Current water quality conditions at the historic Rum Jungle Mine Site, northern Australia

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Abstract

Rum Jungle was one of Australia's first major uranium mines and produced approximately 3,500 tonnes of uranium oxide and 20,000 tonnes of copper in the 1950s and 1960s. After mine closure, acid rock drainage and the mobilization of metals in mine waste led to significant impacts on local groundwater and the nearby East Branch of the Finniss River. Some attempts were made to rehabilitate the site in the 1970s and 1980s but water quality conditions have deteriorated over the last 30 years.

A new rehabilitation plan for the site is currently being developed by the Mining Performance Division of the Northern Territory Department of Resources and a comprehensive site investigation is underway to assist in its development. One aspect of this site investigation is the identification of major contaminant sources to receiving waters and the characterization of current groundwater and surface water quality conditions prior to further rehabilitation. This paper summarizes this aspect of the site investigation and thereby provides an overview of our current understanding of the extent of ARD impact at the site.

Key Words: tailings, waste rock, acid rock drainage, groundwater quality, mine rehabilitation, Australia

Study Area

Location & Climate

The historic Rum Jungle Mine Site is located in Australia's Northern Territory (NT) about 105 km by road south of Darwin near the township of Batchelor. Local climate is considered tropical/monsoonal with 1500 to 2500 mm of annual rainfall and a distinct wet season that lasts from November to April. 90% or more of annual rainfall occurs during that period and no sustained rainfall is observed from May to October.

Mean maximum temperatures at the site typically range from 31°C in July to 37°C in October and savannah woodlands (predominantly *Eucalyptus* trees and various grass species) surround the mine site (Taylor *et al.* 2003).

Local Geology

The study area is located in the Rum Jungle mineral field of northern Australia (McCready *et al.* 2004). Specifically, the Rum Jungle Mine Site is situated in a triangular area of the mineral field that is bounded by the Giant's Reef Fault to the south and by east-trending ridges of the Crater Formation to the north. This triangular area is known as The Embayment and it lies on the shallow-dipping limb of a northeast-trending, southwest plunging asymmetric syncline that has been cut by northerly-dipping faults.

The geology of site is comprised of granites of the Rum Jungle Complex and meta-sedimentary rocks of the Mount Partridge Group (Figure 1). Note that rocks of the entire Mount Partridge Group have been folded, faulted and metamorphosed to sub-greenschist facies but the original stratigraphic succession has been preserved. Brittle failure associated with deformation has produced a number of faults that follow the northeast-southwest structural trends of the Rum Jungle Mine Site.

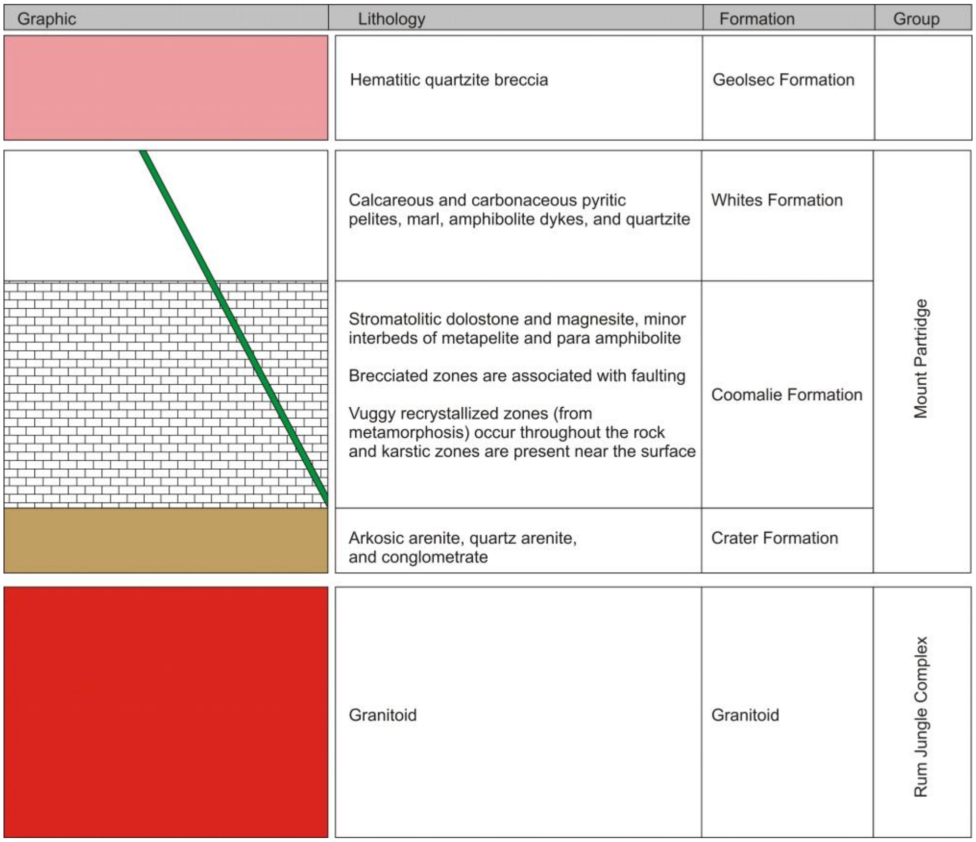

Figure 1. Stratigraphic sequence at the Rum Jungle Mine Site

The Embayment hosts several uranium and polymetallic ore deposits and each occurs within the Whites Formation near its contact with the Coomalie Dolostone. Moreover, mineralization is strongly associated with fault zones (and hence structurally-controlled) so ore is typically deposited in carbonaceous slates by selective replacement along shear zones that intersect local faults (Ahmad *et al.* 2006).

The aquifer system at the Rum Jungle Mine Site is thought to be comprised primarily of relatively shallow (typically < 100 m deep), unconfined bedrock aquifers. The hydraulic properties of the bedrock aquifer differ according to lithology and the degree of weathering and/or fracturing. The Whites Formation and the Coomalie Dolostone are the most permeable of the shallow aquifer units, with K values typically ranging from $1x10^{-5}$ to $5x10^{-4}$ m/s., whereas deeper aquifer units and the Rum Jungle Complex are often an order-of-magnitude less permeable.

Site Layout

The Rum Jungle Mine Site features four open pits and three waste rock dumps (WRDs) (see Figure 2). The Main and Intermediate Open Pits are flooded, the partially-excavated Browns Oxide Open Pit is actively de-watered, and Dyson's Open Pits was backfilled with waste rock and tailings in the mid-1980s. Other notable features of the mine site shown in Figure 2 are the East Finniss Diversion Channel (EFDC), the former tailings dam area along Old Tailings Creek, and the former copper heap leach pad between the flooded Open Pits.

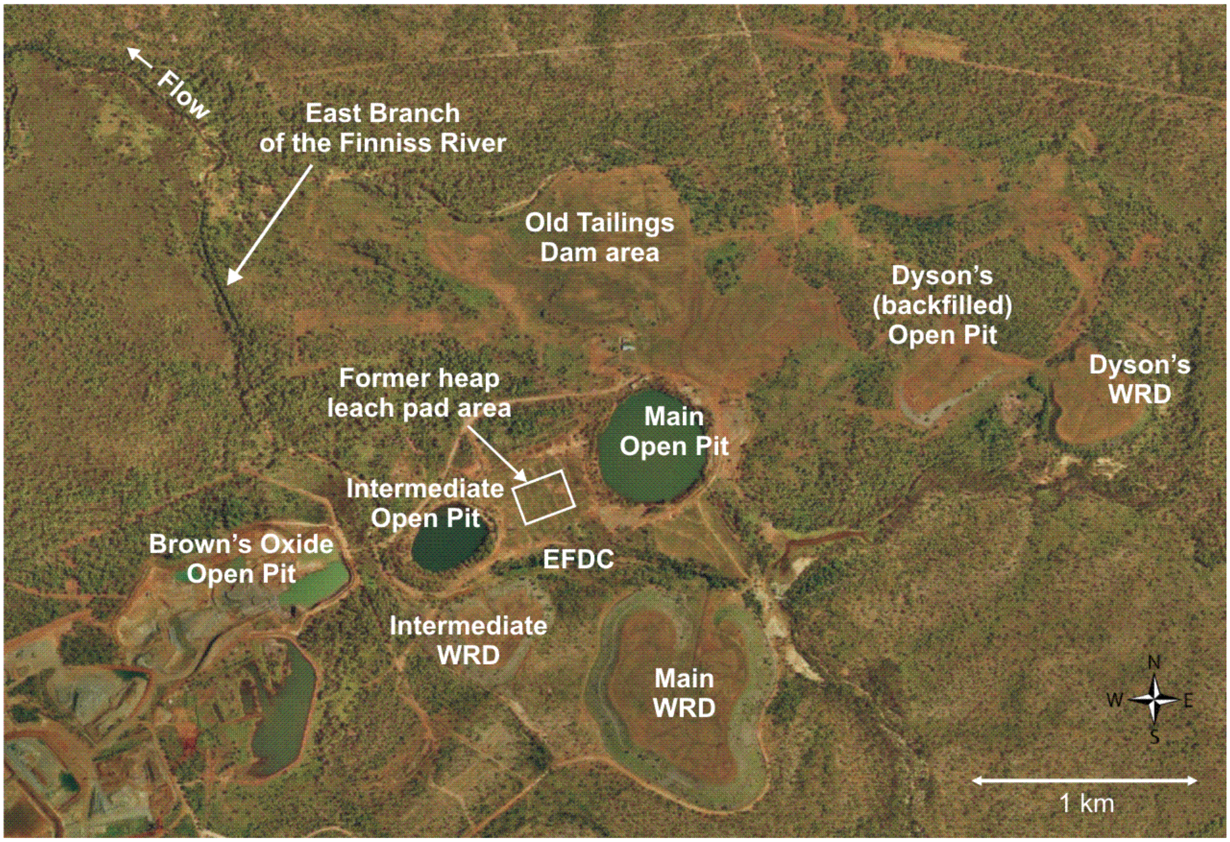

Figure 2. Layout of the Rum Jungle Mine Site.

The main features of the mine site are described briefly in the sub-sections below.

Open Pits

The Main and Intermediate Open Pits were mined out in the 1950s and 1960s and later became flooded with groundwater and highly-contaminated seepage from the former copper heap leach area when mine de-watering ceased (Davy 1975). The Main Open Pit was mined to about 105 m below ground surface (bgs) and is the deeper of the two open pits (although it was partially backfilled with tailings and mine wastes in the 1960s). The Browns Open Pit has only been partially mined-out and hence is the shallowest of the pits (i.e. < 30 m depth).

Dyson's Open Pit was mined to a depth of about 50 m bgs in the late 1950s. Tailings were discharged to this pit from 1961 to 1965 when the Intermediate ore body was being mined and it was later backfilled entirely with additional tailings, heap leach material, and contaminated soils in the 1980s (Allen and Verhoeven 1986). Note that some of the deeper backfill materials (mainly tailings) are flooded but some pyrite-containing materials reside above the water level within the open pit. Moreover, the backfill was not amended with lime to reduce the mobility of soluble contaminants.

Waste rock dumps

The Main, Intermediate, and Dyson's WRDs contain waste rock removed during mining operations. Each of the WRDs was covered in the 1980s to reduce rainfall infiltration although the covers have deteriorated to different extents since that time (Ritchie and Bennett 2003; Taylor *et al.* 2003).

East Finniss Diversion Channel

The mine site is located along the East Branch of the Finniss River about 8.5 km upstream of its confluence with the West Branch of the Finniss River. Surface water enters the mine site via the upper East Branch of the Finniss River and Fitch Creek. Before mining these tributaries met near the northeast corner of the Main Overburden Heap and subsequently flowed eastward via the natural course of the East Finniss River. However, the original course of the East Finniss River ran through the Main and Intermediate ore bodies so flow was diverted to the EFDC during mining operations.

Today, flows from the upper East Finniss River and Fitch Creek flow directly into the EFDC and into Main Open Pit near the former Acid Dam. Water then flows from Main Open Pit to the Intermediate Open Pit via a channel that roughly follows the original course of the East Branch of the Finniss River. Outflow from the Intermediate Open Pit to the EFDC occurs near the western boundary of the mine site and combined flows from the Open Pits and EFDC continues eastward via the natural course of the East Finniss River.

Former heap leach area

In the 1960s, copper from sub-grade ore (and the oxidized capping) of the Intermediate Open Pit was extracted in the 1960s via heap leaching on a 'non-permeable' pad located between the Main and Intermediate Open Pits (Davy 1975). Contamination of local soils during the heap leaching process was extensive and resulted in acidified, metals-laden soils throughout the area. Most of these soils and spent ore were removed during rehabilitation in the 1980s but residual amounts remain in some areas.

Old Tailings Dam area

The former tailings dam area represents a relatively flat area north of Main Open Pit where slurried tailings were discharged during mining operations. Drainage from this area formed a small creek that eventually discharged to the East Branch of the Finniss River (Watson 1979). Perimeter walls were later built towards the eastern end of the creek to form a series of small dams commonly referred to as the "Old Tailings Dam". Most of the tailings in this area were removed during rehabilitation attempts in the 1980s when the area was also limed, re-shaped, and covered to promote the re-establishment of vegetation (Allen and Verhoeven 1986).

Monitoring Well Network

The Rum Jungle Mine Site features a network of historic monitoring wells that have been installed for various purposes since the 1940s (i.e. groundwater monitoring, production, etc.). 103 of these wells remain accessible and have been used for water level monitoring since mid-2010. Most of the historic monitoring wells are shallow (<5 m in depth) and are clustered together near one of the major mine waste units or along the principal drainages of the site.

27 additional monitoring wells were installed in 2010 to augment the existing well network and fill gaps that existing well network (see Figure 3). Most of the new monitoring wells were installed near the open pits and the former copper heap leach area as these areas were particularly under-represented in the historic well network. Each of these bores (and 43 historic monitoring wells) is sampled twice per year for purposes of groundwater quality monitoring, whereas groundwater level measurements are collected monthly in the dry season and bi-monthly during the wet season.

Data

Seepage water quality data are provided in Table 1 and groundwater quality data for a selection of the wells installed in 2010 are provided in Table 2.

Table 1: Selected ARD indicator species in seepage from mine waste units, Rum Jungle Mine Site

Waste Unit	Date	pH	EC µS/cm	SO_4	Al	Fe	Cu	Co	Ni	U	Zn
Seepage from WRDs											
White's	6-Aug-10	3.7	6000	5190	13	5	4	5	4	1	7
Dyson's	6-Aug-10	3.7	4520	2710	88	6	0.2	0.4	1	1	0.2
Intermediate	6-Aug-10	3.3	12600	13800	199	349	35	75	65	2	156
Seepage from Dyson's (backfilled) Open Pit											
-	16-Mar-11	3.4	2872	1730	17	11	27	18	16	1	1

SO_4 and metals concentrations in mg/L

Table 2: Selected ARD indicator species in groundwater, February to April 2011

Well ID	Screened interval m bgs	pH	EC µS/cm	SO_4	Al	Fe	Cu	Co	Ni	U	Zn
Dyson's Area											
PMB1a	1.4 to 3.2	5.1	841	331	0.2	1.0	0.1	1.3	1.3	0.05	0.1
PMB1b	2.2 to 3.7	5.1	782	355	0.1	0.2	0.5	0.3	0.3	0.03	0.03
PMB2	12.7 to 18.7	6.8	2192	934	0.07	0.6	0.001	0.01	0.01	0.1	0.01
Near the WRDs											
PMB3	2.0 to 3.5	4.2	1302	658	6.0	0.6	3.6	0.9	0.9	0.1	1.7
PMB4	9.3 to 15.3	7.2	2195	1090	0.01	0.2	0.004	0.003	0.009	0.09	0.05
PMB5	2.0 to 5.0	6.7	1697	776	0.02	0.2	0.002	0.6	0.5	0.009	0.4
PMB6	13.5 to 25.5	7.2	2243	1090	0.01	0.2	0.003	0.03	0.001	0.005	0.001
Former copper heap leach area											
PMB10	16.0 to 32.0	6.8	1748	426	0.02	2.0	0.03	0.1	0.03	0.1	0.02
PMB11	31.5 to 34.5	5.3	7800	5570	0.3	17.0	87	67	49	0.004	10
PMB22	12.6 to 24.6	7.3	1907	804	0.02	0.4	0.001	0.002	0.003	0.01	0.005
PMB23	13.0 to 25.0	3.5	7200	5290	36	20	587	71	58	0.4	12
PMB24	4.0 to 16.0	3.1	1367	600	18	1	28	31	3	0.1	1
Near the Intermediate Open Pit											
PMB9S	23.4 to 29.4	7.8	685	235	0.04	0.2	0.007	0.004	0.007	0.009	0.002
PMB9D	46.3 to 62.3	6.7	4735	3260	0.05	12	0.1	1.0	0.4	0.2	0.1
North of the Open Pits											
PMB7	9.0 to 18.0	7.5	2679	1520	0.02	0.2	0.01	0.01	0.07	0.009	0.015
PMB12	12.6 to 24.6	7.6	3973	2440	0.1	0.2	0.1	0.1	0.08	0.07	0.01
PMB13	48.8 to 60.8	8.5	363	34	0.01	0.2	0.007	0.001	0.005	0.001	0.004
PMB14	14.2 to 16.2	6.2	2382	1300	0.04	0.2	0.005	0.008	0.05	0.003	0.02
PMB15	12.4 to 24.4	7.4	1276	477	0.02	0.2	0.1	0.4	0.3	0.02	0.1
PMB16	13.5 to 22.5	6.9	4872	2960	0.03	1.2	0.0004	0.002	0.01	0.008	0.005
PMB17	20.0 to 26.0	6.9	853	240	0.007	0.2	0.0002	0.004	0.004	0.006	0.003

SO_4 and metals concentrations in mg/L (concentrations less than indicated detection limit shown in red)

Discussion

After a brief description of background water quality conditions and sources of ARD products to groundwater, groundwater quality and local flow fields in the following 'priority' areas are discussed in separate sub-sections:

- Dyson's Area
- Near the Main and Intermediate WRDs
- Near the former heap leach area and flooded Open Pits
- North of the Open Pits

Groundwater levels in January 2011 were used to infer directions of groundwater flow across the mine site (see Figure 3). The inferred directions of groundwater flow are illustrated by arrows in Figure 3. Blue arrows indicate the movement of unimpacted groundwater, whereas orange and red arrows indicate the movement of moderately- and highly-impacted groundwater, respectively.

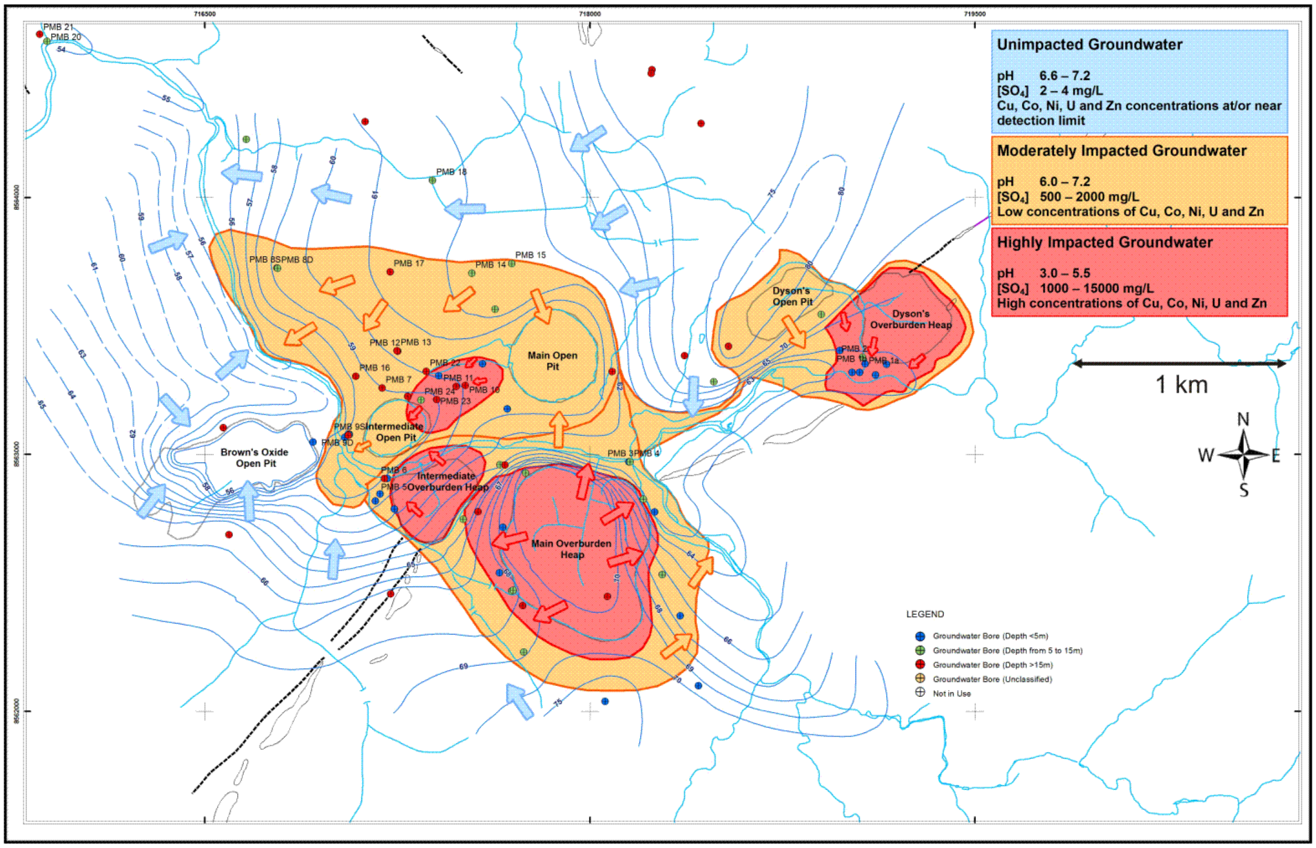

Figure 3. Inferred directions of groundwater flow and contaminant transport at the Rum Jungle Mine Site

Groundwater quality and water level data are discussed together throughout the following sub-sections as sources of recharge and the subsequent movement of groundwater in the sub-surface can often be deduced from the degree (and extent) of ARD impact in receiving groundwater.

Background Conditions

Unimpacted groundwater in the bedrock aquifer at the Rum Jungle Mine Site is typically neutral to slightly alkaline (pH 7 to 8) and characterized by electrical conductivity (EC) less than 500 µS/cm and low concentrations of SO_4 and dissolved metals. Groundwater of this type has been identified upgradient of the mine site, in the relatively high elevation area northeast of Old Tailings Creek, and on the far side of Old Tailings Creek.

Unimpacted groundwater is thought to flow from these areas towards the lower elevation areas of the site near the flooded Open Pits and former copper heap leach area. Note that unimpacted groundwater has also been identified in relatively deep Coomalie Dolostone (at well PMB13), which suggests that ARD contamination in this area is limited to relatively shallow zones (< 25 m bgs) of the bedrock aquifer.

Seepage water quality

Seepages from the four major mine waste units at the site provide the bulk of contaminant loads to groundwater and the East Branch of the Finniss River (via the EFDC or the flooded Open Pits) and are geochemically distinct from one another (see Table 1).

Aside from being highly-acidic (pH<4) and characterized by high concentrations of SO_4, other characteristic features of seepage are summarized as follows:

- Seepage from Dyson's WRD tends to be characterized by higher concentrations of dissolved U and lower concentrations of Cu, Co, Ni, and Zn than seepage from Dyson's (backfilled) Open Pit; this is consistent with Dyson's ore body being mined solely for uranium whereas high metals concentrations in the backfilled pit are related to tailings and contaminated soils stored therein;

- Seepage from the Main WRD is characterized by high concentrations of nearly every dissolved metal as the ore body was mined for uranium and a suite of other metals; seepage from this WRD contributes the most volumetrically to the EFDC and hence the East Branch of the Finniss River downstream; and
- Seepage from the Intermediate WRD is the most concentrated source of contaminants at the mine site as metals concentrations can be orders of magnitude higher than in seepage from the Main WRD or seepages in Dyson's Area; of particular interest is the very high Cu concentrations (which reflect the geochemistry of the Intermediate ore body).

Note that some seasonal variations in seepage water quality are apparent from preliminary monitoring data but data from Table 1 are reasonably representative of current seepage conditions.

Dyson's Area

The bedrock aquifer in Dyson's Area is cross-cut by the Giant's Reef Fault and a series of NE-trending faults. Dyson's WRD lies to the south of the Giant's Reef Fault and hence is underlain exclusively by the Rum Jungle Complex, whereas Dyson's (backfilled) Open Pit lies between two of the NE-trending faults in pyritic black shale of the Whites Formation.

Most of the wells in Dyson's Area are clustered together near the southern toe of Dyson's WRD along the upper East Finniss River channel. Groundwater flow in this area appears limited to shallow deposits of alluvium associated with the upper East Branch of the Finniss River, meaning that most water infiltrating in this area likely moves laterally towards the river channel and not downward into the Rum Jungle Complex. This is supported by the presence of highly-impacted groundwater in shallow alluvium but only modestly-impacted groundwater in the bedrock aquifer at PMB2 (i.e. ~1000 mg/L SO_4 and low metals concentrations).

Most of the other wells in the Dyson's Area are located north of the Giant's Reef Fault closer to Dyson's (backfilled) Open Pit and are screened deeper in the bedrock aquifer. Groundwater quality near the western toe of Dyson's (backfilled) Open Pit is characterized by near-background concentrations of SO_4/dissolved metals and hence appears to be unimpacted by ARD. This suggests that Dyson's (backfilled) Open Pit is not a source of ARD products to deep groundwater in this area. Instead, contaminant loads from Dyson's (backfilled) Open Pit appear to report to the East Branch of the Finniss River via surface seepage or shallow flow in the nearby drainage channel that connects to drains within the landform.

Near the WRDs

The Main and Intermediate WRDs are well-established as the main sources of ARD products to groundwater at the mine site. The Main WRD is underlain by the relatively impermeable Rum Jungle Complex, whereas the Intermediate WRD is underlain by the more permeable rocks of the Whites Formation and Coomalie Dolostone.

Groundwater beneath the heap and along the perimeter of the heap is highly-impacted by ARD (Figure 3). Due to 'tight' bedrock beneath the Main WRD, seepage from the heap has resulted in some mounding of the groundwater table in this area (i.e. groundwater flows out in each direction from Main WRD). Consequently, seepage from the Main WRD is observed at shallow depths year-round and seepage discharges from the toe of the Main WRD throughout the wet season. Note that no such mounding of groundwater levels occurs near the Intermediate WRD due to the higher permeability of bedrock underlying this heap.

High SO_4 and metals concentrations characterize deeper groundwater in this area yet the downward movement of contaminated groundwater downward is likely limited. Moreover, groundwater quality in the Rum Jungle Complex beneath the Main WRD has generally improved since the WRD was covered in the mid-1980s due to reduced infiltration and therefore reduced contaminant loads from waste rock.

Groundwater from wells screened near the perimeter of the Main WRD is highly-acidic (pH 3.6 to 5.2) and characterized by very high concentrations of Mg (2,000 to 2,500 mg/L), SO_4 (9,000 to 11,000 mg/L), and nearly every dissolved metal in the suite (data not provided). The particularly high metals concentrations in several wells close to the toe of the heap are related to their proximity to a seepage face that characterizes the southwestern batter of the Main WRD during the wet season. Contamination from this area extends to the eastern toe of the Intermediate WRD.

Contaminant loads from the Intermediate WRD are likely directed northwest towards Wandering Creek and/or the EFDC near wells PMB5 and PMB6 and not towards the Main WRD. This conception of contaminant transport is consistent with the identification of highly-impacted groundwater in wells located immediately downgradient and suggests some contaminant transport westward towards Wandering Creek. However, groundwater from wells PMB5 and PMB6 is only modestly-impacted by ARD and hence it appears that the majority of contaminant loads from the Intermediate WRD are delivered to the EFDC via the nearby seepage face (and do not report to groundwater via sub-surface flow from the heap).

Upstream near the head of the EFDC, groundwater from well PMB4 is also only modestly-impacted by ARD and hence data support the assertion that only minor loads are delivered to groundwater beneath the channel. This is consistent with local groundwater flow fields and suggests that groundwater does not upwell to the EFDC nor flow westward along the EFDC. Instead, groundwater likely flows northwest beneath the EFDC northwest towards the former heap leach area.

Near the former heap leach area & flooded Open Pits

The direction of groundwater flow near the flooded Open Pits and former heap leach area appears to be influenced by the presence of the Open Pits themselves and fault structures in this area. Specifically, groundwater from the higher-elevation area near well PMB14 flows along the N-S trending fault that cuts across the former heap leach area and groundwater within the former heap leach area itself appears to flow westward towards the Intermediate Open Pit via the fault that hosts mineralization at the site. These faults appear to be preferential flowpaths for groundwater flow (and contaminant transport) although the rate of flow is likely limited by low transmissivity and weak hydraulic gradients in this area.

A strong hydraulic connection between the Intermediate Open Pit and the Coomalie Dolostone was demonstrated by a 'large-scale' pumping test conducted in late 2008. Groundwater quality at PMB9S is relatively unimpacted by ARD but samples from the deeper of the two nested wells (well PMB9D) is highly-impacted by ARD (~3000 mg/L SO_4 and elevated levels of dissolved metals). These data suggest that well PMB9D screens the zone of the Coomalie Dolostone that is well-connected to the Intermediate Open Pit (as an increase in EC levels during that test are thought to reflect highly-impacted groundwater being pulled from the Coomalie Dolostone nearer the Intermediate Open Pit). The implication is that the area near well PMB9D is hydraulically-connected to the bedrock aquifer beneath the former heap leach area.

Wells PMB11, PMB23, and PMB24 are each located near the former heap leach area. Well PMB11 is thought to screen a sand-filled cavity in the bedrock aquifer beneath the former heap leach area whereas wells PMB23 and PMB24 are screened in the Coomalie Dolostone to the southwest. Groundwater from these wells are characterized by extremely high metals concentrations that are thought to represent a mixture of groundwater and seepage lost during the heap leaching process.

Note that groundwater from each of these wells is characterized by concentrations of SO_4 and dissolved metals that are comparable to water currently at the bottoms of the flooded Open Pits. Prior to treatment in the 1980s, the same type of water characterized the entire water columns of the Main and Intermediate Open Pits and hence it seems likely the water that currently resides in the former heap leach area is the same type that initially filled the pits when de-watering ceasing the 1950s. This is consistent with observations from Davy (1975) and explains the relatively clean groundwater at well PMB22 (which is screened in the Coomalie Dolostone slightly north of the former heap leach area and hence not affected by historic seepage losses).

At this time the Intermediate Open Pit is conceptualized as a discharge zone for groundwater from the former heap leach area but weak hydraulic gradients in this area suggest that the amount of groundwater that discharges each year may be rather small. Instead, contaminated groundwater in the former heap leach area could be representative a rather immobile TDS/metals plume that was mobilized temporarily in 2008 by the strong gradients created by the pumping test conducted in 2008.

North of the Open Pits

Detailed water quality surveys conducted in the mid-1990s suggest that the area immediately downstream of gauge GS8150200 is a discharge zone for groundwater (Lawton and Overall 2002). This scenario is consistent with comments from Davy (1975) and the local groundwater flow field shown in Figure 3.

Groundwater quality conditions at wells PMB7 and PMB16 are representative of the type of impacted groundwater that likely discharges to the East Branch of the Finniss River within 750 m of gauge GS8150200 (near well PMB9D). Specifically, groundwater in this area contains elevated levels of SO_4 but low concentrations of metals that are indicative of a neutralized TDS plume. This plume likely originates in the former heap leach area near wells PMB23 and PMB24 and characterizes the bedrock aquifer near the perimeter of the Intermediate Open Pit, well PMB12 (northeast of well PMB16), and wells PMB7 and PMB16 near the East Branch of the Finniss River. It is difficult to ascertain the timing of conservative contaminant transport as groundwater likely moves slowly in this area due to weak hydraulic gradients (and hence the TDS plume could be relatively immobile). However, no detailed assessment of attenuation processes that may be limiting the breakthrough of metals has yet been completed.

Summary & Conclusions

Recent groundwater quality data has enabled a preliminary conception of groundwater quality conditions at the former Rum Jungle Mine Site. Key findings are summarized as follows:

- Groundwater contamination tends to be limited to shallow aquifer zones (< 25 m bgs), as deeper groundwater often appears unimpacted or only modestly impacted by conservatively-transported ARD species; this trend is particularly evident in Dyson's Area, which is characterized by highly-impacted seepage and very shallow groundwater but impacts to deeper groundwater in Dyson's area appear to be minimal;
- The Main and Intermediate WRDs are the main sources of ARD products to shallow groundwater, whereas deeper groundwater near the Open Pits is impacted primarily by residual seepages related to historic heap leaching; very high concentrations of metals in particular reflect the poor condition of groundwater beneath the former heap leach area;
- The impact of ARD on groundwater appears to diminish considerably with distance from seepage sources as groundwater across much of the site tends to be well-buffered and hence characterized by low concentrations of dissolved metals; much of the impact on groundwater is therefore limited to increased TDS (primarily Ca, Mg and SO_4) and groundwater tends to be neutral to slightly alkaline; the presence of the Coomalie Dolostone (and its high buffering capacity) is of particular importance as this unit has received a substantial contaminant load from upgradient but continues to buffer receiving groundwater;
- A TDS plume extends to the north and northwest of the flooded Open Pits and former heap leach area into the vicinity of the East Branch of the Finniss River; the presence of impacted groundwater in this area is consistent with reports of contaminated groundwater discharging to the river immediately downgradient of the mine site.

In summary, groundwater quality across much of the former Rum Jungle Mine Site remains impacted to some extent by ARD despite attempts to rehabilitate the site in the 1970s and 1980s. However, highly-impacted groundwater is restricted to areas immediately downgradient of the major mine waste units or in the former heap leach area as groundwater north of the Open Pits is only modestly-impacted by ARD. This pattern of contamination is consistent with the relatively slow movement of groundwater across the site due to weak hydraulic gradients and, to an extent, the reduction of contaminant loads due to historic rehabilitation attempts. Groundwater quality and the condition of the East Branch of the Finniss River are however expected to deteriorate further and hence preliminary monitoring data highlight the importance of implementing a more comprehensive rehabilitation plan for the mine site.

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