Section Seven

Regional Overview

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7. Regional Overview

7.1 Regional Setting

7.1.1 Landforms and Topography

The Project area is located in the Little Sandy Desert near the boundary with the Great Sandy Desert in the Eastern Pilbara region of Western Australia.

The Great Sandy Desert is characterised by longitudinal sand dunefields overlying Jurassic and Cretaceous sandstones of the Canning, Centralian, Arunta and Amadeus Basins. Calcrete and evaporite surfaces are associated with occluded palaeodrainage systems that traverse the desert and include extensive salt lake chains.

The Little Sandy Desert has red Quaternary dune fields with abrupt Proterozoic sandstone ranges of the Bangemall Basin (Commonwealth of Australia, 2005).

The topography is elevated to the southwest of Karlamilyi National Park and falls away to the northeast to Lake Dora within the national park, southeast to Lake Disappointment and north-northwest towards Lake Waukarlycarly north of Telfer. The Project area lies within a broad valley bounded by rocky flat-topped hills of the Broadhurst Ranges to the East, Watrara Ranges to the south and Throssell Ranges to the west. North of the Project area are northwest-southeast trending dunefields characteristic of the Great Sandy Desert.

The area has been subject to extensive erosion with areas of exposed bedrock, low mesas, ephemeral watercourses and dunefields. The Project area is characterised by Yandagooge Creek, flat aeolian sand dunes, isolated outcropping ridges and hilly range areas with flat mesas about the edge of the Yandagooge Creek floodplain.

7.1.2 Biogeography

The Project area lies within the Little Sandy Desert (LSD1 – Rudall Subregion) as classified by the Interim Biogeographical Regionalisation for Australia (IBRA) category (Thackway and Cresswell, 1995). The LSD1 sub region covers an area of 1,078,070 ha and comprises sparse shrub-steppe over *Triodia basedowii* on stony hills, with River Gum (*Eucalyptus camaldulensis*) communities along drainage lines and bunch grasslands on alluvial deposits associated with ranges (Kendrick, 2001).

Prior to the IBRA classification, the Project area was classified within the Keartland Botanical

Plate 7-1: Topography in the Kintyre area

District of the Eremaean Botanical Province. The Keartland Botanical District is described as shrub steppe of *Acacia*, *Grevillea* and *Triodia* species on and between dunes with patches of Desert oak (*Allocasuarina decaisneana*) and Mulga (*Acacia aneura*) (Beard, 1990).

Extensive areas of tussock grass are associated with the footslopes of the ranges and Triodia hummock grasslands on hills and surrounding plains. River gum communities occur along ephemeral drainage lines. Ecosystems considered at risk within this subregion include semi-permanent pools along the course of the Rudall River and minor rock hole wetlands within the various ranges (Kendrick, 2001). These ecosystems do not occur within the Project area.

7.1.3 Geology and Soils

The Project area lies in the Paterson Province in the Little Sandy Desert. The Project's uranium deposits are located in the Yandagooge Supergroup of the early Proterozoic basement, the Rudall Metamorphic Complex. These metamorphics are unconformably overlain by the Coolbro Sandstone of the mid Proterozoic Yeneena Group. The Yandagooge Formation occurs between the basement gneisses and the overlying Coolbro Sandstone. A description of the geology of the resource is provided in Section 6.2.

Glaciers of Permian age incised the Proterozoic metamorphics and glacial sediments of the Paterson Formation were deposited in U-shaped valleys up to several hundred metres thick. The Permian sediments are typically silts and clays with a basal layer of tillite, coarse sand and gravel.

Central portions of the valley are largely overlain by Cenozoic deposits that range in thickness from 1 m to 12 m. The main course of Yandagooge Creek meanders through a broad valley filled by these alluvial and aeolian deposits. A description of the soils of the Project area is provided in Section 8.2.4 and indicates soils are predominantly red sands or red sandy loam sometimes with rock fragments or gravel bars and lenses.

7.1.4 Hydrogeology

Regional and local aquifer types in the Kintyre area are summarised in the following sections.

7.1.4.1 Cenozoic Deposits

Cenozoic deposits are generally unsaturated, 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 Yandagooge Creek but yielded only minor flow (<90 kL/day). 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.

7.1.4.2 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 by earlier studies (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 is leaky based on the response of shallow piezometers in the upper Paterson Formation during constant rate tests of the Paterson Formation lower aquifer.

7.1.4.3 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 hold the greatest potential to yield significant amounts of groundwater to bores, although the lateral extent and yield potential 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 programmes have shown that the unit is capable of producing up to 1,700 kL/day upon airlift yield. The unit has a saturated thickness of up to 105 m within bores that have intersected it.

The unit is typically thickest in the deepest parts of the palaeovalley, reaching a maximum of thickness of 105 m in bore WEX3 within the Project area, and increases northward forming a laterally continuous aquifer or series of aquifers along the length of the palaeovalley. Basal conglomerates are expected to extend to at least 33 km north of Kintyre based on time domain electromagnetic data interpretation (Pennington Scott, 2012b).

7.1.4.4 Coolbro Sandstone Aquifer

In the Project area the Coolbro Sandstone forms the main component of the upland plateau, where the unit has well developed fractures, particularly in weathered sections near the top and bottom of the unit. The Coolbro Sandstone forms a significant fractured rock aquifer. It is present extensively over the plateau areas flanking the Yandagooge Creek area northwest and northeast of Kintyre, and is situated west of the Kintyre Shear zone adjacent to the proposed Kintyre Pit. Several bores drilled into the Coolbro Sandstone aquifer have targeted higher permeability areas within the Kintyre Shear Zone.

7.1.4.5 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).

Up to 56 m of weathered rock interfaces have been documented in hard-rock around the resource area. 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.

Detail of the hydrogeology of the Project area is provided in more detail in Section 8.4.

7.1.4.6 Groundwater Recharge

Groundwater is recharged directly by rainfall over the Cenozoic deposits, the 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 run off discharging from the plateau area, and along Yandagooge Creek and other tributary channels.

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. 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).

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 run off would concentrate and infiltration may be greatest. The lowest groundwater salinity obtained in the Project area was from the Coolbro Sandstone adjacent to

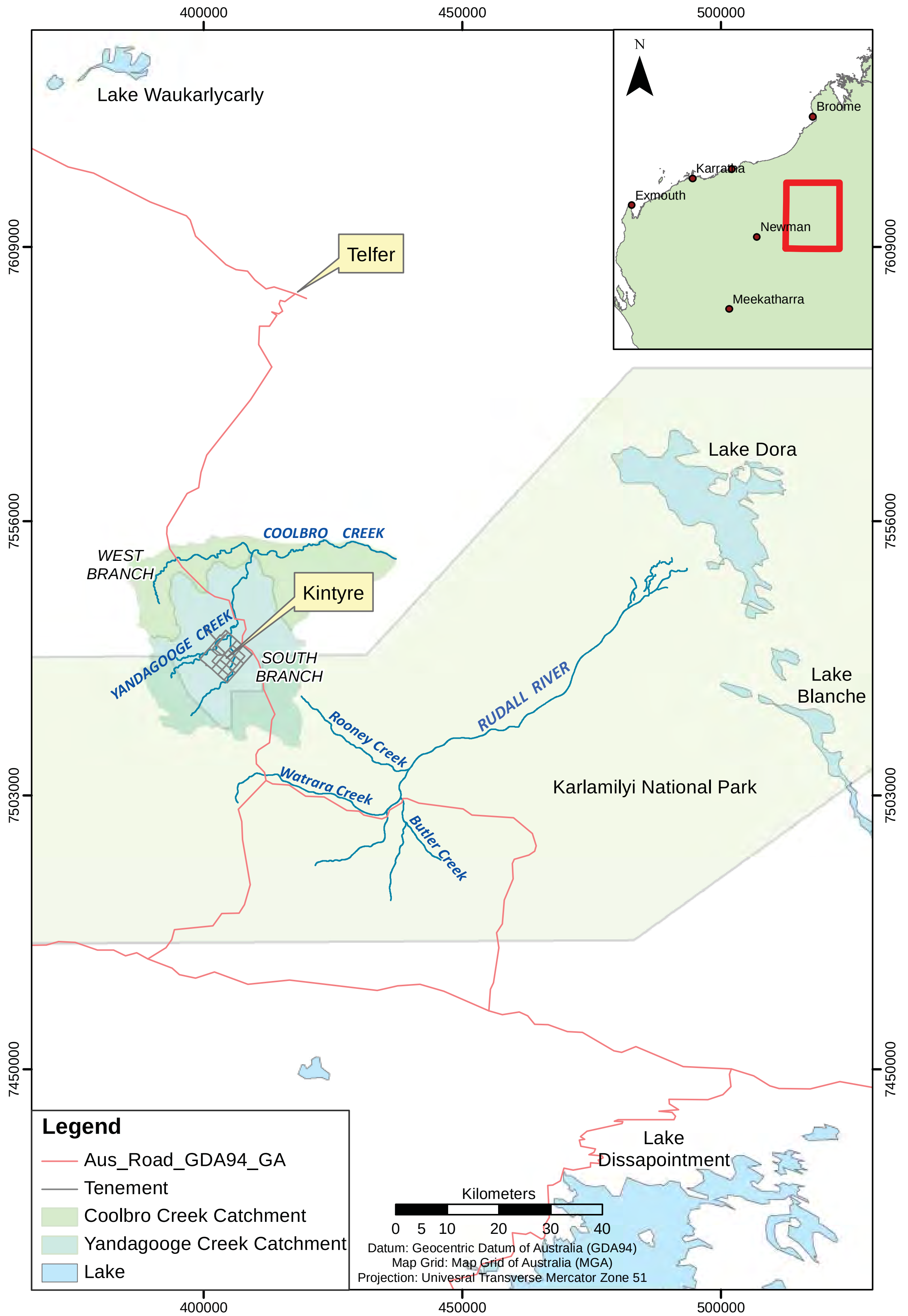

Figure 7-1: Regional drainage

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 run off 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 & 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.

Further information on recharge rates within the Project area is provided in Section 8.4.

7.1.4.7 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.

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 m AHD, and declines to about 348 m AHD around the convergence of the western and southern channels, reaching 344 m AHD in the northern-most part of the investigation area. The watertable continues to decline northward beneath the main channel toward the Canning Basin, although there are no observational data to define the levels.

Groundwater flow is to the north in the west branch and to the northwest in the east branch, and then converges to flow northward along the main valley trunk toward the Canning Basin.

7.1.4.8 Groundwater Discharge

Groundwater may be lost from above the watertable through the up-take and evapotranspiration by plants where the watertable is sufficiently shallow. The watertable is too deep for direct evaporation in the Project area.

Groundwater contained in the confined Paterson Formation aquifer and possibly the 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.

There will be no impact upon Lake Dora, the Rudall River or Lake Waukarlycarly resulting from altered groundwater conditions in the Project area due to the Project's mining activities. These surface water features are remote from the Project area and lie upon low permeability sedimentary rocks of Permian or Proterozoic age at the southern edge of the Canning Basin. The palaeovalley within the Project area discharges to these low permeability formations north of the Broadhurst Range, but flow will be obstructed by the presence of extensive aquitards and faulting. Groundwater flow within the palaeochannel has very slow travel times, taking up to tens of thousands of years for any groundwater originating from the pit area to reach the northern limit of the palaeovalley. During mining operations, groundwater will be pumped from the borefield and pit area creating a sink for groundwater flow, reversing groundwater flow out of the palaeovalley and capturing groundwater emanating from the mine until aquifer water levels fully recover following cessation of pumping.

7.1.5 Surface Hydrology

The Project area lies within the Sandy Desert River Basin (River Basin 025) of the internal drainage division of Australia (Western Plateau Drainage Division No. 12) (AWRC, 1975). The Project area occurs within the Coolbro Creek catchment and the Yandagooge Creek sub-catchment. Yandagooge Creek has two tributaries; the West Branch and the South Branch which converge just north of the Project area (Figure 7-1). The headwaters of the West Branch originate near Yandagooge Gap approximately 14 km west-southwest of the Project area. The South Branch originates approximately 9 km south of the Project area.

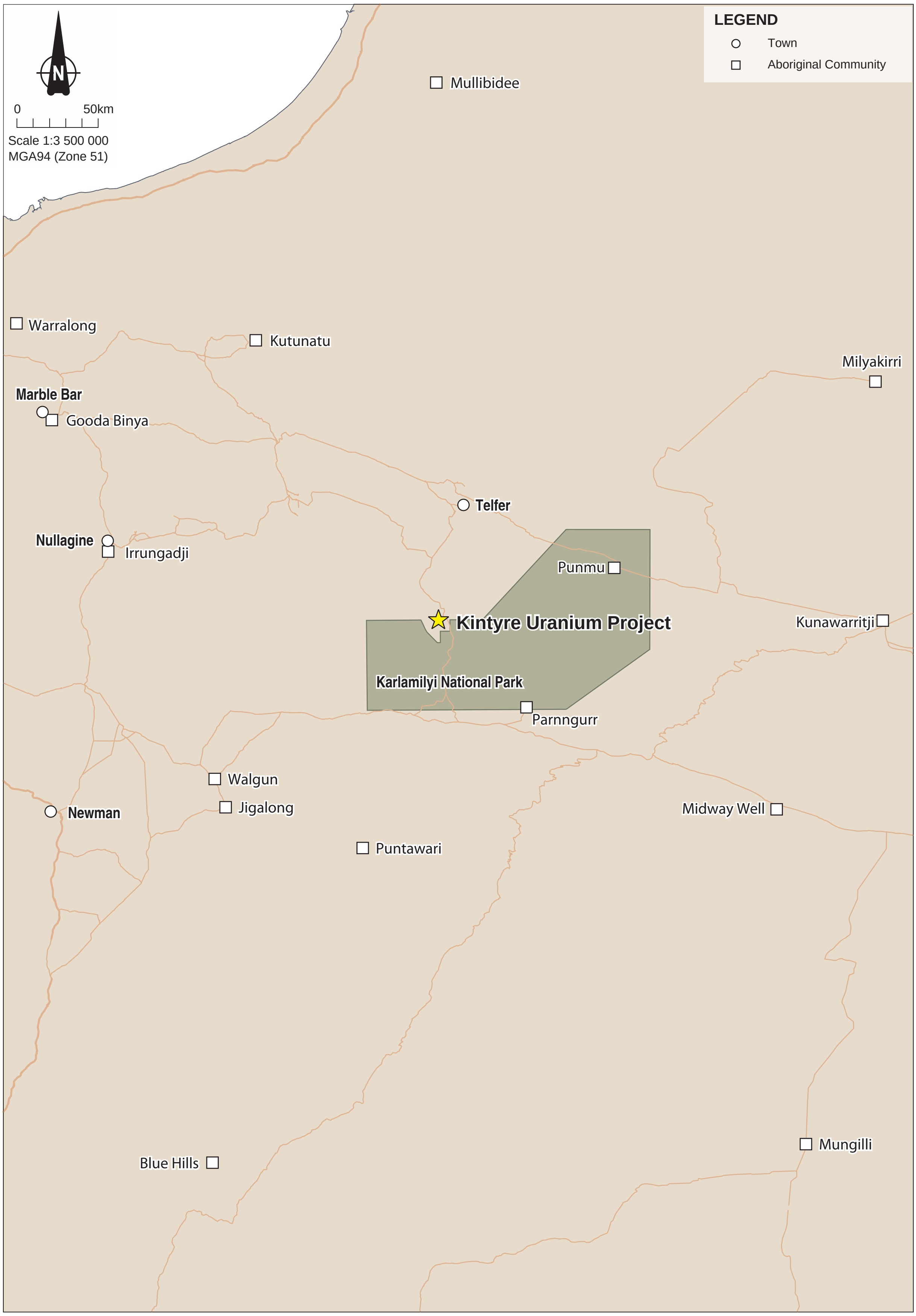

Figure 7-2: Nearest communities to the Project area

Yandagooge Creek drains to the north to become part of the Coolbro Creek drainage system which then flows east and discharges into the interdunal swales of the sand dune system of the Great Sandy Desert at a location approximately 50 km south west of Lake Dora (Figure 7-1). There is no defined drainage beyond the discharge to the dune system. During major flood events surface water discharge is likely to accumulate in the interdunal areas and flow along the northwest – southeast trending dune system and may flow easterly towards Rudall River. The Project area is located within the Rudall River Wild River area as defined by the DoW (Section 7.4.3).

There are no groundwater discharge zones in the area. There are several ephemeral water pools in the Coolbro / Yandagooge Creek catchment, however, these are fed by rainfall and creek flow and are not connected to groundwater. These are located upstream (south) of the Project area on Yandagooge Creek, or in separate sub-catchments such as a minor tributary to Yandagooge Creek and on Coolbro Creek, upstream of the confluence with Yandagooge Creek (Section 8.3.4).

The Coolbro Creek catchment is a separate drainage system from the Rudall River system (Figure 7-1) with the Yandagooge Creek sub-catchment separated from the Rudall River system by low hills including the Watrara Range. The Rudall River catchment system is a much larger system than that of the Coolbro Creek system. It drains to the north east before discharging into Lake Dora, which in turn drains to the southeast towards Lake Blanche.

7.2 Social Setting

This section provides an overview of the social setting and surrounding communities. A snapshot of the baseline socio-economic profile and demographic trends for the communities of interest is provided in Appendix S.

7.2.1 Pilbara Region and Shire of East Pilbara

The Pilbara region comprises an area of approximately 507,896 km^2 in the northwest of Western Australia (WA). The region extends from the Indian Ocean to the Northern Territory border and contains a coastal plain, inland ranges and an arid desert (Pilbara Development Commission [PDC], 2010).

The Shire of East Pilbara is one of four local government areas in the Pilbara region (the others being Shire of Ashburton, Town of Port Hedland and the Shire of Roebourne). The East Pilbara spans an area of approximately 380,000 km^2. The main towns are Newman, Marble Bar and Nullagine with numerous Indigenous communities including Jigalong, Punmu and Parnngurr (Figure 7-2).

The East Pilbara Shire was formed by an amalgamation of the shires of Marble Bar and Nullagine in 1972. The major industries in the shire are mining, pastoral activities and tourism (Shire of East Pilbara, 2008).

7.2.1.1 Population

In 2009, the Pilbara population was 47,528 and the East Pilbara Shire's population was 7,954 (PDC, 2011). One of the key characteristics of the East Pilbara and wider Pilbara population is that almost 75% are of workforce age (ABS, 2007a; 2007b). This reinforces the view that many people are drawn to the region for employment opportunities.

Approximately 24.2% of the Shire's population is Indigenous, which is higher than the Pilbara's Indigenous population proportion of 16.9% (PDC, 2011). A transient workforce also contributes to the Pilbara population. In 2010, the fly-in, fly-out (FIFO) workforces accounted for approximately 15,464 additional people or an additional 32.5%. This is estimated to rise to 33,685 by 2020 (PDC, 2011).

7.2.1.2 Education, Employment and Training

The percentage of secondary school children attending an educational institution in the Shire of East Pilbara and the Pilbara region is 7%, a figure well below the State average (18%) (ABS, 2007a; 2007b; 2007c). This may be due to working families with older children moving out of the region and relocating to areas with more comprehensive secondary educational facilities and regional students attending boarding schools.

In 2009, unemployment in the Shire of East Pilbara was recorded at 3.9%. During the same period this rate was higher than both the Pilbara (3.4%) and the State (3.2%) (Office of Crime Prevention, 2009). In the 2007-08 financial year the mean taxable income in the Pilbara was $76,122. Furthermore, from 1997 to 2008 the Pilbara's mean taxable income was consistently higher than WA averages (PDC, 2011).

7.2.1.3 Health

The Shire of East Pilbara offers medical services for both the Indigenous and the non-Indigenous populations. These services include the Marble Bar Nursing Post, Newman Hospital, Newman Population Health, Nullagine Community Health Service and Puntukurnu Aboriginal Medical Services which provide outreach services in Jigalong, Kunawarritji, Parnngurr and Punmu (DoH, 2011). There are no residential aged care services in the East Pilbara; however, a respite dialysis centre operates in Jigalong for a period on a quarterly basis (Puntukurnu Aboriginal Medical Services, 2011). Aboriginal Medical Services are relatively well represented in the Shire; however, an expansion and upgrade of community services across the Pilbara is required (PDC, 2011).

7.2.1.4 Housing

Home ownership in the Shire is 7.7% compared to 31.4% across WA (ABS, 2007; 2007b; 2007c). This may be due to a proportion of the population pursuing FIFO employment and residing only temporarily in the region.

The Pilbara Housing and Land Snapshot document (PDC, 2012) prepared by the Pilbara Development Commission, stated the cost to purchase property in the region is extremely high. The average settlement price in Karratha during March 2012 was $826,176 and $1,242,833 in Port Hedland.

Occupation rates by government employees of government regional officers housing is high throughout the Pilbara (PDC, 2012). This reflects the inability of many government workers to afford the high rents charged in the Shire. Table 7-1 presents occupancy rates in government regional officers housing.

Table 7-1: Government regional officers housing occupancy rates

Government Regional Officers Housing Occupancy Rates			
Town Site	Housing Stock	Occupied	Waiting List
Tom Price	68	66	2
Newman	130	110	0
Marble Bar	11	8	0
South Hedland	337	289	3

Source: PDC (2012)

7.2.1.5 Social Investment

A range of social investment programmes are underway in the Pilbara and within the Shire of East Pilbara aimed at addressing training and life skills, Indigenous employment, as well as literacy and education. These are delivered via partnerships between resource companies, government agencies and service providers.

7.2.1.6 Remoteness and Community Involvement

According to the Accessibility/Remoteness Index of Australia (Department of Health and Aging [DoHC], 2001), the Shire of East Pilbara is considered very remote; geographically disadvantaged; and has limited access to goods and services, as well as opportunities for social interaction.

The level of volunteering in the Shire and the Pilbara is comparable with the WA average at just over 15% (ABS, 2007a; 2007b; 2007c), indicating a healthy level of community involvement across the region. The existence and implementation of employee community volunteer programmes by mining companies may contribute to this percentage.

7.2.1.7 Profile Summary

A summary of the key facts and figures of local communities in the Shire of East Pilbara are presented in Table 7-2.

7.3 Land Use

The Project is located in a remote area on Vacant Crown Land. There are no commercial land uses active in the area. The local indigenous communities (Parnngurr 80 km southeast; and Punmu 113 km northeast of the Project) use land in the area for traditional purposes including hunting.

Karlamilyi National Park is located approximately 5 km south of the Project area (Figure 7-3) and is an example of a relatively undisturbed desert riverine ecosystem. The Park is rarely visited by tourists due to its remoteness and poor road access.

Table 7-2: Community key facts and figures

Parnngurr	Jigalong
Population size: 111 Medical clinic available	Population size: 200 Unemployment rate: 46.5% Median weekly Income: $224 Respite dialysis centre and clinic available
Kunawarritji	**Warralong**
Population size: 56 Population can reach 700 – 1,000 people during times of cultural business Average population density of 3.3 people per house Clinic staffed by one nurse	Population size: 155 42% of the population are unemployed Average population density of 8.6 people per house No medical services in town
Punmu	**Irrungadji**
Population size: 130 Population completed Year 12: 15.4% Weekly rent is between $1 and $49 Medical clinic available	Population size: 150 Average population density of 8.8 per house
Nullagine	**Marble Bar**
Population size: 218 28.2% of the population are unemployed Median weekly income: $325	Population size: 193 12.3% of the population are unemployed Median weekly income: $542
Newman	**Shire of East Pilbara**
Population size: 4, 244 1.4% of the population are unemployed Median weekly income: $1,095	Population size: 7,954 3.9% of the population are unemployed Median weekly income: $900 (approximately)

Sources: ABS (2007a), ABS (2007d), ABS (2007e), ABS (2007f), ABS (2007g), DIA (2011a), DIA (2011b), DIA (2011c), DIA (2011d), DIA (2011e), DIA (2011f), DIA (2011g) and PDC (2011).

7.4 Conservation Areas

7.4.1 Karlamilyi National Park

The Karlamilyi National Park (formerly Rudall River National Park) was proclaimed an A Class Reserve on 13 April 1977 for the purposes of conserving the arid river system and environment of the Rudall River. The Rudall River has its head waters in a low, dissected plateau and flows to the northeast through sand dune country into Lake Dora. The designated park boundary did not follow any ecological or geomorphic features and originally included part of the Project area (Figure 7-3).

In 1991, a submission was presented to the Director General, Department of Minerals and Energy regarding excising an area from the Karlamilyi National Park which included the Kintyre deposits. In April 1994, the WA State Government approved the excision and compensatory land was added along the western boundary of the national park. The excision measured 151 km^2 and the compensatory land measured 154 km^2. At the same time the area of the National Park was recalculated using current surveying methods to 1,283,406 ha (12,835 km^2). The Project area is outside the boundary of the Karlamilyi National Park (Figure 7-3).

7.4.2 Register of the National Estate

The Register of the National Estate was originally established under the *Australian Heritage Commission Act 1975*. In 2004, responsibility for maintaining the Register shifted to the Australian Heritage Council, under the *Australian Heritage Council Act 2003* (AHC Act). On 1 January 2004, a new national heritage system was established under the EPBC Act. This led to the introduction of the National Heritage List, which was designed to recognise and protect places of outstanding heritage to the nation, and the Commonwealth

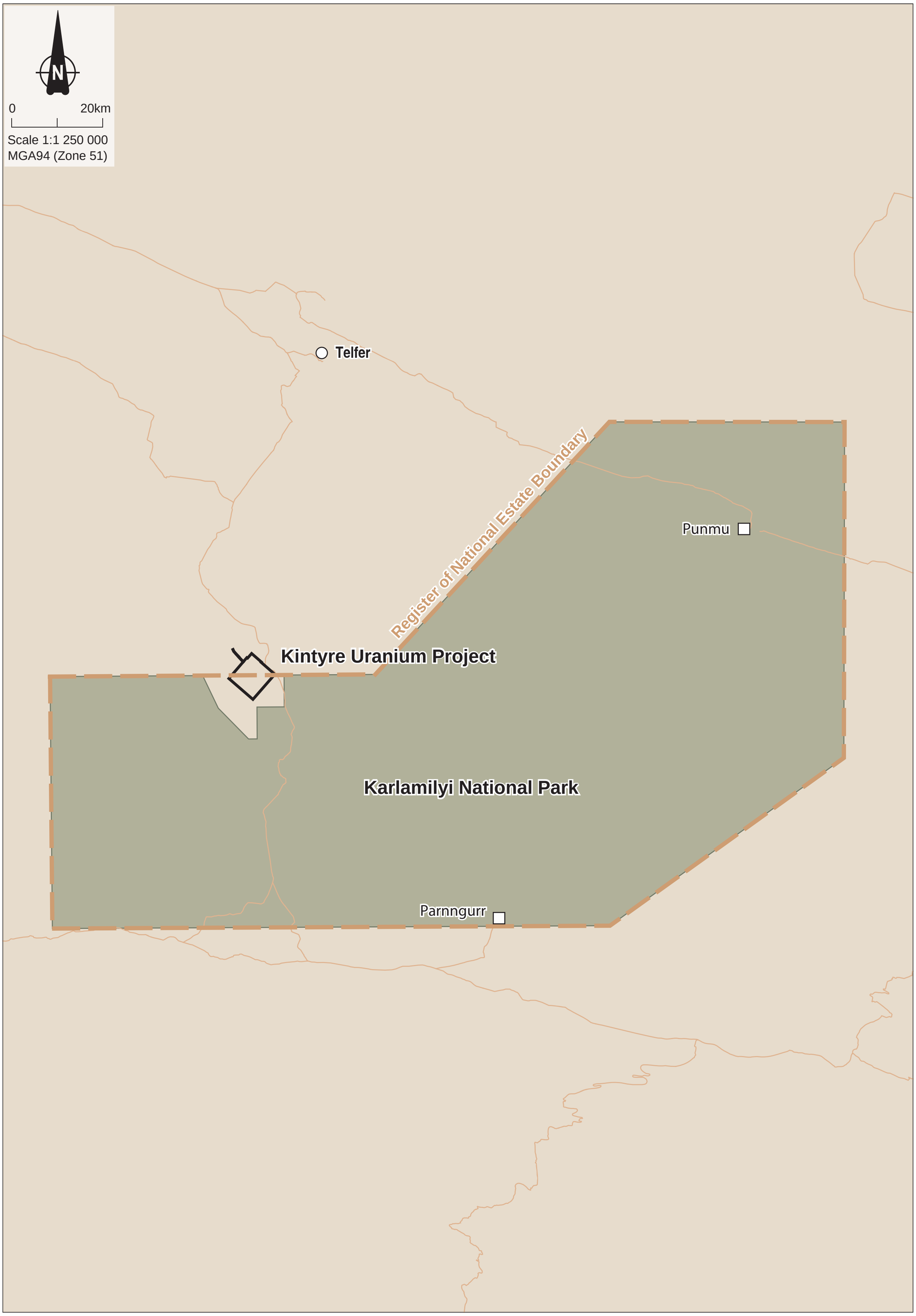

Figure 7-3: Karlamilyi National Park and the Register of the National Estate Area

Heritage List. On 19 February 2007 the Register of National Estate was frozen and listed places were transferred to the National Heritage List, State heritage lists or other heritage lists (such as local government heritage lists). On 19 February 2012, all references to the Register of National Estate were removed from the EPBC Act and the AHC Act.

The Rudall River National Park was listed on the Register of the National Estate in 1978 (Place ID number 10054) and was noted as being:

> *"significant for maintaining ongoing geomorphic and ecological processes within a tropical desert environment. It contains an entire landscape sequence which includes extensive dune fields, table lands, an entire river/creek system, alluvial formations, saline lakes and palaeodrainage lines."*

The boundary of the place identified on the Register of the National Estate followed the old Rudall River National Park boundary and included part of the Project area (Figure 7-3).

The Rudall River National Park (1978 boundary) is not listed on the National Heritage List. However, the site is listed on the State Register of Heritage Places under the *Heritage of Western Australia Act 1990*. The majority of the site is also within the Karlamilyi National Park protected under the State *Conservation and Land Management Act 1984*, but this does not include the Project area (Figure 7-3).

7.4.3 Wild Rivers

Wild rivers are defined as those rivers which are undisturbed by the impacts of modern technological society. They remain undammed, and exist in catchments where biological and hydrological processes continue without significant disturbance. Wild Rivers occur in a variety of landscapes, and may be permanent, seasonal or dry watercourses that flow or only flow occasionally (Water and Rivers Commission [WRC], 1999).

Through a project with the Australian Heritage Commission, the Department of Water (DoW) originally recognised 49 wild rivers in Western Australia (WRC, 1999). Thirty-seven of these wild rivers are located in the Kimberley and Pilbara regions.

The Rudall River, one of the recognised wild rivers, occurs approximately 20 km south of the Project. According to the mapping provided by the DoW the Project occurs within the Rudall River Wild River area. The Project occurs in the Yandagooge Creek sub-catchment which feeds the Yandagooge and Coolbro Creeks. In years of average rainfall, when stream flow occurs, the discharge dissipates into the floodplain and sand dunes at the outflow of Coolbro Creek and does not reach the Rudall River. There is anecdotal evidence from Aboriginal elders suggesting that in years of significant flood events the discharge from Coolbro Creek ultimately flows along sand dunes in an easterly direction towards Rudall River. This is supported by contour data and landforms in particular the presence of claypans suggesting inundation of these areas.

In recognition of the classification, Cameco planned the Project layout to minimise the impact on both the form and function of Yandagooge Creek. Cameco has imposed a buffer along both sides of the Creek and other than a planned creek crossing and some environmental monitoring activities the creeks will remain largely physically undisturbed. The Project has also been designed to retain stormwater during operations with scope to store any flood water from within the site in ponds for use in ore processing (Section 8.3.5).

Cameco has installed stream flow and sampling equipment in Yandagooge Creek to improve knowledge of catchment run off characteristics and build a baseline of water quality information during flood events.

7.5 Climate

The Project area has an arid climate with hot summers and warm dry winters. Since the discovery of the Project, a series of meteorological monitoring programmes have been undertaken within the region in order to define the existing environmental characteristics of the Project area.

Meteorological monitoring programmes commenced in 1987 and continued until 1992 when the Project was put into care and maintenance. Monitoring recommenced in 1996 with the advancement of a full feasibility study and ended in 1998 as the Project was once again placed under care and maintenance.

Cameco commenced meteorological and particulate monitoring in July 2010. The monitoring network consists of a meteorological monitoring station to measure wind speed and direction, temperature, solar radiation, relative humidity, barometric

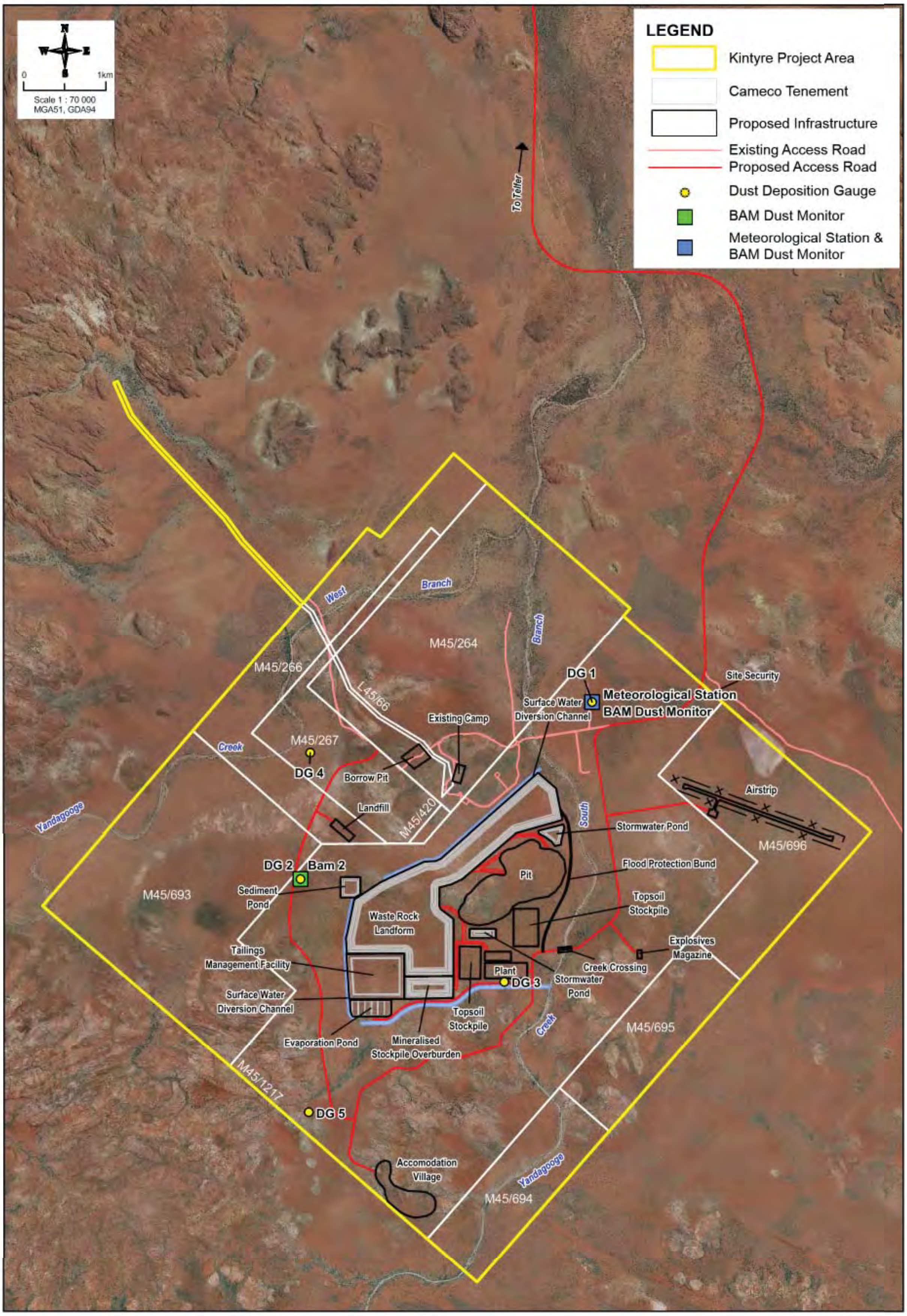

Figure 7-4: Location of meteorological and dust monitors

pressure and rainfall; a portable continuous Beta Attenuation Monitor (BAM) to measure particulate matter less than 10 microns (µm) in equivalent aerodynamic diameter (PM_{10}), and five dust deposition gauges. In addition, two Environmental Radon Daughter Monitors and two air pumps for sampling particulate matter (PM_{10}) for alpha radiation analysis have also been installed. The location of the meteorological and dust monitoring sites are shown on Figure 7-4.

A summary of the site's climate is summarised below:

- The prevailing winds originate from the southeast quadrant and dominate the autumn, winter and late-summer months. Winds during spring and early-summer exhibit a greater degree of variability and the frequency of west-north-westerly winds increases.
- The average monthly wind speed is around 3.5 m/s. Peak wind speeds are generally experienced during the summer months and tend to correspond with winds from the southeast. The maximum 15-minute average wind speed reported for the monitoring periods was 18.5 m/s in February 1997.
- The annual average temperature measured at Kintyre is around 25°C. The highest maximum daily temperatures can reach over 40°C during the summer months. Lower temperatures are recorded during the winter months, with monthly average minimum temperatures around 10°C.
- Higher evaporation rates are also associated with higher temperatures during the summer months.
- Total annual rainfall varies between years. However, the highest monthly rainfalls tend to occur in the summer months, indicative of the influence of cyclonic conditions in the region.
- Higher measurements of relative humidity and lower measurements of barometric pressure also tend to coincide with wetter summer months, which may experience some cyclonic effects. Lower humidity and higher pressures are more common during the drier winter months (Dames & Moore, 1990; 1998).

7.5.1 Climate Change

Information on climate change and how it affects Australia's climate is available on the website www.climatechangeinaustralia.gov.au (accessed 23 November 2011). A technical report on climate change in Australia was produced by CSIRO (2007). The information presented in this report is drawn from international climate change research including conclusions from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), research completed within the Australian Climate Change Science Programme by CSIRO and the Australian Bureau of Meteorology in partnership with the Australian Greenhouse Office. The document also gives projections of future changes to Australia's climate and provides information on how to apply the projections in impact studies and in risk assessments.

The CSIRO (2007) indicates that the northwest of Australia has experienced an increase in rainfall since 1950. Trends in the most extreme rainfall events are also rising faster than trends in the mean. Australian surface temperatures have risen significantly over the past century with warming since the middle of the 20th century most likely due to anthropogenic increases in greenhouse gases. Average temperatures have increased by 0.9°C since 1950, with significant regional variations (CSIRO, 2007).

The Bureau of Meteorology also has a series of trend maps that show changes in rainfall, temperature and evaporation over selected time periods (http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi accessed 23 November 2011). In the East Pilbara where the Project is located there has been a trend of increasing rainfall and increasing temperatures particularly since 1950, consistent with the CSIRO report. For example annual rainfall has increased on average 10 mm every 10 years since 1900, and annual rainfall has increased on average 50 mm every 10 years since 1950 mostly during the summer months. Mean and maximum temperatures have shown an increase in 0.1°C every 10 years since 1910 and mean and maximum temperatures have increased 0.3°C on average since 1950. Minimum temperatures have also increased 0.15°C every 10 years since 1910 and 0.2°C every 10 years since 1950.

The best estimate of annual warming over Australia by 2030 relative to the climate of 1990 is approximately 1.0°C with warmings of around 0.7°C to 0.9°C in coastal areas and 1°C to 1.2°C inland, based on the high emission scenario. Allowing for emission scenario uncertainty, warming is still predicted to be at least 0.4°C in all regions and may be as much as 1.8°C in some inland regions. Later in the century the warming is more dependent upon the assumed emission scenario with the best estimate of 1.2°C for the low emissions scenario and 2.2°C for the high emissions scenario by 2050 (relative to 1990 temperatures). Best estimates for changes in temperature by 2070 are 1.8°C under the low emissions scenario and 3.4°C under the high emissions scenario (CSIRO, 2007).

Annual potential evapotranspiration is projected to increase over most of Australia with the largest increase in the north and east where the predicted change by 2030 ranges from little change to a 6% increase with the best estimate of around 2% increase (CSIRO, 2007).

Australian regional studies indicate a likely increase in the proportion of severe tropical cyclones but a possible decrease in the total number of cyclones experienced (CSIRO, 2007).

In summary, the northwest of Western Australia has experienced an increasing trend in rainfall and surface temperatures, particularly since the middle of the 20th century. Predictions of future climate change are dependent on the selected emission scenario modelled. Overall temperatures are expected to increase across Australia with greatest increases observed in inland Australia.

Cameco has taken the above findings into consideration in the design of the Project accounting for a possible increasing trend in annual rainfall and extreme weather events. Surface water design parameters are discussed in further detail in Section 8.3.

7.6 Natural Hazards

7.6.1 Fire

Fire is a natural part of the Australian landscape with many of the fires in remote areas such as the Eastern Pilbara started by lightning strikes. The Indigenous people have also used fire for thousands of years as part of their traditional land management practices. However, with the arrival of Europeans the patterns, frequency and intensity of fires has changed, resulting in changes to floristic and faunal characteristics (DEC *et al*., 2011). Fires, whether naturally occurring or as a result of human activities, can also pose a threat to human life and property.

Some vegetation communities such as mulga (*Acacia aneura*) or snakewood (*Acacia xiphophylla*) shrublands are considered to be “fire sensitive” where adult plants are killed if the entire canopy is burnt during very hot fires (Latz, 1995). However, many Acacia species regenerate from seed following fire. In spinifex-dominated communities fire management aimed at providing a mosaic of fuel ages and vegetation structure is considered important to enhance and maintain species diversity (DEC *et al*., 2011).

The Project is located in a remote arid environment which can experience severe thunderstorms and cyclonic activity. Parts of the Project area were burnt by a severe fire in 2009 which resulted in changes to the vegetation structure (Bennett Consulting, 2010). Due to the remoteness of the site, emergency services will not be readily available to assist in fire fighting should this be needed. The site will have one main access road from the north, although the track through Karlamilyi National Park could be used for fire fighting purposes if required. Cameco will therefore need to have on-site fire fighting equipment and personnel trained to respond to accidental fires and wildfires. A Fire Prevention and Management Plan is presented as Appendix D4.

7.6.2 Drought

Drought is commonly defined as a prolonged period of below average rainfall resulting in acute water shortages. The Project area lies within the Little Sandy Desert subregion (Thackway and Cresswell, 1995) and is characterised by low rainfall and high rainfall variability. The land is considered marginal for pastoral activities and unsuitable for agriculture.

The BoM Telfer meteorological station has recorded an average annual rainfall of 367 mm since 1974. Below average rainfall for more than two successive years was experienced in 1974 to 1977; 1984 to 1987; 1989 to 1992; and 2008 to 2010 (www.bom.gov.au accessed 23 November 2011). However, as outlined in Section 7.5.1 the area has experienced a trend of increasing rainfall since the 1950s.

Water supplies for the Project will be from groundwater sources, although an extensive system of water recycling will also be incorporated into the metallurgical plant design (Section 6.5).

7.6.3 Dust Storms

Located between the Great Sandy Desert to the north, the Little Sandy Desert to the south and the semi-arid Pilbara to the west the Project area could experience dust storms as a result of strong winds following drought conditions. However, a study by Middleton (1984), which estimated the frequency of dust storms across Australia, indicated the majority of Western Australia, including the Project area is likely to be subject to less than one dust storm per year.

The management of dust emissions from the Project is an important aspect from a radiation management and health and safety and perspective. A Dust Management Plan for the Project is presented as Appendix D5.

7.6.4 Tropical Cyclones and Storm Events

Tropical cyclones are low pressure systems that form over warm tropical waters and produce sustained gale force winds of at least 63 km/ hr. Severe tropical cyclones produce sustained hurricane force winds of at least 118 km/hr. During the cyclone season (typically November to April) an average of ten tropical cyclones develop over Australian waters, of which six cross the coast mostly over the northwest of Western Australia and northeast Queensland. However, there may be considerable variability in cyclone numbers from year to year (http://www.bom.gov.au/cyclone/about/ accessed 23 November 2011).

The National Climate Centre of the Bureau of Meteorology has collated a southern hemisphere tropical cyclone archive consisting of cyclone track data for a 36 year period from 1969/70 to 2005/06 (http://reg.bom.gov.au/jsp/ncc/climate_averages/tropical-cyclones/index.jsp?period=eln#maps accessed 23 November 2011). This dataset shows the average number of cyclones per cyclone season in El Niño years, La Niña years, neutral years and all years. The Project area is located in a region which experiences an average of 0.2 to 0.4 cyclones per year when considering data from all years (i.e. one to two cyclones every five years). However, this frequency may be reduced to 0.1 to 0.2 cyclones per year in years that experience a La Niña event.

The Project is located in Region A4 (greater than 150 km from the northwest coast) as defined by the Australian and New Zealand Standard *AS/NZS 1170.2:2002 Structural design actions – Wind actions*. Irrespective of the distance from the coastline, cyclones do penetrate into the inland regions of the State. The Department of Mines and Petroleum (DMP) recommends that under the *Mines Safety and Inspection Act 1994* employers err on the side of caution in relation to the design and construction of buildings and other structures and the development of emergency plans and procedures (DoCEP, 2008).

Severe thunderstorms can occur anywhere in Australia and are more common between September and March in the northern part of Australia. A severe thunderstorm is defined by the Bureau of Meteorology as one which produces hail greater than 2 cm diameter, wind gusts of 90 km/h or greater, flash flooding and/or tornadoes (http://www.bom.gov.au/info/thunder/ accessed 23 November 2011).

Cameco has taken the risk of cyclonic weather and severe storms into consideration in the design of stormwater management structures (Section 8.3) and will ensure buildings and other structures are designed and built to withstand extreme climatic conditions. Under the *Mines Safety and Inspection Act 1994* Cameco will also be required to prepare emergency plans and procedures that include actions to be undertaken in the threat of cyclonic or storm activity.

7.6.5 Seismic Activity

The University of Western Australia's School of Earth and Geographical Sciences has produced a webpage with information on seismic activity within Western Australia (http://www.seismicity.see.uwa.edu.au/welcome/seismicity_of_western_australia accessed 23 November 2011). Relative to the rest of the Australian continent, northern Western Australia is quite seismically active. Much of this seismicity occurs off the northwest coast, but large earthquakes have also been recorded onshore. One of the largest earthquakes (magnitude of 7.75) known in the Australian region occurred off the northwest coast on 19 Nov 1906 and was felt over the entire western half of Western Australia. More recently a number of earthquakes exceeding magnitude 6 have been recorded in the northwest of Western Australia.

The closest seismic monitoring station to the Project area is located in Marble Bar and was opened in 2001. A map of significant earthquakes in the north of Western Australia provided by the University of Western Australia's website indicates that several earthquakes of magnitude 5.5 or greater have occurred north and east of the Project area (http://www.seismicity.see.uwa.edu.au/welcome/seismicity_of_western_australia accessed 23 November 2011).

The seismicity of the region has been taken into account in the design of the pit and the TMF.