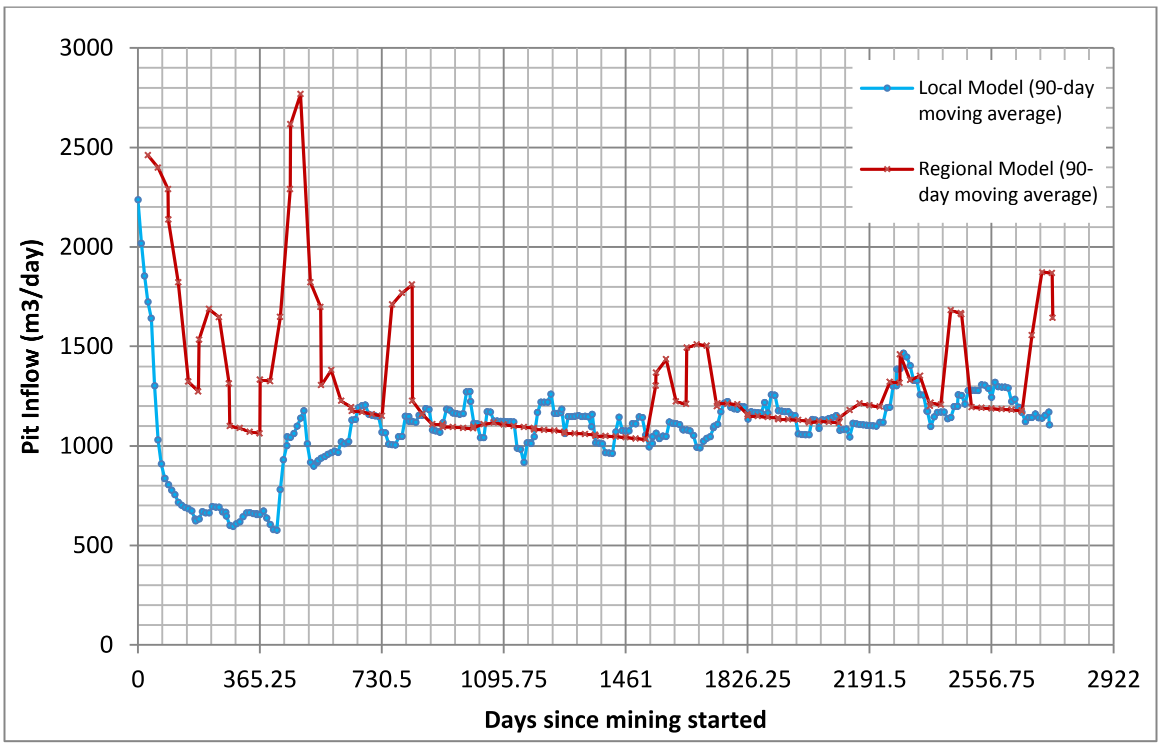


Figure C4-22. Comparison of Regional and Local Model Predicted Pit Inflows

Predicted groundwater inflows initially are on the order of 2,250 m^3/d (2.25 ML/d) for the local model and 2,450 m^3/d (2.45 ML/d) for the regional model and decrease rapidly to between 600 and 700 m^3/d (0.6 to 0.7 ML/d) for the local model and to between 1,000 and 1,100 m^3/d (1.0 to 1.1 ML/d) for the regional model. The results for the two models converge at inflows of approximately 1,100 m^3/d (1.1 ML/d) after the first 1½ years of the mining period and increase very slightly during the course of the mining period.

The difference between the early inflows predicted by the two models is related to grid spacing both vertically and horizontally. The regional model's initial dewatering was to the bottom of the first saturated layer, the equivalent of the first two saturated layers in the local model. The finer grid mesh in the local model allowed the early dewatering to proceed in smaller steps vertically and for the mine pit size to decrease horizontally between the first and second layers of the model. The larger "spikes" in the inflows predicted by the regional model are caused by the larger vertical steps as drain cells are activated in sequentially deeper layers.

4.8.6.3 Potential Ranges of Mine Inflow Predictions

It is possible that geologic complexities, including faults and fractures, that are not discretely simulated in the flow model may result in observed groundwater inflows that are higher or lower than the predicted range. There is geologic evidence of fracture zones (Hickman and Clarke, 1994) that could be areas of higher permeability which, if intersected by the mine pit, could produce inflows higher than predicted. Data from the aquifer tests and the model calibration also suggest either the presence of barriers to groundwater flow or geologic complexity that has not been fully characterized. Because no explicit information on the hydraulic properties of the rocks in the fracture zones was available, no geologically-evidenced fracture zones were included in the model. In addition, not all such features are known, and not all can be explicitly simulated in either the regional- or local-scale models developed for this project. However, the influences of known hydrogeologic features were incorporated into the model if they affected calibration to the steady-state or transient water-level targets.

Additionally, evaporation from the walls and ramps in the open pit can remove a significant portion of the pit inflows before the water reaches collection sumps from which it will be pumped. This evaporation was not simulated by the model. In terms of the total predicted inflows to the open pit operations, the potential reductions of net inflow (and thus also of pumping requirements) from in-pit evaporation, though undetermined at this time, could be significant.

In general, monitoring of groundwater inflow to underground and open pit mines in low-permeability rocks with relatively low fracture density and connectivity has shown that fractures can initially yield substantial rates of inflow that decrease rapidly over time. The degree to which this occurs depends on how well connected the fracture network is over large areas. The equivalent porous media (EPM) conceptual flow model assumes that the fracture network is connected enough to be simulated as a porous media at the scales of both the regional model and the local dewatering model. This conceptual model has been shown to be applicable on a regional scale. However, as the scale becomes more local, small-scale fracturing and geologic structures play an increasingly significant role in groundwater inflow to the mine and the EPM assumption can become less appropriate. The inflows predicted by these models are therefore averages that do not account for extreme high or low flows due to faults, fractures or other local-scale geologic features. However, on the scales of these models, changes to the hydrogeologic and groundwater system can be adequately simulated with the flow models.

4.8.7 Results from Water Supply Borefield Simulation

The water supply borefield was simulated using the regional model in tandem with the pit dewatering. As shown in Figure C4-22, the regional model was able to simulate the pit inflows during dewatering reasonably well, despite the coarser grid. At the same time, the water supply borefield was simulated operating at full capacity. The depth to water at each of the bores was estimated at the end of mining, and the flow rates during the simulation were checked to ensure that each well was continuously producing at full capacity (0.5 ML/day).

The bores each produced at full capacity during the entire simulation. The predicted water levels at the bores ranged from 14 m below land surface in the furthest-north bore (G) to 52 mbgl in the furthest-south bore (CWB17). These bores range from 128 m to 200 m in total depth, with the northern 7 bores all planned to be 200 mbgl. Therefore, the bores do not appear to be likely to dewater as a result of water supply pumping, based on the current understanding of the aquifer hydraulic properties.

4.8.8 Drawdown and Water-Level Change Predictions

The mining-phase simulation also provided estimates of predicted drawdown related to mine dewatering operations. Figure C4-23 shows the predicted water table drawdown at the end of active mining. The drawdown was calculated by subtracting the water table elevation at the end of mining from the steady-state water table elevation. The maximum drawdown at the end of mining is approximately 220 m, the depth of the pit below the water table. Drawdown decreases rapidly with distance from the pit, and the 1-metre predicted drawdown contour at the end of mining extends approximately 2.5 km to the northwest, 1.6 km to the southwest, 2.3 km to the southeast, and 1 km to the northeast of the open pit. For comparative purposes, the regional model drawdown contours at end of mining are also shown; these include the drawdown due to water supply borefield pumping.

The drawdown related to mine dewatering and water supply pumping extends past the boundary of the palaeochannel, as shown on Figure C4-23. This is because the hydraulic conductivity values of the Permian units and the Coolbro Sandstone are similar to each other (see Table C4-2). Had the palaeochannel been incised into very low-K units, the drawdown would be expected to propagate primarily down the palaeochannel. Because of the similarity in hydraulic conductivity of the incised unit (Coolbro Sandstone) and the infilling materials (Permian units), the drawdown propagates laterally past the edges of the palaeochannel.

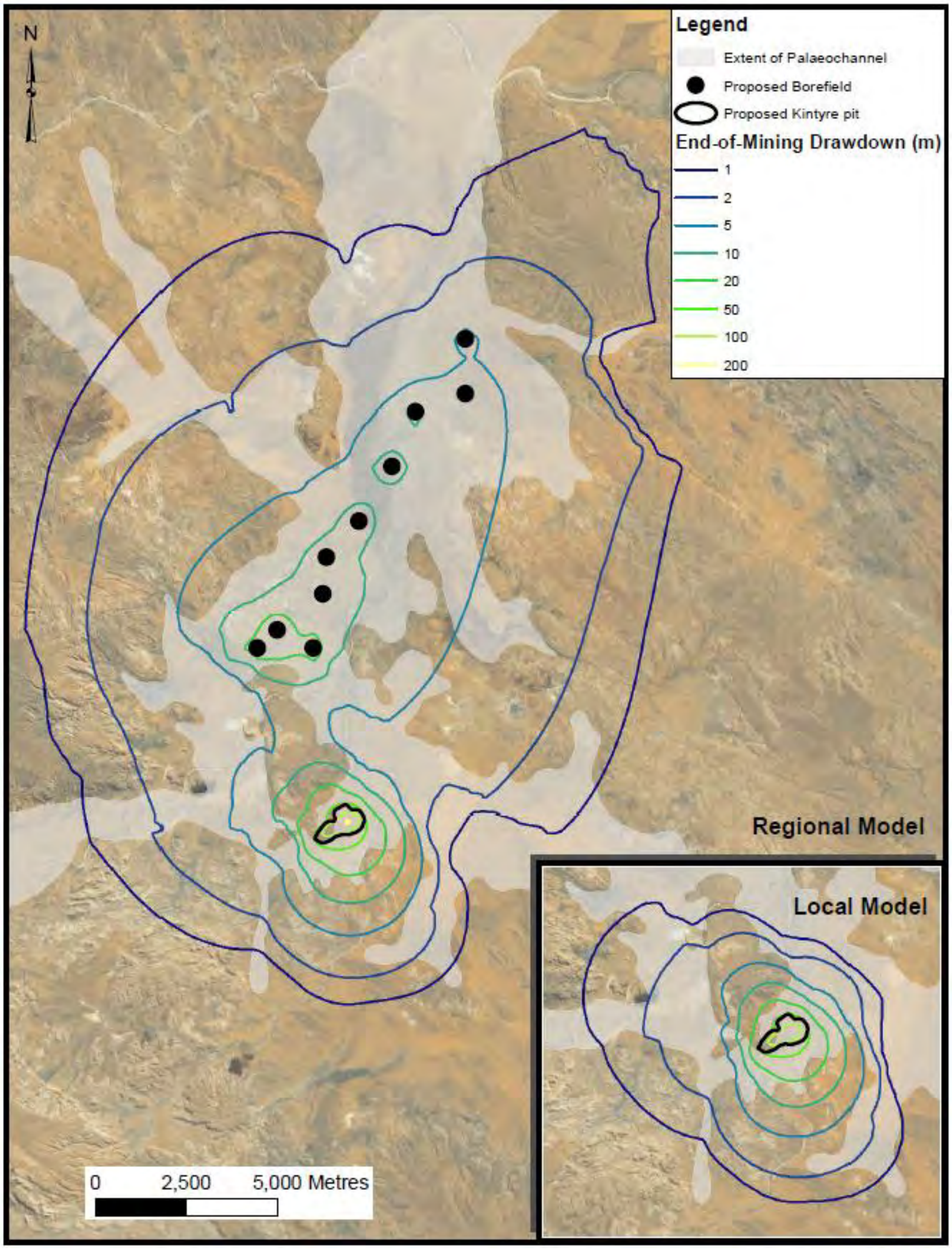


Figure C4-23. Regional and Local Model Drawdown Contours at End of Mining

4.9 Predictive Simulation – Post-Mining Phase

Predictive simulations of post-mining conditions were completed by modifying the numerical models previously discussed. These modifications were made to simulate post-closure conditions related to pit-lake development. The pit lake water balance is simulated with the LAK3 Package (Merritt and Konikow, 2000).

4.9.1 Pit Lake Water Balance

Upon cessation of mining activities and active pit dewatering, the pit will begin to fill with water. The pit configuration could allow for the development of two independent pit lakes, one in the deeper northeast section of the pit and one in the shallower southwest section of the pit. The sill elevation between to two sections is approximately 300 m. At pit lake stages below that elevation, two independent pit lakes would exist. If the pit lake stage were to rise above that elevation, the two independent lakes would coalesce into a single pit lake.

The rate at which the pit fills and the ultimate depth and stage of the pit lake(s) will depend on the pit lake water balance, which describes how water flows into and out of the lake. Depending on the relative magnitudes of these flows, a pit lake may form or the pit could remain dry.

Conceptually, the post-closure water balance for the mine pits can be expressed as:

$$\Delta_{\text{pit lake volume}} = I_{precip} + I_{runoff} + I_{\text{pit runoff}} + GW_{inflow} – E_{pit} - GW_{outflow}$$

where:

I_{precip} is the inflow from direct precipitation falling on the lake surface;

I_{runoff} is the inflow from runoff from upgradient drainages (zero in this case, as no runoff into the pits will occur from outside the pit itself);

$I_{\text{pit runoff}}$ is the inflow from pit wall runoff (the fraction of precipitation falling on the pit walls that ultimately reaches the pit lake);

GW_{inflow} is the groundwater inflow to the pit lake;

E_{pit} is the open-water evaporation from the pit lake surface; and

$GW_{outflow}$ is the outflow of groundwater from the pit lake.

There are two types of pit lakes: terminal-sink and flow-through. A terminal-sink pit lake has no groundwater leaving the pit ($GW_{outflow} = 0$). A flow-through pit has a component of groundwater leaving the pit ($GW_{outflow} > 0$). The interaction between the above parameters for a terminal pit lake (one which has no groundwater outflow; $GW_{outflow} = 0$) is presented schematically on Figure C4-24. This water balance is solved in the groundwater flow model using the LAK3 package (Merritt and Konkow, 2000).

Due to the steep, roughly cone-shaped walls of the proposed open pit, the surface area of pit lakes would be small initially, but as the lake stages rise, the surface areas would increase. The evaporation losses increase as the surface area increases. The water-surface elevation in the pit lake(s) will stabilize when the evaporation rate for each pit lake equals the sum of the inflow components. The stabilized lake stage(s) will dictate the long-term, steady-state groundwater inflow and drawdown associated with the pit lake(s).

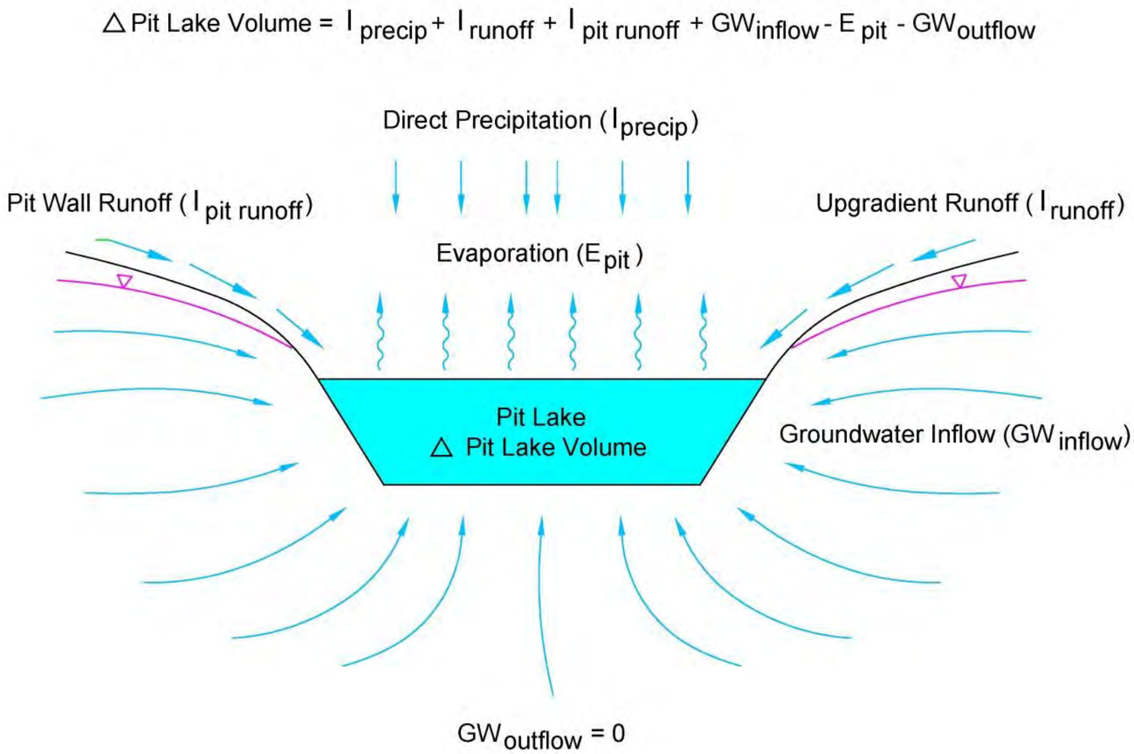


Figure C4-24. Conceptual Model of Pit Lake Water Balance

4.9.2 Pit Lake Simulation

The LAK3 package was selected to simulate post-mining pit lake formation because it can calculate the transient stage of a pit lake as the lake fills and determine groundwater inflows and outflows across multiple model layers. The LAK3 package couples the lake water balance and the groundwater flow model, thereby allowing the lake stage to vary according the hydraulic stresses applied to the aquifer and the lake water budget. The inputs and outputs for the LAK3 package are:

- Direct precipitation onto the lake's water surface (L/T);
- Evaporation from the lake's water surface (L/T);
- Runoff into the pit (L^3);
- Pit wall runoff (L/T); and
- Conductance values for LAK cells (L/T).

Using the three-dimensional representation of the final configuration of the pit, model cells within the pit were designated as "lake cells." The lake cells occupy the same locations in the model grid as did the drain cells of the dewatering simulation. The deeper northeast section of the pit was designated "lake 1," and the shallower southwest section was designated as "lake 2." The groundwater inflow into the pit varies depending on heads in the surrounding aquifer cells, lake stage, and cell conductance. The conductance of the lake cells was based on the aquifer material properties and the grid block geometry. The lake cell conductance was set equal to or greater than the conductance of the adjacent aquifer material. The bottoms of the lakes were set to the final pit floor elevations of 128 mAHD for the northeast (lake 1) section and 210 mAHD for the southwest (lake 2) section. In the local model, the lake cells for the northeast section span 11 model layers, and those for the southwest section span 10 layers. In the regional model, they span 6 and 5 layers, respectively. The stage-area relationships for the pit lakes are generated in the LAK3 package are a function of the areas of the simulated lake cells for each model layer, and the stage-volume relationship is a function lake cell areas for each layer and the layer thicknesses. Similarly, accurate simulation of the stage-area relationships is essential to accurately predicting evaporation, precipitation and pit-wall runoff.

Precipitation is estimated to be 367 mm/year, and pan evaporation is estimated to be 4,124 mm/year, based on data for the Telfer Aero weather station, approximately 90 km north of the Project area (Australia Bureau of Meteorology, 2012). Correction of the pan evaporation rate to a lake or water-surface evaporation rate was made using data from Luke et al. (1987), which indicated that lake evaporation was approximately 62 percent of pan evaporation. Thus, an evaporation rate of 2,556 mm/year was used for the pit lakes in this model.

Precipitation falling on the catchment of the pit that does not infiltrate, pond, or evaporate will run off from the pit walls and flow toward the lakes at the base of the pit sections. The average fraction of precipitation that becomes pit-wall runoff was calculated using the SCS method (NRCS, 1986). The applicable equation is:

$$Q = (P - I_a)^2 / (P - I_a + S)$$

where:

Q is the runoff in millimetres;

P is the precipitation in a single event, in millimetres;

I_a is the initial abstraction (all losses before runoff begins, such as interception by vegetation, water retained in surface depressions, and water lost by evaporation and infiltration), in millimetres; and

S is the potential maximum retention after runoff begins, in millimetres, calculated from the runoff curve number (CN) by the equation S = 1000/(CN-10).

The average runoff was calculated based on daily precipitation data from January 1, 1974 through April 30, 2012 (Australia Bureau of Meteorology, 2012), using a curve number of 95. Based on the precipitation data from that period of record, the fraction of precipitation that becomes runoff to the pit lakes was 52.34 percent. The volumetric rate of runoff into the pit lakes varies with lake stage, decreasing as the stage rises and less pit wall area is exposed above the lake water surface. To maintain the model input as close to expected conditions as possible, post-mining runoff was assigned a constant rate of 210 m^3/d for lake 1 in the northeast portion of the pit and 99.34 m^3/d for lake 2 in the southwest portion of the pit. These values were calculated from the pit area lying outside of the lakes with equilibrated pit lake stages of about 270 mAHD for both lakes 1 and 2. This value was considered conservative for model input, as runoff into the pit lakes decreases with increasing pit lake stage. The greater runoff into the pit that would occur during early pit-lake formation, when pit lake water surface elevations are low, would tend to very slightly increase the rate of water-level rise, but because of the relatively rapid rate of lake stage equilibration, only the very short-term water level rise would be affected, The longer-term equilibrium water level elevation would not be noticeably affected by the model input applied for pit runoff.

4.9.3 Stress Period Set-up

The pit lake(s) were expected to reach steady state within 1,000 years of the end of mining. Thus, a simulation period of 1,000 years was selected for the post-mining model. This simulation period was modelled as a single stress period, as the hydrologic stresses comprising model input, other than the precipitation and evaporation calculated by the LAK3 package, are constant with time.

4.9.4 Post-Mining Simulation Results

The objectives of the post-mining simulation were to predict pit lake formation and estimate post-mining impacts on groundwater levels.

4.9.4.1 Pit Lake Predictions

The post-mining simulation predicts that two independent pit lakes will form in the two sections of the open pit after mining ceases. The pit lakes area will comprise a terminal sink for groundwater flow. The predicted pit-lake water-surface elevations and water balances are illustrated on Figures C4-25 and C4-26. Lake water-surface elevations are predicted to rise rapidly after cessation of mining and approach steady state at lake stages of about 266.9 mAHD for the northeast pit lake and about 268.8 mAHD for the southwest pit lake. The stage, inflows and outflows for the northeast pit lake approaches steady state by about 120 years after mining, and the southwest pit lake approaches steady state by 80 years after mining. At that time, the pit lake stages are predicted to have recovered 99.5% of the maximum drawdown at the end of mining, the lake stages are within about 0.1 m of those at the end of the 1,000-year simulation, and evaporation rates have stabilized.

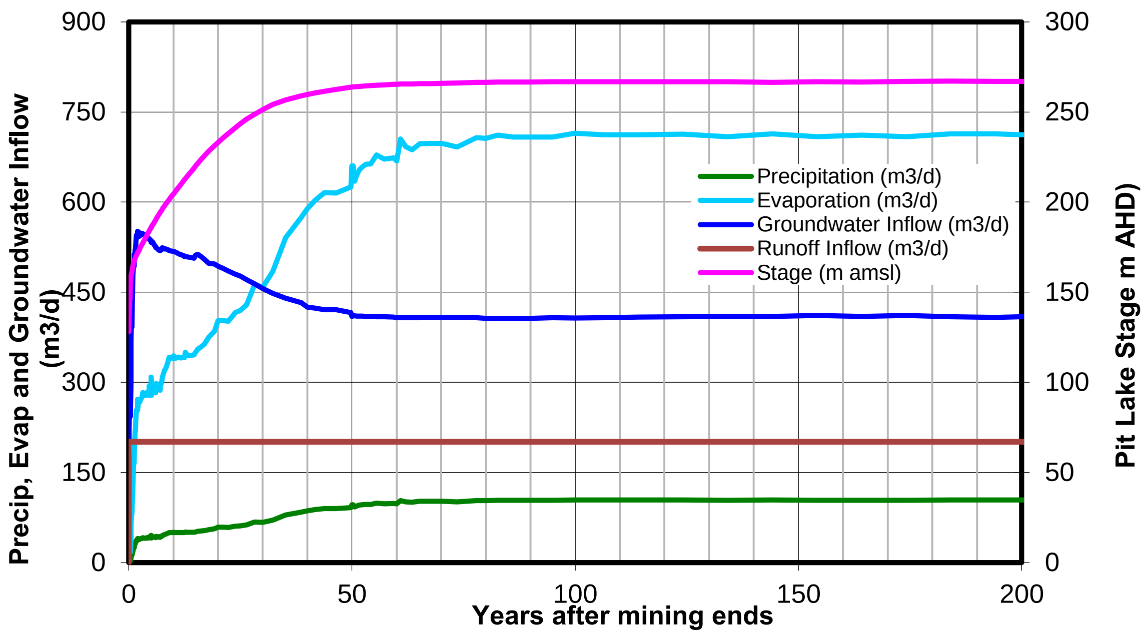


Figure C4-25. Water Balance for Northeast Pit Lake

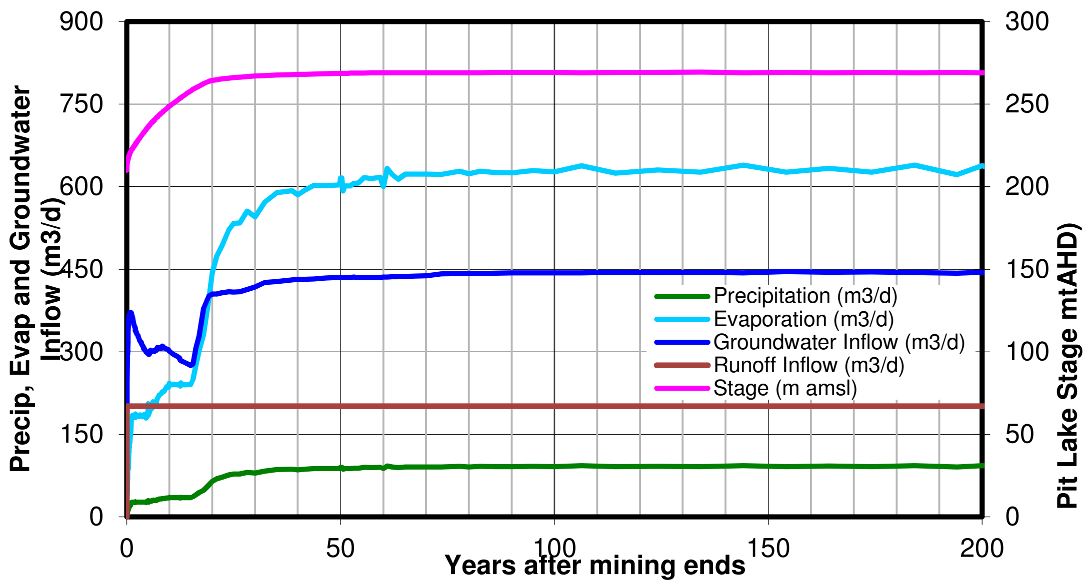


Figure C4-26. Water Balance for Southwest Pit Lake

Once steady state is attained, outflow by evaporation is balanced by inflows from precipitation and groundwater inflow. Components of the pit lakes water balance from when the pit lakes have equilibrated at about 120 years after the end of mining through the end of the 1,000-year simulation period are summarized in Table 4-8. The steady-state groundwater inflows are 410 m^3/d for the northeast pit lake and 426 m^3/d for the southwest pit lake. These rates represent the long-term water consumption rates due to evaporation from the pit lakes; manual calculations of evaporation and rainfall over the final pit lake dimensions confirm that these numbers are realistic. The surface areas for both steady-state pit lakes are estimated to be 0.1 km^2, and the final volumes are estimated to be approximately 5,710 ML for the northeast pit lake and 1,890 ML for the southwest pit lake.

Table C4-10: Simulated Pit Lakes Water Balance at Post-Mining Steady State (t >120 years)

Inflows	Average Annual Rate (m^3/d)	
	Northeast Pit Lake	Southwest Pit Lake
Direct Precipitation	104.44	89.02
Groundwater Inflow	409.83	426.25
Pit Wall Runoff	201.00	94.31
Total Inflow	714.94	609.57
Outflows		
Evaporation	713.04	609.79
Groundwater Outflow	0	0
Total Outflow	713.04	609.79
Inflow - Outflow	1.91	-0.21
Percent Discrepancy	0.27%	-0.03%

4.9.4.2 Groundwater Elevation and Drawdown Predictions

In the post-mining simulation, groundwater levels near the open pits begin to recover when pit dewatering ceases. As the open pits fill with water from precipitation, runoff and groundwater inflow, the developing pit lakes constitute a groundwater sink. Some of the inflow is lost to evaporation, and the remainder goes into storage in the pit lakes. Because evaporation from the lake surfaces will occur as long as the pit lakes are present, the pit lakes constitute a long-term hydraulic sink. Water-level contours near the pit lakes indicate that groundwater will flow into the pit lakes from all directions and will not flow out of either lake; that is, the pit lakes are permanent, terminal sinks.

As the pit lake stages increase, the cone of depression around the pit lakes becomes shallower but continues to expand laterally as it equilibrates with the groundwater inflow induced by evaporative losses from the lakes. Predicted 1-m drawdown distributions at the end of mining and at 1, 10, 50, 100 and 1,000 years after mining ends are illustrated on Figure C4-27. After comparison of results for numerous times, this set of times was selected as a good representation of the changes through time. The drawdown stabilizes between 100 and 200 years after mining ends and does not change beyond that time; contours for times from 200 to 1,000 years are virtually identical. To provide more detail of the degree of drawdown ultimately predicted, additional contours are shown for 1,000 years after the end of mining in Figure C4-28.

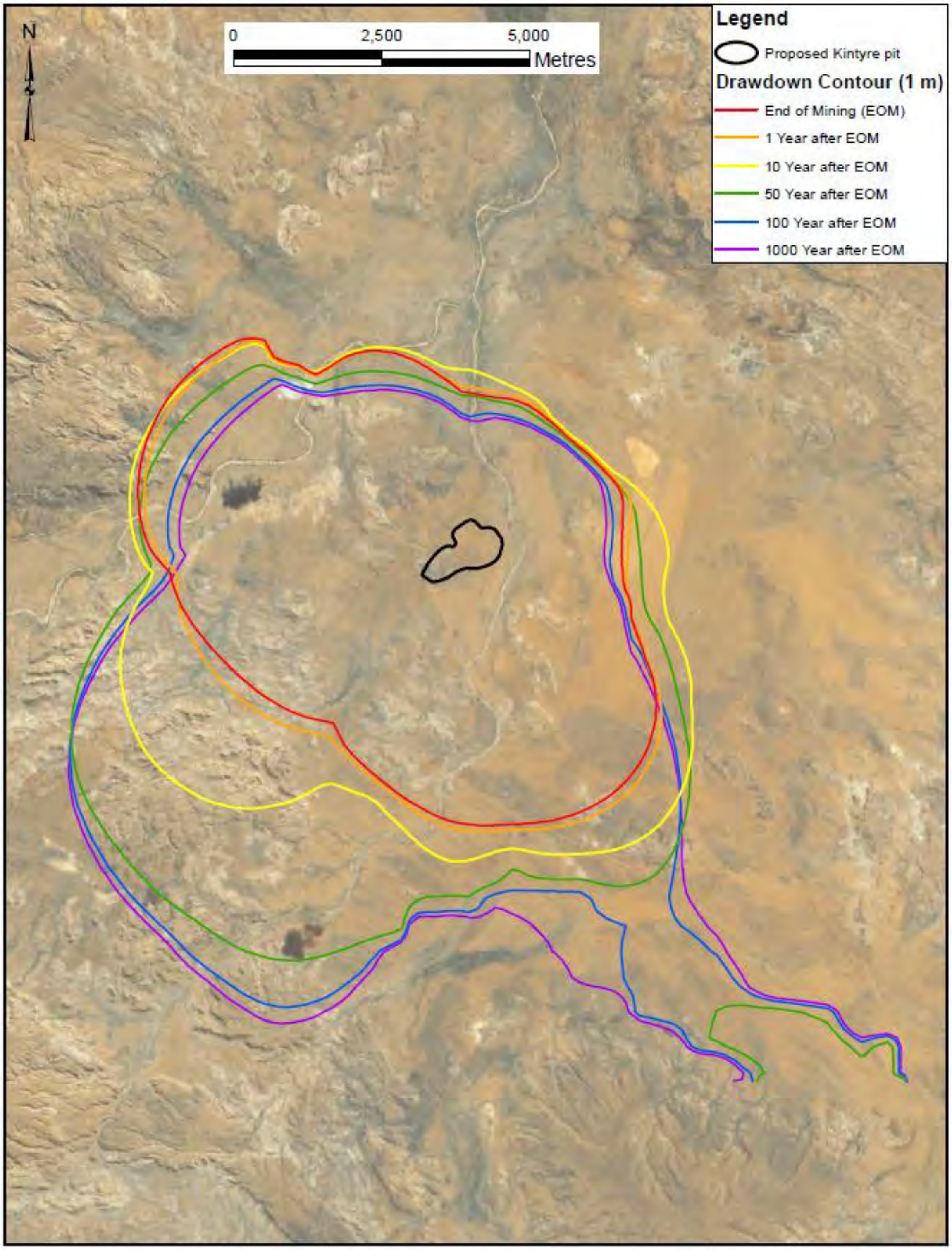


Figure C4-27. Predicted Post-Mining Drawdown Over Time

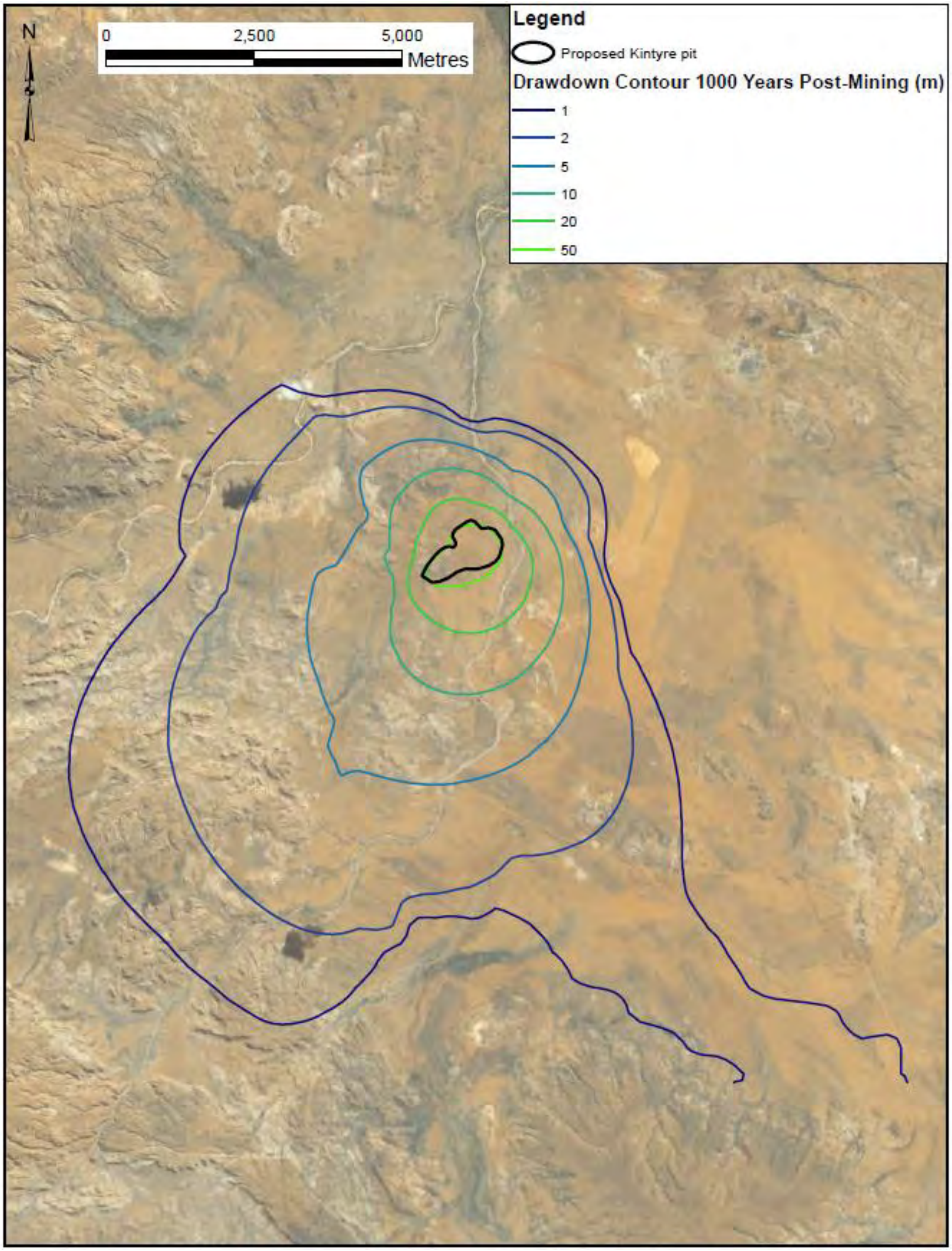


Figure C4-28. Predicted Post-Mining Drawdown Contours After 1000 Years

Figures C4-27 and C4-28 show drawdown contours which are elongated to the north-northwest, southwest and southeast and are most limited to the northeast. The area predicted to experience drawdown of 1 m or more extends to the northwest about 2.5 km at the end of mining; afterwards the extent in that direction lessens, finally equilibrating at a distance of about 2 km from the pit. In the southwest direction, the area with 1 m or more of predicted drawdown extends approximately 1.5 km from the pit at the end of mining and, over the next 100 years, expands to finally equilibrate at a distance of 3.7 km from the pit. Drawdown of 1 m or more is predicted to extend about 2 km to the southeast at the end of mining and ultimately 3 to 3.5 km from the pit. The further extension of the 1-m contours to the southeast in Figures C4-27 and C4-28 is thought to be an artefact produced by the model, as the 2-m contour does not exhibit this extension. The extent of the predicted 1-m drawdown to the northeast of the pit remains relatively stable at 0.9 to 1 km from the pit.

The water supply borefield also experiences recovery after cessation of mining. The rate of recovery is shown in Figure C4-29. The water levels equilibrate in the bores after about 100 years, as shown in the figure.

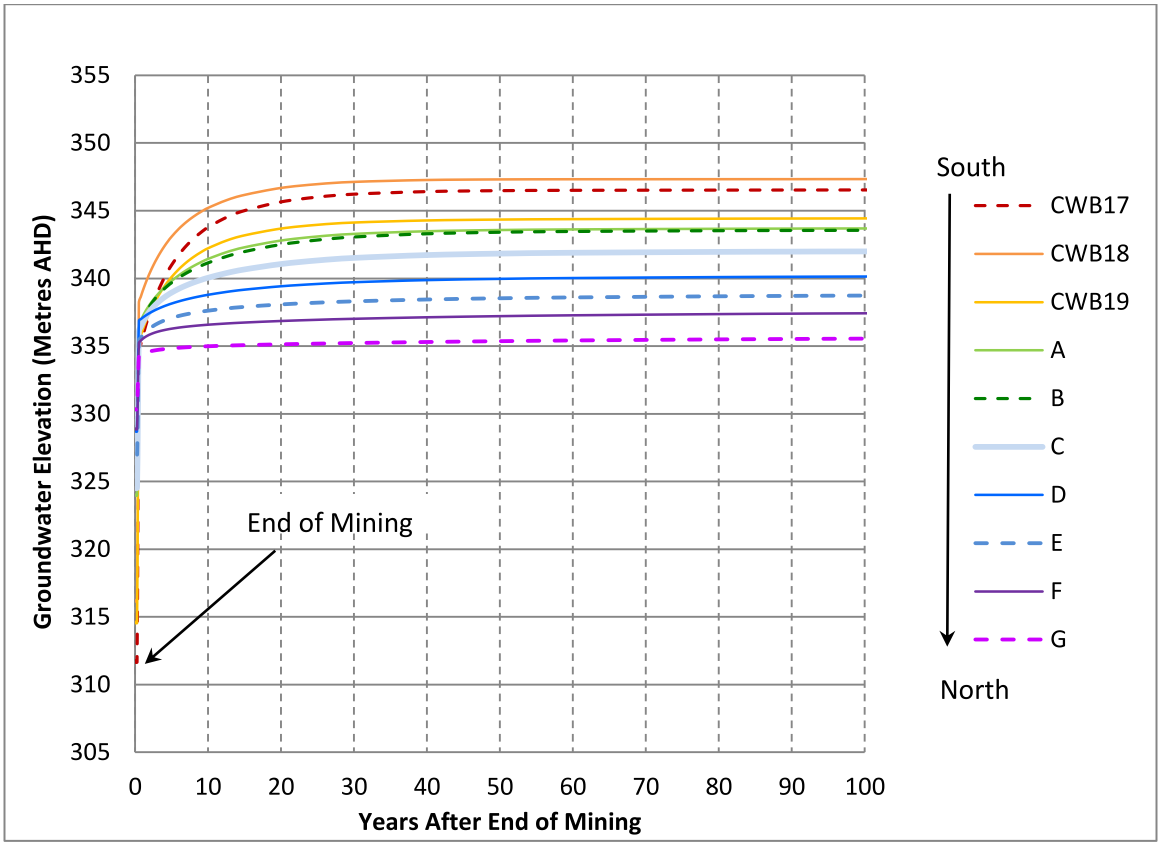


Figure C4-29. Water Supply Bore Recovery

4.10 Predictive Simulation – Particle Tracking

Particle tracking simulations were performed to determine the flow path of particles starting at the tailings management facility (TMF), which is to be located about 1,200 m southwest of the proposed pit. MODPATH (Pollock, 1994) was used to perform the particle tracking simulations.

The particle tracking analysis showed that particles originating at the TMF all eventually migrated into the southwest pit lake, which is a terminal sink. Thus, if the TMF were to have a release, it would be expected to be captured by the nearby pit lake.

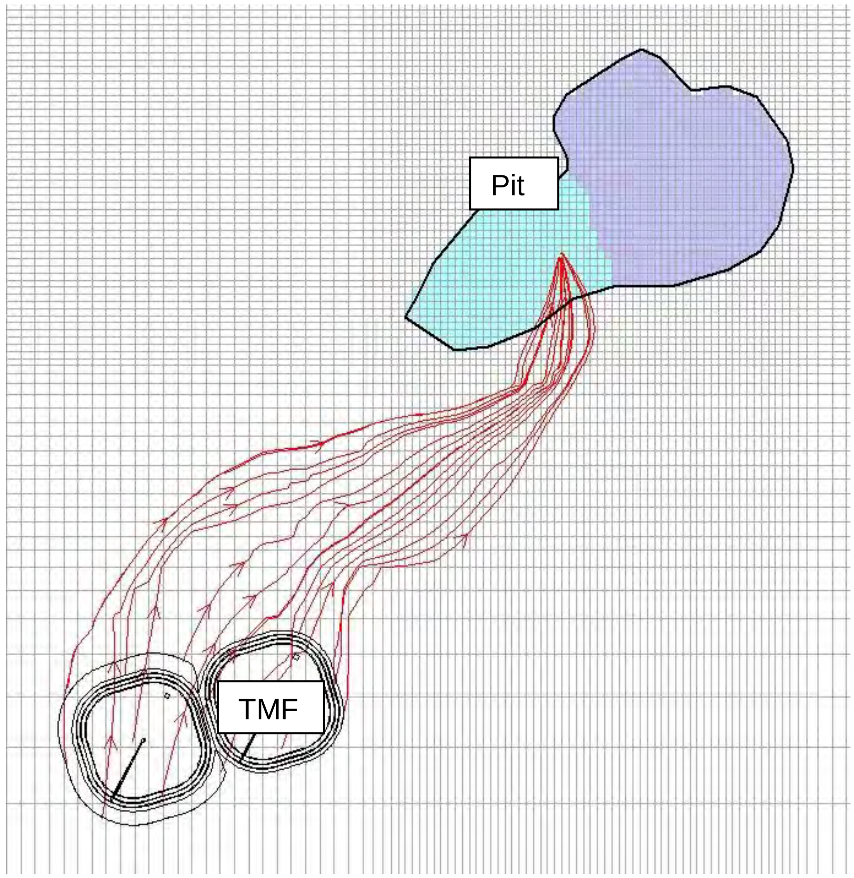


Figure C4-30. Particle Pathways from TMF to Pit

4.11 Predictive Simulation – Sensitivity Analysis

A limited sensitivity analysis was performed using two scenarios identified as reasonable alternative model parameters. The scenarios selected resulted in improved calibration with minimal drawbacks. These scenarios were increased recharge to the Rudall Complex, and decreased Kh in the Rudall Complex. These two scenarios also had the potential to impact both dewatering and pit lake formation scenarios, since they affect the primary geologic unit in which the pit is located (Rudall Complex). The following provides a brief summary of the impact of these two scenarios on the pit inflows and the pit lake stage.

<u>Increased recharge to the Rudall Complex</u>. The scenario in which the recharge to the Rudall Complex was doubled resulted in pit lake inflows stabilizing at about 1,200 m^3/day. This is about 10% higher than the calibrated model. The final pit lake stages were 267.5 mAHD (northeast lake) and 268.9 mAHD (southwest lake). These pit lake stages are very slightly higher than those produced by the calibrated model. The average groundwater inflows were 414.0 m^3/day (northeast lake) and 434.7 m^3/day

(southwest lake). These groundwater inflows are not significantly different than the calibrated model.

Decreased Kh of the Rudall Complex. The scenario in which the Kh of the Rudall complex was cut in half resulted in pit lake inflows stabilizing at about 860 m^3/day, which is approximately 20% lower than the calibrated model inflows. The final pit lake stages were 266.8 mAHD (northeast lake) and 262.7 mAHD (southwest lake). These pit lake stages are very slightly lower than those produced by the calibrated model. The average groundwater inflows were 404.9 m^3/day (northeast lake) and 239.4 m^3/day (southwest lake). For the southwest lake, the inflow is about 56% of those produced by the calibrated model, which probably contributes to the 6-meter lower final lake stage.

This limited sensitivity analysis indicates that the recharge is not as significant to the flows into the pit as the hydraulic conductivity of the mined geologic units. Although neither scenario resulted in significantly different final lake stages, the groundwater inflow numbers indicate that the hydraulic conductivity has a bigger influence on the overall lake water balance. Thus, this limited sensitivity analysis underscores the need for thorough aquifer testing when predicting pit inflows and pit lake formation.

5.0 Flow-Model Limitations

The regional-scale flow models used to simulate the groundwater system have limitations due to the simplifications necessary to represent complex natural systems. Flow model grid size and available data constrain the resolution and accuracy of the predictions. Estimation of approximate magnitudes and timing of groundwater system changes is possible with regional scale predictive flow models. Small changes in water levels and stream flows are inherently difficult for a regional model to accurately simulate, but the predictions are useful for assessing the potential range of impacts.

The groundwater inflows to the open pit mine during mining and post-mining are quantified by simulating the mine dewatering operations, and the effects of these hydraulic stresses on the system are quantified by predicting the water-level drawdowns, changes in surface water flows, and pit-lake development and water balances. Some of these changes are small relative to the model scale, which limits the resolution of the predictions. While the local model improves these estimates, there is still expected to be some uncertainty.

Groundwater inflows to the open pit and post-mining pit lakes may differ from what was simulated. The necessary simplifying assumptions required to simulate the system as an equivalent porous media prevent simulation of the small-scale faults and fractures that could impact the groundwater inflows. Also, there has not been significant hydrogeologic characterization of the regional faults, shear zones, or other structural geologic features, so their potential effect on pit and pit lake inflows (either as conduits or barriers) could not be accurately simulated.

The models are also constructed based on present-day conditions, but natural and possibly anthropogenic changes can be expected over the simulation period. No attempt has been made to simulate possible future changes that could alter the groundwater system. As simulations extend further in time, the error associated with the predictions increases. These factors limit the precision and accuracy of the model predictions. However, the results presented here represent Tetra Tech's best estimate of groundwater system changes associated with the Project.

6.0 Conclusions

Steady-state and transient model calibrations were performed to simulate groundwater flow conditions and to estimate hydraulic parameters based on average water levels and short term aquifer testing conducted at Kintyre. The transient model was calibrated to short term (3 days or less in duration) constant rate tests conducted at nine bores.

Based on the results of water supply modelling, it appears that the proposed borefield consisting of 7 water supply bores with 3 backup bores will be adequate to supply water for the proposed mining activities. Extremely conservative assumptions were used. All 10 bores were operated simultaneously at their maximum rate for a total of 5 ML/day, pumping was initiated 2 years prior to mining, and it was assumed that the pit inflows during dewatering could not be utilized to supply any portion of the water demand. Despite these conservative assumptions, no excessive drawdown was observed at the water supply bores, and each bore was capable of producing 0.5 ML/day during the entire simulation.

Dewatering will be necessary for the open-pit mining operations. Groundwater inflow to the open pit will begin when mining intersects the water table and will increase gradually as the pit is deepened. The predicted final inflows stabilize at about 1,100 m^3/day (1.1 ML/day). Total predicted inflows range from about 0.6 to 2.25 ML/day.

Following completion of mining, pit lakes are predicted to develop in the two lobes of the open pit, with steady-state water surface elevations of approximately 270 mAHD for each of the two lobes. The pit lake area will be a terminal sink for groundwater flow. Water balances for the pit lakes indicate that groundwater inflow accounts for about 57% of the total inflow to the northeast pit lake, and 70% of the total inflow to the southwest pit lake. Precipitation falling on the lake surface and on the sides of the pit (as runoff) account for the remaining inflows. Groundwater inflow is predicted to stabilize at approximately 410 m^3/day for the northeast pit lake and 426 m^3/day for the southwest pit lake. Outflow from the pit lakes area is exclusively by evaporation.

The mine dewatering activities and groundwater inflow to the post-mining pit lakes will result in lowering of the water table in the area around the mine. At the end of the mining period, drawdowns of 1 metre will extend approximately 2.5 km to the northwest, 1.6 km to the southwest, 2.3 km to the southeast, and 1 km to the northeast of the open pit. After mining has ended, groundwater inflow to the pit lakes will continue to lower the water table until equilibrium conditions are attained. The maximum distance predicted to experience drawdown of 1 metre or more extends is about 2.5 km after 10 years, 3.5 km after 50 years, and 4 km after 1,000 years. The extent of drawdown does not change substantially beyond about 100 years after mining ends.

Post-mining particle tracking was performed to assess the flow path of particles originating in the TMF. These particles all entered the southwest pit lake, which is a terminal sink. Therefore, it is expected that if the TMF experienced a release, it would be captured by the nearby pit lake.

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Cameco Australia Pty Ltd

Attachment C – Geochemical Pit Lake Predictive Model Report

Kintyre Joint Venture Project

penningtonscott
securing your water future

Geochemical Pit Lake Predictive Model Report – Non-backfill Scenario

Kintyre Uranium Project

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EXECUTIVE SUMMARY

The Kintyre Joint Venture (KJV) is developing a uranium project, which will require mining below the water table. Following closure, the pit will remain open and upon cessation of dewatering activities, two spatially distinct pit lakes are anticipated to form: Lake 1 and Lake 2.

Based on expected inflows to the pit lake (groundwater seepage and precipitation) in relation to the annual evaporation from the pit lake surfaces, the groundwater flow modelling predicted both pit lakes will be hydraulic sinks. It is predicted that the groundwater table will rebound and the pit lakes will fill to the post closure static water levels approximately 50 and 70 years after cessation of dewatering for Lake 2 and Lake 1, respectively.

The geochemical testing of non-ore rock expected to comprise the final pit walls is presented in the report, *Geochemical Characterisation of the Cameco Kintyre Uranium Project* (Tetra Tech, 2012a). Utilising the information from the geochemical characterisation program, a post closure pit lake model was developed, including the expected physical and chemical behaviour. Water chemistry in both pit lakes is predicted to be highly saline and alkaline after simulation periods of 600 years. Boron, chlorine, manganese, molybdenum, sodium, and uranium are expected to be above ADWG over the entire life of the pit lake and arsenic, chromium, copper, nickel, and selenium start below the ADWG, but quickly exceed the limit during the early years of filling due to the slug inputs of salts from the pit walls. Aluminium is below ADWG in Lake 1, but exceeds the ADWG value over the entire life of the lake. Values of constituents in the final lake waters were compared with the Australian Drinking Water Guidelines (ADWG). The conclusions of the predictive geochemical modelling are:

- The majority of inflow water entering the pits will be from precipitation landing on the lake surface, with only minimal contribution from groundwater;
- pH values for Lake 1 (east) and Lake 2 (west) are predicted to be circum-neutral to slightly alkaline and within the acceptable range;
- Due to the high rate of evaporation, many constituents in the final pit lake solutions are expected to increase due to evapo-concentration and may exceeded the ADWG; and
- Overall lake chemistries were different between the two lakes due to the different geologic units in contact with the lake water.

1.0 INTRODUCTION

The Kintyre Uranium Project (Project) is an advanced-stage, joint venture exploration project between Cameco Australia Pty Ltd (Cameco) and Mitsubishi Development Pty Ltd (The Kintyre Joint Venture [KJV]). The Kintyre Uranium Deposit (Kintyre) will be developed using open pit mining techniques. Kintyre is an unconformity-related vein-type deposits that occurs near major unconformities in faulted and brecciated metasedimentary rocks. The deposit is "world-class" and contains between 28,000 and 36,000 tonnes of U_3O_8 with a reported grade of 0.3 – 0.4 wt% U_3O_8, (Redport, 2005 and Environ, 2011). There are five major deposits delineated as part of the Kintyre Project:

- Kintyre
- Whale
- Whale East
- Pioneer
- Pioneer East

In addition to these five major deposits, a smaller deposit, named Little Pioneer is situated between the Pioneer and the Pioneer East deposits. The areas to be developed are Kintyre, Whale, and Pioneer. It is anticipated that mining activities will occur below the water table, and a dewatering system will be employed during operation. Following cessation of dewatering activities at the end of active mining, the pumps will be turned off and the groundwater system will be allowed to rebound to the post closure static water level condition. Groundwater modelling performed to support the Kintyre Environmental Review and Management Program (ERMP) suggests two spatially distinct post closure pit lakes are anticipated to form, Lake 1 and Lake 2.

This report documents the development and results of a post closure pit lake model to assist in understanding the water quality and long term physical behaviour of the lakes. This information is being used to further develop on-going mine planning and permitting activities. There are two scenarios that are currently under consideration: a backfill scenario and a non-backfill scenario. The following report presents the findings of the non-backfill scenario.

1.1 Background

A brief review of background information relevant to the Project is presented in the following subsections.

1.1.1 Project Location

The Project is located in northwestern Australia at the western edge of the Great Sandy Desert in the eastern portion of the Pilbara region. The Project is 60 kilometres (km) south of Telfer and 270 km northeast of the town of Newman. Figure C1-1 presents a generalised location map.

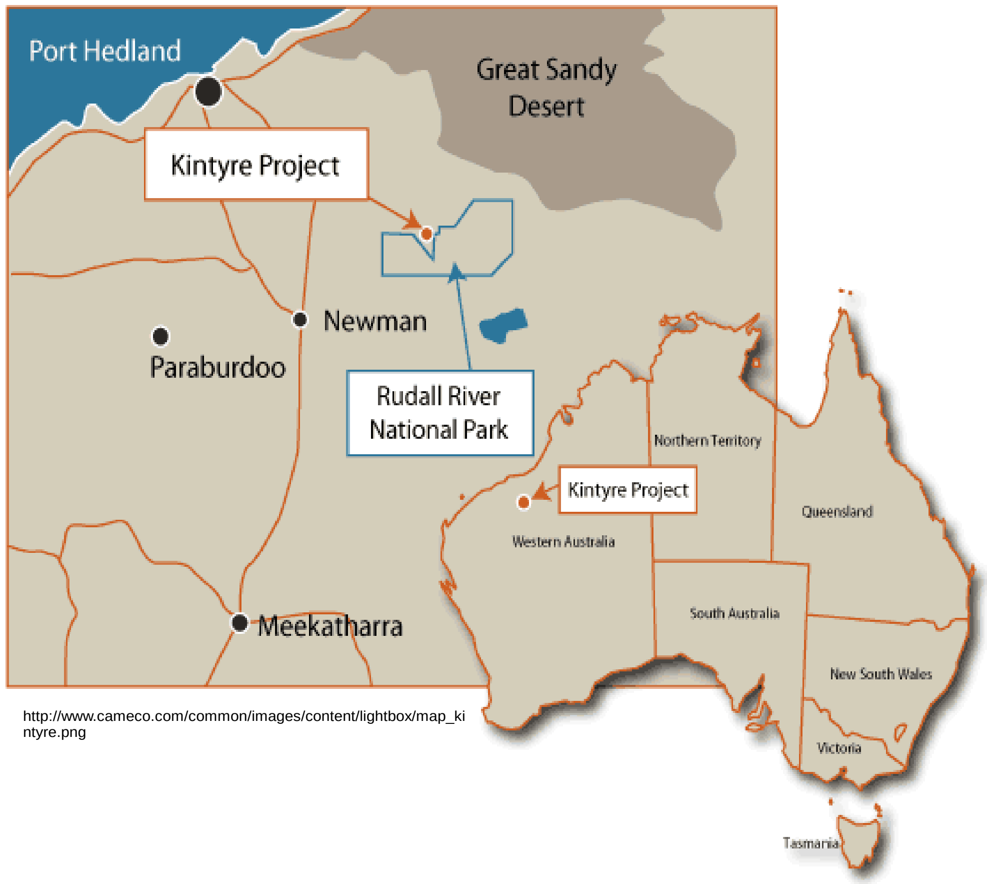


Figure C1-1. Project Location

1.1.2 Climate

The Project area is characterised as an arid and tropical climate, hot summers with low irregular rainfall and warm dry winters. Daily high temperatures, measured approximately 60 km north of Project area at Telfer, are 40°C in summer with winter daily low temperatures around 26°C. Evaporation exceeds precipitation for the majority of the year. The annual potential evaporation is over four metres (m). Although precipitation is sparse, the region can receive extreme precipitation events during the monsoonal months between December and March. Historically rainfall ranges from 110 mm/year to 820 mm/year with an average of 370 mm/year. The availability of seasonal precipitation is relevant when considering the water quality of a post closure pit lake that will be subject to high levels of evapo-concentration.

Table 1.1 shows climate information from Marble bar, which is the nearest weather recording station to the Kintyre project area.

Table C1-1. Climate Data for Marble Bar, Western Australia

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record High °C	49.2	48.3	48.7	45.0	39.5	35.8	35.0	37.2	42.6	45.6	47.2	48.3	49.2
Average High °C	41.0	39.8	39.0	36.0	30.7	27.1	26.8	29.6	33.9	37.6	40.5	41.6	35.3
Average Low °C	26.1	25.7	24.8	21.4	16.6	13.2	11.7	13.3	16.7	20.3	23.6	25.5	19.9
Record Low °C	18.9	13.9	15.0	10.0	5.6	1.1	2.2	3.9	5.6	10.0	14.4	17.0	1.1
Precip mm	76.3	87.8	56.7	21.9	23.0	23.0	12.6	6.4	0.9	3.8	9.1	39.6	361.7

1.1.3 Geology

The Project and corresponding properties are situated in metamorphic sedimentary skarn deposits. The dominant rock types are metamorphic gneisses and schists with varying degrees of ancillary minerals such as hornblende, chlorite, muscovite, garnet, epidote, and calcite. Figure C1-2 depicts the general geologic makeup of the area. The uranium mineralisation is present in the Paleoproterozoic Yandagooge Formation (Belyk et al, 2011) with an approximate age between 1.6 and 2.5 Ga. This is the younger of two metasedimentary rock suites in the Rudall River Metamorphic Complex. Unconformably over-lying the Yandagooge Formation are the Neoproterozoic beds of the Yeneena Group (1.0 – 0.54 Ga). The dominant member of this group is the Coolbro Sandstone. Permian glacial tills are also present as extensive valley fill. Mineralised veins in the region typically contain pitchblende along with calcite, dolomite, chlorite, hematite, and trace sulphides.

Of the original 65 individual rock-types defined in the area, it is feasible to consolidate these based on mineralogy and overall chemistry into six major rock-type categories which build upon the CSA (2011) report:

- Hanging Wall Schists (Plgi, Pt, Ptl);
- Carbonate Rocks (Pk, Pkl);
- Tillite (Pgc, Pgg);
- Ore Host (Pl, Pli, Plki, Plig, Plik, Plk, Plg);
- Fault/Breccia (Ft, Bxx, Fb, FT, Pb); and
- Other Schists (Pcg, Pga, Pka, Pkt, Pla, Plc, Pls, Ps, Psi, Psik, Psk, Ptg, Pti, Ptk).

Of these rock types, only four are used in the pit lake modelling (schists, carbonate rocks, tillite, and ore host.

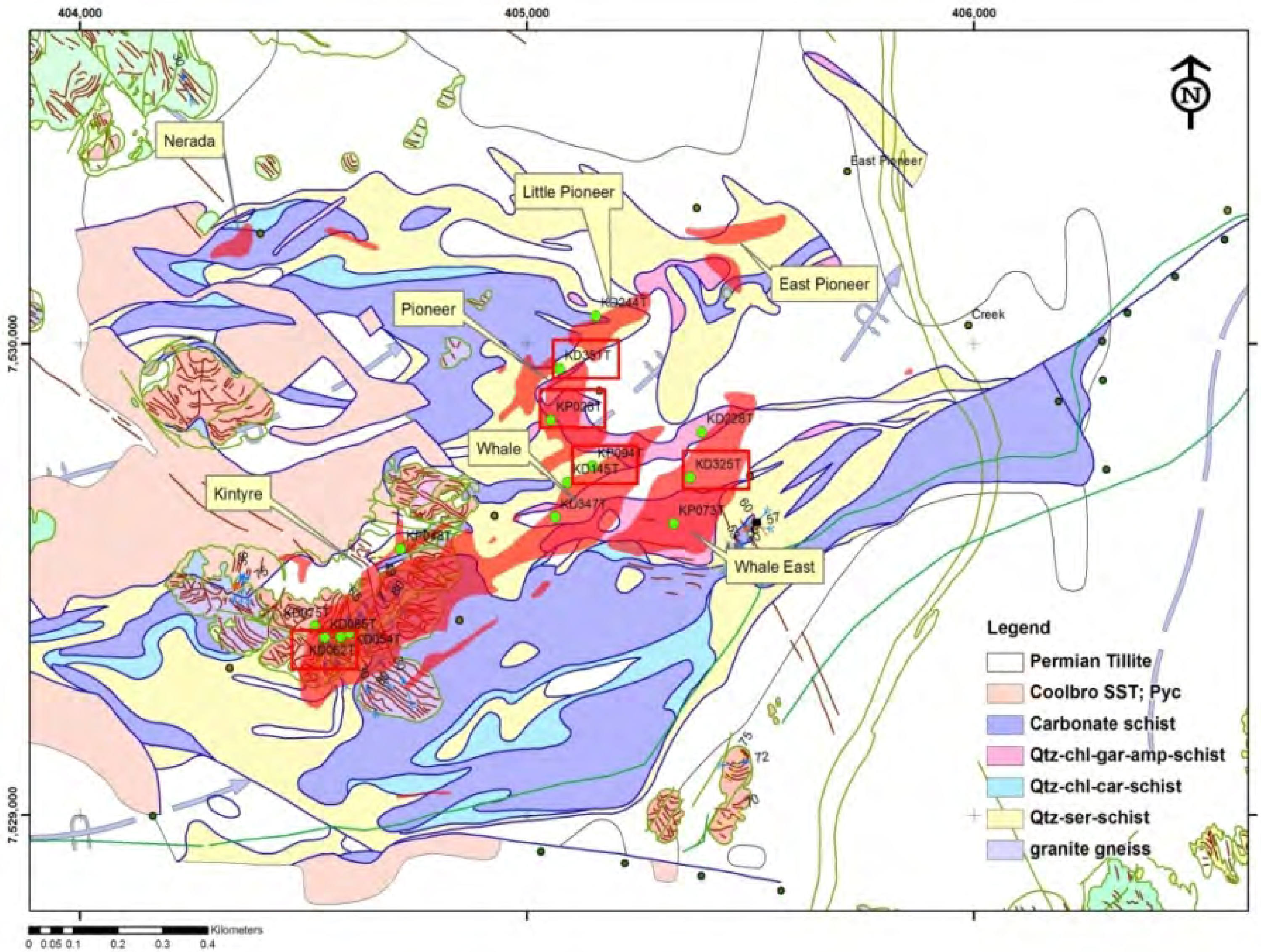


Figure C1-2. Generalised Geologic Map of Project Area

2.0 PIT LAKE CONCEPTUAL MODEL

Following mining activities and the cessation of dewatering, the following conceptual model has been developed based on the available data:

- Groundwater will enter the pit, as the groundwater level rebounds and returns to static conditions.

- Groundwater chemistry is sodium/potassium-chloride type (Table C2-1 and Figure C2-1) with sodium much greater than potassium, on average (Table C2-2). Additionally, the groundwater contains elevated concentrations of aluminium and minor iron. Metals of concern above Australian Drinking Water Guidelines (ADWG), NHMRC and NRMMC (2004) include arsenic, fluoride, manganese, molybdenum, and lead.

- Evaporation is much greater than precipitation resulting in concentration of elements;

- Due to the pit configuration, two lakes will form (Figure C2-2). The eastern pit (Pit Lake 1) consists predominately of schist with lesser and approximately equal areas of ore host, carbonate, and tillite. The western lake (Pit Lake 2) is predominantly ore host rock.

- Based on mineralogical analysis, aluminosilicate minerals dominate the lithology, with dolomite dominating the carbonate rocks. Sulphide minerals were not identified by x-ray diffraction (XRD).

- Based on kinetic testing, water-rock interactions will not generate any acid rock drainage/metal leaching conditions and maintains neutral to alkaline pH. Water-rock interactions expected include:

  - Short intense rainfall producing short wetting/long drying reactions;

  - Alkaline weathering reactions within the pit lake with oxygen concentrations dependent on limnological considerations (Section 4).

- Given the low rainfall, high evaporation, and generally low reactiveness of the pit wall, the following reactions are predicted:

  - Concentration of sodium and chloride through evaporation, increasing salinity and subsequent precipitation of halite;

- The precipitation of amorphous aluminium and iron hydroxides at a neutral pH with co-precipitation of potential metals of concern. Fluorine may also precipitate as aluminium-complexes or fluorite.

Table C2-1. Groundwater Chemistry Summary

Bore ID	12PD	15PS	9PS	CWB2D	CWB4s	CWB7D	KEB1	KEB2
pH	7.1	7.24	7.9	8.12	7.83	7.63	7.3	7.4
Silver	-	-	0.007	-	-	-	-	-
Aluminium	1.64	2.28	1.76	-	0.02	0.04	-	-
Arsenic	0.01	-	0.01	-	-	0.003	-	-
Boron	-	0.7	0.76	-	1.9	1.4	-	-
Barium	0.1	-	0.016	-	0.11	0.060	-	-
Beryllium	-	-	-	-	-	0.0025	-	-
Calcium	161	133	63.1	32.5	120	117	110	78
Chlorine	2,006	3,442	1,518	1,020	3,075	1,560	1,900	720
Cobalt	-	0.05	0.002	-	-	0.02	-	-
Chromium	-	-	0.004	-	-	-	-	-
Copper	-	-	0.066	-	-	0.009	-	-
Fluorine	1.37	2.37	2.17	-	-	-	-	-
Iron	0.44	0.303	0.547	0.037	0.237	0.198	0.41	0.03
Potassium	62.67	101.67	893.25	37.75	35.2	50.83	76	27
Magnesium	201.33	295	87.5	69.5	202	164	210	98
Manganese	-	4.887	0.071	-	0.73	0.46	-	-
Molybdenum	0.6	-	0.012	-	-	0.01	-	-
Nitrate as Nitrogen	6	0.2	26.72	0.5	0.035	-	9.4	4.5
Sodium	1,623	2,359	619.5	1,055	2,300	1,133	1,500	520
Nickel	-	-	0.006	-	0.006	0.01	-	-
Phosphorous	0.3	0.08	0.899	-	-	0.06	-	-
Lead	-	0.267	0.06	-	-	-	-	-
$Lead^{210}$	-	1,200	14	-	-	-	-	-
$Polonium^{210}$	28	4,700	28.8	-	-	-	-	-
$Radium^{226}$	795	19,500	15	-	-	-	-	-
Sulphate	1,632	1,808	902	663	1,320	1,060	990	280
Antimony	-	-	-	-	-	0.025	-	-
Selenium	0.005	-	0.001	-	0.004	0.004	-	-
Silicon	-	-	22	-	16	12	-	-
Silica	10.3	15.57	29	-	-	-	-	-
Strontium	-	-	-	-	2.8	1.4	-	-
Titanium	-	-	0.003	-	0.001	0.004	-	-
Uranium	0.213	0.467	0.079	-	0.01	0.045	-	-
Vanadium	0.05	-	0.04	-	0.01	-	-	-
Zinc	0.02	-	1.63	-	-	0.13	-	-
Alkalinity	473	630	554	170	430	380	720	440
Total Dissolved Solids	5,952	8,486	4,405	3,750	7,200	3,940	4,800	2,000

Notes:

Average concentrations 1987-2011
Concentrations in mg/L
Radioactivity in mBq/L
- = no data available

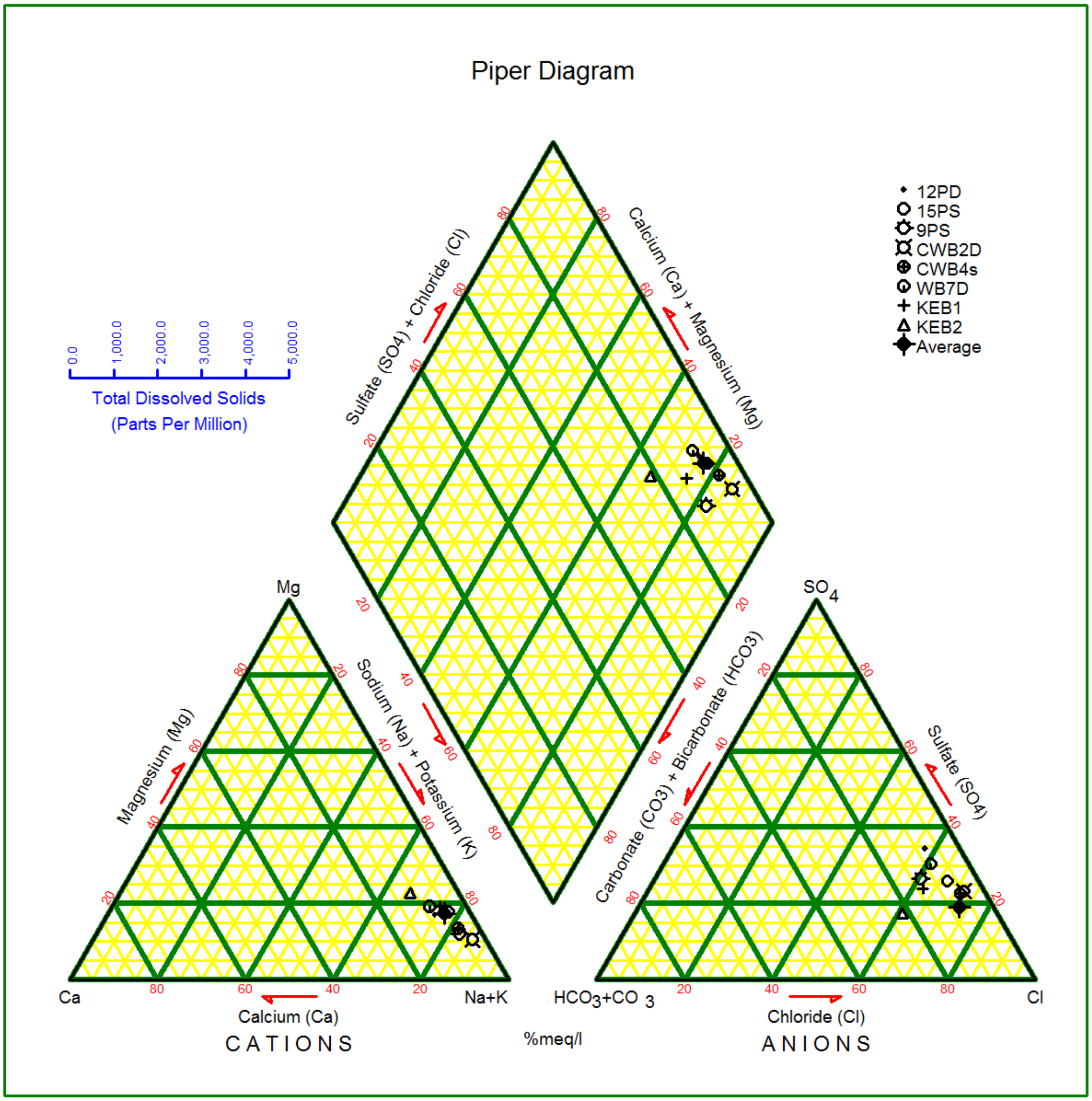


Figure C2-1. Piper Diagram of Groundwater Chemistry

Table C2-2. Average Groundwater Concentrations with Respect to ADWG

Analyte	ADWG	Average
pH	6.5-8.5	7.57
Alkalinity	-	475
Aluminium	0.2	1.15
Arsenic	0.007	**0.008**
Boron	4	1.19
Barium	0.7	0.072
Beryllium	-	0.003
Calcium	-	102
Chlorine	250	**1,905**
Cobalt	-	0.024
Chromium	0.05	0.004
Copper	1	0.038
Fluorine	1.5	**1.97**
Iron	-	0.275
Potassium	-	161
Magnesium	-	166
Manganese	0.1	**1.54**
Molybdenum	0.05	**0.207**
Nitrate as Nitrogen	50	6.77
Sodium	180	**1,389**
Nickel	0.02	0.007
Phosphorous	-	0.335
Lead	0.01	**0.164**
$Lead^{210}$	-	607
$Polonium^{210}$	-	1,586
$Radium^{226}$	-	6,770
Sulphate	-	1,082
Antimony		0.025
Selenium	0.01	0.004
Silicon	-	16.7
Silica	-	18.3
Silver	-	0.007
Strontium	-	2.1
Titanium	-	0.003
Uranium	0.02	**0.163**
Vanadium	-	0.033
Zinc	3	0.593
Total Dissolved Solids	-	5,067

Notes:
All results mg/L
ADWG = Australian Drinking Water Guidelines, NHMRC and NRMMC (2004)
Bold results above ADWG

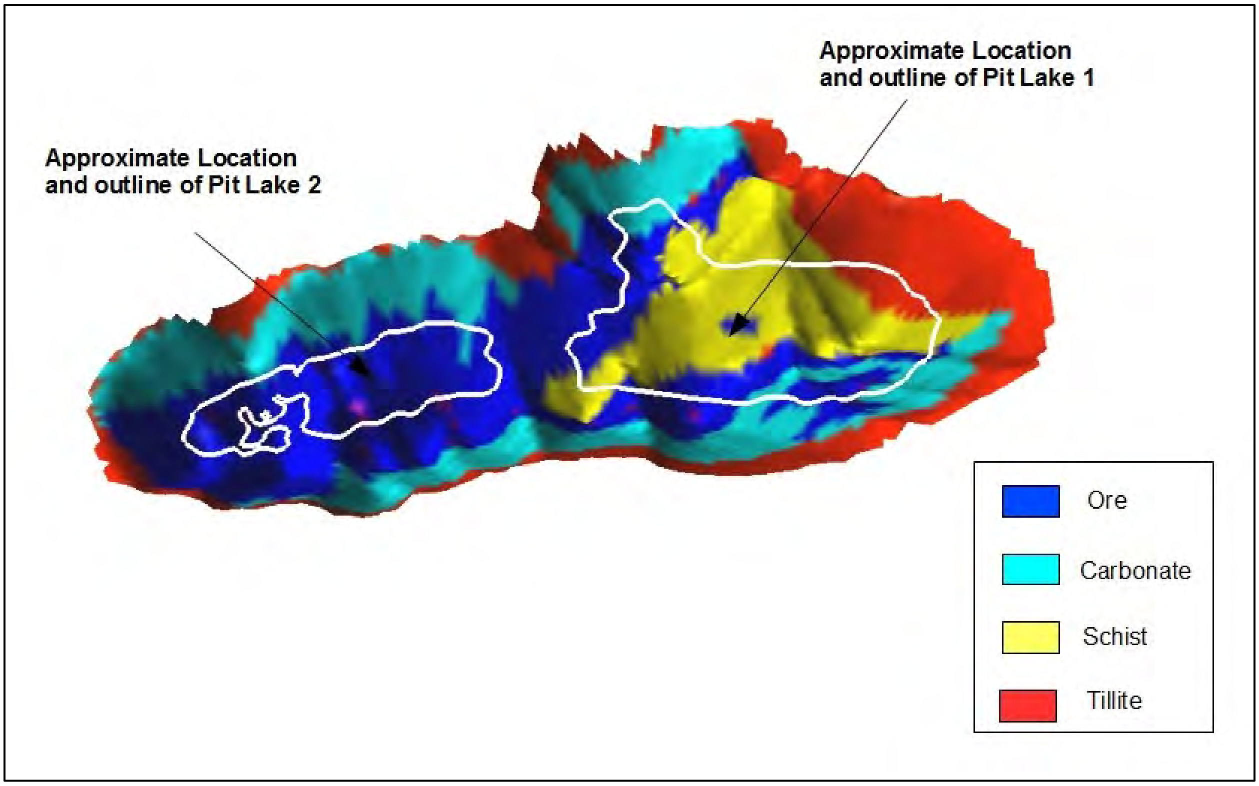


Figure C2-2. Pit Lake Configuration and Lithology

3.0 PIT LAKE WATER BALANCE

During the post-closure stage of the Project, two separate pit lakes are expected to form. The rate of pit filling and the ultimate level or stage of the pit lake will be controlled by the post-closure water balance (Tetra Tech, 2012b). Conceptually, the post-closure water balance can be expressed as:

$$\Delta_{\text{pit lake volume}} = I_{\text{precip}} + I_{\text{run-on}} + I_{\text{pit run-off}} + GW_{\text{inflow}} - E_{\text{pit}} - GW_{\text{outflow}}$$

Where:

- $\Delta_{\text{pit lake volume}}$ is the change in lake volume;
- I_{precip} is the inflow from direct precipitation falling on the lake surface;
- $I_{\text{run-on}}$ is the inflow from upgradient drainages;
- $I_{\text{pit run-off}}$ is the inflow from pit wall run-off (the fraction of precipitation falling on the pit walls that ultimately reaches the pit lake);
- GW_{inflow} is the groundwater inflow to the pit lake;
- E_{pit} is the open water evaporation from the pit lake surface; and
- GW_{outflow} is the outflow of groundwater from the pit lake, which is assumed to be zero.

The interaction between these parameters is presented schematically in Figure C3-1. Figures C3-2 and C3-3 present the water balance values for Lake 1 and Lake 2, respectively. The components of the pit lake water balance are discussed below.

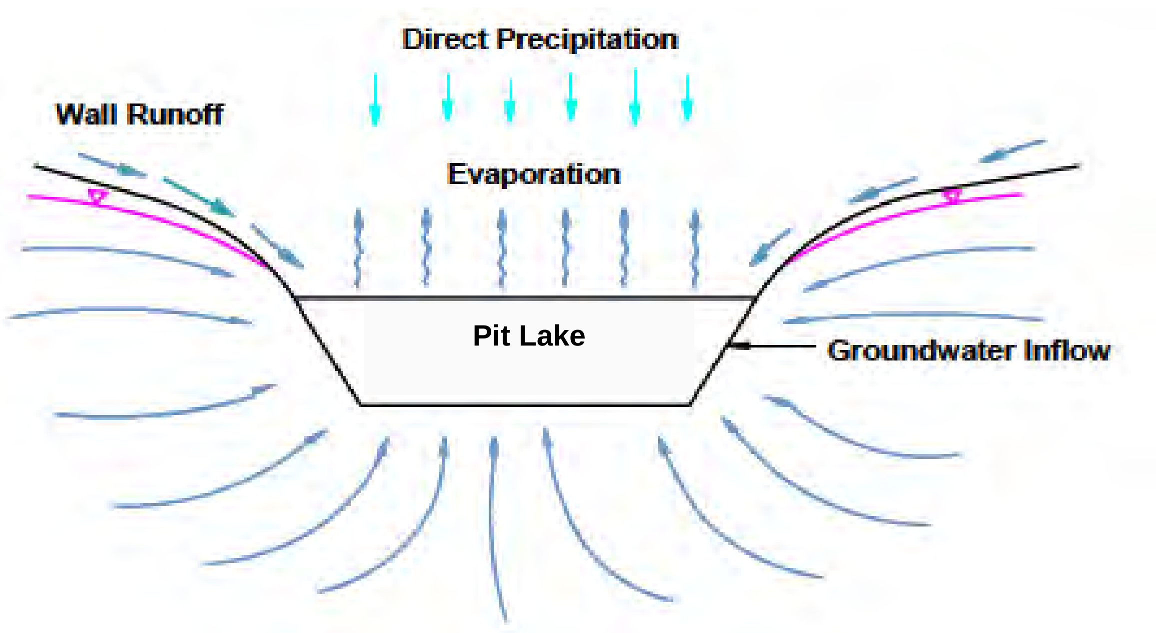


Figure C3-1. Conceptual Hydrologic Model of Pit Lake

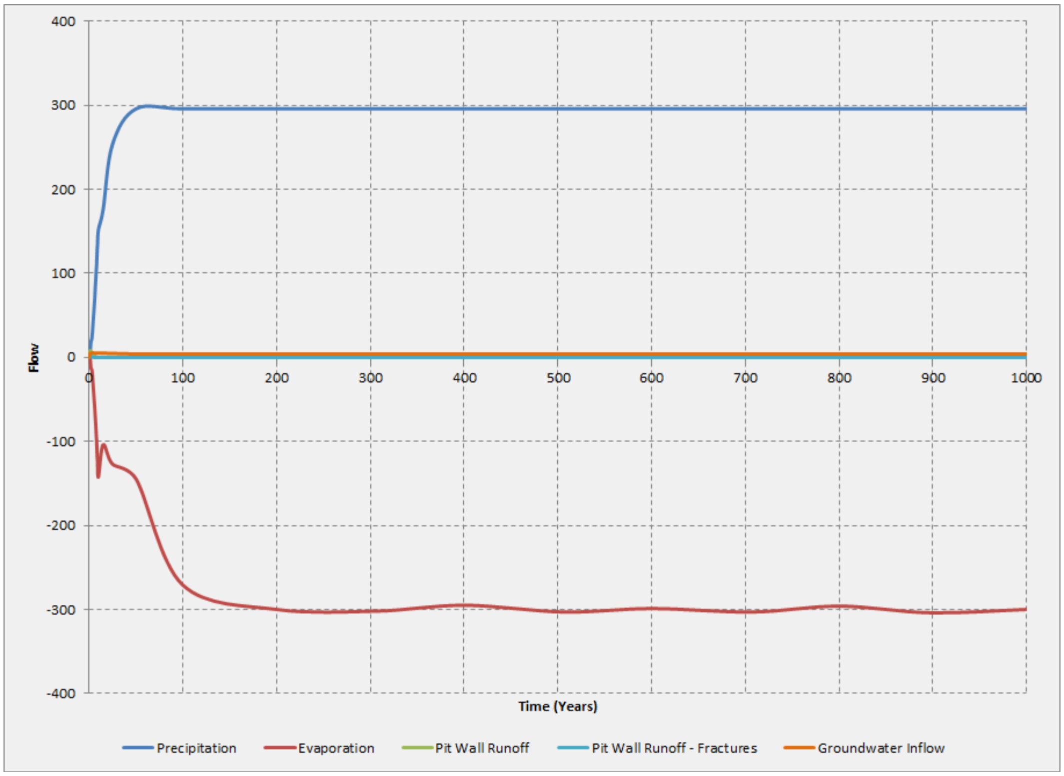


Figure C3-2. Lake 1 Water Balance

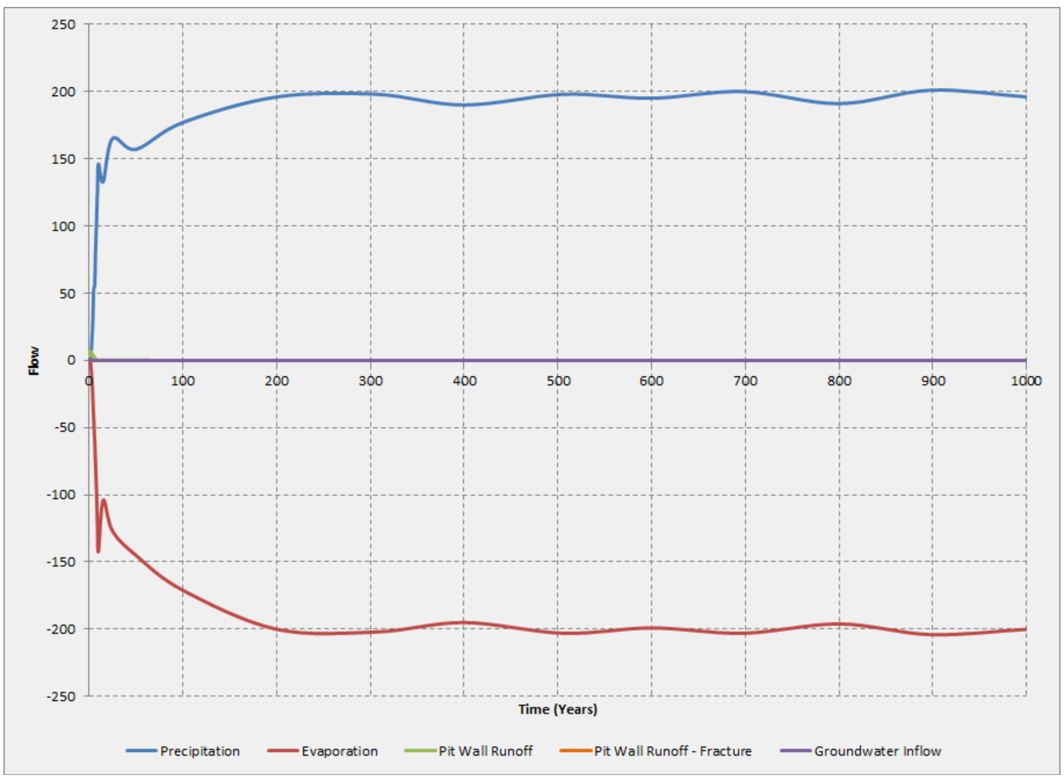


Figure C3-3. Lake 2 Water Balance

3.1 Direct Precipitation (I_{precip})

The post closure pit lake will receive an inflow source of water from precipitation. The amount of contribution from precipitation will be low in the early years of pit filling due to the small surface area of the lake. As the lake fills and the lake surface increase in size, the contribution from precipitation will become the largest inflow source of water. If sufficient, this inflow can expedite the rebound of groundwater gradients, or can provide a means to alter pit lake chemistry temporally via dilution effects. However, in areas such as Kintyre in Western Australia, the low annual rainfall (370 mm/year) suggests that dilution will not be a major factor in the overall pit lake water quality.

3.2 Upgradient Drainages ($I_{run\text{-}on}$)

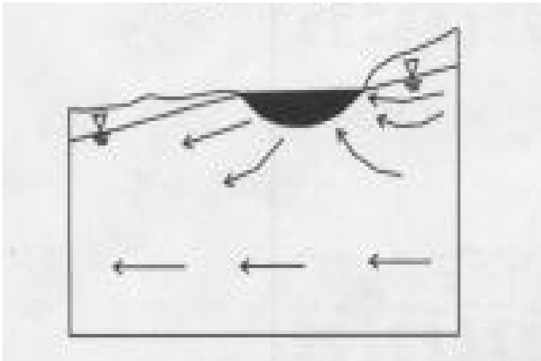
There are no upgradient drainages that are expected to provide run-on water inflows to the Kintyre post closure pit lakes.

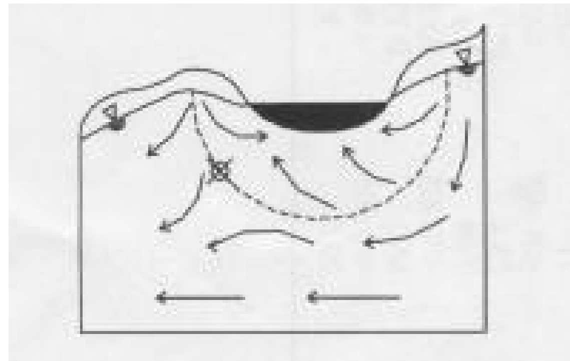
3.3 Pit Wall Runoff ($I_{pit\ run\text{-}off}$)

Surface run-on and/or direct precipitation on the wall rock of the pit above the pit lake water level can effectively flush metal “salts” from the wall material and over time affect the pit lake quality. The efficiency of such a process depends on the character of the wall rock material (i.e., porous versus non-porous, fractured versus non-fractured, grain size, and composition). Furthermore, steep gradients might afford less time for runoff/wall rock interaction than shallower slopes, which allow deeper water penetration and longer residence times. While rainfall is low at the Project site, under some conditions, appreciable amounts of metals and/or salts could be introduced into the pit lakes by this mechanism. In the models presented, 20% of precipitation will interact with the pit wall chemistry, with the remaining 80% experiencing direct runoff into the pit. These numbers are generally accepted in pit lake models in arid regions.

3.4 Groundwater Inflow (GW_{inflow})

When the dewatering system is turned off, the regional groundwater system will begin to rebound to a post mining static level. If the groundwater gradients and inflow to the lake are sufficiently high, the resulting pit lake forms a flow-through system with the regional aquifer. If groundwater inflows are low and evaporation is high, the lake surface can be depressed relative to the groundwater surface and can result in a sink. Figure C3-4 presents these two pit lake dynamics. Due to the high rate of evaporation and relatively low groundwater inflow, the Kintyre post closure pit lakes are expected to be terminal sinks.





Flow through Pit **Terminal Sink**

Figure C3-4. Schematic of Pit Lake Flow Dynamics

3.5 Evaporation (E_{pit})

Evaporation is the most significant contribution to the pit lake water balance. High levels of evaporation can impact the flow dynamics of the post closure pit lake and the water quality of the system. As described in Section 3.4, if evaporation is sufficiently high, the stage of the lake may be lower and a sink can form. This can be advantageous if poor water quality conditions are expected in the post closure pit lakes, because downgradient contaminant plumes are not likely to form and impact the regional groundwater system. However, the evaporation and decrease of lake volume can result in the concentration of constituents present in the lake water. The groundwater flow modelling provided an evaporation rate for each stage that was utilized at the end of each pit lake time step to adjust the pit lake chemistry accordingly.

3.6 Groundwater Outflow ($GW_{outflow}$)

Based on the results of the groundwater flow models, both Lake 1 and Lake 2 will be terminal sinks, and thus will have no groundwater outflow.

3.7 Lake Stage and Storage

Lake water-surface elevations are predicted to rise rapidly after cessation of mining and approach static lake levels of 267 and 268 m above mean height datum (aMHD) in Lake 1 and Lake 2, respectively. The stage, inflows, and outflows for Lake 1 approach steady state by about 70 years after mining, and by 50 years for Lake 2. At those times, the pit lake stages are predicted to have recovered 99.5% of the maximum drawdown at the end of mining and the predicted lake stages are stable at those elevations through the end of the 1,000-year simulation. Figure C3-5 presents the lake surface elevation over time for both post closure pit lakes and Figure C3-6 presents a stage-storage curve for each lake.

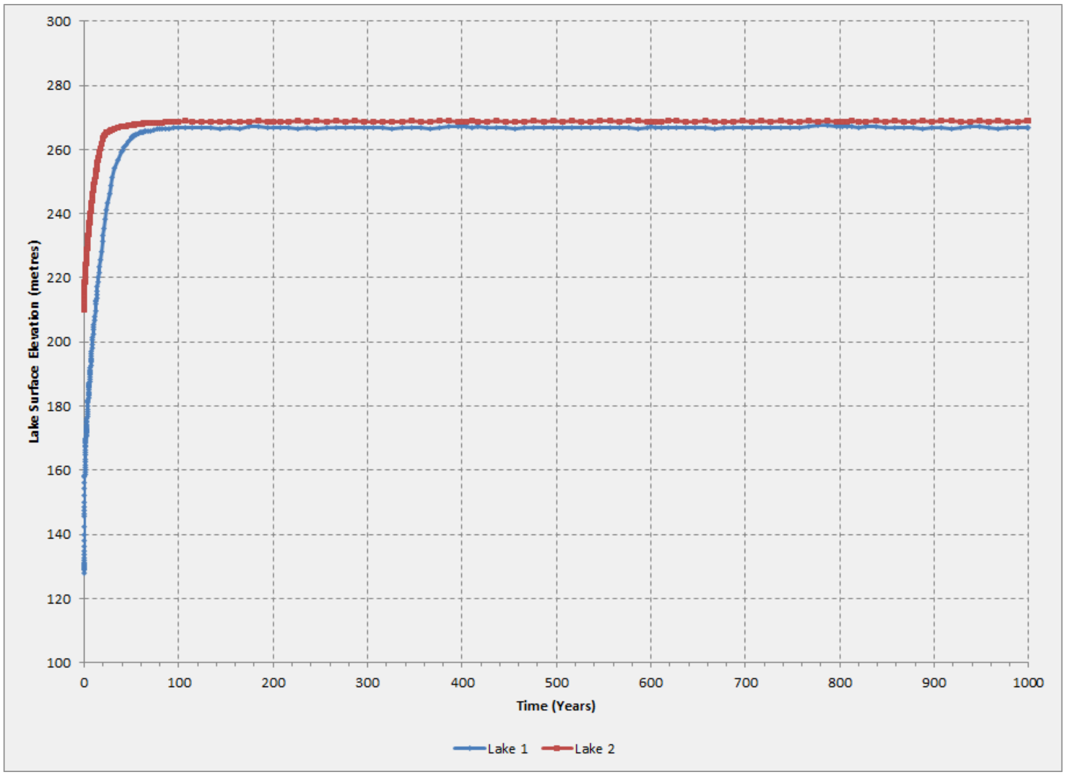


Figure C3-5. Filling Curves for Post Closure Pit Lakes

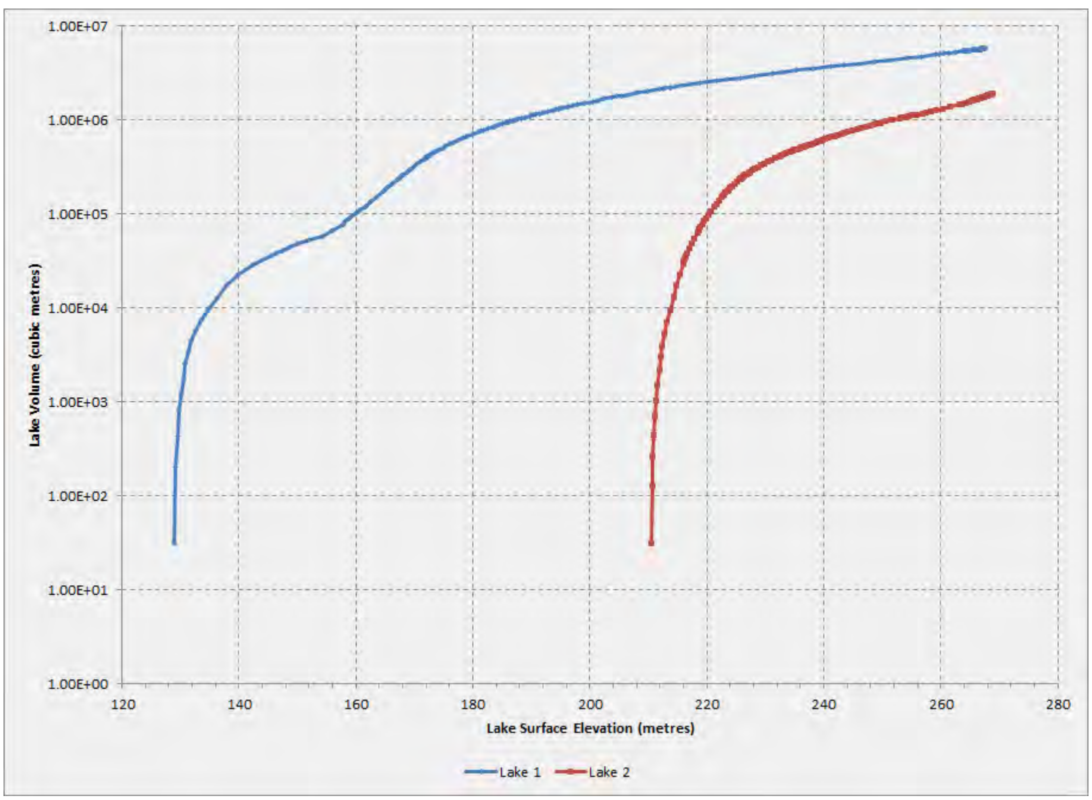


Figure C3-6. Stage vs. Storage Relationship of Lakes

4.0 PHYSICAL LIMNOLOGY

The following section describes the physical limnology of the post-closure pit lake. Physical limnology is the study of the physics of water movement within a lake. Physical limnology is critical to the pit lake study because it considers all of the forces acting on the lake water to determine the existence, location, occurrence, and stability of the stratified layers. The limnological characterization focuses on the following issues:

- Lake geometry;
- Climactic impacts;
- Depth/temperature profiles;
- Depth/water density relationships; and
- Lake stability calculations.

Lake stratification is driven by density differences between the upper and the lower areas of the lake. The density differences can be driven by temperature or chemistry. For temperatures above 4^{o}C, water with lower temperature has a higher density than water at higher temperatures. This relationship is non-linear and changes in density are greater at higher temperatures. For example, the difference in density between water at 40^{o}C and 30^{o}C is 3.5 kilograms per cubic metre (kg/m^3), whereas the difference in density between water at 30^{o}C and 20^{o}C is 2.5 kg/m^3. Dissolved solids have a great impact on water density with 1,000 milligrams per litre (mg/L) adding 1 kg/m^3 of density.

Several key terms that will be used in this section, are defined below:

- Thermocline (metalimnion): Layer of rapid temperature change with depth that acts as a boundary in thermally-stratified lakes;
- Chemocline: A layer of rapid chemical change with depth that acts as a boundary in chemically-stratified lakes;
- Meromictic: A partially mixing lake that results in a bottom stagnant layer;
- Monomictic: A lake that mixes once per year (common for shallow tropical lakes);
- Polymictic: A lake that stratifies and mixes numerous times per year;
- Dimictic: A lake that has two mixing periods associated with seasonal temperate changes;
- Epilimnion: The upper, well-mixed, and oxygenated layer of a stratified lake; and
- Hypolimnion: The deep, stagnant, and anoxic layer of a stratified lake.

4.1 Climatic Effects

Lake location and lake geometry play a key role in physical limnology. Location is important because lake mixing is often driven by seasonal changes. In temperate environments, summer heating and winter cooling typically causes two distinct mixing events (dimictic), one in spring and one in fall. However, in tropical environments solar heating is relatively constant over the course of a year resulting in more consistent epilimnion temperatures (Lewis, 2000). Tropical lakes often have small temperature changes between the epilimnion and hypolimnion compared to temperate lakes (Serruya and Pollingher, 1983). Figure C4-1 presents a simulated temperature profile for a lake in a tropical climate with a similar daily temperature of the Project.

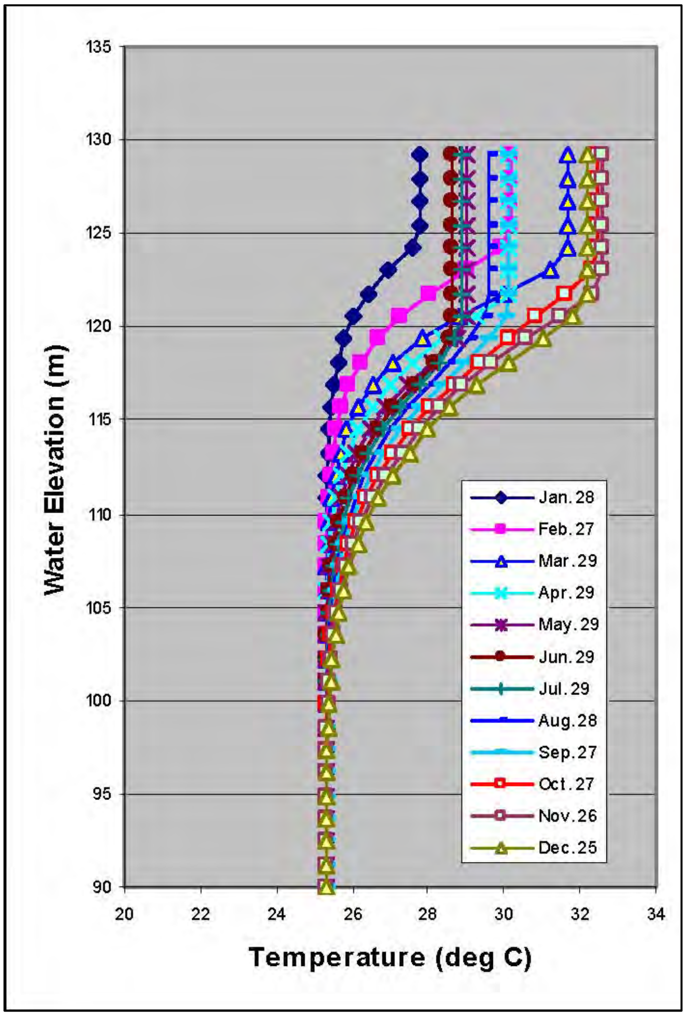


Figure C4-1. Lake Temperature Profile for Tropical Climate

Consistent heating does not mean that tropical lakes are stratified and do not mix. In fact, lakes in the tropics are often more susceptible to mixing because the forces required to mix them are less than in temperate lakes due to their small temperature difference creating a small density difference. Natural lakes in the tropics are often polymicitic, turning frequently during precipitation and storm events.

Wind is also an important climactic factor. Wind mixes by two main mechanisms: 1) direct creation of surficial currents and mixing, and 2) seiche formation. Seiches are waves caused by sustained wind blowing water to the downwind end of a lake. The wind force creates an uneven lake surface that falls back to an even level when the wind ceases. Seiche waves often supply mixing energy deeper into a lake than surficial wave effects.

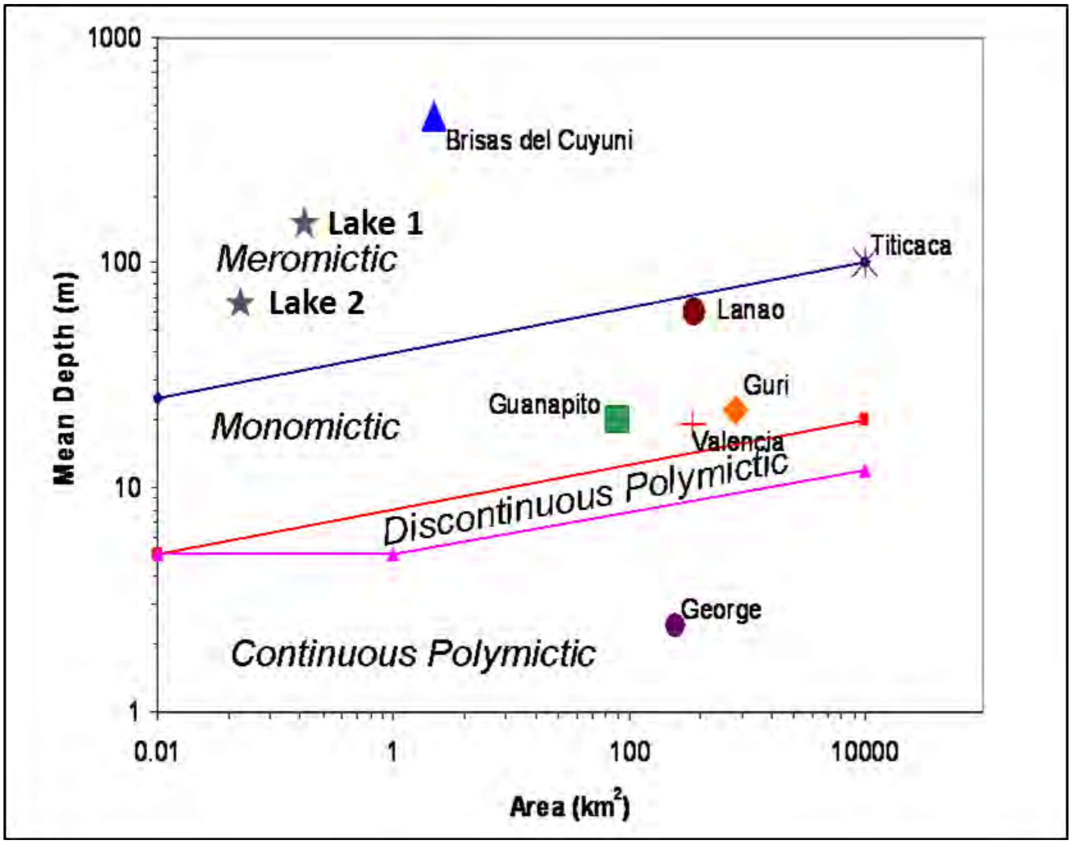
Specifically, the Kintyre post closure pit lakes will have consistent solar heating throughout the year, but very small wind stress. Based on wind data collected from 1939 to 2006 at the Marble Bar meteorological station, the average wind speed is approximately 10 km/hour. These windspeeds indicate a moderately calm environment, suggesting that the greatest stress on the stability of the lake will be heavy, cool wet season rains. However, because the Project is located in an area that is frequently subject to southeast trending tropical cyclones, it is highly likely that the post closure pit lakes will be subject to mixing by wind forces during these events.

4.2 Shape Effects

Shape plays a very important role in physical limnology. The shape of a lake impacts the following:

- The solar heating of the lake;
- The impacts of wind stress; and
- The depth to which physical stresses can be seen.

Pit lakes have very different geometry than a natural lake (Bowell, 2002). Pit lakes are far deeper compared to surface area than natural lakes. Lake 1 will have a ratio of 335 m^2/m and Lake 2 will have a ratio of 222 m^2/m. This different shape means that the bottom of the lake is more isolated from solar heating and wind stress and is often sufficient to create a meromictic lake. Figure C4-1 shows the relationship between lake area, mean lake depth, and typical mixing behaviour for similar lakes, and includes Lake 1 and Lake 2.



From Lewis, 2000

Figure C4-2. Mixing of Lakes by Area and Depth

Another critical factor in the pit lake shape is that it will be engineered to have no incoming streams. Most of the lakes in Figure C4-1 have significant river inputs which impart mechanical energy and thermal gradients that disrupt thermoclines. The Project pit lake will have only groundwater inputs, and minimal precipitation. Based on shape, the pit is deep within the meromictic zone of Figure C4-1, showing that its shape gives it inherent resistance to mixing forces.

Another common technique used to determine if lakes will mix is the relative depth factor defined by:

$$D_r = \frac{50 \times Z_m \times \sqrt{\pi}}{\sqrt{A}}$$

Where:
D_r = Relative depth (in percent)
Z_m = Maximum lake depth
A = Lake area

As a rule of thumb, if the relative depth is greater than 20 percent, the lake will be permanently stratified (Castendyk and Jewell, 2002). Table C4-2 shows the relative depths of several natural and mining lakes, as well as Lake 1 and Lake 2.

Table C4-1. Relative Depth of Lakes

Lake	Z_m	A		Relative depth (%)
	m	km^2	m^2	
Lake 1	139	0.102	1.02E+05	38.6
Lake 2	58	0.0869	8.69E+04	17.4
Berkeley Pit Lake	242	0.29	2.90E+05	39.8
Island Copper Pit Lake	380	1.9	1.90E+06	24.4
Brisas del Cuyuni Pit Lake	450	2.23	2.20E+06	26.7
Guri Reservoir	31	800	8.00E+08	0.1
Guanapito Reservoir	40	80	8.00E+07	0.4

Pit lakes have significantly higher relative depth than natural lakes, and are therefore more likely to be permanently stratified. However, even though the relative depth number for the Lake 1 and Lake 2 are much higher than other lakes, the calculated relative depth is still below 20% for Lake 2. This suggests that the both lakes will stratify, but Lake 2 will not permanently stratify and will be subject to mixing. Mixing will reintroduce oxygen into the deeper portions of the lake allowing chemical reactions to continue under oxygenated conditions. Lake 1 will likely permanently stratify and not be subject to mixing.

4.3 Lake Stability

In order to combine climactic and shape effects on stability, the total lake stability was calculated using a method that combines the lake's resistance to mixing forces with the forces the lake is likely to experience. Robertson and Imberger (1994) have derived a factor called the

Lake Number that accounts for wind stress, density gradients with depth, and lake shape (1994). The first factor is the Schmidt stability factor that determines the work required to turn a column of water around its centre of mass:

$$S_t = \frac{1}{A_m}\int_0^{z_m}(z - z_g)A(z)(1 - \rho(z))dz$$

Where:

S_t = Schmidt stability (g-cm)

A_m = area of the lake (cm^2)

z = height above lake bottom (cm)

z_m= maximum depth (cm)

z_g = centre of volume above lake bottom (cm)

A(z) = area of the lake at height z (cm^2)

ρ(z)= density of water at depth z (g/cm^3)

S_t is then entered into the Lake Number Calculation:

$$L_N = \frac{\left(g \times S_t \times \left(1 - Z_t / Z_m\right)\right)}{\left(\rho_m \times u_*^{\,2} \times A_m^{\,0.5} \times \left(1 - Z_g / Z_m\right)\right)}$$

Where:

g = acceleration due to gravity (cm/sec^2)

A_m= area of the lake (cm^2)

z_t = thermocline height above the bottom (cm)

ρ_m = water density at the surface (g/cm^3)

u_*^2 = water friction velocity from wind stress (cm/s) approximated by:

$$u_*^2 = \frac{p_a}{p_m} \times C_D \times U_{10}^2$$

Where:

U_{10} = Wind velocity 10 m above the water surface (cm/s). Average over seven days.

C_D = Drag coefficient = $1.3x10^{-3}$ (unitless)

$\rho_a \backslash \rho_m$ = ratio of air/water density = $1.2x10^{-3}$

If the Lake Number is much greater than 1, the lake is stratified and stable; if the Lake Number is much less than 1, the lake is prone to mixing events (Robertson and Imberger, 1994 with a corrected equation for Lake Number from Schladow and Thompson, 2000).

Even though the shape of the pit lakes does provide a more protected bottom, the stability of any stratification that will form will be strong. The Lake Number calculated for Lake 1 and Lake 2 are approximately $2x10^9$. This infers that the pit lake will have very strong stratification, and will have a permanently separated hypolimnion. This will prevent the entire water column from being mixed and periodically re-oxygenated, allowing any oxidation reactions to discontinue at depth.

5.0 GEOCHEMICAL MODELLING

The geochemical modelling was conducted using PHREEQC (Parkhurst and Appelo, 1999), chemical equilibrium model supplied by the United States Geological Survey (USGS). PHREEQC is able to process multiple equilibrium and mixing reactions and produce the final chemical speciation. It is able to do the following:

- Process the acid rock drainage (ARD) and neutralization reactions;
- Account for precipitation of solids from solution;
- Simulate groundwater and surface water mixing chemistry; and
- Estimate a steady-state chemical makeup of the groundwater and surface water discharge from the pit.

5.1 Model Construction

The geochemical modelling was constructed as a series of simple mixing models to simulate the filling of the post closure pit lakes and the long term static conditions. The geochemical model of the pit filling period must be mixed such that the contributions to the lakes are representative of the water balance. Utilizing the water balance discussed in Section 3.0, the pit lake geochemical model mixing proportions were developed. Table C5-1 presents simulated time steps and the mixing of Lake 1 and Table C5-2 presents the time steps and mixing of Lake 2.

Table C5-1. Lake 1 Geochemical Model Mixing Proportions

Time(yrs)	Stage(mAHD)	Precipitation	Evaporation	Runoff/Wall Rock	Groundwater
0	128.0	0	0	0	0
1	165.4	0.455	-0.50	0.159	0.385
2	171.8	0.715	-0.50	0.077	0.208
3	176.7	0.713	-1.00	0.077	0.210
4	181.4	0.646	-1.50	0.096	0.258
5	185.8	0.269	-1.25	0.200	0.531
6	190.0	0.587	-1.15	0.114	0.299
7	194.2	0.610	-1.00	0.109	0.281
8	198.0	0.859	-1.00	0.039	0.102
9	201.3	0.874	-1.00	0.035	0.091
10	204.5	0.853	-1.00	0.041	0.106
15	220.1	0.914	-1.00	0.024	0.061
25	243.5	0.974	-1.00	0.008	0.018
50	263.9	0.940	-1.00	0.020	0.040
100	266.8	0.960	-1.00	0.001	0.040
200	266.9	0.960	-1.00	0.001	0.040
300	266.7	0.960	-1.00	0.001	0.040
400	267.1	0.960	-1.00	0.001	0.040
506	266.9	0.960	-1.00	0.001	0.040
600	267.0	0.960	-1.00	0.001	0.040
700	266.8	0.960	-1.00	0.001	0.040
800	267.1	0.960	-1.00	0.002	0.040
900	266.7	0.960	-1.00	0.001	0.040
1000	266.8	0.960	-1.00	0.003	0.040

Table C5-2 Lake 2 Geochemical Model Mixing Proportions

Time(yrs)	Stage(mAHD)	Precipitation	Evaporation	Runoff/Wall Rock	Groundwater
0	210.0	0	0	0	0
1	221.6	0.586	-0.50	0.086	0.328
2	225.6	0.757	-0.50	0.053	0.190
3	229.3	0.749	-1.00	0.057	0.193
4	232.7	0.691	-1.50	0.073	0.236
5	236.0	0.317	-1.25	0.166	0.518
6	238.9	0.644	-1.15	0.086	0.271
7	241.6	0.671	-1.00	0.078	0.251
8	244.1	0.885	-1.00	0.027	0.087
9	246.4	0.895	-1.00	0.025	0.080
10	248.5	0.882	-1.00	0.028	0.089
15	257.5	0.936	-1.00	0.017	0.048
25	265.4	0.985	-1.00	0.003	0.012
50	267.6	0.932	-1.00	0.012	0.056
100	268.7	0.960	-1.00	0.001	0.040
200	268.7	0.960	-1.00	0.001	0.040
300	268.7	0.960	-1.00	0.000	0.040
400	268.7	0.960	-1.00	0.001	0.040
506	268.6	0.960	-1.00	0.000	0.040
600	268.7	0.960	-1.00	0.001	0.040
700	268.8	0.960	-1.00	0.000	0.040
800	268.7	0.960	-1.00	0.001	0.040
900	268.8	0.960	-1.00	0.000	0.040
1000	268.8	0.960	-1.00	0.001	0.040

5.2 Model Input Parameters

Hydrologic components of Pit Lakes 1 and 2 have an associated mass loading component. Some of the chemical components are easily defined since they can be directly measured (i.e., groundwater quality and precipitation chemistry). Other chemical components, such as chemical loading associated with pit wall runoff, must be estimated from geochemical testing using representative samples of wall rock. The geochemical model input parameters of the both lakes are described in the following section.

5.2.1 Precipitation and Pit Wall Runoff Chemistry

Precipitation will fall on the lake surface and provide limited dilution to the lake water. The contribution provided by precipitation will increase over time as the lake surface increases; however, because evaporation is sufficiently high precipitation will have a minimal impact on the overall water quality of the lake. Table C5-3 defines the precipitation chemistry used in this study.

Table C5-3. Precipitation Chemistry

Analyte	Value	Units
pH	5.6	pH Unit
Temp	25	C
Calcium	0.384	mg/L
Magnesium	0.043	mg/L
Sodium	0.141	mg/L
Potassium	0.036	mg/L
Chloride	0.1	mg/L
Sulphate	1.3	mg/L
Nitrite as Nitrogen	0.208	mg/L
Nitrate as Nitrogen	0.237	mg/L
Carbon Dioxide(g)	-3.5	atm
Oxygen (g)	-0.67	atm

The pit wall runoff contribution is a relatively small part of the water balance for both lakes (Figures C3-2 and C3-3). As described in Section 3.3, the pit wall runoff can take two different flow paths into the lake, over the surface of the pit walls and through the fractures in the pit wall due to blasting. The water that runs over the surface of the pit walls will be represented by average precipitation water quality (Table C5-3) and is included as part of the precipitation in the model.

A portion of the precipitation that lands on the pit walls will not just flow over the surface and into the lake, but will infiltrate into the fractures in the pit walls. The act of mining has been shown to increase the fracture network of the pit walls due to blasting. The water that infiltrates into these fractures will be exposed to mineral surfaces and metal salts, which can be leached into the precipitation and contributed to the lake. In addition to the wall rock contributions as runoff, the dewatered wall rock will also add a “slug” of metal salts as it is wetted.

During dewatering, a zone outside of the pit forms where air, minerals, and water can interact (Figure C5-1). Due to the interactions of minerals with air and water and the infrequent precipitation events, salts may form and build-up in the pit wall rocks. During either rain events or pit flooding the salts in the wall rock will be released into the lake water. The chemical contribution used to represent this part of the geochemical composition of the pit lake is the first flush values from the humidity cell tests. The first flush of the humidity cells represents a build-up of salts that occurs during the period between sample collection and construction of the tests. The data used in the geochemical modelling is presented in Table C5-4.

Figure C5-1. Schematic of Salt Build-up in Wall Rock

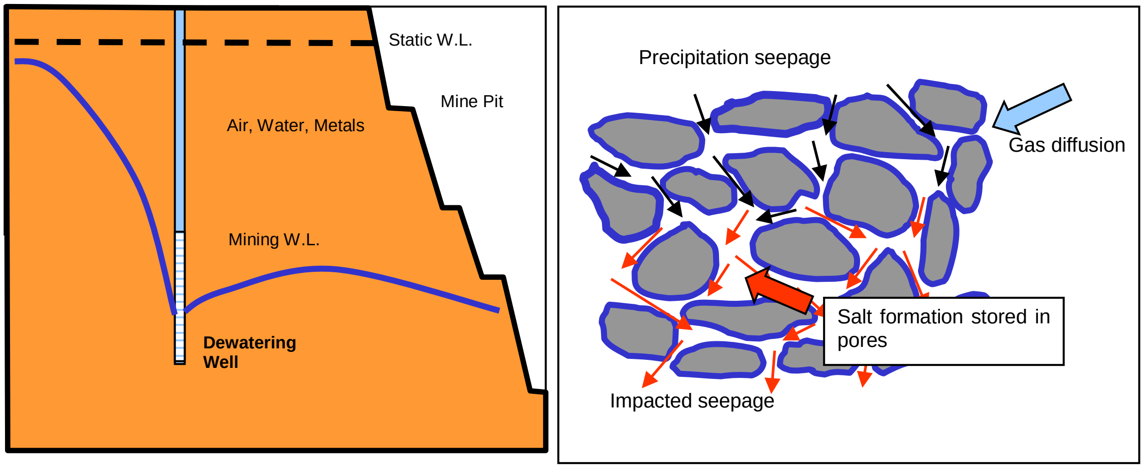


Table C5-4. Wall Rock Chemistry

Analyte	KDH004 120-123	KDH037 148-151	KDH160 126-129	Average	KDH174 80-83	KDH221 69-72	KDH058 32-35
	Schist	Schist	Schist	Schist	Carbonate	Ore Host	Tillite
pH	7.9	7.7	7.5	7.7	7.1	7.7	8.2
Alkalinity	30	22	20	24.0	31	24	75
Conductivity	70	80	77	75.7	1700	73	540
Sulphate	2	15	14	10.3	4.0	7.0	62
Fluorine	0.1	0.1	<0.1	0.083	-	-	0.8
Chlorine	5	4	6	5.0	14.0	7.0	110
Aluminium	0.23	0.3	0.31	0.280	0.057	0.052	0.097
Antimony	0.002	<0.001	<0.001	0.001	-	-	-
Barium	0.002	0.002	0.002	0.002	0.002	0.001	0.003
Cadmium	<0.0001	0.0001	<0.0001	0.0001	-	-	-
Copper	<0.001	9	1	3.33	-	-	-
Iron	0.096	0.35	0.25	0.232	0.1	0.033	0.046
Lead	<0.001	0.002	0.001	0.001	-	-	0.009
Manganese	0.018	0.025	0.008	0.017	0.043	0.079	0.015
Molybdenum	0.002	0.011	<0.001	0.005	0.004	0.015	0.002
Nickel	<0.001	<0.001	0.002	0.001	-	-	-
Selenium	<0.002	<0.002	<0.002	-	-	0.004	0.058
Rubidium	0.006	0.012	0.011	0.010	0.004	0.008	-
Silver	<0.001	<0.001	<0.001	-	-	-	-
Strontium	0.011	0.008	0.007	0.009	0.013	0.01	0.081
Titanium	0.006	0.007	0.009	0.007	0.001	-	-
Uranium	<0.001	<0.001	<0.001	-	-	-	0.016
Vanadium	<0.001	<0.001	<0.001	-	-	-	0.023
Zinc	0.03	0.018	0.004	0.017	0.008	0.006	0.013
Zircon	0.002	0.001	0.001	0.001	0.001	0.001	0.002
Calcium	7.0	2.8	3.4	4.4	4.3	3.8	6.9
Potassium	7.5	11	11	9.8	5.0	5.2	8.6
Magnesium	0.6	1.6	1.1	1.1	2.5	2.5	7.1
Sodium	4.1	5.3	4.7	4.7	11	5.6	100

Note:
Units are mg/L
- = not detected and not used in developing model solutions
< = not detected at or above provided reporting limit

The pit walls that will contact runoff that will enter the lake, or that will be in contact with the lake will be composed of schist, carbonates, ore host, and tillite. The solution representing the schist is the average of the three humidity cell test shown in Table C5-4. Each of the representative solutions was mixed in relative proportions to represent the specific locations in the pit contributing to the loading of the lake. The mixed solution is then used in the pit lake to represent the fractures in the wall rock. Table C5-5 presents the proportions used to develop the fracture chemistry for Lake 1 and Table C5-6 presents the mixing used for Lake 2.

Table C5-5. Lake 1 Wall Rock Fracture Contribution

Time	Schist	Tillite	Carbonate	Ore Host
1	0.22	0	0.34	0.44
2	0.39	0	0.26	0.36
3	0.43	0	0.23	0.33
4	0.38	0	0.43	0.19
5	0.41	0	0.22	0.37
6	0.28	0	0.25	0.47
7	0.35	0	0.18	0.47
8	0.19	0	0.23	0.58
9	0.27	0	0.18	0.55
10	0.07	0	0.27	0.66
15	0.16	0.01	0.15	0.68
25	0.25	0.04	0.12	0.59
50	0.25	0	0.17	0.57
100	0.47	0	0.23	0.30

Table C5-6. Lake 2 Wall Rock Fracture Contribution

Time	Schist	Tillite	Carbonate	Ore Host
1	0	0	0.44	0.56
2	0	0.002	0.42	0.58
3	0	0	0.27	0.73
4	0	0	0.33	0.67
5	0	0	0.38	0.62
6	0	0.001	0.34	0.66
7	0	0	0.29	0.71
8	0	0	0.29	0.71
9	0	0	0.26	0.74
10	0.01	0	0.27	0.72
15	0.02	0.001	0.17	0.81
25	0.03	0.005	0.16	0.80
50	0.03	0	0.23	0.74
100	0.06	0	0.29	0.66

5.2.2 Groundwater Inflow Chemistry

The character of the groundwater utilised in this study was derived from eight discrete groundwater monitoring bores. Groundwater quality data from these eight bores were averaged over the period of record (1987-2011) (Table C2-1). The average result of each borehole was then used to calculate an average overall groundwater chemical composition (Table C2-2).

5.3 Mineral Precipitation

As the chemical concentrations in the pit lakes increase over time, mineral phases may precipitate from solution. Chemical precipitation removes chemical mass from the pit lake and establishes a limit on the maximum dissolved concentration for the associated components of that mineral. Mineral species that were allowed to precipitate are shown in Table C5-7.

Table C5-7. Mineral Equilibrium Phases

Mineral Name	Ideal Formula
Silver Selinide	Ag_2Se
Aluminum Hydroxide	$Al(OH)_{3(am)}$
Alunite	$KAl_3(SO_4)_2(OH)_6$
Aragonite	$CaCO_3$
Bariumarsenate	$Ba_3(AsO_4)_2$
Barite	$BaSO_4$
Boehmite	$AlO(OH)$
Calcite	$CaCO_3$
Cerrusite	$PbCO_3$
Chalcedony	SiO_2
Carbon Dioxide	$CO_{2(g)}$
Cuprousferrite	$CuFeO_2$
Dolomite	$CaMg(CO_3)_2$
Ferrihydrite	$Fe(OH)_{3(am)}$
Ferrihydroxichloride	$Fe(OH)_{2.7}Cl_{0.3}$
Fluorite	CaF_2
Gibbsite	$Al(OH)_3$
Goethite	$FeO(OH)$
Gypsum	$CaSO_4\ 2H_2O$
Halite	$NaCl$
Na-Jarosite	$NaFe^{3+}{}_3(OH)_6(SO_4)_2$
Natron	$Na_2CO_3.10H_2O$
Pyromorphite	$Pb_5(PO_4)_3Cl$

5.4 Geochemical Model Results

The geochemical model was constructed to simulate the filling period of the lakes, as well as the long term water quality of the lakes under the influence of evapo-concentration. Table C5-8 presents the results of the Lake 1 model and Table C5-9 presents the results of Lake 2.

The results of the hydrogeochemical pit lake model are in agreement with the general conceptual model for Pit Lake 1. Of particular interest are:

- pH values are slightly alkaline ranging between 7.58 and 7.98 and within the acceptable ADWG range;
- Alkalinity is moderate;
- Sodium and chlorine are extremely high through the entire life of the pit lake, with concentrations over 50,000 mg/L chlorine and 20,000 mg/L sodium. The background groundwater quality data showed naturally elevated levels of both sodium and chlorine in the system, which is concentrated due to the high rate of evaporation and relatively low rate of water inputs after the lakes reach static water level;
- Boron, fluorine, manganese, molybdenum, and uranium are expected to be above ADWG over the entire life of the pit lake and increase over time due to the high evaporation;

- Arsenic, chromium, copper, lead, nickel, and selenium start below the ADWG, but quickly exceed the limit during the early years of filling due to the slug inputs of salts from the pit walls;

- Because of the slightly alkaline pH of the lake and the relatively low concentrations in the groundwater and pit wall contributions, iron is not present in the lake solution; and

- Aluminium remains below the ADWG over the life of the pit lake.

The results of the hydrogeochemical pit lake model are in agreement with the general conceptual model for Pit Lake 2. Of particular interest are:

- pH values are slightly alkaline ranging between 7.52 and 7.93 and within the acceptable ADWG range;

- Alkalinity is moderate;

- Sodium and chlorine are extremely high through the entire life of the pit lake, with concentrations over 60,000 mg/L chlorine and 25,000 mg/L sodium. The high concentrations are the same as those for Lake 1. Lake 2 is more saline than Lake 1 because it is shallower, with only a slightly smaller surface area allowing a greater rate of evaporation and concentration;

- Aluminium, boron, fluorine, manganese, molybdenum, and uranium are expected to be above ADWG over the entire life of the pit lake and increase over time due to the high evaporation;

- Arsenic, chromium, copper, lead, nickel, and selenium start below the ADWG, but quickly exceed the limit during the early years of filling due to the slug inputs of salts from the pit walls; and

- Because of the slightly alkaline pH of the lake and the relatively low concentrations in the groundwater and pit wall contributions, iron is not present in the lake solution.

Table C5-8. Lake 1 Water Quality over Time

	ADWG	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 15	Year 25	Year 50	Year 100	Year 200	Year 300	Year 400	Year 500	Year 600	Year 700	Year 800	Year 900	Year 1000
pH	6.5 - 8.5	7.98	7.84	7.76	7.69	7.82	7.71	7.68	7.67	7.66	7.65	7.64	7.64	7.63	7.63	7.62	7.62	7.61	7.61	7.60	7.60	7.59	7.59	7.58
pe	-	12.6	12.8	12.8	12.9	12.8	12.9	12.9	12.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Alkalinity (as mg/l $CaCO_3$)	-	10.1	8.03	11.0	28.3	85.2	163	185	193	200	208	216	217	221	221	221	221	220	220	220	219	219	219	219
		Milligrams per litre (mg/L)																						
Aluminium	0.2	0.058	0.042	0.036	0.033	0.048	0.040	0.038	0.037	0.036	0.035	0.034	0.034	0.034	0.033	0.033	0.033	0.032	0.032	0.032	0.031	0.031	0.031	0.030
Antimony	-	0.004	0.003	0.004	0.010	0.030	0.091	0.105	0.110	0.114	0.119	0.123	0.124	0.126	0.127	0.128	0.128	0.129	0.130	0.130	0.131	0.131	0.132	0.132
Arsenic	0.007	0.000	0.000	0.000	0.000	0.001	0.004	0.006	**0.007**	**0.008**	**0.009**	**0.009**	**0.009**	**0.010**	**0.010**	**0.010**	**0.010**	**0.011**	**0.011**	**0.011**	**0.011**	**0.011**	**0.012**	**0.012**
Barium	-	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Beryllium	-	0.003	0.002	0.003	0.008	0.023	0.069	0.079	0.083	0.087	0.090	0.094	0.094	0.096	0.096	0.097	0.097	0.098	0.098	0.099	0.099	0.100	0.100	0.101
Boron	4	**11.7**	**9.01**	**12.2**	**32.3**	**97.1**	**291**	**334**	**350**	**364**	**380**	**393**	**396**	**403**	**405**	**407**	**409**	**411**	**413**	**415**	**417**	**419**	**421**	**422**
Cadmium	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcium	-	80.7	62.2	84.4	223	622	453	439	436	433	431	429	429	429	429	430	430	430	430	431	431	431	432	432
Carbon	-	8.58	7.26	10.24	26.47	69.62	84.0	86.7	87.7	88.7	89.8	90.8	91.1	91.6	91.0	90.4	89.9	89.3	88.8	88.2	87.7	87.2	86.7	86.3
Chlorine	250	**1,482**	**1,139**	**1,543**	**4,082**	**12,272**	**36,708**	**42,175**	**44,160**	**45,929**	**47,993**	**49,684**	**50,038**	**50,932**	**51,194**	**51,449**	**51,701**	**51,949**	**52,190**	**52,428**	**52,658**	**52,889**	**53,112**	**53,332**
Chromium	0.05	0.003	0.002	0.003	0.009	0.026	**0.077**	**0.088**	**0.092**	**0.096**	**0.101**	**0.104**	**0.105**	**0.107**	**0.107**	**0.108**	**0.108**	**0.109**	**0.109**	**0.110**	**0.110**	**0.111**	**0.111**	**0.112**
Copper	1	0.104	0.151	0.255	0.676	**1.75**	**5.59**	**6.98**	**7.27**	**7.62**	**7.76**	**8.00**	**8.07**	**8.28**	**8.22**	**8.17**	**8.12**	**8.07**	**8.02**	**7.98**	**7.93**	**7.89**	**7.84**	**7.80**
Fluorine	1.5	**1.53**	1.18	**1.60**	**4.23**	**6.14**	**17.3**	**20.7**	**22.1**	**23.4**	**24.9**	**26.2**	**26.5**	**27.3**	**27.5**	**27.7**	**27.9**	**28.1**	**28.3**	**28.5**	**28.7**	**28.9**	**29.1**	**29.3**
Iron	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lead	0.01	0.000	0.000	0.000	0.000	0.000	0.005	**0.014**	**0.020**	**0.028**	**0.041**	**0.056**	**0.059**	**0.069**	**0.073**	**0.077**	**0.081**	**0.085**	**0.089**	**0.093**	**0.097**	**0.102**	**0.106**	**0.111**
Magnesium	-	293	225	305	806	2,423	7,235	8,312	8,704	9,054	9,461	9,795	9,866	10,043	10,095	10,146	10,197	10,246	10,295	10,342	10,389	10,434	10,479	10,523
Manganese	0.1	**4.42**	**3.40**	**4.60**	**12.15**	**36.5**	**109.3**	**125.6**	**131.6**	**136.8**	**143.0**	**148.1**	**149.1**	**151.8**	**152.6**	**153.3**	**154.0**	**154.7**	**155.5**	**156.1**	**156.8**	**157.5**	**158.1**	**158.8**
Mercury	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Molybdenum	0.05	**0.16**	**0.13**	**0.17**	**0.45**	**1.35**	**4.04**	**4.64**	**4.86**	**5.06**	**5.29**	**5.47**	**5.51**	**5.61**	**5.64**	**5.67**	**5.69**	**5.72**	**5.74**	**5.77**	**5.79**	**5.82**	**5.84**	**5.87**
Nickel	0.02	0.001	0.001	0.002	0.004	0.012	**0.037**	**0.043**	**0.045**	**0.047**	**0.049**	**0.051**	**0.051**	**0.052**	**0.052**	**0.052**	**0.053**	**0.053**	**0.053**	**0.053**	**0.053**	**0.054**	**0.054**	**0.054**
Nitrogen	-	23.70	19.10	26.44	70.1	203.3	609	702	748	791	837	881	905	936	957	977	996	1015	1034	1052	1070	1088	1105	1122
Oxygen	-	16.19	16.25	16.18	15.75	14.59	12.12	11.65	11.49	11.34	11.17	11.04	11.01	10.94	10.92	10.90	10.88	10.86	10.84	10.82	10.80	10.78	10.76	10.75
Phosphorous	-	0.31	0.24	0.33	0.86	2.60	7.77	8.93	9.35	9.73	10.17	10.53	10.61	10.80	10.86	10.91	10.97	11.02	11.08	11.13	11.18	11.23	11.28	11.33
Potassium	-	79	61	82	218	654	1,958	2,249	2,356	2,451	2,561	2,652	2,671	2,720	2,734	2,748	2,762	2,775	2,788	2,801	2,813	2,826	2,838	2,850
Selenium	0.01	0.004	0.003	0.004	**0.011**	**0.032**	**0.097**	**0.112**	**0.118**	**0.123**	**0.129**	**0.134**	**0.135**	**0.138**	**0.138**	**0.139**	**0.139**	**0.140**	**0.140**	**0.140**	**0.141**	**0.141**	**0.141**	**0.142**
Silicon	-	20.70	15.91	21.57	57.0	171.5	513	590	617	642	671	695	700	712	716	719	723	726	730	733	736	740	743	746
Silver	-	0.001	0.001	0.001	0.004	0.011	0.034	0.039	0.040	0.042	0.044	0.046	0.046	0.047	0.047	0.047	0.047	0.048	0.048	0.048	0.048	0.048	0.049	0.049
Sodium	180	**658**	**506**	**685**	**1,812**	**5,448**	**16,298**	**18,724**	**19,607**	**20,394**	**21,310**	**22,062**	**22,220**	**22,617**	**22,734**	**22,849**	**22,961**	**23,072**	**23,180**	**23,286**	**23,390**	**23,492**	**23,593**	**23,691**
Strontium	-	0.60	0.46	0.62	1.65	4.9	14.8	17.0	17.8	18.5	19.3	20.0	20.2	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5
Sulphate	-	946	728	987	2,610	7,732	19,370	22,036	23,009	23,881	24,895	25,730	25,909	26,352	26,486	26,618	26,747	26,873	26,997	27,119	27,239	27,356	27,472	27,584
Sulphide	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Titanium	-	0.003	0.002	0.003	0.009	0.026	0.077	0.089	0.093	0.096	0.100	0.103	0.104	0.105	0.106	0.106	0.106	0.106	0.106	0.107	0.107	0.107	0.107	0.107
Uranium	0.02	**0.126**	**0.097**	**0.132**	**0.348**	**1.05**	**3.13**	**3.60**	**3.77**	**3.92**	**4.10**	**4.24**	**4.27**	**4.35**	**4.37**	**4.39**	**4.41**	**4.43**	**4.45**	**4.48**	**4.50**	**4.51**	**4.53**	**4.55**
Vanadium	-	0.026	0.020	0.027	0.071	0.212	0.634	0.729	0.763	0.794	0.829	0.859	0.865	0.880	0.885	0.889	0.894	0.898	0.902	0.906	0.910	0.914	0.918	0.922
Zinc	-	0.463	0.356	0.482	1.28	3.83	11.5	13.2	13.8	14.4	15.0	15.5	15.6	15.9	16.0	16.1	16.1	16.2	16.3	16.4	16.4	16.5	16.6	16.7

Note: Bold values exceed ADWG

Table C5-9. Lake 2 Water Quality over Time

	ADWG	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 15	Year 25	Year 50	Year 100	Year 200	Year 300	Year 400	Year 500	Year 600	Year 700	Year 800	Year 900	Year 1000
pH	6.5 - 8.5	7.93	7.71	7.57	7.52	7.72	7.67	7.64	7.62	7.61	7.59	7.59	7.59	7.58	7.57	7.57	7.56	7.55	7.55	7.54	7.54	7.53	7.53	7.52
pe	-	12.7	12.9	13.0	13.1	12.9	12.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Alkalinity (as mg/l $CaCO_3$)	-	6.45	5.24	7.44	20.2	63.8	179	204	217	226	240	243	244	250	250	249	248	247	247	246	245	244	244	243
		Milligrams per litre (mg/L)																						
Aluminium	0.2	**0.052**	**0.031**	**0.023**	**0.022**	**0.039**	**0.037**	**0.034**	**0.033**	**0.032**	**0.031**	**0.031**	**0.031**	**0.030**	**0.030**	**0.029**	**0.029**	**0.029**	**0.028**	**0.028**	**0.028**	**0.027**	**0.027**	**0.027**
Antimony	-	0.003	0.002	0.003	0.009	0.028	0.107	0.122	0.130	0.135	0.142	0.143	0.144	0.147	0.148	0.148	0.149	0.149	0.150	0.150	0.151	0.151	0.152	0.152
Arsenic	0.007	0.000	0.000	0.000	0.000	0.001	0.005	**0.008**	**0.009**	**0.009**	**0.010**	**0.011**	**0.011**	**0.012**	**0.012**	**0.012**	**0.012**	**0.013**	**0.013**	**0.013**	**0.013**	**0.014**	**0.014**	**0.014**
Barium	-	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Beryllium	-	0.002	0.002	0.003	0.007	0.021	0.082	0.093	0.099	0.103	0.108	0.109	0.110	0.112	0.113	0.113	0.114	0.114	0.114	0.115	0.115	0.115	0.116	0.116
Boron	4	**10.0**	**7.87**	**10.8**	**28.8**	**89.0**	**343**	**392**	**415**	**431**	**455**	**458**	**461**	**472**	**474**	**475**	**477**	**479**	**480**	**482**	**483**	**485**	**486**	**487**
Cadmium	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcium	-	68.4	54.2	74.5	199	606	438	429	427	427	427	428	429	430	431	432	433	434	434	435	436	437	438	439
Carbon	-	5.14	4.76	7.19	19.66	53.75	86.5	90.1	91.9	93.3	95.4	95.7	95.7	96.6	95.8	95.0	94.2	93.4	92.7	92.0	91.3	90.6	90.0	89.4
Chlorine	250	**1,259**	**994**	**1,365**	**3,640**	**11,240**	**43,267**	**49,538**	**52,392**	**54,420**	**57,430**	**57,877**	**58,193**	**59,611**	**59,827**	**60,036**	**60,242**	**60,440**	**60,635**	**60,827**	**61,011**	**61,192**	**61,366**	**61,539**
Chromium	0.05	0.003	0.002	0.003	0.008	0.024	**0.091**	**0.104**	**0.110**	**0.114**	**0.120**	**0.121**	**0.122**	**0.125**	**0.125**	**0.126**	**0.126**	**0.127**	**0.127**	**0.127**	**0.128**	**0.128**	**0.129**	**0.129**
Copper	1	0.025	0.020	0.027	0.072	0.22	0.86	0.99	**1.04**	**1.08**	**1.16**	**1.18**	**1.19**	**1.23**	**1.24**	**1.25**	**1.25**	**1.26**	**1.26**	**1.27**	**1.27**	**1.28**	**1.28**	**1.29**
Fluorine	1.5	**1.30**	1.03	**1.41**	**3.76**	**5.92**	**21.5**	**26.1**	**28.5**	**30.3**	**33.0**	**33.5**	**33.8**	**35.2**	**35.4**	**35.6**	**35.8**	**36.0**	**36.2**	**36.4**	**36.6**	**36.8**	**37.0**	**37.2**
Iron	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lead	0.01	0.000	0.000	0.000	0.000	0.000	**0.017**	**0.054**	**0.089**	**0.126**	**0.203**	**0.226**	**0.236**	**0.282**	**0.311**	**0.328**	**0.342**	**0.355**	**0.369**	**0.383**	**0.397**	**0.411**	**0.426**	**0.440**
Magnesium	-	248	196	270	719	2,220	8,535	9,772	10,337	10,738	11,333	11,422	11,485	11,767	11,809	11,852	11,893	11,933	11,972	12,011	12,048	12,084	12,119	12,154
Manganese	0.1	**3.75**	**2.96**	**4.07**	**10.85**	**33.5**	**129**	**148**	**156**	**162**	**171**	**173**	**174**	**178**	**178**	**179**	**180**	**180**	**181**	**181**	**182**	**182**	**183**	**183**
Mercury	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Molybdenum	0.05	**0.14**	**0.11**	**0.15**	**0.40**	**1.24**	**4.76**	**5.45**	**5.77**	**5.99**	**6.32**	**6.37**	**6.41**	**6.56**	**6.59**	**6.61**	**6.63**	**6.65**	**6.67**	**6.69**	**6.71**	**6.73**	**6.75**	**6.76**
Nickel	0.02	0.001	0.001	0.001	0.004	0.011	**0.043**	**0.050**	**0.052**	**0.054**	**0.057**	**0.058**	**0.058**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.061**	**0.061**	**0.061**	**0.061**	**0.061**	**0.062**
Nitrogen	-	20.89	17.27	24.20	64.5	190.1	734	843	909	961	1030	1057	1086	1130	1153	1176	1198	1220	1241	1261	1281	1301	1320	1338
Oxygen	-	16.2	16.3	16.2	15.8	14.7	11.6	11.0	10.8	10.7	10.4	10.4	10.4	10.3	10.3	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.1	10.1
Phosphorous	-	0.27	0.21	0.29	0.77	2.38	9.17	10.5	11.1	11.6	12.2	12.3	12.4	12.7	12.8	12.8	12.9	12.9	13.0	13.0	13.0	13.1	13.1	13.2
Potassium	-	67	53	72	193	596	2,293	2,626	2,778	2,887	3,047	3,072	3,090	3,165	3,178	3,189	3,201	3,212	3,223	3,233	3,243	3,253	3,263	3,273
Selenium	0.01	0.003	0.003	0.004	**0.010**	**0.031**	**0.119**	**0.137**	**0.145**	**0.150**	**0.159**	**0.160**	**0.161**	**0.165**	**0.165**	**0.166**	**0.166**	**0.166**	**0.166**	**0.166**	**0.166**	**0.167**	**0.167**	**0.167**
Silicon	-	17.60	13.90	19.09	50.9	157.2	605	693	733	761	803	809	814	834	837	840	842	845	848	851	853	856	858	861
Silver	-	0.001	0.001	0.001	0.003	0.010	0.040	0.045	0.048	0.050	0.053	0.053	0.053	0.055	0.055	0.055	0.055	0.055	0.056	0.056	0.056	0.056	0.056	0.056
Sodium	180	**559**	**441**	**606**	**1,617**	**4,990**	**19,210**	**21,995**	**23,264**	**24,164**	**25,502**	**25,701**	**25,842**	**26,473**	**26,569**	**26,665**	**26,756**	**26,845**	**26,933**	**27,019**	**27,102**	**27,183**	**27,263**	**27,340**
Strontium	-	0.51	0.40	0.55	1.47	4.5	17.4	20.0	21.1	21.9	23.1	23.3	23.5	24.0	24.1	24.2	24.3	24.4	24.4	24.5	24.6	24.7	24.7	24.8
Sulphate	-	804	635	873	2,328	7,180	22,563	25,636	27,044	28,046	29,536	29,763	29,926	30,633	30,748	30,859	30,968	31,074	31,177	31,277	31,376	31,472	31,565	31,657
Sulphide	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Titanium	-	0.002	0.002	0.002	0.006	0.018	0.070	0.081	0.085	0.088	0.093	0.094	0.095	0.097	0.097	0.098	0.098	0.098	0.098	0.099	0.099	0.099	0.099	0.100
Uranium	0.02	**0.107**	**0.085**	**0.117**	**0.311**	**0.96**	**3.69**	**4.23**	**4.47**	**4.65**	**4.90**	**4.94**	**4.97**	**5.09**	**5.11**	**5.13**	**5.14**	**5.16**	**5.18**	**5.19**	**5.21**	**5.22**	**5.24**	**5.25**
Vanadium	-	0.022	0.017	0.024	0.063	0.194	0.748	0.856	0.906	0.941	0.993	1.00	1.01	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06	1.06
Zinc	-	0.392	0.309	0.425	1.13	3.50	13.5	15.4	16.3	17.0	17.9	18.0	18.1	18.6	18.6	18.7	18.8	18.8	18.9	18.9	19.0	19.1	19.1	19.2

Note: Bold values exceed ADWG

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APPENDIX A
LAKE 1 MODEL INPUT FILE

```
TITLE Kintyre Pit Lake Model

SOLUTION 1 Precipitation
    temp      25
    pH        5.6
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    Ca        0.384
    Mg        0.043
    Na        0.141
    K         0.136
    Cl        0.01
    S(6)      1.3
    N(3)      0.208
    N(5)      0.237
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 2 Average Groundwater
    temp      25
    pH        7.57
    pe        4
    redox     pe
    units     mg/l
    density   1
    Al        1.15
    As        0.0008
    B         1.19
    Ba        0.072
    Be        0.003
    Ca        102
    Cl        1905
    Co        0.024
    Cr        0.004
    Cu        0.038
    F         1.97
    Fe        0.275
    K         161
    Mg        166
    Mn        1.54
    Mo        0.207
    N(5)      6.77
    Na        1389
    Ni        0.007
    P         0.335
    Pb        0.164
    S(6)      1082
    Sb        0.025
    Se        0.004
    Si        16.7
    Ag        0.007
    Sr        2.1
    Ti        0.003
    U         0.163
    V         0.033
    Zn        0.593
    -water    1 # kg

SOLUTION 3 Schist - Wall rock
    temp      25
    pH        7.7
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
```

```
    S(6)      10.3
    F         0.083
    Cl        7
    Al        0.28
    Sb        0.001
    Ba        0.002
    Cd        0.0001
    Cu        3.33
    Fe        0.232
    Pb        0.001
    Mn        0.017
    Mo        0.005
    Ni        0.001
    Sr        0.009
    Ti        0.007
    Zn        0.017
    Ca        4.4
    K         9.83
    Mg        1.1
    Na        4.7
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 4 Carbonate - Wall Rock
    temp      25
    pH        7.1
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    S(6)      4
    Cl        25
    Al        0.057
    Ba        0.002
    Fe        0.1
    Mn        0.043
    Mo        0.004
    Sr        0.013
    Ti        0.001
    Zn        0.008
    Ca        4.3
    Mg        2.5
    Na        11
    K         5
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 5 Ore Host - Wall Rock
    temp      25
    pH        7.7
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    S(6)      7
    Cl        10
    Al        0.052
    Ba        0.001
    Fe        0.033
    Mn        0.079
    Mo        0.015
    Se        0.004
    Sr        0.01
    Zn        0.006
    Ca        3.8
    K         5.2
    Mg        2.5
```

```
    Na        5.6
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 6 Tillite - Wall Rock
    temp      25
    pH        8.2
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    S(6)      62
    F         0.8
    Cl        110
    Al        0.097
    Ba        0.003
    Fe        0.046
    Pb        0.009
    Mn        0.015
    Mo        0.002
    Se        0.058
    Sr        0.081
    U         0.016
    V         0.023
    Ca        6.9
    K         8.6
    Mg        7.1
    Na        100
    C         1 CO2(g)     -3.5
    Zn        0.013
    -water    1 # kg

SOLUTION 7 Pure Water
    temp      25
    pH        7
    pe        4
    redox     pe
    units     mmol/kgw
    density   1
    -water    1 # kg
SELECTED_OUTPUT
    -file                 C:\Users\amy.hudson\Documents\Projects\Kintyre\Lake 1
geochemical model results.sel
    -water                true
    -totals               Ag  Al  Alkalinity  As  B  Ba  Be
                          C  Ca  Cd  Cl  Cr  Cu  F
                          Fe  Hg  K  Mg  Mn  Mo  N
                          Na  Ni  O(0)  P  Pb  S(-2)  S(6)
                          Sb  Se  Si  Sr  Ti  U  V
                          Zn
END

MIX 1 year 1 fracture mix
    3    0.22
    4    0.34
    5    0.44

SAVE solution 8

END

MIX 2 lake year 1
    7    -0.5
    1    0.455
    8    0.159
    2    0.385
```

```
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0

SAVE solution 9

END

MIX 3 year 2 fracture mix
    3    0.39
    4    0.26
    5    0.36

SAVE solution 10

END

MIX 4 Year 2 Lake
    9    1
    7    -0.5
    1    0.715
    10    0.077
    2    0.208

EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
```

```
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 11
END
MIX 5 year 3 fracture mix
    3    0.43
    4    0.23
    5    0.33
SAVE solution 12
END
MIX 6 Year 3 Lake
    11    1
    7    -1
    1    0.713
    12    0.077
    2    0.21
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 13
END
MIX 7 year 4 fracture
    3    0.38
    4    0.43
    5    0.19
SAVE solution 14
END
MIX 8 Year 4 Lake
    13    1
    7    -1.5
    1    0.646
    14    0.096
    2    0.258
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
```

```
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 15
END
MIX 9 year 5 fracture
    3    0.41
    4    0.22
    5    0.37
SAVE solution 16
END
MIX 10 Year 5 Lake
    15    1
    7    -1.25
    1    0.269
    16    0.2
    2    0.531
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 17
END
MIX 11 year 6 fracture
    3    0.28
    4    0.25
    5    0.47
SAVE solution 18
END
MIX 12 Year 6 Lake
    17    1
    7    -1.15
    1    0.587
    18    0.114
    2    0.299
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
```

```
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 19
END
MIX 13 year 7 fracture
    3    0.35
    4    0.18
    5    0.47
SAVE solution 20
END
MIX 14 Year 7 Lake
    19    1
    7    -1
    1    0.61
    20    0.109
    2    0.281
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 21
END
MIX 15 year 8 fracture
    3    0.19
    4    0.23
    5    0.58
SAVE solution 22
END
MIX 16 Year 8 Lake
```

```
    21    1
    7    -1
    1    0.859
    22    0.039
    2    0.102
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 23
END
MIX 17 year 9 fracture
    3    0.27
    4    0.18
    5    0.55
SAVE solution 24
END
MIX 18 Year 9 Lake
    23    1
    7    -1
    1    0.874
    24    0.035
    2    0.091
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
```

```
SAVE solution 25
END
MIX 19 year 10 fracture
    3    0.07
    4    0.27
    5    0.66
SAVE solution 26
END
MIX 20 Year 10 Lake
    25    1
    7    -1
    1    0.853
    26    0.041
    2    0.106
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 27
END
MIX 21 year 15 fracture
    3    0.16
    6    0.01
    4    0.15
    5    0.68
SAVE solution 28
END
MIX 22 Year 15 Lake
    27    1
    7    -1
    1    0.914
    28    0.024
    2    0.061
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
```

```
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 29
END
MIX 23 year 25 fracture
    3    0.25
    6    0.04
    4    0.12
    5    0.59
SAVE solution 30
END
MIX 24 Year 25 Lake
    29    1
    7    -1
    1    0.974
    30    0.008
    2    0.018
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 31
END
MIX 25 year 50 fracture
    3    0.25
    4    0.17
    5    0.57
SAVE solution 32
END
MIX 26 Year 50 Lake
    31    1
    7    -1
    1    0.94
    32    0.02
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
```

```
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 33
END
MIX 27 year 100+ fracture
    3    0.47
    4    0.23
    5    0.3
SAVE solution 34
END
MIX 28 Year 100 Lake
    33    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 35
END
MIX 29 Year 200 Lake
    35    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
```

```
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 36
END
MIX 30 Year 300 Lake
    36    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 37
END
MIX 31 Year 400 Lake
    37    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
```

```
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 38
END
MIX 32 Year 500 Lake
    38    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 39
END
MIX 33 Year 600 Lake
    39    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
```

```
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 40
END
MIX 34 Year 700 Lake
    40    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 41
END
MIX 35 Year 800 Lake
    41    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
```

```
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 42
END
MIX 36 Year 900 Lake
    42    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 43
END
MIX 37 Year 1000 Lake
    43    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
```

```
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 44
END
```

APPENDIX B
LAKE 2 MODEL INPUT FILE

```
TITLE Kintyre Pit Lake Model

SOLUTION 1 Precipitation
    temp      25
    pH        5.6
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    Ca        0.384
    Mg        0.043
    Na        0.141
    K         0.136
    Cl        0.01
    S(6)      1.3
    N(3)      0.208
    N(5)      0.237
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 2 Average Groundwater
    temp      25
    pH        7.57
    pe        4
    redox     pe
    units     mg/l
    density   1
    Al        1.15
    As        0.0008
    B         1.19
    Ba        0.072
    Be        0.003
    Ca        102
    Cl        1905
    Co        0.024
    Cr        0.004
    Cu        0.038
    F         1.97
    Fe        0.275
    K         161
    Mg        166
    Mn        1.54
    Mo        0.207
    N(5)      6.77
    Na        1389
    Ni        0.007
    P         0.335
    Pb        0.164
    S(6)      1082
    Sb        0.025
    Se        0.004
    Si        16.7
    Ag        0.007
    Sr        2.1
    Ti        0.003
    U         0.163
    V         0.033
    Zn        0.593
    -water    1 # kg

SOLUTION 3 Schist - Wall rock
    temp      25
    pH        7.7
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
```

```
    S(6)      10.3
    F         0.083
    Cl        7
    Al        0.28
    Sb        0.001
    Ba        0.002
    Cd        0.0001
    Cu        3.33
    Fe        0.232
    Pb        0.001
    Mn        0.017
    Mo        0.005
    Ni        0.001
    Sr        0.009
    Ti        0.007
    Zn        0.017
    Ca        4.4
    K         9.83
    Mg        1.1
    Na        4.7
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 4 Carbonate - Wall Rock
    temp      25
    pH        7.1
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    S(6)      4
    Cl        25
    Al        0.057
    Ba        0.002
    Fe        0.1
    Mn        0.043
    Mo        0.004
    Sr        0.013
    Ti        0.001
    Zn        0.008
    Ca        4.3
    Mg        2.5
    Na        11
    K         5
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 5 Ore Host - Wall Rock
    temp      25
    pH        7.7
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    S(6)      7
    Cl        10
    Al        0.052
    Ba        0.001
    Fe        0.033
    Mn        0.079
    Mo        0.015
    Se        0.004
    Sr        0.01
    Zn        0.006
    Ca        3.8
    K         5.2
    Mg        2.5
```

```
    Na        5.6
    C         1 CO2(g)     -3.5
    -water    1 # kg

SOLUTION 6 Tillite - Wall Rock
    temp      25
    pH        8.2
    pe        4 O2(g) -0.67
    redox     pe
    units     mg/l
    density   1
    S(6)      62
    F         0.8
    Cl        110
    Al        0.097
    Ba        0.003
    Fe        0.046
    Pb        0.009
    Mn        0.015
    Mo        0.002
    Se        0.058
    Sr        0.081
    U         0.016
    V         0.023
    Ca        6.9
    K         8.6
    Mg        7.1
    Na        100
    C         1 CO2(g)     -3.5
    Zn        0.013
    -water    1 # kg

SOLUTION 7 Pure Water
    temp      25
    pH        7
    pe        4
    redox     pe
    units     mmol/kgw
    density   1
    -water    1 # kg
SELECTED_OUTPUT
    -file                 C:\Users\amy.hudson\Documents\Projects\Kintyre\Lake 2
geochemical model results.sel
    -water                true
    -totals               Ag  Al  Alkalinity  As  B  Ba  Be
                          C  Ca  Cd  Cl  Cr  Cu  F
                          Fe  Hg  K  Mg  Mn  Mo  N
                          Na  Ni  O(0)  P  Pb  S(-2)  S(6)
                          Sb  Se  Si  Sr  Ti  U  V
                          Zn
END

MIX 1 year 1 fracture mix
    4    0.44
    5    0.56

SAVE solution 8

END

MIX 2 lake year 1
    7    -0.5
    1    0.586
    8    0.086
    2    0.328

EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
```

```
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0

SAVE solution 9

END

MIX 3 year 2 fracture mix
    4    0.42
    5    0.58
    6    0.002

SAVE solution 10

END

MIX 4 Year 2 Lake
    9    1
    7    -0.5
    1    0.757
    10    0.053
    2    0.19

EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
```

```
    O2(g)     -0.67 0
SAVE solution 11
END
MIX 5 year 3 fracture mix
    4    0.27
    5    0.73
SAVE solution 12
END
MIX 6 Year 3 Lake
    11    1
    7    -1
    1    0.749
    12    0.057
    2    0.193
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 13
END
MIX 7 year 4 fracture
    4    0.33
    5    0.67
SAVE solution 14
END
MIX 8 Year 4 Lake
    13    1
    7    -1.5
    1    0.691
    14    0.073
    2    0.236
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
```

```
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 15
END
MIX 9 year 5 fracture
    4    0.38
    5    0.62
SAVE solution 16
END
MIX 10 Year 5 Lake
    15    1
    7    -1.25
    1    0.317
    16    0.166
    2    0.518
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 17
END
MIX 11 year 6 fracture
    4    0.25
    5    0.47
    6    0.001
SAVE solution 18
END
MIX 12 Year 6 Lake
    17    1
    7    -1.15
    1    0.644
    18    0.086
    2    0.271
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
```

```
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 19
END
MIX 13 year 7 fracture
    4    0.29
    5    0.71
SAVE solution 20
END
MIX 14 Year 7 Lake
    19    1
    7    -1
    1    0.671
    20    0.078
    2    0.251
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 21
END
MIX 15 year 8 fracture
    4    0.29
    5    0.71
SAVE solution 22
END
MIX 16 Year 8 Lake
    21    1
    7    -1
    1    0.885
    22    0.027
    2    0.087
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
```

```
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 23
END
MIX 17 year 9 fracture
    4    0.26
    5    0.74
SAVE solution 24
END
MIX 18 Year 9 Lake
    23    1
    7    -1
    1    0.895
    24    0.025
    2    0.08
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 25
END
MIX 19 year 10 fracture
    3    0.01
    4    0.27
    5    0.72
SAVE solution 26
```

```
END
MIX 20 Year 10 Lake
    25    1
    7    -1
    1    0.882
    26    0.028
    2    0.089
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 27
END
MIX 21 year 15 fracture
    3    0.02
    6    0.001
    4    0.17
    5    0.81
SAVE solution 28
END
MIX 22 Year 15 Lake
    27    1
    7    -1
    1    0.936
    28    0.017
    2    0.048
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
```

```
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 29
END
MIX 23 year 25 fracture
    3    0.03
    6    0.005
    4    0.16
    5    0.8
SAVE solution 30
END
MIX 24 Year 25 Lake
    29    1
    7    -1
    1    0.985
    30    0.003
    2    0.012
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 31
END
MIX 25 year 50 fracture
    3    0.03
    4    0.23
    5    0.74
SAVE solution 32
END
MIX 26 Year 50 Lake
    31    1
    7    -1
    1    0.932
    32    0.012
    2    0.056
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
```

```
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 33
END
MIX 27 year 100+ fracture
    3    0.06
    4    0.29
    5    0.66
SAVE solution 34
END
MIX 28 Year 100 Lake
    33    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 35
END
MIX 29 Year 200 Lake
    35    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
```

```
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 36
END
MIX 30 Year 300 Lake
    36    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 37
END
MIX 31 Year 400 Lake
    37    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
```

```
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 38
END
MIX 32 Year 500 Lake
    38    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 39
END
MIX 33 Year 600 Lake
    39    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
```

```
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 40
END
MIX 34 Year 700 Lake
    40    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 41
END
MIX 35 Year 800 Lake
    41    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
```

```
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 42
END
MIX 36 Year 900 Lake
    42    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 43
END
MIX 37 Year 1000 Lake
    43    1
    7    -1
    1    0.96
    34    0.001
    2    0.04
EQUILIBRIUM_PHASES 1 Phase that can precipitate and equilibrium with atmosphere
    Ag2Se     0 0
    Al(OH)3(am) 0 0
    Alunite   0 0
    Aragonite 0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite  0 0
    Calcite   0 0
    Cerrusite 0 0
    CO2(g)    -3.5 0
    Cuprousferrite 0 0
    Dolomite(disordered) 0 0
    Ferrihydrite 0 0
    Fe(OH)2.7Cl.3 0 0
    Fluorite  0 0
    Gibbsite  0 0
    Goethite  0 0
    Gypsum    0 0
    Halite    0 0
```

```
    Na-Jarosite 0 0
    Natron    0 0
    Pyromorphite 0 0
    O2(g)     -0.67 0
SAVE solution 44
END
```

Cameco Australia Pty Ltd

Attachment D – Site-Wide Water Balance Report

Kintyre Joint Venture Project

penningtonscott
securing your water future

Kintyre Site-Wide Water Balance Report

Western Australia

Prepared for:

Cameco Australia Pty Ltd

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August 2012

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1.0 INTRODUCTION

Cameco Australia Pty Ltd and Mitsubishi Development Pty Ltd are developing the Kintyre Joint Venture (KJV) uranium project on the western edge of the Great Sandy Desert in the East Pilbara of Western Australia, hereafter referred to as the 'Project.' The Project lies 90 km south of Telfer and 270 km northeast of Newman and encompasses five mineralized bodies; the Kintyre, Kintyre East, Whale, Whale East and Pioneer deposits. The Project is expected to have a project life of 13.5 years and involves the development of open cut pits, waste landforms, ore stockpiles, accommodation village, site drainage and stormwater ponds, a processing facility, and a Tailings Management Facility (TMF) within the operational area.

Tetra Tech Inc. has been commissioned to create two site-wide water balance (SWWB) models in GoldSim to explore two options: an Alkaline Leach processing facility and an Acid Leach processing facility. The purpose of these SWWB models is to clarify the water network, and refine the estimated water supply needs. This report presents results from the Acid Leach processing facility SWWB modelling efforts for the Project.

2.0 BACKGROUND

To determine the Project site-wide water balance, a GoldSim model was developed which sums all the water uses, incorporating water loops and losses, to provide an estimate of the required water supply. The major components of the Acid Leach processing method SWWB model include (Figure D2-1):

- A processing facility designed to process 75.2 tons per hour of uranium ore at full operation with a 92% annual availability factor
- A conventional tailings management facility
- A freshwater reverse osmosis (RO) plant to treat fresh water from the water supply borefield.

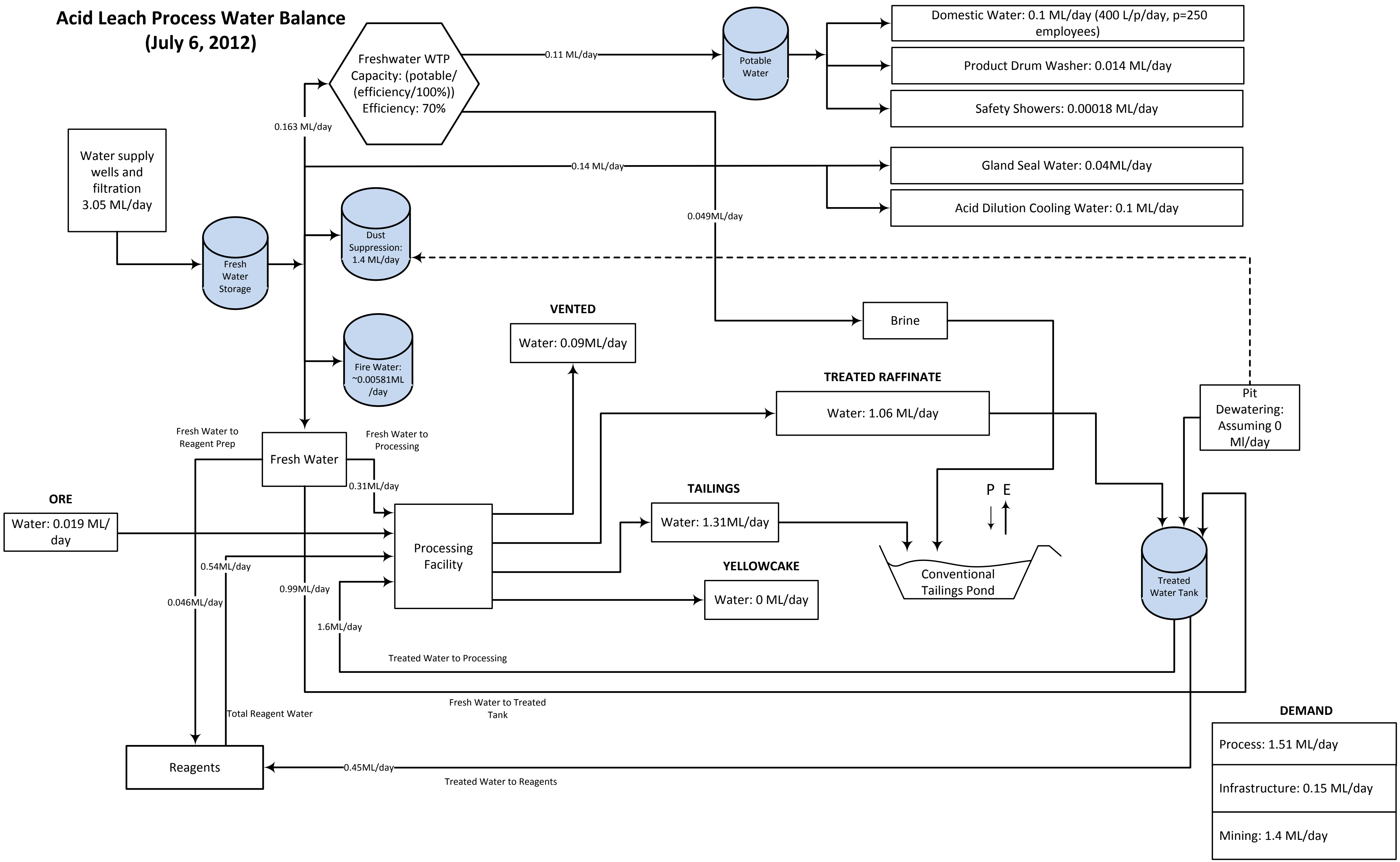
The borefields will supply fresh water for the project. After solids filtration the quality of the bore water is adequate enough to service the water requirements for dust suppression, fire protection, gland seal water, reagent preparation, cooling water, calciner scrubbing and Solvent Extraction (SX) without requiring any further water treatment.

In addition, the borefields will supply water to an RO plant that will distribute potable water to the accommodation village for domestic use, the product drum washer and the safety showers.

Overflow water from the gypsum thickener in processing will be routed to the treated water tank and recycled back into the processing facility. Due to the quantity of dissolved salts in the water, the treated water tank is limited to supply water to areas of the processing facility that do not require a "clean" water source. Fresh borefield water is routed to the treated water tank in order to limit the build of impurities, as well as supply the processing facilities water demand.

Water from the dewatering of the pit will be used in processing and will be stored in the treated water tank. If the pit dewatering is in excess of the processing water needs, the excess water will be routed for use in dust suppression - offsetting the amount of fresh water required for that need.

Some water will be lost in the processing through venting to the atmosphere. The tailings slurry and the brine waste from the RO plant will be routed to the TMF for long term storage. There is a possibility of decanting the water from the TMF in order to tighten the water balance, pending on the quality the water in tailings and whether it is viable to treat. It is recommended in future work to investigate the potential treatment of tailings decant in attempt to recover water and reduce demand at the borefields.



Acid Leach Process Water Balance
(July 6, 2012)
Freshwater WTP
Capacity: (potable/
(efficiency/100%))
Efficiency: 70%
0.11 ML/day
Potable Water
Domestic Water: 0.1 ML/day (400 L/p/day, p=250 employees)
Product Drum Washer: 0.014 ML/day
Safety Showers: 0.00018 ML/day
Gland Seal Water: 0.04ML/day
Acid Dilution Cooling Water: 0.1 ML/day
0.163 ML/day
0.14 ML/day
0.049ML/day
Water supply wells and filtration 3.05 ML/day
Fresh Water Storage
Dust Suppression: 1.4 ML/day
Fire Water: ~0.00581ML /day
VENTED
Water: 0.09ML/day
Brine
TREATED RAFFINATE
Water: 1.06 ML/day
Pit Dewatering: Assuming 0 Ml/day
Fresh Water to Reagent Prep
Fresh Water
Fresh Water to Processing
0.31ML/day
ORE
Water: 0.019 ML/ day
Processing Facility
TAILINGS
Water: 1.31ML/day
P
E
YELLOWCAKE
Water: 0 ML/day
Conventional Tailings Pond
Treated Water Tank
0.54ML/day
0.046ML/day
0.99ML/day
1.6ML/day
Treated Water to Processing
Fresh Water to Treated Tank
Total Reagent Water
Reagents
0.45ML/day
Treated Water to Reagents
DEMAND
Process: 1.51 ML/day
Infrastructure: 0.15 ML/day
Mining: 1.4 ML/day

3.0 MODEL CODE: GOLDSIM

Tetra Tech Inc. has chosen GoldSim (GoldSim, 2005) as the platform for the Project SWWB models. GoldSim is a general-purpose simulation environment capable of simulating a wide variety of systems. Some of the key features of GoldSim include the ability to simulate complex system dynamics, to simulate how these systems evolve over time, to explicitly represent interrelationships and feedback mechanisms between system components, and to capture and capitalize on inherent component uncertainty all within an object-oriented, graphical interface that allows the user to quickly understand the system structure. GoldSim works within a hierarchical, modular paradigm ideally suited for representing complex systems characterized by interrelated subsystems.

In general, a water balance model solves the following equation:

$$\Delta S = \int (I - O)\, dt \quad (1)$$

where ΔS is the change in storage, I is the sum of the inflows and O is the sum of the outflows over the model time step dt. This equation must be satisfied within some pre-defined area (the model domain) as a whole, within each subsystem, and within each component of each subsystem.

3.1 Steady-State vs. Transient

The terms steady-state and transient refer to the behaviour of a specific component with respect to time.

A steady-state parameter is one whose value is constant with respect to time. For example, the maximum volume of storage in a stormwater pond does not change over time (assuming no sediment accumulation). Other parameters may be treated as steady-state only because there is not enough information to know with certainty how these parameters may change with time. In this case a single, steady-state value has been assigned for these parameters. Examples include the uranium concentration of the ore, the percent of uranium recovered from the ore, and the uranium concentration of the concentrate. In future modelling, these parameters could be treated as stochastic with various probability distributions, such as normal or Poisson.

Conversely, a transient parameter's value changes through time. Examples of transient parameters include precipitation, evaporation, and groundwater inflow into the pit.

Other parameters are treated as potentially transient. These may include parameters that possess a constant value for a limited amount of time relative to the overall life of mine or parameters for which there is not enough information at this time to know with certainty how these parameters will change through time. Accordingly, these parameters are defined as time-series elements but possess constant values. Examples of these pseudo-transient parameters could include ore production from pit and the processing rates.

3.2 Deterministic vs. Stochastic

Most of the model design parameters are deterministic in nature. That is, their magnitude is accurately known, or assumed, for all times.

In contrast, certain inputs will necessarily be uncertain. Examples of uncertain parameters include the rainfall on any particular day in the modelled timeframe, or the day that a piece of equipment may breakdown. GoldSim offers a variety of techniques for estimating uncertain parameters. Model parameters that are specified with probability distributions are called stochastic parameters.

Some parameters may be stochastic in nature however, for this round of modelling they have been treated as deterministic. Examples include the moisture content of ore as it's removed from the ground as well as the uranium concentration of the ore and yellowcake as described above.

4.0 MODEL CONSTRUCTION

4.1 General Model Assumptions

A sound conceptual model involves an analysis of the system, a breakdown of this system into individual subsystems that define the key components of the system, and a definition of the relationships between system components. For the Kintyre Project, the conceptual site-wide water balance model involved inputs from engineering disciplines from across the entire project including process, mining, hydrogeology, tailings management, and operations. Upon completion of the breakdown phase, the individual components were integrated into a conceptual model of the site-wide system.

It is important to understand that robust results from this model are dependent on an accurate representation of the site in the form of a conceptual model. Not only is the SWWB dependent on a good conceptual model, but also on high quality data. At this stage there are multiple unknowns that need to be quantified during value engineering or the Definitive Feasibility Study (DFS) phase to reduce uncertainty in the water balance (e.g., seepage from landforms). The model currently has placeholders for these data gaps and they are highlighted in Section 6 of this report.

4.2 Sources of Data

Historic daily precipitation and temperature, and average monthly evaporation data come from the Australia Government Bureau of Meteorology for the Telfer Aero station (station number 013030). More details on the precipitation can be found in Section 4.3.1, and on the evaporation in Section 4.3.2. Summaries of monthly precipitation and evaporation are shown in Table D4-1.

Table D4-1: Average Monthly Precipitation and Evaporation

Month	Average Precipitation [1] (mm)	Average Evaporation [2] (mm)
January	49.1	443.3
February	97.6	364.4
March	79.1	381.3
April	20.4	321.0
May	19.0	241.8
June	12.3	192.0
July	13.5	213.9
August	5.6	260.4
September	2.5	336.0
October	2.9	440.2
November	16.3	465.0
December	47.6	468.1
Total	366.0	4,127.4

Notes:

1. Summarized from daily precipitation records collected from January 1, 1974 through March 19, 2012.
2. The Australian Government Bureau of Meteorology website provides average evaporation rate by month (in mm/day) collected from 1974 through 1995.

The rate for groundwater dewatering from the pit comes from the groundwater flow modelling report (Tetra Tech, 2012b).

Components involving the ore processing comes from the Acid Leach Process Flow Diagrams (Appendix A). This information includes; the uranium content in the ore, tailings, and yellowcake; the processing rate, and the water losses through vented steam, over-flows, and entrained in the tailings. The uranium mass recovery was calculated from values contained in these diagrams. Additional information, such as the number of people at the site for potable water consumption calculations, dust suppression water needs, or safety shower water requirements come from the Kintyre Pre-Feasibility Report (Tetra Tech, 2012a).

4.3 Climate

The Project area has an arid climate with hot wet summers and warm dry winters. Mean maximum temperatures at Telfer, approximately 90 km north of the Project area, average about 40°C in summer while winter minima are around 26°C.

4.3.1 Precipitation

A 38 year precipitation record exists from the Telfer Aero Station (Australia Bureau of Meteorology, 2012). These daily values are available from 1974 through 2012. Historical rainfall at Telfer ranges from 114 to 817 mm/year with a long term average of approximately 366 mm/year.

The standard deviation of the total monthly precipitation by year was calculated from the precipitation record described above.

4.3.2 Potential Evaporation

Average monthly pan evaporation data, in mm/day, is available from the Telfer Aero Station. These statistics are calculated from data collected from 1974 through 1995. The annual pan evaporation at Telfer averaged over this period is approximately 4,127 mm.

Daily or monthly by year pan evaporation data does is not available for the Telfer station to calculate a standard deviation. As evaporation is closely linked to temperature, the maximum daily temperature data was used to calculate the monthly standard deviations for temperatures, and these monthly standard deviation values were implemented as a substitute for the evaporation monthly standard deviation values.

4.3.3 Precipitation and Evaporation Implementation

A stochastic method, based on the above mentioned statistics, was used to model precipitation and evaporation throughout the life of mine SWWB models. The long term historic precipitation record was analysed for monthly average and monthly standard deviation values. The probabilities of having a wet (rainy) day following a wet day (W/W) and of having a wet day following a dry day (W/D) were calculated. These values were used in a second order Markov chain, where the probability of a rainy day is based on one of two probabilities, the chance of rain if the previous day was dry (W/D) or the chance of rain if the previous day was wet (W/W). If a wet day is predicted, a lognormal distribution fit to all the wet days of the current month is used to generate the depth of rainfall.

The average monthly evaporation and standard deviation calculated from the long term historic temperature record were fit to a truncated normal distribution to generate the depth of evaporation.

5.0 SITE-WIDE WATER BALANCE

The site-wide water balance for Kintyre consists of the following major components as shown in Figure 1:

- Water Supply Borefield;
- Pit;
- Run-of-Mine Facility (ROM);
- Tailings Management Facility (TMF);
- Ore Processing Facility (OPF);
- Reserve Osmosis (RO) Plant;
- Mineralised Overburden Stockpile (MOBS);
- Waste Rock Landforms (WRLF);
- Accommodation Village; and
- Site Drainage and Stormwater Ponds.

The water balance (i.e., inflows and outflows), risks, and outstanding items for the DFS will be discussed for each component.

5.1 Water Supply Borefield

A borefield is being constructed north of the Kintyre site to provide potable water for the mine. The current water demand from the borefield is 3.1 ML/day. This water will be provided by seven main production bores with three standby bores for contingency. Freshwater from the water supply borefield will be treated at a reverse osmosis plant to provide potable water for the project.

5.1.1 Water Supply Borefield Water Balance

Water enters the bore from the aquifer through pumping. Water is conveyed from the borefield by pipeline. Within the model GoldSim sums the water required to be sent to the RO plant for treatment (0.163 ML/day), the fresh water required for dust suppression (averaged as 1.4 ML/day), the water required for fire suppression (5.48 KL/day: 2,000 m^3 per year), gland seal water (0.04 ML/day), acid dilution cooling water (0.1 ML/day), the required fresh water needed for processing (0.31 ML/day), the fresh water required for reagent preparation (0.046 ML/day) and the fresh water required to balance the treated water storage needs (varying between 0 and 0.99 ML/day. This sum is the amount of water that the fresh water borefield must supply for the project.

Kintyre Project
Isometric view of the
Conceptual project layout
Figure 6-2

5.1.2 Water Supply Borefield Risks and Future Work

Refer to Appendix B – Kintyre ERMP Groundwater Modelling Report for additional detail on the water supply modelling methodology. The recommendations for increasing the confidence in the water supply are:

1. Undertake packer testing program on site (August 2011)
2. Update DFS Geotechnical Report with structural model (September 2012)
3. Scope and design 30 day pump test of paleochannels (September 2012)
4. Execute 30 day pump test
5. Update regional water supply model
6. Update Kintyre ERMP Groundwater Modelling Report
7. Evaluate exploration/off-site water supply potential (if required).

5.2 Open Pit

In-pit sumps and mobile diesel dewatering pumps will be used to manage the water levels in the bottom of the pit during operations. The water usage estimate for the mining operation is based on delivery by water truck: CAT 777 equivalent with 70,000 L tank operating 20 hours per day. The estimate includes, but is not limited to:

- dust suppression at the mining face (using a water cannon)
- dust suppression on haul and site roads
- refilling water tanks on mobile drilling equipment
- wall washing (using a water cannon).

Water carts are expected to refill at a water tower facility (Quickfill equivalent), recharged by either the pit dewatering boreholes or the in-pit dewatering system.

Table D4-2 and D4-3 list the PFS pit dimensions and material type by quantity.

Table D4-2: Ultimate Pit Dimensions

PFS Pit Design	Dimensions (m)
Maximum Length	1,400
Maximum Width	750
Maximum Depth	220

Table D4-3: Pit Design - Material Type by Quantity

PFS Pit Design	Tonnes (t)
Ore	3.8
Mineralized Overburden	6.0
Unmineralized Overburden	134.0
Total	143.8

5.2.1 Pit Water Balance

The post-closure water balance for the Kintyre pit can be expressed as:

$$\Delta_{pit\ lake\ volume} = I_{precip} + I_{pit\ runoff} + GW_{inflow} - E_{pit} \quad (2)$$

where:

I_{precip} is the inflow from direct precipitation falling on the lake surface;

$I_{pit\ runoff}$ is the inflow from pit wall runoff (the fraction of precipitation falling on the pit walls that ultimately reaches the pit lake);

GW_{inflow} is the groundwater inflow to the pit lake; and

E_{pit} is the open-water evaporation from the pit lake surface.

Water enters the pit void through precipitation, seepage from pit walls, and groundwater inflow. Since the pit is a terminal sink, water leaves the pit through evaporation only. However, due to mining activities water also leaves the pit through dewatering bores and sumps. Groundwater flow modelling was used to simulate the pit lake water balance and dewatering (Tetra Tech, 2012b). Results of the groundwater flow model show that two pit lakes will form post closure, if the western pit is not backfilled. The backfill option will be evaluated during the DFS phase.

Within the model, GoldSim uses a time series element to account for pit dewatering by year. These dewatering rates are supplied to GoldSim by the groundwater flow modelling. This water is then routed to the treated water storage tank in GoldSim.

5.2.2 Pit Risks and Future Work

The quality of the pit water was not defined during the PFS and as a result the management of the pit water was not clearly defined. For the ERMP Cameco assumed that the pit water that is not used for dust suppression would report directly to the evaporation ponds or Tailings Management Facility (TMF). During the DFS the following is required:

- Confirm the water quality from the pit lake modelling
- Update the quantity of water from any updates to the Kintyre ERMP Groundwater Modelling Report
- Evaluate whether the pit water may be used for the acid leach processing method
- Evaluate the potential build-up of radiation in the water being recycled for dust suppression to ensure Health and Safety Standards are achieved
- Evaluate the turbidity of the water during the wets season and pumping operations
- Define the Pit Water Management Plan outlining the potentially uses for pit water
- Design appropriate pumping and piping infrastructure based on the Pit Water Management Plan.

There is a risk that water quality from the pit dewatering is not suitable for the processing of the Kintyre ore. Groundwater monitoring in bores near the pit should be used to assess and predict the water quality expected during mining operations.

5.3 Run-of-Mine (ROM) Facility

ROM ore from the open pit mine would be delivered directly to the plant feed bin or to the ROM stockpile by haul trucks. The ROM stockpile would have a capacity equivalent to around 12 months (approximately 600,000 tonnes) of grinding mill feed.

5.3.1 ROM Water Balance

Water enters the ROM facility through infiltration from precipitation. Water leaves the ROM facility through seepage at the base of the facility.

5.3.2 ROM Risks and Future Work

A risk associated with the ROM facility is the amount of seepage that occurs through the base of the facility into the foundation soil. To mitigate this risk, seepage modelling of the ROM facility will need to be conducted during the DFS phase to quantify the seepage flux and fate and transport.

5.4 Tailings Management Facility

The conventional tailings management facility (TMF) was designed based on the following:

- acid processing of ore
- conventional tailings slurry disposal
- above-ground facility with embankments constructed with waste rock and/or overburden material from the pit
- facility location will be south of the planned rock storage facility
- maximum elevation of the facility will be 400 masl to limit visual impacts.

The PFS and ERMP assume that no water will be recycled. This will be further evaluated during the DFS.

The TMF is sized to store approximately 7 Mt of tailings. This includes tailings from the use of the radiometric sorter on both ore and mineralized overburden and contingency.

5.4.1 TMF Water Balance

Within the model, water enters the TMF by multiple pathways: through precipitation falling directly on the pond water surface (incident rain), through water entrained in the tailings slurry, and through the RO plant brine water stream. Water exits the TMF through evaporation off the water surface area, seepage through the base of the TMF, and possibly through pumping to a tailings water treatment plant (WTP). The water balance for the TMF is:

$$V_p = \int (I_p \cdot A_p + E_w + B_{RO} - E \cdot A_w - S)\, dt \quad (3)$$

Where:

V_p is the volume of water in the pond (m^3),

I_p is the incident precipitation (mm/day),

A_p is the area of direct precipitation: the water surface of the pond or the area of the bottom of the pond in the event the pond is dry (m^2),

E_w is the entrained water contained in the tailings slurry (tons/hr converted to m^3/day),

B_{RO} is the brine from the RO plant (m^3/day),

E is the actual evaporation (mm/day),

A_w is the area of the water surface of the pond (m^2), and

S is the seepage flux (m^3/day).

Incident Rain

Some precipitation will fall directly on the water surface of the pond, or the bottom of the pond facility if the pond is dry. As such, there is no wetting of the ground surface required before this precipitation will add to the volume of water in the pond. In the model, GoldSim uses a function called a lookup table to determine the daily area of the water surface based on the volume of water the pond contains that day and a storage-area relationship for that structure. The precipitation for that time is then multiplied by the water surface area and that volume for that day (m^3/day) is added to the pond volume.

Entrained Water

The tailings slurry from the processing facility is composed of 38.9% water entrained in the slurry.

Brine Water

The brine water output from the freshwater RO plant is routed to the TMF. The brine water quantity is determined by the demand for potable water and the efficiency of the RO plant, which was assumed to recover 70% of the freshwater supply to the RO plant.

Evaporation

As with the incident rain, GoldSim uses a lookup table to determine the surface area of the water in the pond on a given day based on the volume of water contained therein at that time. The stochastically determined evaporation for that day is then multiplied by the area of the water surface, and by a pan evaporation factor to obtain a potential evaporation (m^3/day). Given the arid nature of the site there is potential for times when the potential evaporation is greater than the volume of water available to evaporate. To prevent artificially evaporating more water than actually exists, GoldSim looks at the available volume of water contained in the pond that day and uses a selector element to evaporate the available volume of water or to evaporate the full potential volume. The evaporated amount is called the actual evaporation.

5.4.2 TMF Risks and Future Work

Risks associated with the TMF are the amount of seepage that occurs through the base of the facility into the foundation soil and the amount of radon flux through the soil layers. To mitigate the seepage risk, seepage modelling of the TMF will need to be updated in the DFS phase to quantify the seepage flux and fate and transport. To mitigate the radon risk, radon flux modelling of the TMF will need to be updated in the DFS phase.

5.5 Ore Processing Facility

The acid ore processing facility (OPF) includes, but is not limited to, the following areas:

- primary crushing
- provisional radiometric sorting
- grinding (Semi-Autogenous Grinding (SAG) mill, pebble crusher), classification and thickening
- atmospheric acid tank leaching
- leach residue solid/liquid separation
- solvent extraction
- Ammonium Diuranate (ADU) precipitation, dewatering, calcining, and packaging
- tailings neutralization
- water recovery and water treatment plant
- reagents and utilities.

5.5.1 OPF Water Balance

Water enters the facility entrained in the ore, water entrained in the reagents and makeup water. Water leaves the facility entrained in the tailings, vented, and through bleed streams. It is assumed that no water leaves the facility entrained in the yellowcake.

OPF Water Balance Calculations

The following calculations were performed assuming a plant availability of 92%.

The ore water content is calculated from:

$$M_{w|o} = (M_o \cdot C_{w|o}) \quad (4)$$

where $M_{w|o}$ is the tonnage of water entering the processing facilities entrained in the ore (0.8 tons/hr), M_o is the facility process rate of ore (75.2 tons/hr), $C_{w|o}$ is the concentration of water in the ore (1.00%).

The yellowcake production is calculated from:

$$M_{yc} = (M_{s|o} \cdot C_{u|o} \cdot PR) / C_{u|yc} \quad (5)$$

where M_{yc} is the yellowcake production (0.4 tons/hr), $M_{s|o}$ is the solids content of the ore (74.4 tons/hr), $C_{u|o}$ is the concentration of uranium in the ore (%, discussed below), PR is the percent recovery of the uranium (%, discussed below), and $C_{u|yc}$ is the concentration of the uranium in the yellowcake (%, discussed below).

The concentration of water in the ore is calculated from:

$$C_{w|o} = M_{w|o} / M_{t|o} \quad (6)$$

where $C_{w|o}$ is the concentration of water in the ore (1.00%), $M_{w|o}$ is the processing mass of water in the ore (0.8 tons/hr), and $M_{t|o}$ is the total ore processed (75.2 tons/hr).

The concentration of uranium in the ore is calculated from:

$$C_{u|o} = M_{u|o} / M_{s|o} \quad (7)$$

where $C_{u|o}$ is the concentration of uranium in the ore (0.488 $\%U_3O_8$), $M_{u|o}$ is the processing mass of uranium in the ore (363.07 kg/hr), and $M_{s|o}$ is the processing mass of solids (uranium plus other solids) in the ore (74.4 tons/hr).

The concentration of uranium in the yellowcake is calculated from:

$$C_{u|yc} = M_{u|yc} / M_{s|yc} \quad (8)$$

where $C_{u|yc}$ is the concentration of uranium in the yellowcake (98.3 $\%U_3O_8$), $M_{u|yc}$ is the processing mass of uranium of the yellowcake (354.11 kg/hr), and $M_{s|yc}$ is the processing mass of solids (uranium plus other solids) in the yellowcake (0.36 tons/hr).

The percent recovery of uranium is calculated from:

$$PR (\%) = M_{u|yc} / M_{u|o} = 97.5\% \quad (9)$$

The concentration of water in the yellowcake is calculated from:

$$C_{w|yc} = M_{w|yc} / M_{t|yc} \quad (10)$$

where $C_{w|yc}$ is the concentration of water in the yellowcake (0%), $M_{w|yc}$ is the processing mass of water in the yellowcake (0 tons/hr), and $M_{t|yc}$ is the processing mass of the total yellowcake (0.4 ton/hr).

The concentration of uranium in the tailings is calculated from:

$$C_{u|t} = M_{u|t} / M_{s|t} \quad (11)$$

where $C_{u|t}$ is the concentration of uranium in the tailings (0.01%), $M_{u|t}$ is the processing mass of uranium in the tailings (8.96 kg/hr), and $M_{s|t}$ is the processing mass of solids (uranium plus other solids) in the tailings (78.62 tons/hr).

The concentration of water in the tailings is calculated from:

$$C_{w|t} = M_{w|t} / M_{t|t} \quad (12)$$

where $C_{w|t}$ is the concentration of water in the tailings (39.76%), $M_{w|t}$ is the processing mass of water in the tailings (56.84 tons/hr), and $M_{t|t}$ is the processing mass of the total tailings (142.94 tons/hr).

The makeup water required to operate the processing facility is calculated from:

$$M_{w|mu} = \sum(\text{water out}) - \sum(\text{water in}) \quad (13)$$

where $M_{w|mu}$ is the processing mass of the required makeup water. The water traveling out of the processing system is composed of water entrained in the yellowcake (0 tons/hr), water entrained in the tailings (54.8 tons/hr), H_2O gas vented to the atmosphere (3.69 tons/hr), and water entrained in the raffinate treatment gypsum thickener overflow routed to the TMF (44.15 tons/hr) for a total of 102.64 tons/hr at full capacity. The water entering the processing system is composed of water entrained in the ore (0.8 tons/hr), water entrained in the reagents (21.1 tons/hr composed of 1.9 tons/hr fresh water, 18.9 tons/hr treated water, and 0.3 tons/hr water as delivered), fresh water required for processing (12.93 tons/hr composed of calciner scrubber water at 5.73 tons/hr and the SX water at 7.2 tons/hr), and treated water (66.8 tons/hr for the grinding circuit at 55.2 ton/hr and the crushing circuit at 11.5 tons/hr) for a total of 101.6 tons/hr.

5.5.2 OPF Risks and Future Work

Further test work is planned during the DFS to evaluate the potential of recycling components of the OPF water balance.

5.6 Fresh Water Reverse Osmosis Plant

Freshwater from the water supply borefield will be treated at a reverse osmosis plant to provide potable water for the project.

5.6.1 RO Plant Water Balance

Water enters the RO Plant from the treated water storage tank. To determine how much water must be treated, the model sums the potable water needs: domestic water (currently set to 0.1 ML/day: 400 L/person/day, assuming 250 employees), product drum washer water (14.16 KL/day or 0.59 m^3/hr), and safety shower water (0.18 KL/day: 4.5 m^3/hr/shower, assuming 15 showers per year). The total potable water demand is therefore 0.11ML/day. As the RO plant recovers 70% of the total fresh borewater delivered to the RO plant as potable water the model then divides the total potable water requirement by the efficiency to calculate the running capacity of the RO plant (0.163 ML/day).

The model multiplies the running capacity of the RO plant by the inefficiency of the plant (92%) to determine how much brine from the RO plant is sent to the TMF (0.049 ML/day).

5.6.2 RO Plant Risks and Future Work

No significant risks have been identified. The RO plant will be designed in the DFS.

5.7 Mineralised Overburden Storage Area

The mineralized overburden or mineralized rock mined during extraction of the ore would be stockpiled separately within the final footprint of the western WRLF, nominally at the southern end, in an area that would be lined to manage any potential rainfall infiltration and leachate, as shown in Figure 18-1. A peak of 6 Mt of mineralized overburden is expected to be stored in the mineralized overburden storage area.

In the event the mineralized overburden is not processed, which will be dependent on metal prices and the potential effectiveness of the radiometric sorter, the mineralized overburden storage area would be designed so that rehandle of this material will not be required. Liners and sufficient offset from the limits of the RSF would be designed to enable in-situ closure.

5.7.1 MOBS Water Balance

Water enters the MOBS area through infiltration from precipitation. Water leaves the MOBS area through seepage at the base of the facility.

5.7.2 MOBS Risks and Future Work

A risk associated with the MOBS area is the amount of seepage that occurs through the base of the facility into the foundation soil. To mitigate this risk, seepage modelling of the MOBS facility will need to be conducted in the DFS phase to quantify the seepage flux and fate and transport.

5.8 Waste Rock Landforms

The north and west rock storage facilities (RSF) would be constructed to contain a total of approximately 63 Mm^3 of overburden (including 20% contingency). An additional 11 Mm^3 may be dumped within the Kintyre pit. The total RSF capacities are listed in Table D4-4.

Table D4-4: WRLF Capacities and Dimensions

PFS Pit Design	Dimensions (x,y,z) (m)	Volume (Mm^3)
North	600 x 520 x 50	8
West	1,300 x 1,300 x 45	55
Inpit	570 x 300 x 140	11

5.8.1 WRLF Water Balance

Water enters the WRLFs through infiltration from precipitation. Water leaves the WRLFs through seepage at the base of the facility.

5.8.2 WRLF Risks and Future Work

A risk associated with the WRLFs is the amount of seepage that occurs through the base of the facility into the foundation soil. To mitigate this risk, seepage modelling of the WRLFs will need to be conducted in the DFS phase to quantify the seepage flux and fate and transport.

5.9 Treated Water Storage

A treated water storage tank will store water from the raffinate treatment gypsum thickener overflow (44.15 tons/hr), water from the pit dewatering, and freshwater from the fresh water supply bores. The required storage is designed to equal the water uses from the treated water, namely treated water for processing (66.8 tons/hr for the grinding circuit at 55.2 tons/hr and the crushing circuit at 11.6 tons/hr) and treated water for reagent preparation (18.9 tons/hr for the flocculants at 1.5 tons/hr, the acid dilution water at 11.9 tons/hr, the pyrolusite at 1.7 tons/hr, and the lime at 3.8 tons/hr).

5.9.1 Treated Water Storage Water Balance

Water from the fresh water supply will only be routed to the treated water storage if the pit dewatering rate falls below 41.4 tons/hr or 993.6 KL/day and will be supplied at a rate needed to meet the treated water supply needs.

If the pit dewatering rate is greater than needed for balancing the treated water storage needs (pit dewater > 993.6 KL/day) then the excess pit water is routed to use for dust suppression, offsetting the freshwater required for dust suppression needs.

5.9.2 Treated Water Storage Risks and Future Work

No significant risks have been identified. The water storage requirements will be designed in the DFS.

5.10 Accommodation Village

The accommodation village will comprise up to 500 rooms based on the following:

- a permanent village of around 200 rooms would be constructed for a fly-in/fly-out workforce, to be used during construction and operations

- an additional 250 rooms at a lower specification would be constructed adjacent to the permanent Accommodation Village, to be used primarily during construction the existing exploration camp of around 50 rooms may continue to be utilized during operations
- kitchen facilities
- recreational facilities.

Additional temporary accommodation may be sourced at the Telfer mine site approximately 90 km north of Kintyre. This would be dependent on availability and would require bus transportation of personnel from Telfer to Kintyre.

The accommodation units would consist of a number of modules, each module containing four living quarters, each quarter having a bed, desk, television, wardrobes and an air conditioner. Permanent accommodation modules would be fitted with individual en-suite bathrooms while construction rooms would share one bathroom facility between four units. The village would include playing fields, a gymnasium, a swimming pool, and a tennis court.

5.10.1 Accommodation Village Water Balance

Water enters the accommodation village from either directly from the fresh water supply or from the treated water storage tank. Domestic water (currently set to 0.1 ML/day: 400 L/person/day, assuming 250 employees) is utilised for domestic water needs. Water leaves the accommodation village through the sewage leachfield.

5.10.2 Accommodation Village Risks and Future Work

No significant risks have been identified. The accommodation requirements should be updated in the DFS but will not have a significant impact.

5.11 Site Drainage and Stormwater Ponds

Facilities have been designed to accommodate a 1-in-100 year 72-hour storm event during operations. The primary structures that have been proposed are:

- surface water diversion channels
- three lined stormwater ponds
- an open pit flood protection bund
- a decant system for the conventional TMF design.

5.11.1 Site Drainage and Stormwater Ponds Water Balance

Site drainage is used to convey water between different water balance components. Water enters the stormwater ponds from direct precipitation and stormwater runoff. Water leaves the stormwater ponds through evaporation and seepage.

5.11.2 Site Drainage and Stormwater Ponds Risks and Future Work

The primary risk is that in an extreme weather event water is discharged into the creek system. The design of the site drainage and storm water ponds should be updated during the DFS and the impact of any offsite discharge evaluated (if required).

6.0 RECOMMENDATIONS

Tetra Tech recommends that the following actions are undertaken during the DFS to potentially reduce the overall water demand and increase the accuracy of the GoldSim model output:

- Increase the level of confidence in the water supply and pit dewatering by executing a packer testing program to evaluate hydraulic conductivity, update the DFS Geotechnical Report incorporating a structural fault model, perform a 30-day pump test and re-run the regional and local ground water models
- Develop a Pit Water Management Plan based on expected quantity and quality to outline the storage, pumping and use for the pit water
- Evaluate dust suppression alternatives for the pit and haul roads including organic based products;
- Model the seepage from the ROM and update the design of the liner system (if required)
- Incorporate the findings from the Acid Tailings Management Facility Design Report and further investigate the option of recycling and treating tailings reclaim water;
- Update the water demand for the process based on the DFS flowsheet and SysCad model (when available)
- Design the RO plant based on the GoldSim model
- Model the seepage from the MOBS and update the design of the liner system (if required)
- Model the seepage from the WRLFs and design a liner system (if required)
- Design the Treated Water Storage based on the GoldSim model
- Update the accommodation village water demand based on the DFS (when available)
- Update the GoldSim model to include variability of all inputs over the Life of Mine to allow sensitivity analysis in the DFS;
- Design the supply of water from each borehole to meet water quantity and quality for each demand area (mine, process, infrastructure) for the Project
- Update the design of the stormwater ponds and site drainage, evaluate the need for any liner systems and the impact of any discharge into the Yandagooge Creek.

Noting that after each of the recommendations above, GoldSim should be updated.

Ongoing monitoring of water bores, rainfall events and extreme weather events should continue to be documented and the information in Goldsim updated as required.

7.0 REFERENCES

Australia Bureau of Meteorology, website accessed March 20, 2012: http://www.bom.gov.au/climate/data/index.shtml .

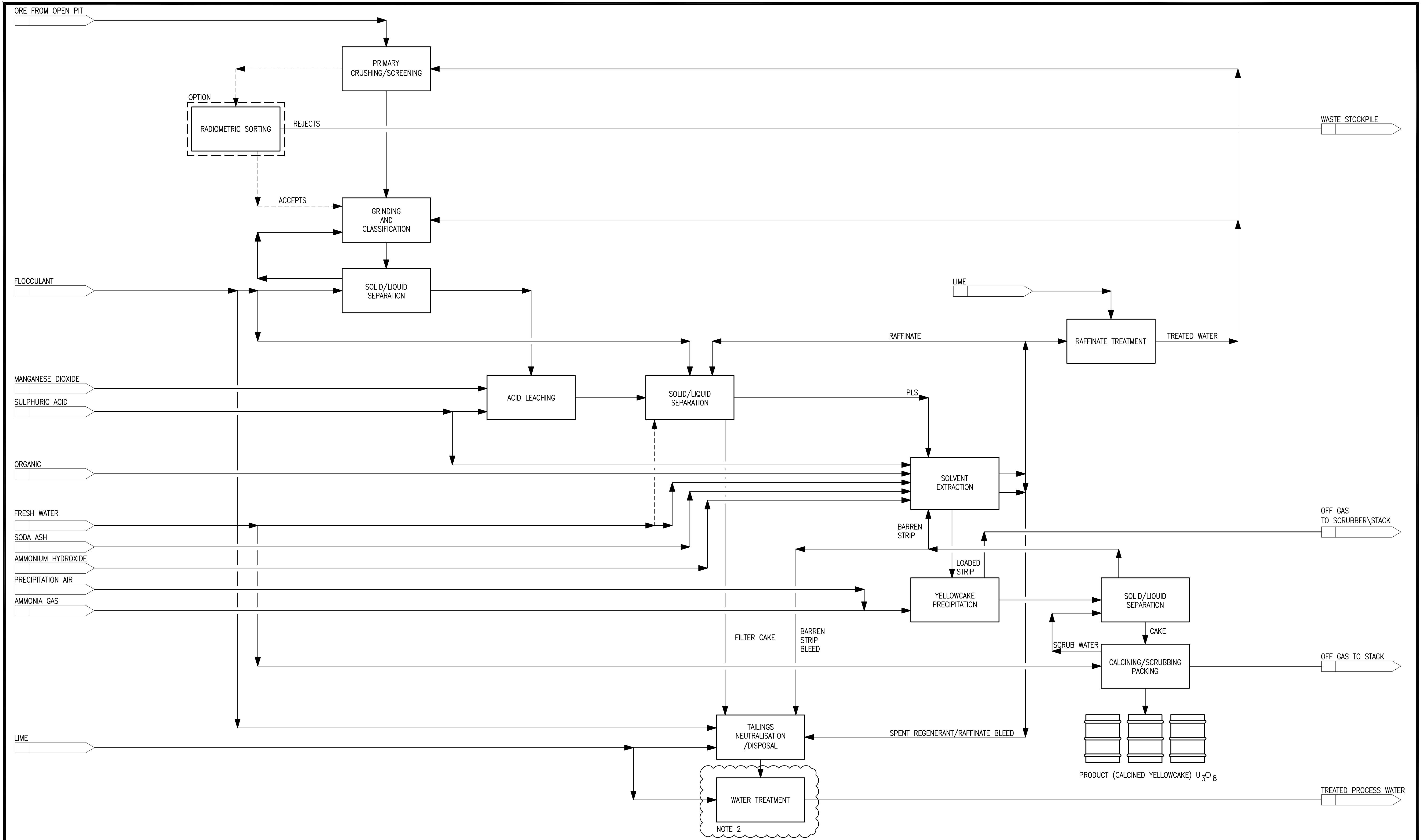
GoldSim Technology Group, (2005). User's Guide GoldSim Probabilistic Simulation Environment, Version 9. Washington, USA.

Tetra Tech, 2012a, Kintyre Pre-Feasibility Report, Prepared for Cameco Australia Pty Ltd, April 2012.

Tetra Tech, 2012b, Kintyre ERMP Groundwater Modelling Report, Prepared for Cameco Australia Pty Ltd, July 2012.

APPENDIX A

ACID LEACH PROCESS FLOW DIAGRAMS



NOTES:

1. FOR ALL FLOWSHEETS, THE MASS BALANCE VALUES ARE ROUNDED TO THE NEAREST HUNDREDTH DECIMAL PLACE. VALUES LESS THAN 0.1 MAY NOT BE AS SHOWN. REFER TO THE APPROPRIATE MASS BALANCE DOCUMENT IF EXACT VALUES ARE DESIRED.
2. PENDING DEVELOPMENT OF TAILINGS FACILITY.

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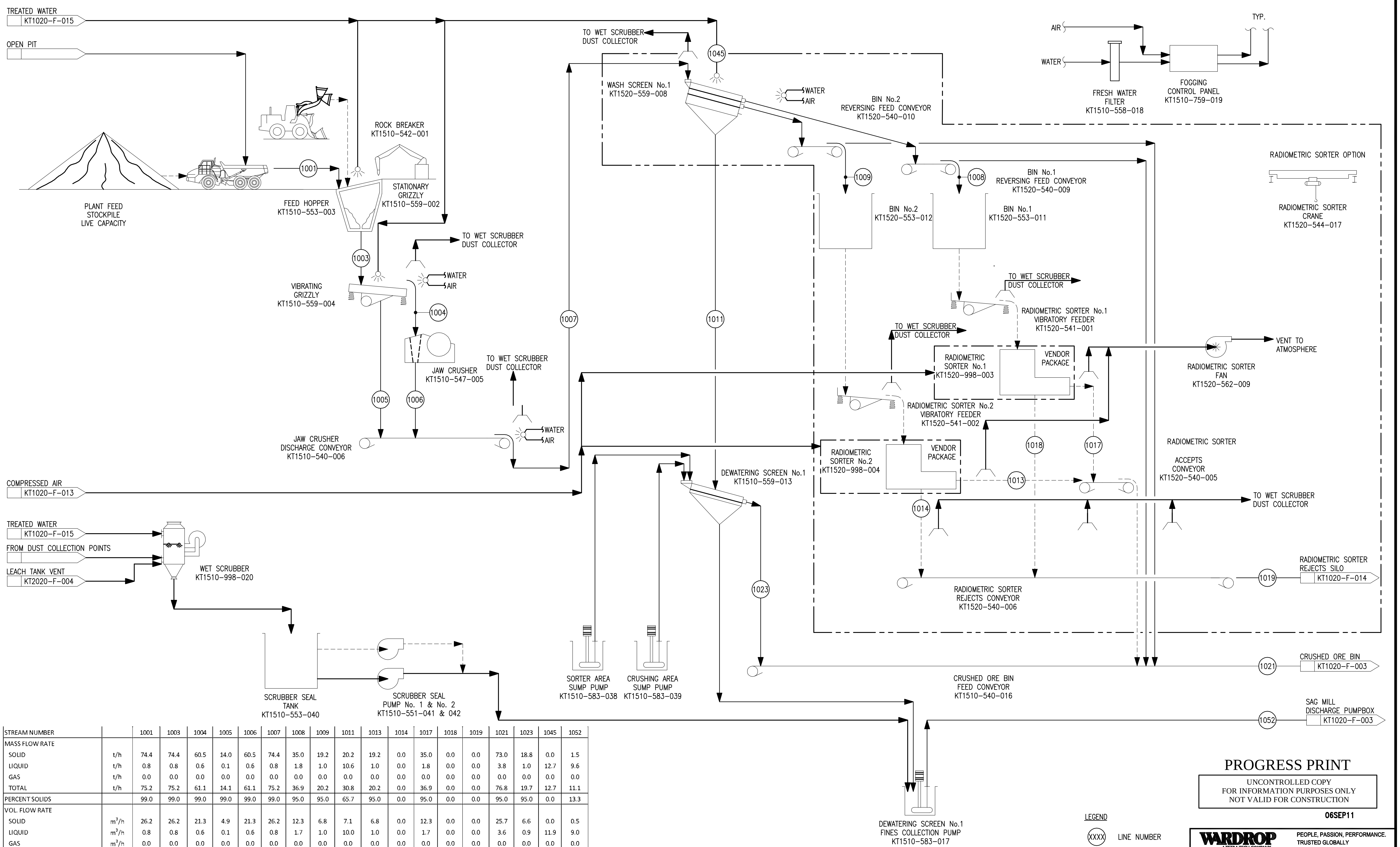
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH SIMPLIFIED OVERALL FLOWSHEET PROCESS FLOW DIAGRAM SHEET 1 OF 15

DWG. No. KT1020-F-001 REV E



STREAM NUMBER		1001	1003	1004	1005	1006	1007	1008	1009	1011	1013	1014	1017	1018	1019	1021	1023	1045	1052
MASS FLOW RATE																			
SOLID	t/h	74.4	74.4	60.5	14.0	60.5	74.4	35.0	19.2	20.2	19.2	0.0	35.0	0.0	0.0	73.0	18.8	0.0	1.5
LIQUID	t/h	0.8	0.8	0.6	0.1	0.6	0.8	1.8	1.0	10.6	1.0	0.0	1.8	0.0	0.0	3.8	1.0	12.7	9.6
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	75.2	75.2	61.1	14.1	61.1	75.2	36.9	20.2	30.8	20.2	0.0	36.9	0.0	0.0	76.8	19.7	12.7	11.1
PERCENT SOLIDS		99.0	99.0	99.0	99.0	99.0	99.0	95.0	95.0	65.7	95.0	0.0	95.0	0.0	0.0	95.0	95.0	0.0	13.3
VOL. FLOW RATE																			
SOLID	m^3/h	26.2	26.2	21.3	4.9	21.3	26.2	12.3	6.8	7.1	6.8	0.0	12.3	0.0	0.0	25.7	6.6	0.0	0.5
LIQUID	m^3/h	0.8	0.8	0.6	0.1	0.6	0.8	1.7	1.0	10.0	1.0	0.0	1.7	0.0	0.0	3.6	0.9	11.9	9.0
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	27.0	27.0	21.9	5.1	21.9	27.0	14.1	7.7	17.1	7.7	0.0	14.1	0.0	0.0	29.3	7.5	11.9	9.5
URANIUM CONTENT																			
SOLID FLOW U_3O_8	kg/h	363.12	363.12	294.92	68.20	294.92	363.12	170.85	93.60	98.67	93.60	0.00	170.85	0.00	0.00	355.95	91.51	0.00	7.17
LIQUID CONCENTRATION U_3O_8	g/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01

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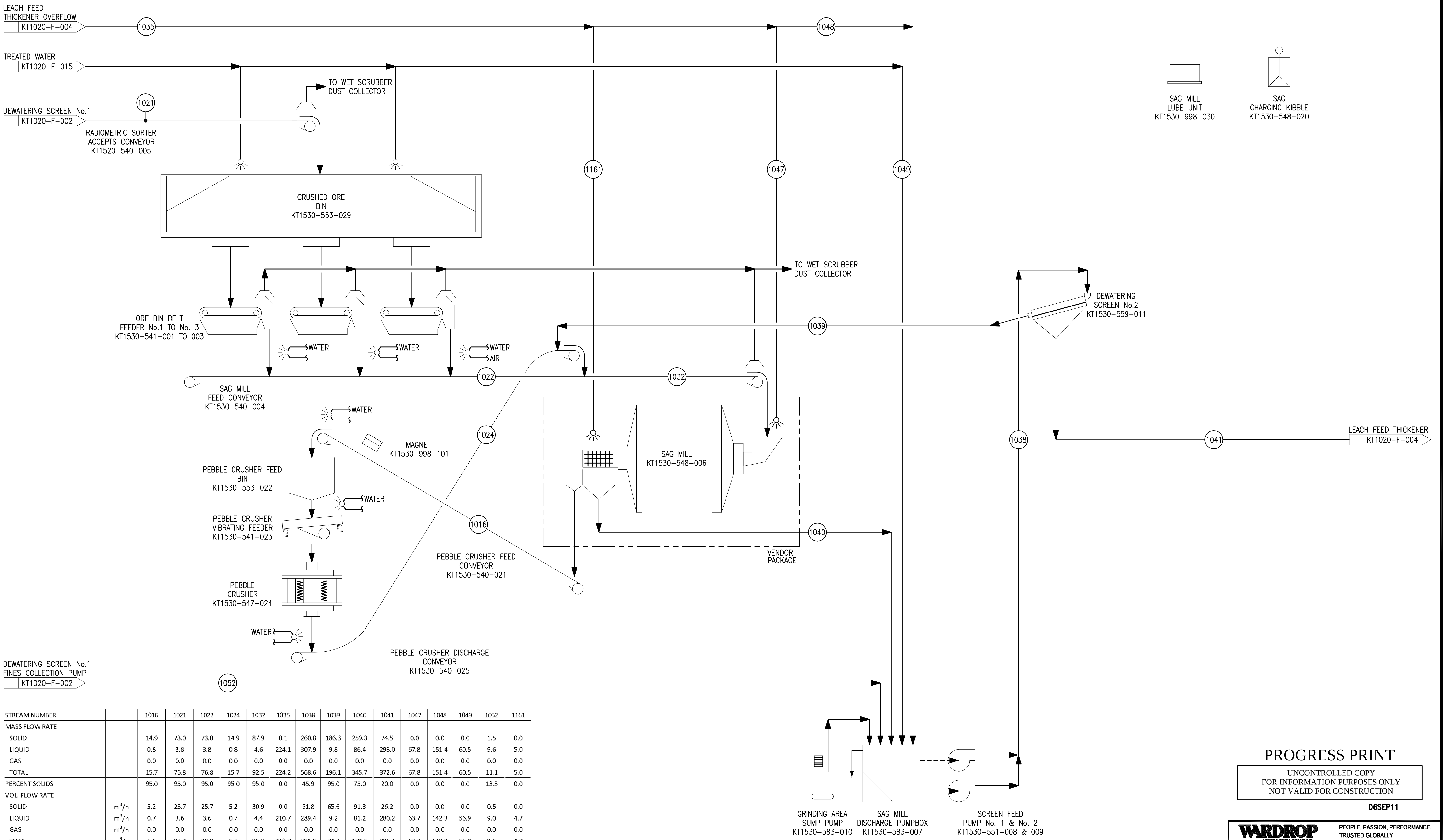
AREA PROCESS

TITLE ACID LEACH
PRIMARY CRUSHING & RADIOMETRIC SORTING
PROCESS FLOW DIAGRAM
SHEET 2 OF 15

DWG. No. KT1020-F-002 REV E



STREAM NUMBER		1016	1021	1022	1024	1032	1035	1038	1039	1040	1041	1047	1048	1049	1052	1161
MASS FLOW RATE																
SOLID		14.9	73.0	73.0	14.9	87.9	0.1	260.8	186.3	259.3	74.5	0.0	0.0	0.0	1.5	0.0
LIQUID		0.8	3.8	3.8	0.8	4.6	224.1	307.9	9.8	86.4	298.0	67.8	151.4	60.5	9.6	5.0
GAS		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		15.7	76.8	76.8	15.7	92.5	224.2	568.6	196.1	345.7	372.6	67.8	151.4	60.5	11.1	5.0
PERCENT SOLIDS		95.0	95.0	95.0	95.0	95.0	0.0	45.9	95.0	75.0	20.0	0.0	0.0	0.0	13.3	0.0
VOL. FLOW RATE																
SOLID	m^3/h	5.2	25.7	25.7	5.2	30.9	0.0	91.8	65.6	91.3	26.2	0.0	0.0	0.0	0.5	0.0
LIQUID	m^3/h	0.7	3.6	3.6	0.7	4.4	210.7	289.4	9.2	81.2	280.2	63.7	142.3	56.9	9.0	4.7
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	6.0	29.3	29.3	6.0	35.3	210.7	381.2	74.8	172.5	306.4	63.7	142.3	56.9	9.5	4.7
URANIUM CONTENT																
SOLID FLOW U_3O_8	kg/h	72.62	355.95	355.95	72.62	428.58	0.33	1272.07	908.62	1264.69	363.45	0.10	0.22	0.00	7.17	0.01
LIQUID CONCENTRATION U_3O_8	g/L	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.02

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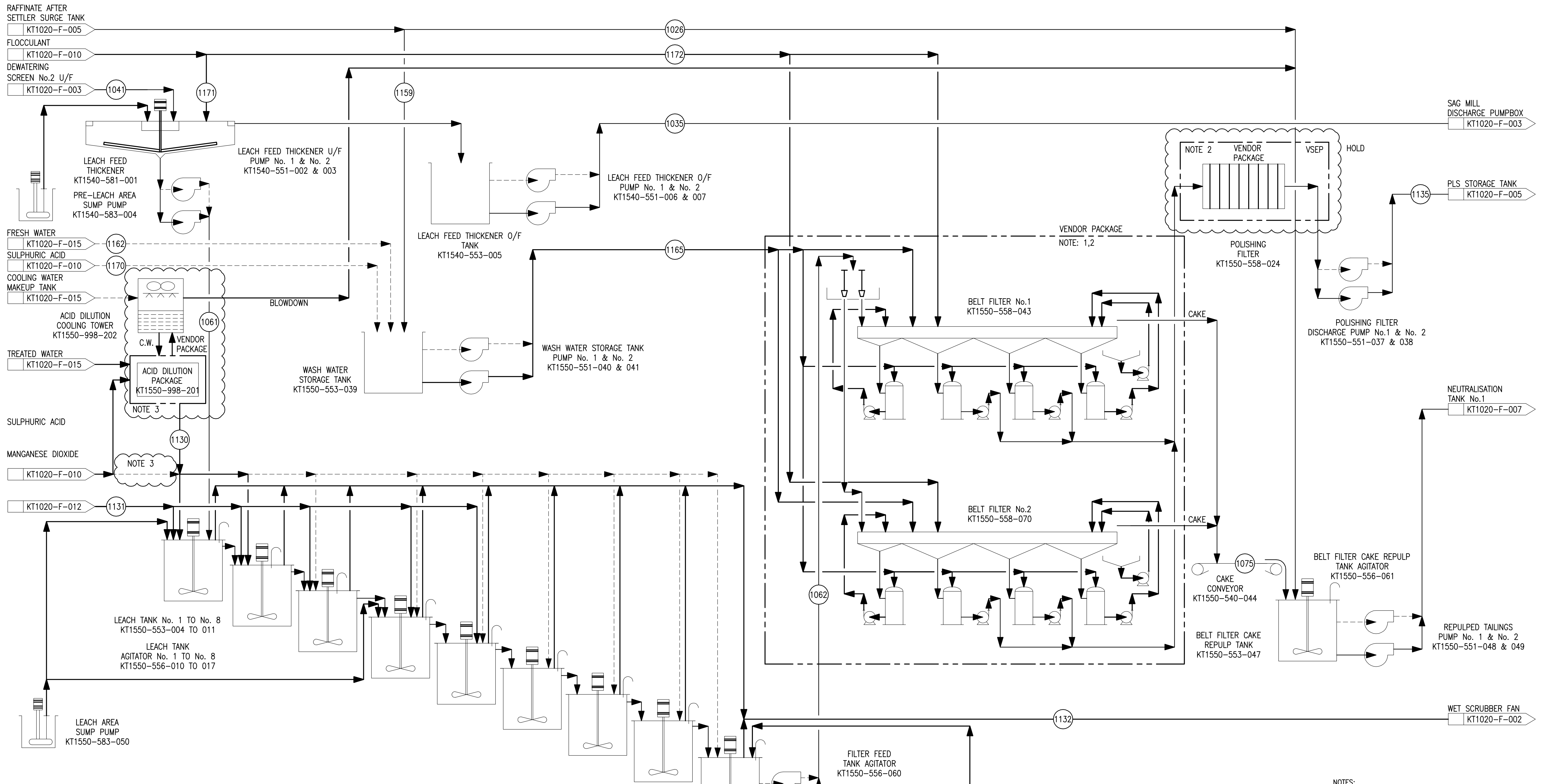
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
GRINDING AND CLASSIFICATION
PROCESS FLOW DIAGRAM
SHEET 3 OF 15

DWG. No. KT1020-F-003 REV E



STREAM NUMBER		1026	1035	1041	1061	1062	1075	1130	1131	1132	1135	1159	1162	1165	1170	1171	1172
MASS FLOW RATE																	
SOLID	t/h	0.0	0.1	74.5	74.4	74.0	74.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	t/h	23.5	224.1	298.0	74.4	100.3	31.7	25.9	1.9	0.0	152.5	83.4	0.0	83.4	0.0	0.5	0.5
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	23.5	224.2	372.6	148.9	174.3	105.7	25.9	3.7	4.2	152.5	83.4	0.0	83.4	0.0	0.5	0.5
PERCENT SOLIDS		0.0	0.0	20.0	50.0	42.4	70.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOL. FLOW RATE																	
SOLID	m^3/h	0.0	0.0	26.2	26.2	26.4	26.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	m^3/h	20.9	210.7	280.2	70.0	88.4	28.2	17.7	1.9	0.0	134.8	74.0	0.0	74.0	0.0	0.5	0.5
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2699.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	20.9	210.7	306.4	96.2	114.8	54.5	17.7	2.3	2699.9	134.8	74.0	0.0	74.0	0.0	0.5	0.5
URANIUM CONTENT																	
SOLID FLOW U_3O_8	kg/h	0.00	0.33	363.45	363.12	7.26	7.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.03	0.02	0.01	0.01	3.11	0.02	0.01	0.00	0.00	2.66	0.03	0.00	0.03	0.00	0.00	0.00

NOTES:

1. FOUR STAGES OF COUNTER CURRENT WASHING.
2. VENDOR PACKAGE INCLUDES ALL ANCILLARIES.
3. OPTION TO BE DECIDED AT NEXT PHASE OF STUDY.

LEGEND

(XXXX) LINE NUMBER

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WARDROP A TETRA TECH COMPANY — PEOPLE. PASSION. PERFORMANCE. TRUSTED GLOBALLY

REFERENCE

DWG No.	DESCRIPTION

REVISIONS

No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.
E	09/03/12	ISSUED FOR FINAL PREFEASIBILITY STUDY			
D	08/12/11	ISSUED AS FINAL	AO		
C	07/29/11	ISSUED FOR FINAL APPROVAL	AO		
B	05/27/11	ISSUED FOR TECH OVERSIGHT			
A	05/06/11	ISSUED FOR TECH OVERSIGHT			
		DWG RE-NUMBERED (WAS 50000-09-02)			

REVISIONS

No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.

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SCALE (A1): NONE		DATE
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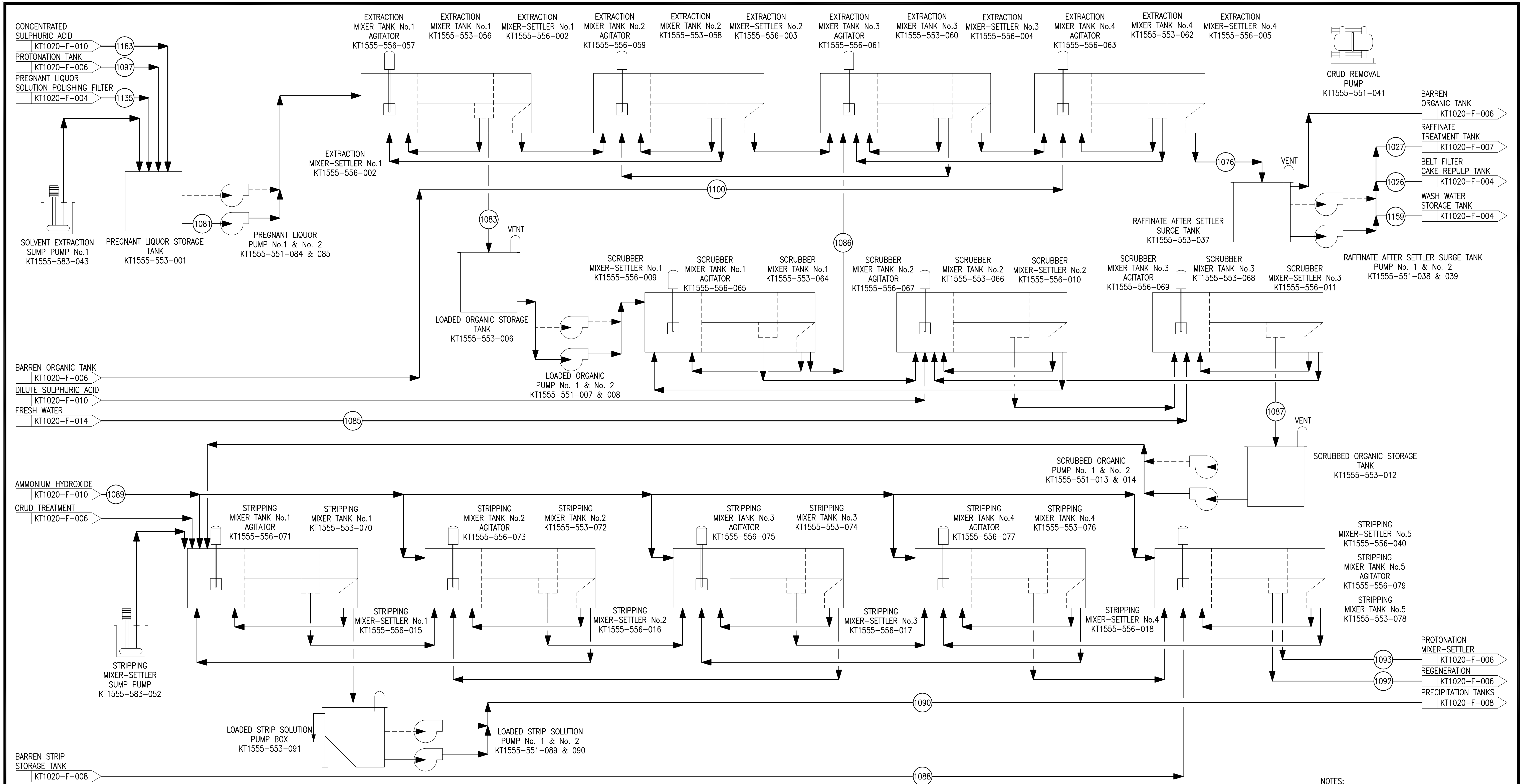
DRAWN:	DP	05/07/11
CHECKED:		
DESIGN LEAD APPROVAL:		
DESIGN AUTH. APPROVAL:		

LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
ACID LEACHING & SOLID/LIQUID SEPARATION
PROCESS FLOW DIAGRAM
SHEET 4 OF 15

DWG. No. KT1020-F-004 REV E



STREAM NUMBER		1026	1027	1076	1081	1083	1085	1086	1087	1088	1089	1090	1092	1093	1097	1100	1135	1159	1163
MASS FLOW RATE																			
SOLID	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	t/h	23.5	52.1	159.1	153.0	61.2	6.8	7.0	61.0	14.5	0.9	16.1	9.7	50.6	0.0	60.3	152.5	83.4	0.5
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	23.5	52.1	159.1	153.0	61.2	6.8	7.0	61.0	14.5	0.9	16.1	9.7	50.6	0.0	60.3	152.5	83.4	0.5
PERCENT SOLIDS		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOL. FLOW RATE																			
SOLID	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	m^3/h	20.9	46.2	141.1	135.0	72.0	6.8	7.0	71.8	13.5	0.9	15.0	11.4	59.6	0.0	71.0	134.8	74.0	0.2
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	20.9	46.2	141.1	135.0	72.0	6.8	7.0	71.8	13.5	0.9	15.0	11.4	59.6	0.0	71.0	134.8	74.0	0.2
URANIUM CONTENT																			
SOLID FLOW U_3O_8	kg/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.03	0.03	0.03	2.66	4.98	0.00	0.03	4.99	0.00	0.00	23.67	0.06	0.06	23.72	0.05	2.66	0.03	0.00

VENDOR PACKAGE

FIRE PROTECTION SYSTEM
KT1870-998-010

SOLVENT EXTRACTION AREA SAFETY SHOWER No.1
KT1555-902-054

LEGEND

(XXXX) LINE NUMBER

NOTES:

1.)PLS COOLER IS PROVISIONAL. COOLING WATER SOURCE AND REQUIREMENTS TO BE ADVISED.

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WARDROP A TETRA TECH COMPANY — PEOPLE. PASSION. PERFORMANCE. TRUSTED GLOBALLY

REFERENCE	
DWG No.	DESCRIPTION

REVISIONS No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.
E	09/03/12	ISSUED FOR FINAL PREFEASIBILITY STUDY			
D	08/12/11	ISSUED AS FINAL	AO		
C	07/29/11	ISSUED FOR FINAL APPROVAL	AO		
B	05/27/11	ISSUED FOR TECH OVERSIGHT			
A	05/06/11	ISSUED FOR TECH OVERSIGHT			
		DWG RE-NUMBERED (WAS 50000-09-02)			

REVISIONS No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.

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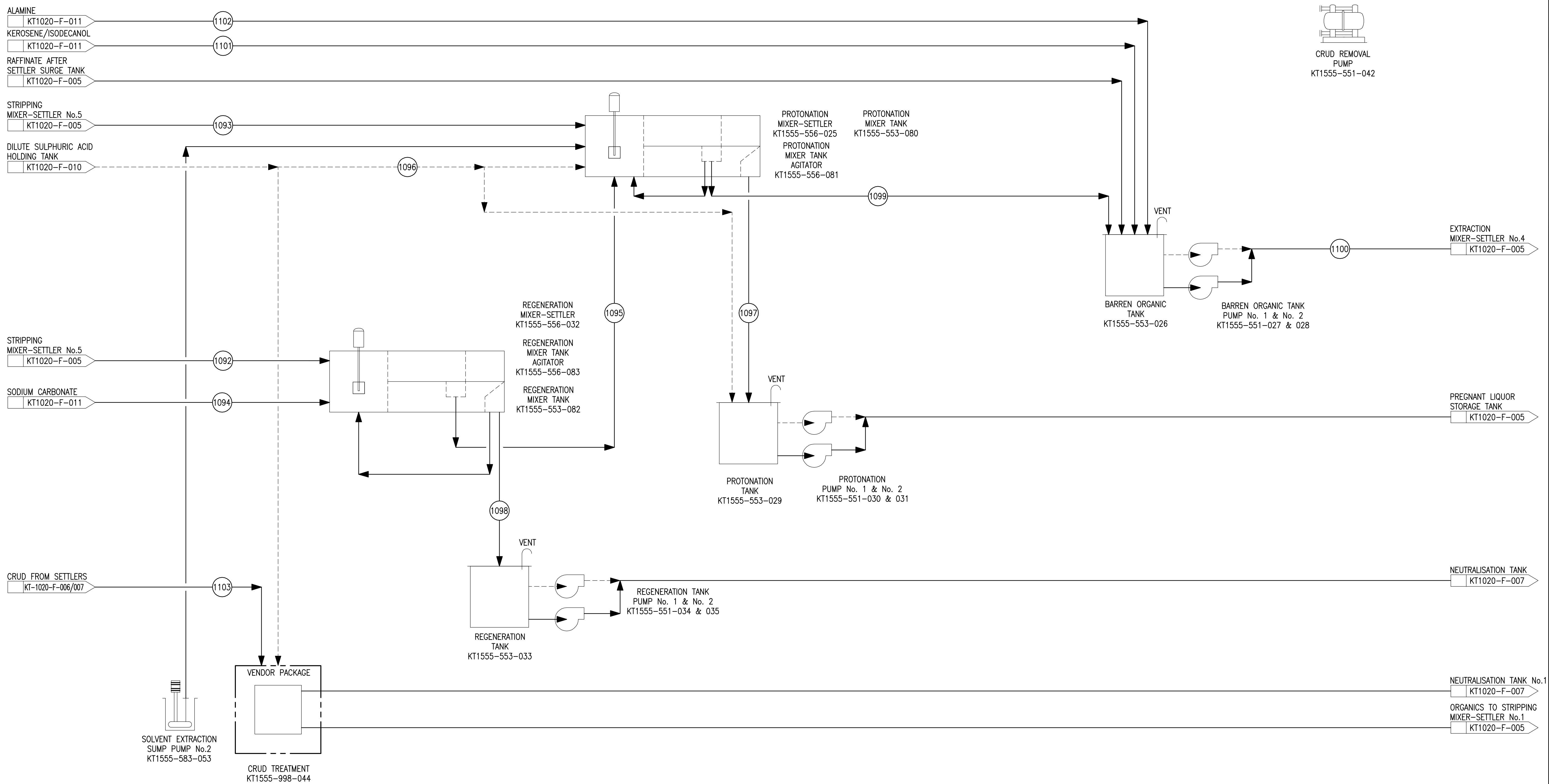
LOC. KINTYRE (PFS)

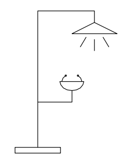
AREA PROCESS

TITLE ACID LEACH SOLVENT EXTRACTION PROCESS FLOW DIAGRAM SHEET 5 OF 15

DWG. No. KT1020-F-005 REV E



STREAM NUMBER		1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103
MASS FLOW RATE													
SOLID	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	t/h	9.7	50.6	1.3	9.7	0.0	0.0	1.3	60.3	60.3	0.1	0.0	0.1
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	9.7	50.6	1.3	9.7	0.0	0.0	1.3	60.3	60.3	0.1	0.0	0.1
PERCENT SOLIDS		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOL. FLOW RATE													
SOLID	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	m^3/h	11.4	59.6	1.1	11.4	0.0	0.0	1.1	71.0	71.0	0.1	0.0	0.1
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	11.4	59.6	1.1	11.4	0.0	0.0	1.1	71.0	71.0	0.1	0.0	0.1
URANIUM CONTENT													
SOLID FLOW U_3O_8	kg/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.06	0.06	0.00	0.05	0.00	23.72	0.05	0.05	0.05	0.00	0.00	0.05



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WARDROP A TETRA TECH COMPANY — PEOPLE, PASSION, PERFORMANCE. TRUSTED GLOBALLY

LEGEND

(XXXX) LINE NUMBER

REFERENCE

DWG No.	DESCRIPTION

REVISIONS

No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.
E	09/03/12	ISSUED FOR FINAL PREFEASIBILITY STUDY			
D	08/12/11	ISSUED AS FINAL	AO		
C	07/29/11	ISSUED FOR FINAL APPROVAL	AO		
B	05/27/11	ISSUED FOR TECH OVERSIGHT			
A	05/06/11	ISSUED FOR TECH OVERSIGHT			
		DWG RE-NUMBERED (WAS 50000-09-02)			

REVISIONS

No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.

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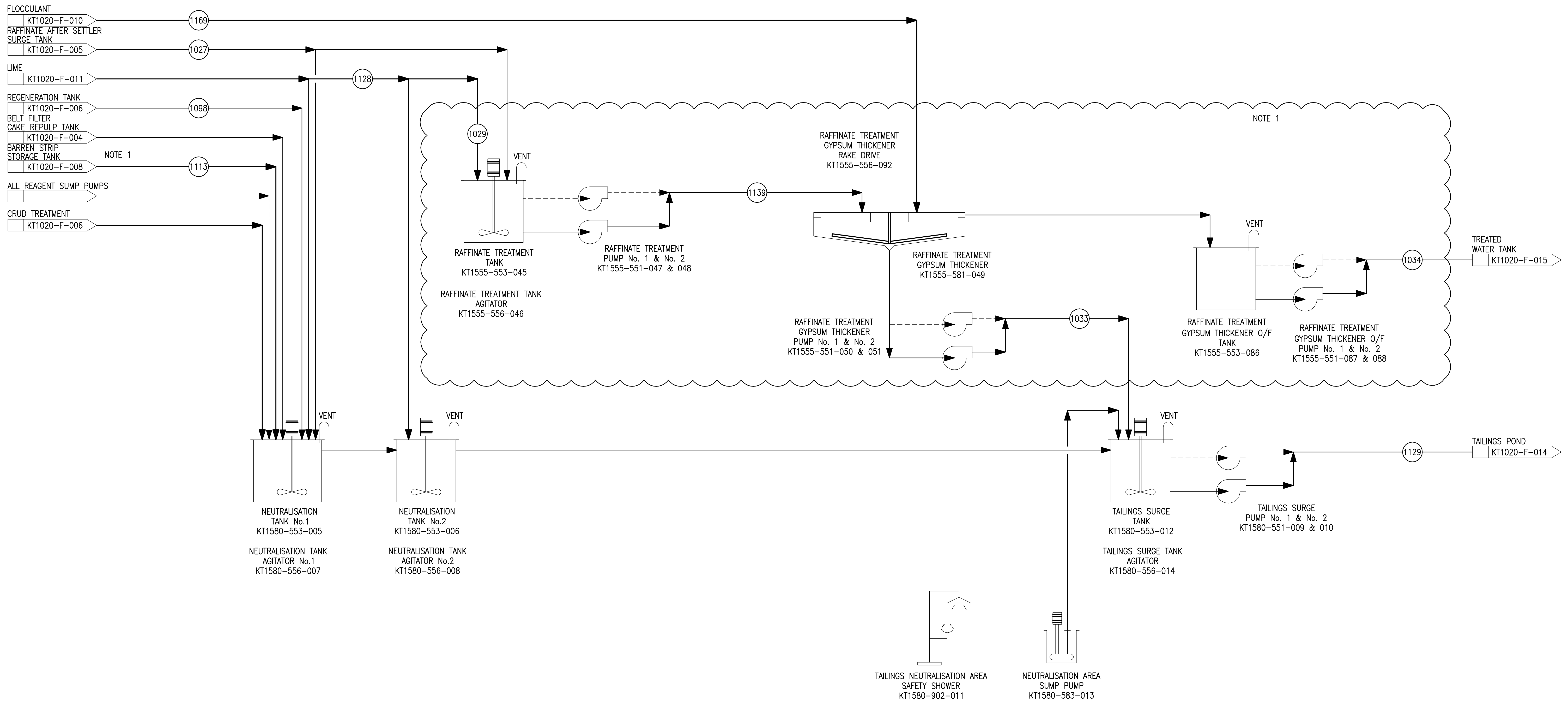
DESIGN AUTH. APPROVAL:		

LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH SOLVENT EXTRACTION PROCESS FLOW DIAGRAM SHEET 6 OF 15

DWG. No. KT1020-F-006 REV E



STREAM NUMBER		1027	1029	1033	1034	1039	1098	1113	1128	1129	1139	1169
MASS FLOW RATE												
SOLID	t/h	0.0	0.2	0.7	0.0	186.3	0.0	0.0	1.5	78.6	0.7	0.0
LIQUID	t/h	52.1	0.6	1.0	51.7	9.8	1.3	3.6	3.6	62.3	52.2	0.5
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	52.1	0.8	1.7	51.7	196.1	1.3	3.6	5.2	140.9	52.9	0.5
PERCENT SOLIDS		0.0	30.0	40.0	0.0	95.0	0.0	0.0	30.0	55.8	1.3	0.0
VOL. FLOW RATE												
SOLID	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	m^3/h	11.4	59.6	1.1	11.4	0.0	0.0	1.1	71.0	71.0	0.1	0.0
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	11.4	59.6	1.1	11.4	0.0	0.0	1.1	71.0	71.0	0.1	0.0
URANIUM CONTENT												
SOLID FLOW U_3O_8	kg/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.06	0.06	0.00	0.05	0.00	23.72	0.05	0.05	0.05	0.00	0.00

LEGEND

(XXXX) LINE NUMBER

NOTES:

1. TO BE CONFIRMED WITH ENVIRONMENTAL.

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B	05/27/11	ISSUED FOR TECH OVERSIGHT			
A	05/06/11	ISSUED FOR TECH OVERSIGHT			
		DWG RE-NUMBERED (WAS 50000-09-02)			

REVISIONS

No.	DATE	DESCRIPTION	BY	DES. LEAD APPL.	DES. AUTH. APPL.

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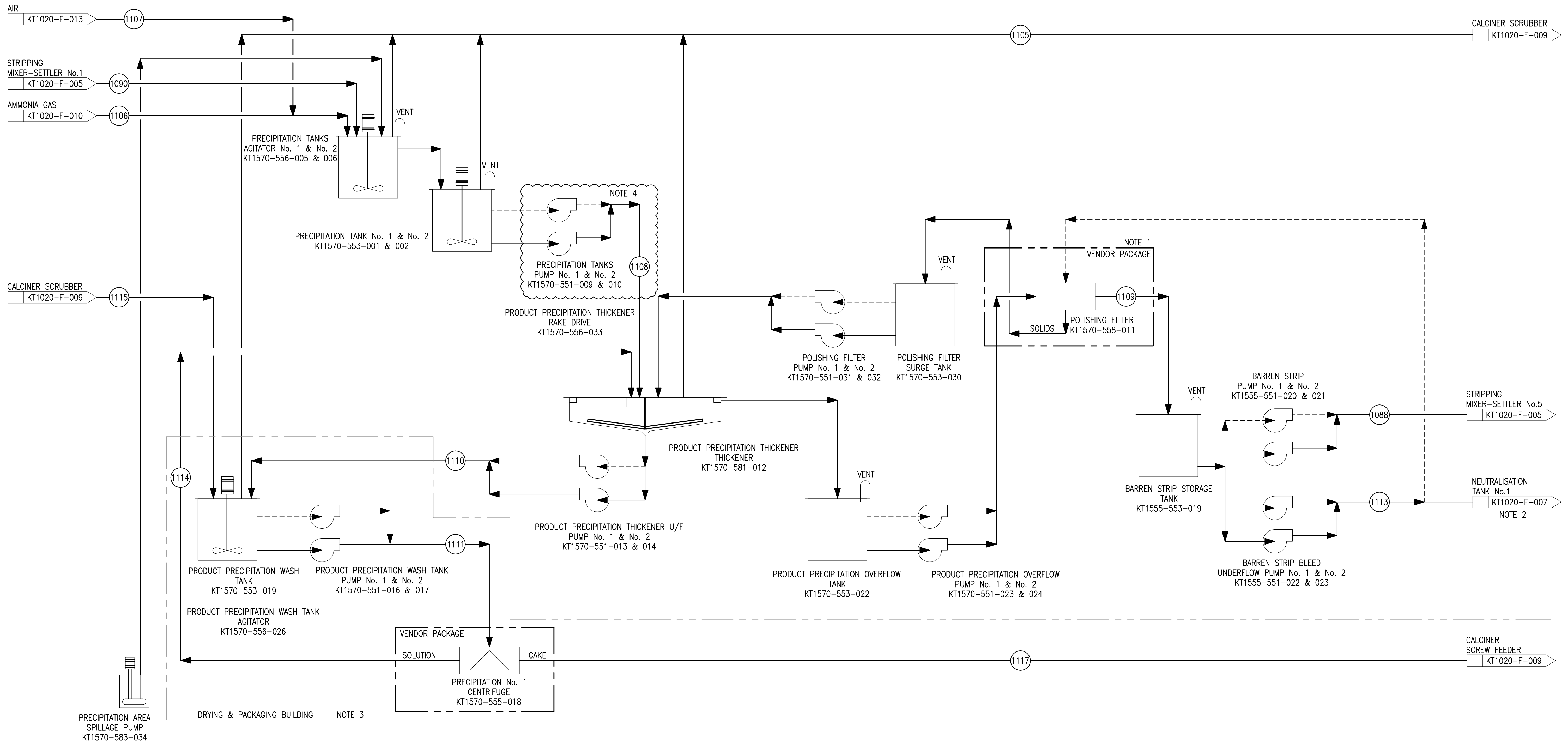
WARDROP A TETRA TECH COMPANY — PEOPLE, PASSION, PERFORMANCE. TRUSTED GLOBALLY

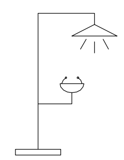
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH TAILINGS NEUTRALISATION PROCESS FLOW DIAGRAM SHEET 7 OF 15

DWG. No. KT1020-F-007 REV E





PRECIPITATION AREA
SAFETY SHOWER
KT1570-902-029

STREAM NUMBER		1088	1090	1105	1106	1107	1108	1109	1110	1111	1113	1114	1115	1117
MASS FLOW RATE														
SOLID	t/h	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.4	0.0	0.0	0.0	0.4
LIQUID	t/h	14.5	16.1	0.0	0.0	0.0	15.8	18.1	0.4	2.8	3.6	2.7	2.4	0.1
GAS	t/h	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	14.5	16.1	0.1	0.1	0.1	16.2	18.1	0.8	3.2	3.6	2.7	2.4	0.5
PERCENT SOLIDS		0.0	0.0	0.0	0.0	0.0	2.4	0.0	50.0	12.5	0.0	0.4	0.0	75.0
VOL. FLOW RATE														
SOLID	m^3/h	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1
LIQUID	m^3/h	13.5	15.0	0.0	0.0	0.0	14.5	16.8	0.4	2.8	3.3	2.7	2.5	0.1
GAS	m^3/h	0.0	0.0	59.9	99.8	49.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	13.5	15.0	59.9	99.8	49.9	14.5	16.8	0.4	2.9	3.3	2.7	2.5	0.2
URANIUM CONTENT														
SOLID FLOW U_3O_8	kg/h	0.13	0.13	0.00	0.00	0.00	354.27	0.16	365.06	365.06	0.03	10.95	0.00	354.11
LIQUID CONCENTRATION U_3O_8	g/L	0.00	23.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

LEGEND

(XXXX) LINE NUMBER

NOTES:

1. VENDOR PACKAGE INCLUDES ALL ANCILLARIES.
2. TO BE CONFIRMED WITH ENVIRONMENTAL.
3. TO BE LOCATED IN THE MAIN BUILDING ON DRAWING KT1020-F-009
4. CAN BE GRAVITY OVERFLOW

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A	05/06/11	ISSUED FOR TECH OVERSIGHT			
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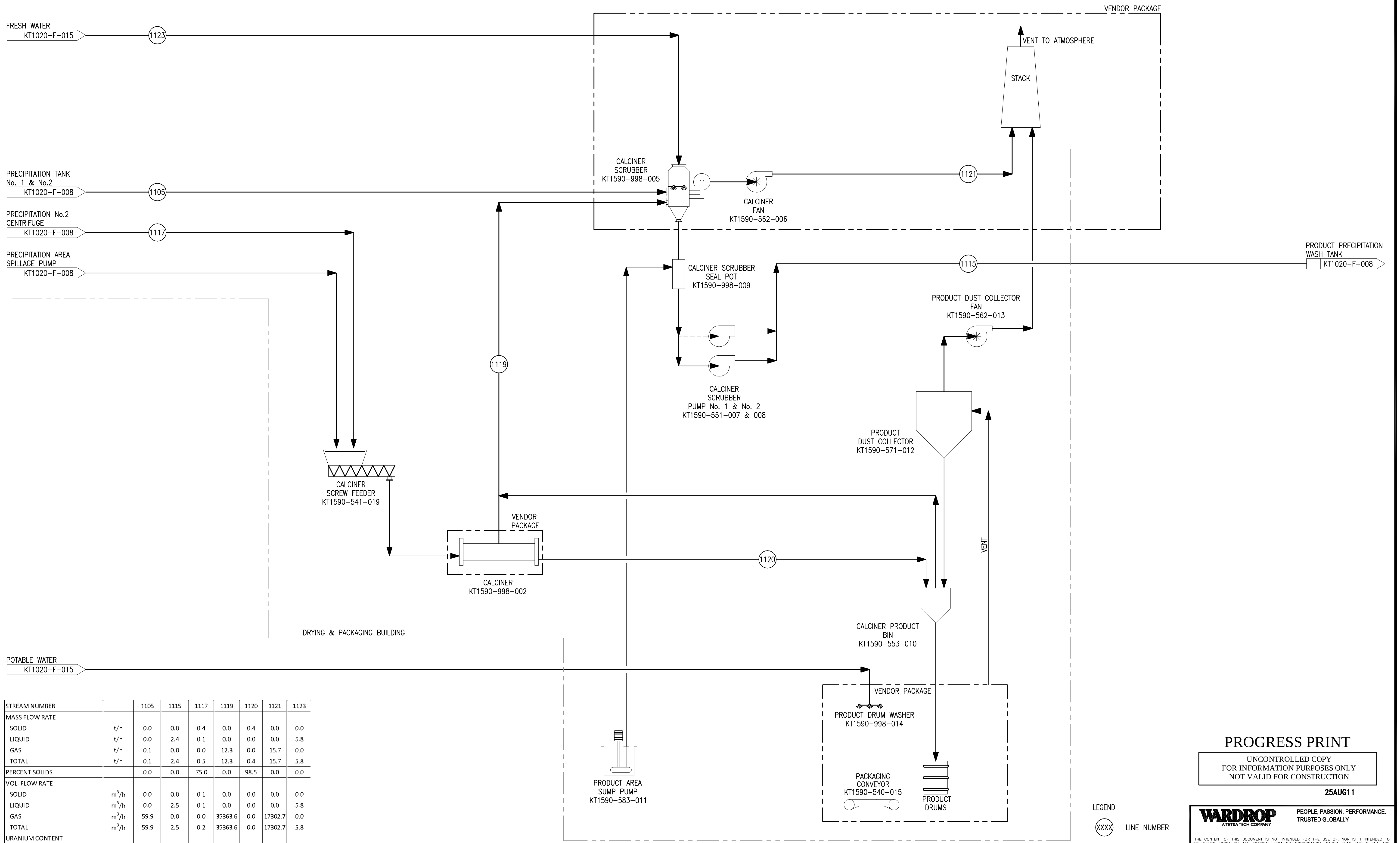
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
YELLOWCAKE PRECIPITATION
PROCESS FLOW DIAGRAM
SHEET 8 OF 15

DWG. No. KT1020-F-008 REV E



STREAM NUMBER		1105	1115	1117	1119	1120	1121	1123
MASS FLOW RATE								
SOLID	t/h	0.0	0.0	0.4	0.0	0.4	0.0	0.0
LIQUID	t/h	0.0	2.4	0.1	0.0	0.0	0.0	5.8
GAS	t/h	0.1	0.0	0.0	12.3	0.0	15.7	0.0
TOTAL	t/h	0.1	2.4	0.5	12.3	0.4	15.7	5.8
PERCENT SOLIDS		0.0	0.0	75.0	0.0	98.5	0.0	0.0
VOL. FLOW RATE								
SOLID	m^3/h	0.0	0.0	0.1	0.0	0.0	0.0	0.0
LIQUID	m^3/h	0.0	2.5	0.1	0.0	0.0	0.0	5.8
GAS	m^3/h	59.9	0.0	0.0	35363.6	0.0	17302.7	0.0
TOTAL	m^3/h	59.9	2.5	0.2	35363.6	0.0	17302.7	5.8
URANIUM CONTENT								
SOLID FLOW U_3O_8	kg/h	0.00	0.00	354.11	0.00	354.11	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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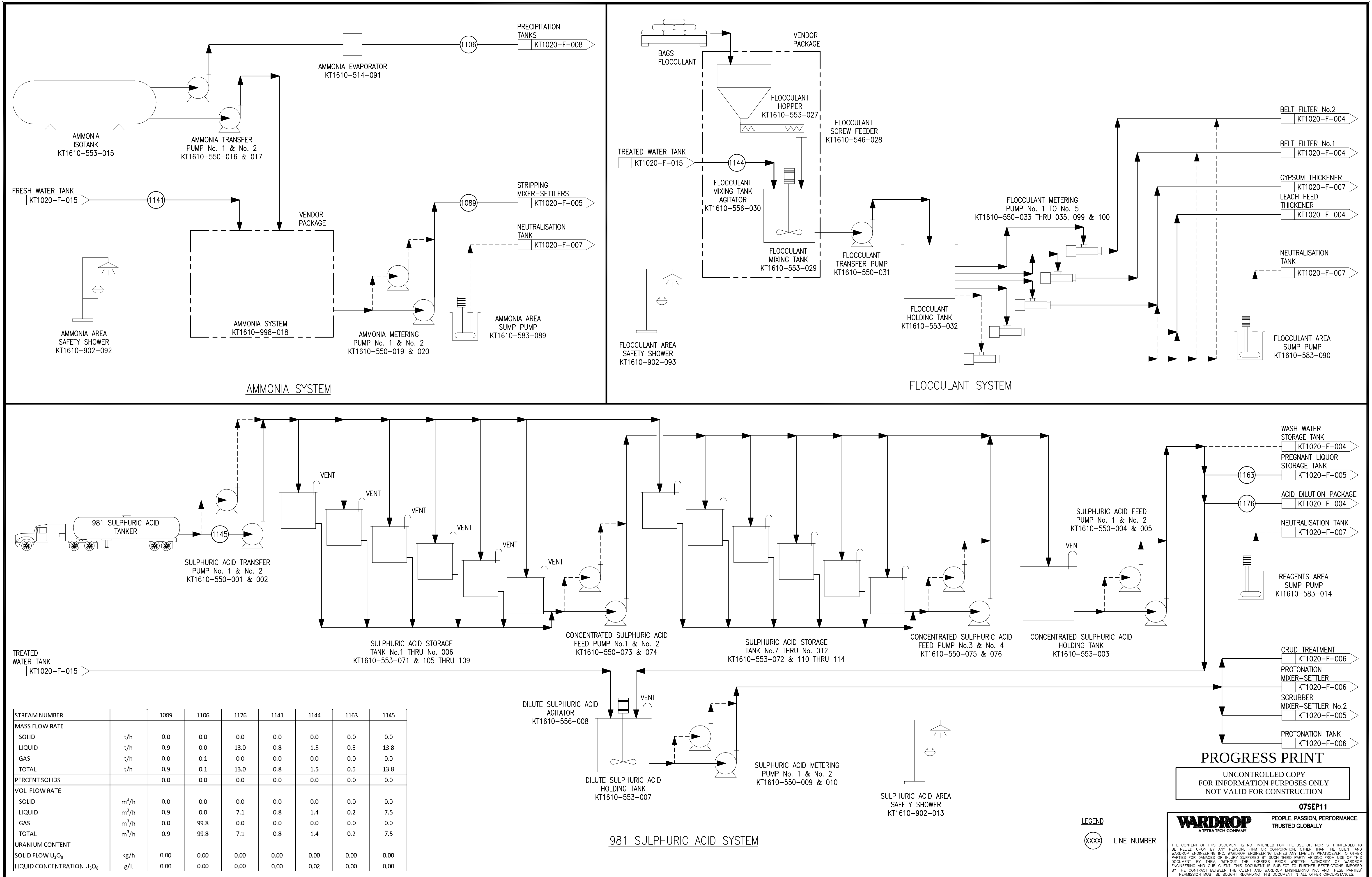
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
CALCINING SCRUBBING & PACKAGING
PROCESS FLOW DIAGRAM
SHEET 9 OF 15

DWG. No. KT1020-F-009 REV E



STREAM NUMBER		1089	1106	1176	1141	1144	1163	1145
MASS FLOW RATE								
SOLID	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	t/h	0.9	0.0	13.0	0.8	1.5	0.5	13.8
GAS	t/h	0.0	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	0.9	0.1	13.0	0.8	1.5	0.5	13.8
PERCENT SOLIDS		0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOL. FLOW RATE								
SOLID	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	m^3/h	0.9	0.0	7.1	0.8	1.4	0.2	7.5
GAS	m^3/h	0.0	99.8	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	0.9	99.8	7.1	0.8	1.4	0.2	7.5
URANIUM CONTENT								
SOLID FLOW U_3O_8	kg/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.00	0.00	0.00	0.00	0.02	0.00	0.00

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D	08/12/11	ISSUED AS FINAL	AO		
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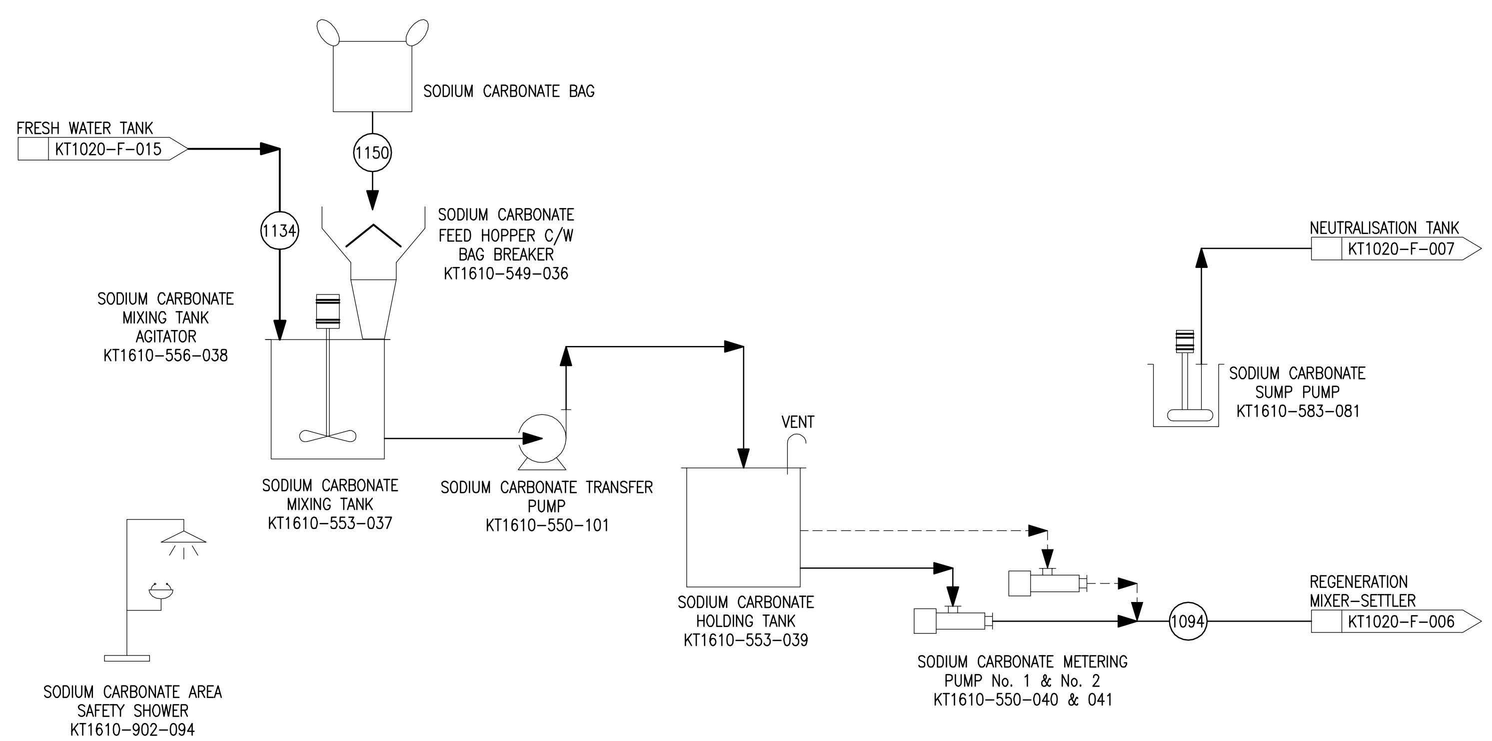
LOC. KINTYRE (PFS)

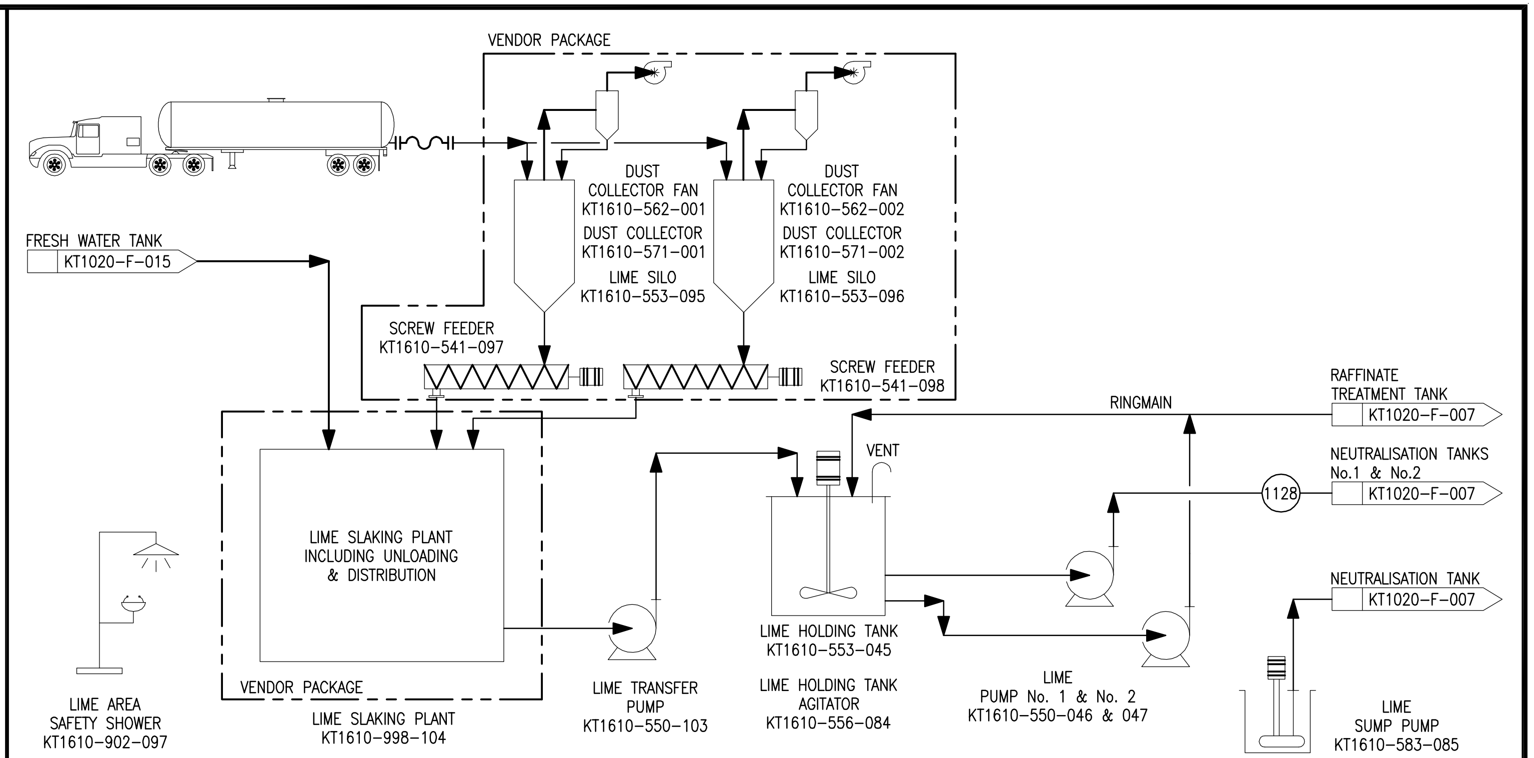
AREA PROCESS

TITLE ACID LEACH
REAGENT #1
PROCESS FLOW DIAGRAM
SHEET 10 OF 15

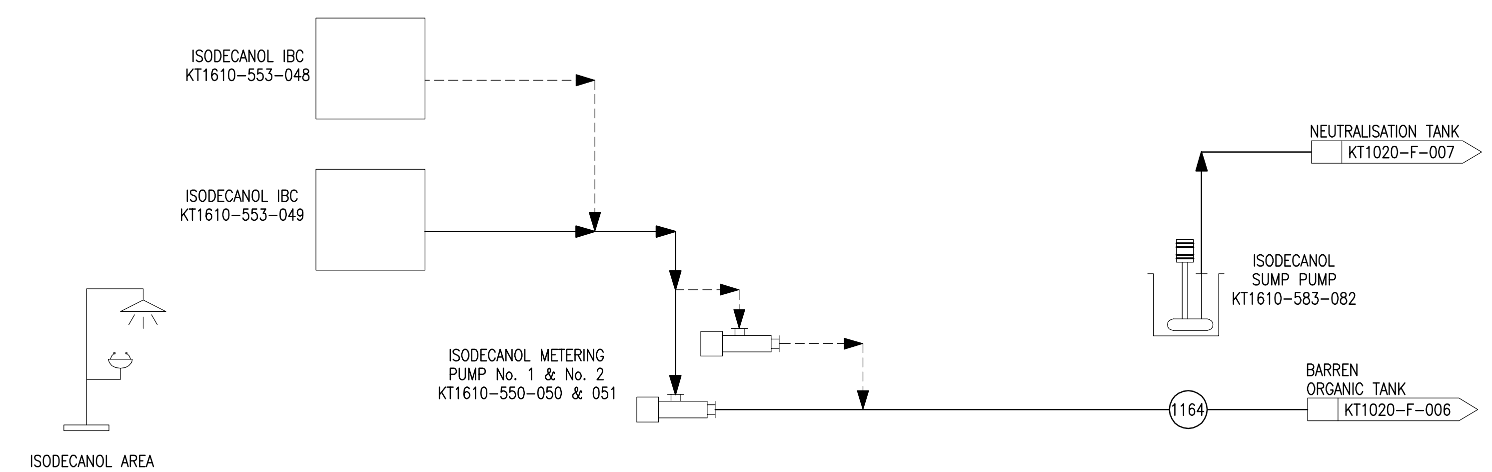
DWG. No. KT1020-F-010 REV E



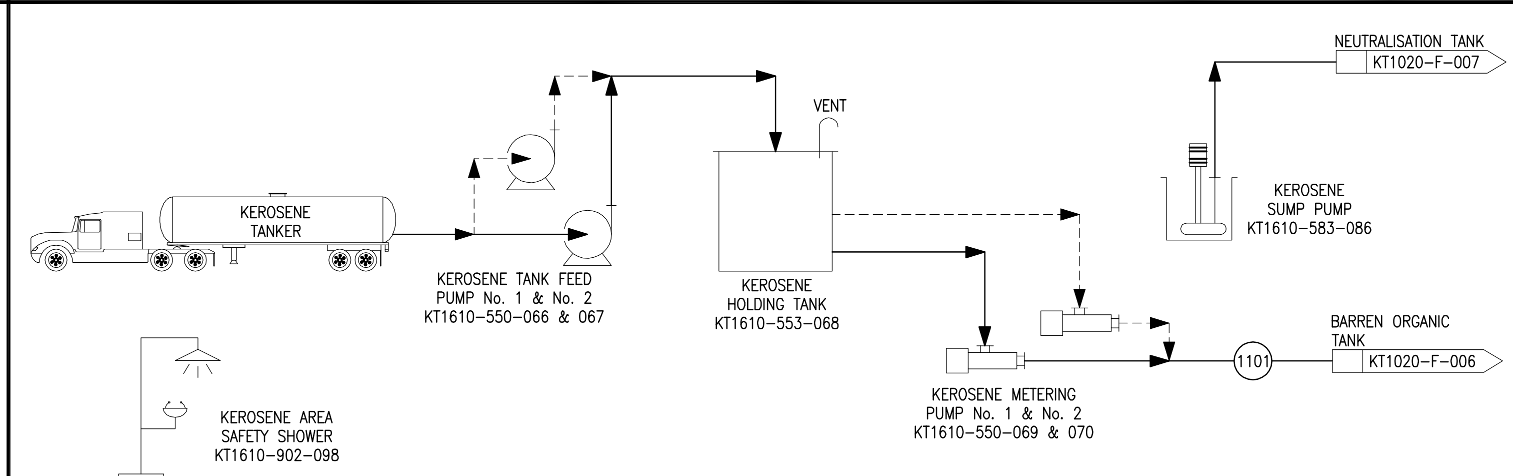
SODIUM CARBONATE SYSTEM



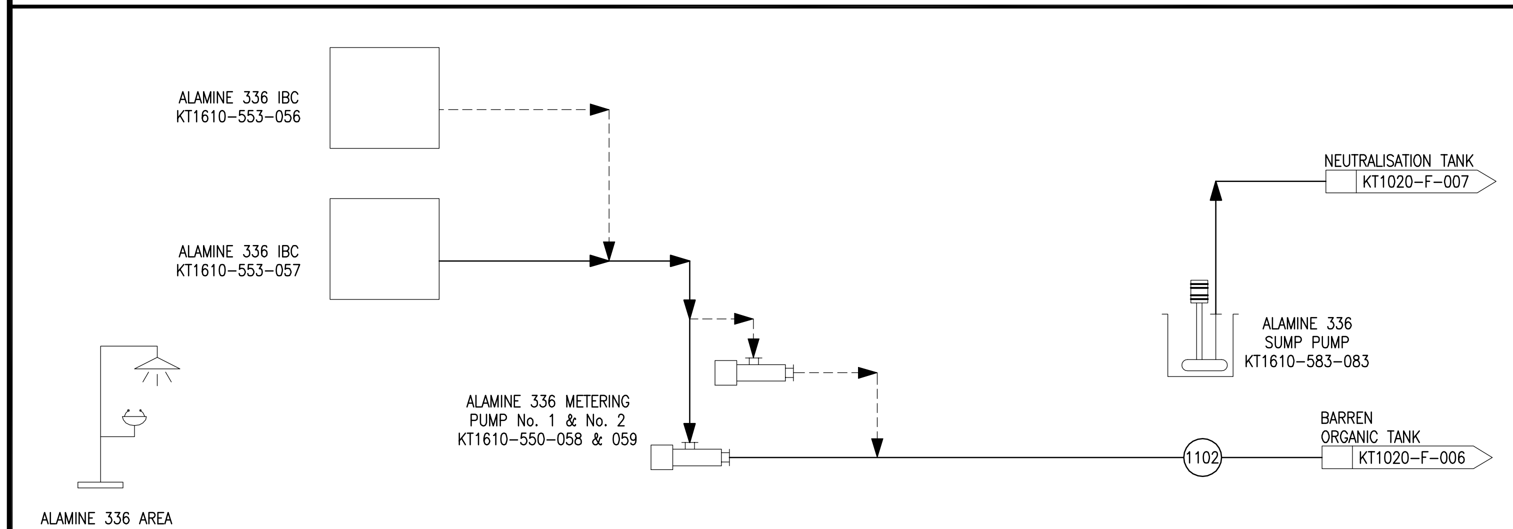
30% LIME SYSTEM



100% ISODECANOL SYSTEM



KEROSENE SYSTEM



100% ALAMINE 336 SYSTEM

STREAM NUMBER		1029	1094	1101	1102	1128	1150	1134	1164
MASS FLOW RATE									
SOLID	t/h	0.2	0.0	0.0	0.0	1.5	0.1	0.0	0.0
LIQUID	t/h	0.6	1.3	0.1	0.0	3.6	0.0	1.1	0.0
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	0.8	1.3	0.1	0.0	5.2	0.1	1.1	0.0
PERCENT SOLIDS		30.0	0.0	0.0	0.0	30.0	100.0	0.0	0.0
VOL. FLOW RATE									
SOLID	m^3/h	0.1	0.0	0.0	0.0	0.7	0.0	0.0	0.0
LIQUID	m^3/h	0.6	1.1	0.1	0.0	3.6	0.0	1.1	0.0
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	0.7	1.1	0.1	0.0	4.3	0.0	1.1	0.0
URANIUM CONTENT									
SOLID FLOW U_3O_8	kg/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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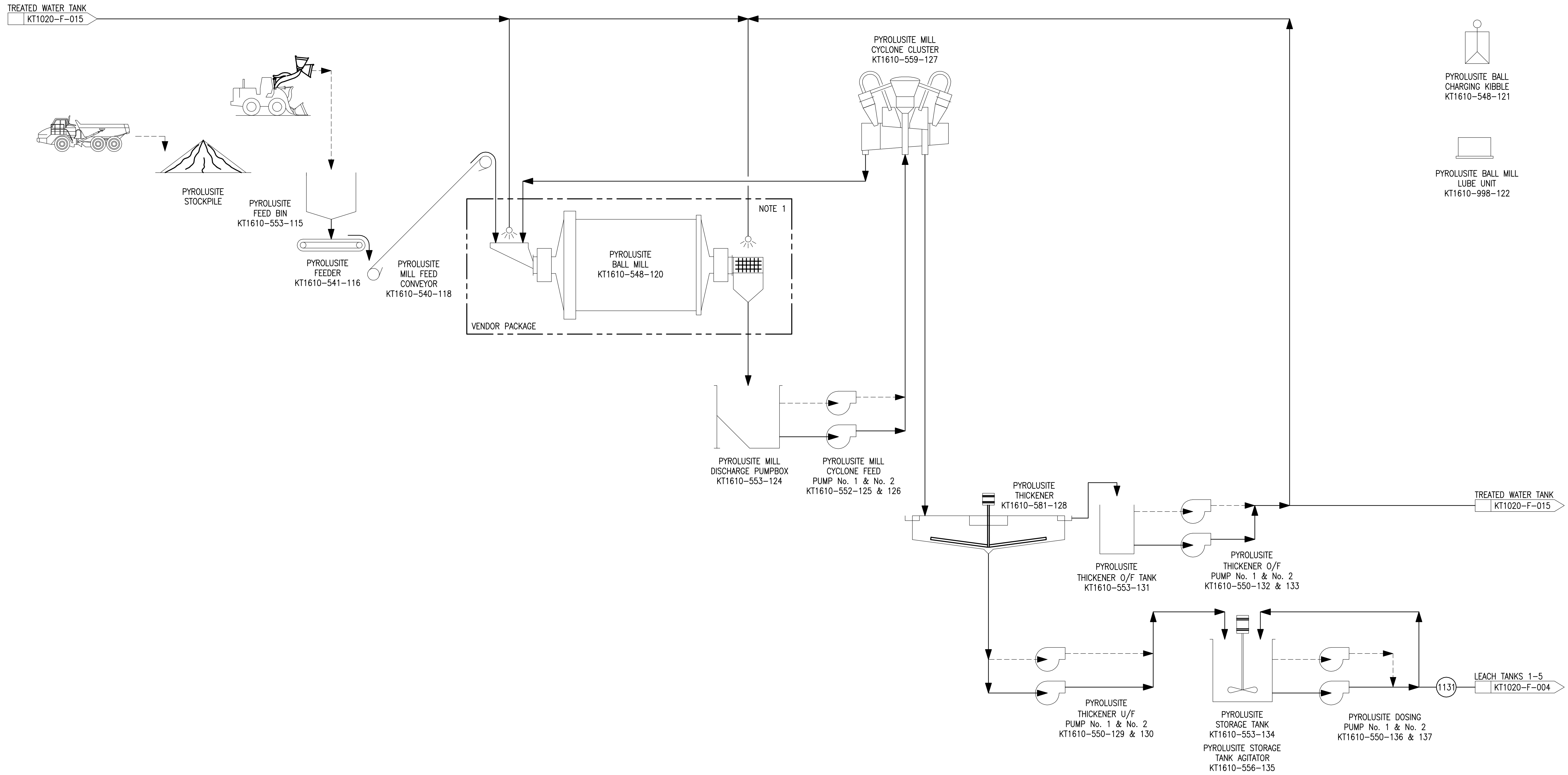
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
REAGENT #2
PROCESS FLOW DIAGRAM
SHEET 11 OF 15

DWG. No. KT1020-F-011 REV E



STREAM NUMBER		1131
MASS FLOW RATE		
SOLID	t/h	1.9
LIQUID	t/h	1.9
GAS	t/h	0.0
TOTAL	t/h	3.7
PERCENT SOLIDS		50.0
VOL. FLOW RATE		
SOLID	m^3/h	0.4
LIQUID	m^3/h	0.9
GAS	m^3/h	0.0
TOTAL	m^3/h	1.4
URANIUM CONTENT		
SOLID FLOW U_3O_8	kg/h	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.00

PYROLUSITE SYSTEM

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NOTES:

1. INCLUDES BALL CHARGER

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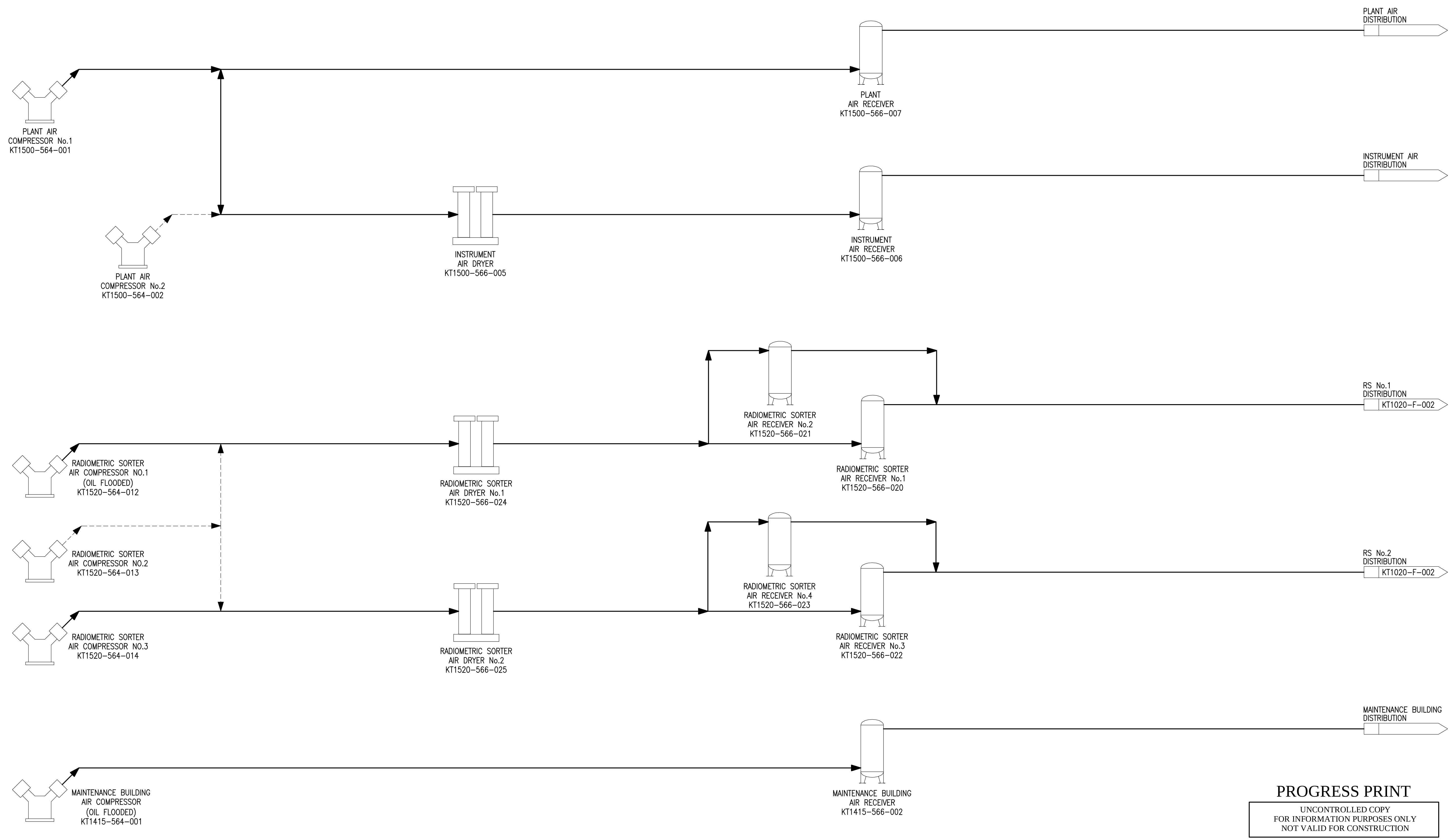
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH REAGENT #3 PROCESS FLOW DIAGRAM SHEET 12 OF 15

DWG. No. KT1020-F-012 REV E



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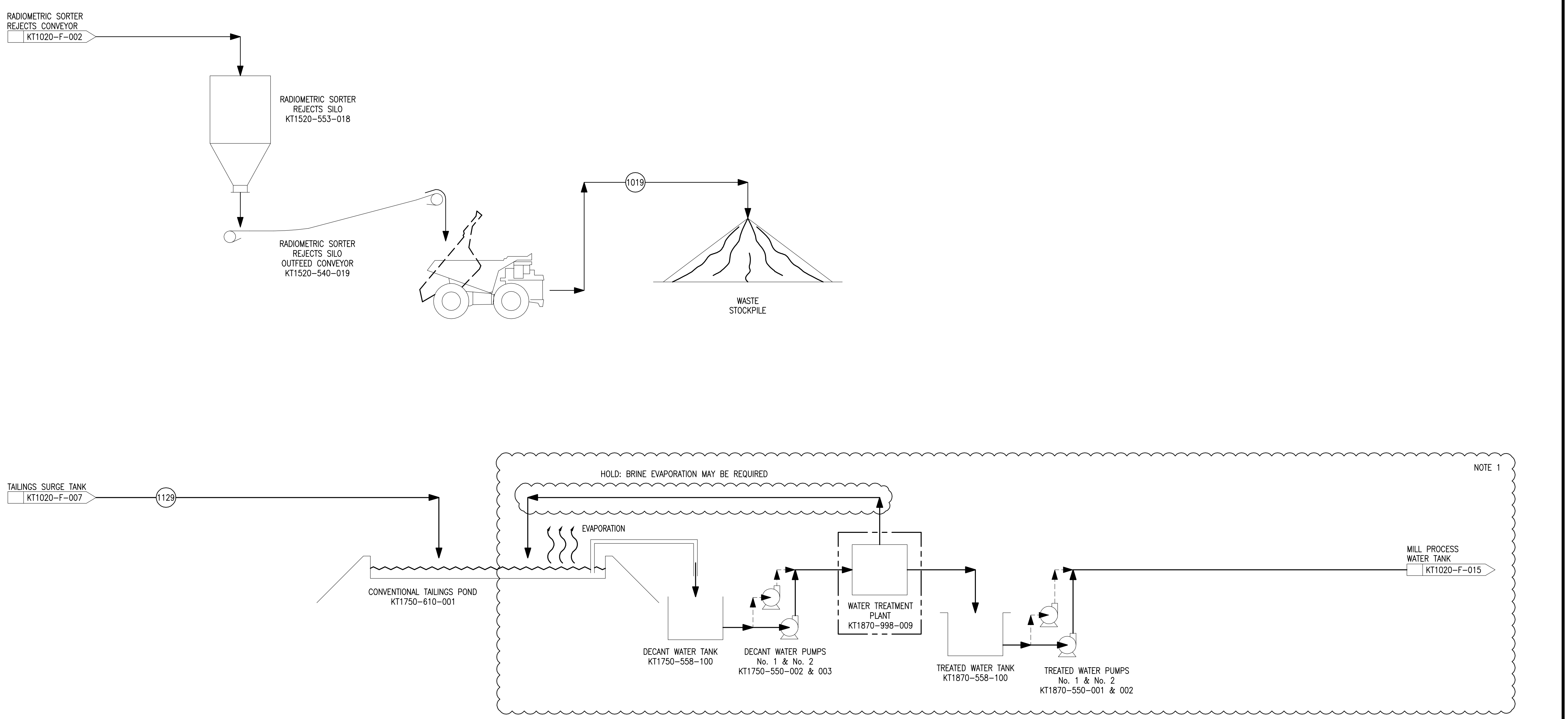
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH AIR SUPPLY AND DISTRIBUTION PROCESS FLOW DIAGRAM SHEET 13 OF 15

DWG. No. KT1020-F-013 REV E



STREAM NUMBER		1019	1129
MASS FLOW RATE			
SOLID	t/h	0.0	78.6
LIQUID	t/h	0.0	62.3
GAS	t/h	0.0	0.0
TOTAL	t/h	0.0	140.9
PERCENT SOLIDS		0.0	55.8
VOL. FLOW RATE			
SOLID	m^3/h	0.0	28.1
LIQUID	m^3/h	0.0	56.4
GAS	m^3/h	0.0	0.0
TOTAL	m^3/h	0.0	84.5
URANIUM CONTENT			
SOLID FLOW U_3O_8	kg/h	0.00	7.29
LIQUID CONCENTRATION U_3O_8	g/L	0.00	0.02

NOTE:

1. PENDING DEVELOPMENT OF TAILINGS FACILITY.

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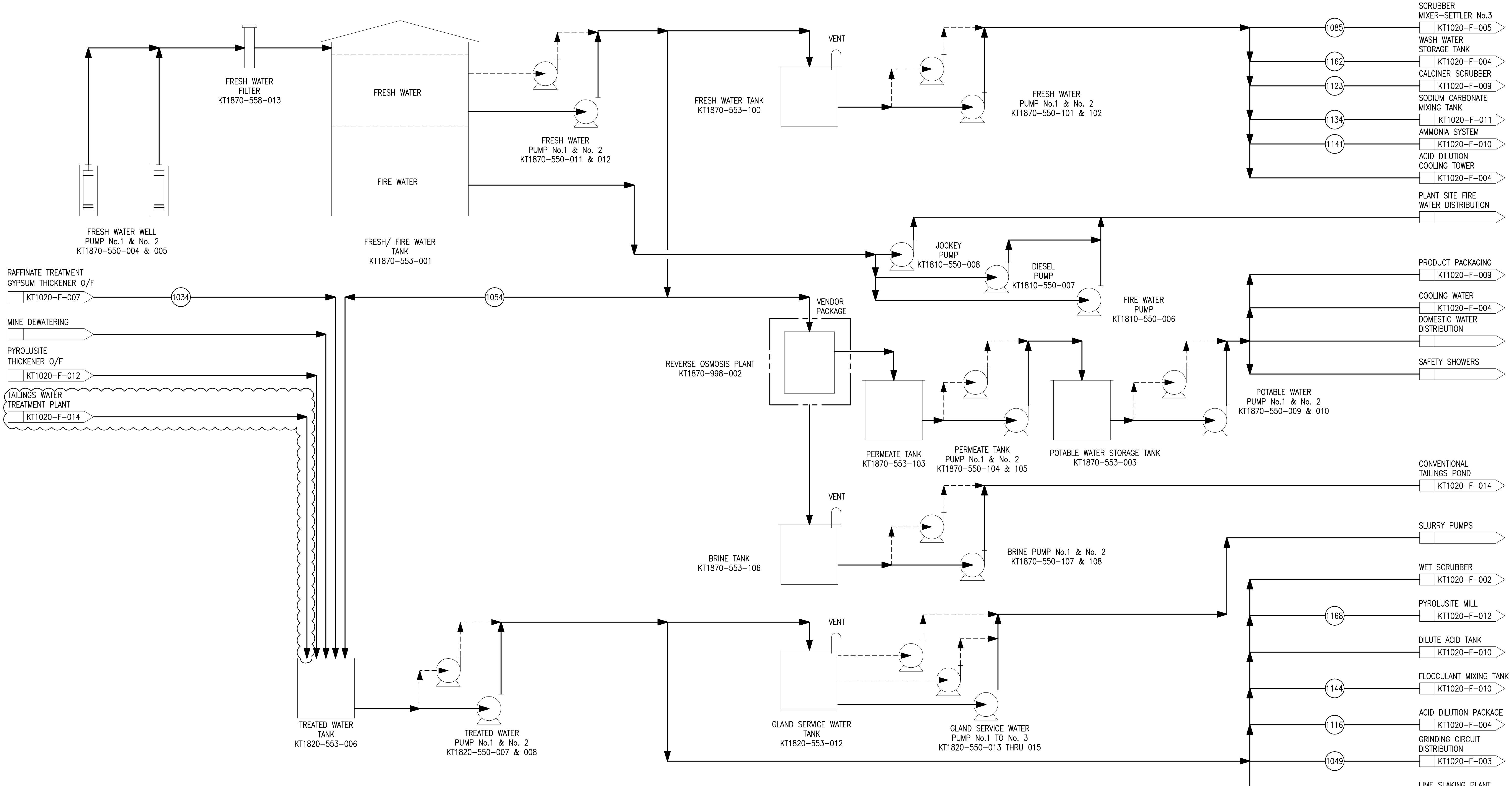
LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
TAILINGS DISPOSAL / WATER TREATMENT
PROCESS FLOW DIAGRAM
SHEET 14 OF 15

DWG. No. KT1020-F-014 REV E



STREAM NUMBER		1034	1045	1049	1054	1085	1116	1123	1134	1138	1141	1144	1162	1168	1136
MASS FLOW RATE															
SOLID	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	t/h	51.7	12.7	60.5	42.0	6.8	12.9	5.8	1.1	0.0	0.8	1.5	0.0	1.9	4.2
GAS	t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	t/h	51.7	12.7	60.5	42.0	6.8	12.9	5.8	1.1	0.0	0.8	1.5	0.0	1.9	4.2
PERCENT SOLIDS		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VOL. FLOW RATE															
SOLID	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIQUID	m^3/h	46.2	11.9	56.9	42.0	6.8	12.1	5.8	1.1	0.0	0.8	1.4	0.0	1.7	3.9
GAS	m^3/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	m^3/h	46.2	11.9	56.9	42.0	6.8	12.1	5.8	1.1	0.0	0.8	1.4	0.0	1.7	3.9
URANIUM CONTENT															
SOLID FLOW U_3O_8	kg/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LIQUID CONCENTRATION U_3O_8	g/L	0.03	0.02	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.02

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LOC. KINTYRE (PFS)

AREA PROCESS

TITLE ACID LEACH
WATER SUPPLY AND DISTRIBUTION
PROCESS FLOW DIAGRAM
SHEET 15 OF 15

DWG. No. KT1020-F-015 REV E