Woodsreef Mine Major Rehabilitation Project

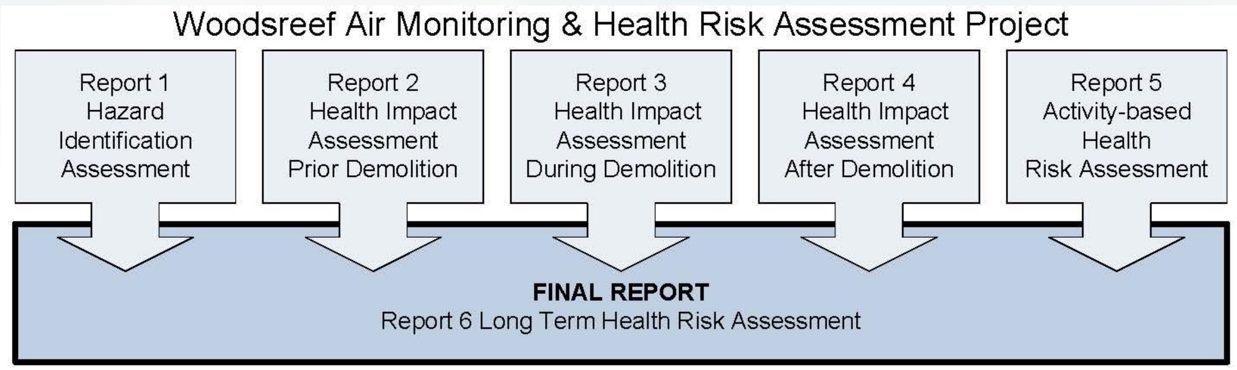
Report 6: Long Term Health Risk Assessment

Report Number 610.10893.00230

25 October 2017

NSW Department of Planning and Environment
516 High Street
Maitland NSW 2320

Version: v0.1



Woodsreef Mine Major Rehabilitation Project

Report 6: Long Term Health Risk Assessment

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Executive Summary

NSW Department of Planning and Environment engaged SLR Consulting Australia Pty Ltd (SLR) to undertake a series of Health Impact Assessments of the Woodsreef Mine site as part of the Woodsreef Mine Major Rehabilitation Project. This report is the sixth and final report, relating to the long term health risk component of the task.

Woodsreef Mine is a derelict, open cut asbestos mine located approximately 15 km east of Barraba in the Northern NSW Tablelands. The mine extends over an area of about 290 hectares, comprising predominantly Crown Land and is situated in an area where naturally occurring asbestos is found in significant concentrations in the soil and ground surfaces over a broad area both inside and outside the mine footprint. Thus the local environment may be impacted by both the effects of previous mining operations as well as areas of naturally occurring asbestos being subject to natural weathering of the parent material potentially leading to the enrichment of local soils with asbestos fibres.

This final Health Risk Assessment Report relates to long term public health risk associated with the mine after completion of the demolition works project and people conducting activities that are regularly undertaken near the mine as well as people living near the mine.

Health Effects

Inhalation of asbestos fibres is a potential health risk, leading to a number of lung disorders, including lung cancer and mesothelioma. The likelihood of disease arising from exposure to asbestos is generally associated with cumulative exposure over a lifetime. Factors that add up to the lifetime exposure include frequency of exposure, concentration of airborne asbestos during each exposure and length of exposure. Put simply a short isolated exposure at low concentration is unlikely to cause disease but long term heavy exposure is likely to lead to asbestos related diseases in those exposed.

Risk Factors

To classify potential public health risk for local communities and other members of the public, a semi quantitative and qualitative method was used based on the risk factors considered to influence the likelihood of asbestos exposure to persons and communities. These factors were broadly divided into primary risk factors and secondary risk factors as set out below:

Primary risk factors were considered to be the following:

- Airborne asbestos fibre concentrations recorded at locations near Exposure Groups from historic records and monitoring data collected during the remediation works.
- Proximity of Exposure Groups to the mine.
- Proximity of Exposure Groups to naturally occurring asbestos (NOA).
- Conducting recreational activities that disturb the soil.

Secondary risk factors were considered to be the following:

- Possibility for airborne asbestos fibre concentrations exceeding 0.01 fibres/mL air during short term disturbances (due to either natural or man-made forces) of asbestos contaminated soils at locations near Exposure Groups.
- Likelihood of Exposure Groups being near mine site during short term disturbances of potentially asbestos contaminated soils by forces of nature, including wind and rain.
- Likelihood of Exposure Groups creating short term disturbances of potentially asbestos contaminated soils near the mine.
- Frequency of visits to mine site vicinity.

- Time spent near mine vicinity during each visit.

Asbestos fibre monitoring

Airborne asbestos fibre monitoring in the vicinity of the mine has been undertaken a number of times between 1992 and 2016. Monitoring occurred either offsite as background monitoring or onsite as part of the monitoring during site works and remediation works. The findings from these studies were:

The majority of the monitoring at and around the mine site from 1992 to 2016 indicated that airborne asbestos fibre concentrations were at levels less than 0.01 fibres per mL of air. That is concentrations were below the detection limit of the monitoring method. Therefore, the likely concentrations of airborne asbestos during the monitoring periods were at least ten times lower than the current occupational exposure limit of Safe Work Australia which is 0.1 fibres per mL of air.

REPORT FINDINGS:

Air Monitoring

1. Asbestos fibres are only likely to be airborne at detectable concentrations when there is a physical disturbance on the mine site itself.

2. Detectable concentrations of airborne asbestos fibres have not been recorded outside the mine site in the surrounding communities and locations.

3. Airborne asbestos fibre concentrations above 0.01 fibres per mL air, that is the detection limit of the method, have only been recorded during three periods on the mine site. These occurred when remediation activities have occurred on the mine site and only at sampling locations on the mine site itself. The indicative approximation of samples above the detection limit is one sample above the detection limit per 1,825 samples taken on the mine site.

4. Repeated monitoring of airborne asbestos fibre concentrations conducted at locations near the mine site, from 2013 to 2016. All samples recorded airborne asbestos fibre concentrations were at levels less than 0.01 fibres per mL of air (the detection limit of the methodology).

5. For Exposure Groups that may be routinely exposed to airborne asbestos fibres, concentrations would likely be below the minimum detection limit of the measurement technique (less than 0.01 fibres per mL of air).

Exposure Risk

Based on the above selected Primary and Secondary risk factors, long term exposure risks to the community from exposure to airborne asbestos have been determined for communities adjacent to the mine and members of the public who access areas adjacent to the site. These are set out in **Table 1**.

Table 1 Community Exposure Groupings - Estimated Long Term Risks from Exposure to Airborne Asbestos Fibres Associated with the Woodsreef Mine and Surrounds

Exposure Group	Estimated Long Term Exposure Risk from Airborne Asbestos Fibres
Barraba Residents	Negligible*
Rural Residents in immediate vicinity to the Mine	Negligible
Tamworth – Control Group	Negligible
Woodsreef Residents	Negligible to Low#
Passive Recreation conducted in proximity to the Mine	Negligible to Low
Active Recreation conducted in proximity to the Mine	Negligible to Low

Note

* Health risk is unlikely given the combination of all known factors described above

Health risk is unlikely to be low, but clearly possible given the expected combination of factors, including proximity to both the mine and naturally occurring asbestos.

Site Risk Mitigation Measures

The current report outlines suggested mitigation measures that should be considered as part of the long term planning for the site and recommends engineering-based expansion of restricted areas, encapsulation, review of siltation and drainage around road cuttings, or more administrative controls such as improved signage and monitoring.

A number of locations around the mine have been determined as priority areas due to the high potential for public interaction in the area or potential for run-off onto private lands. Ultimately, maintaining site containment and restricting access, alongside routine inspection and monitoring is considered the most effective method in minimising potential long term health risks to the surrounding populations. Furthermore, health risk communication through education and information sharing to the local community will be an important factor to prevent inadvertent exposure risk.

It is concluded that the long term public health risk is likely to be negligible to low, for potential asbestos exposure arising from the abandoned mine site for adjacent communities and to members of the public that may have intermittent access to areas adjacent to the mine site.

Several controls are proposed that are considered critical in minimising potential long term asbestos exposure health risks.

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1 GLOSSARY

ABS	Australian Bureau of Statistics
ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substance and Disease Registry
BOM	Australian Government Bureau of Meteorology
^{O}C	Degrees Celsius
CCMA	Clear Creek Management Area (US EPA, 2008.)
COPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
F/mL	Fibres per millilitre
F/mL/year	Fibres per millilitre per year
$g/s/m^2$	Grams per second per square metre
IARC	International Agency for Research on Cancer
JSA	Job safety analysis
km	Kilometre
m	Metre
m^2	square metre
m/s	Metres per second
mL	Millilitre
µm	micrometre, one millionth of a metre
NOA	naturally occurring asbestos
NOHSC	National Occupational Health and Safety Commission
NSW	New South Wales
PCM	Phase contrast microscopy
PPE	Personal protective equipment
RPE	Respiratory protective equipment
SEIFA	Socio-Economic Indexes for Areas
SLR	SLR Consulting Australia Pty Ltd

SSC	State suburb
TWA	Time weighted average
US EPA	United States Environmental Protection Agency

2 INTRODUCTION

2.1 Introduction

The NSW Department of Planning and Environment engaged SLR Consulting Australia Pty Ltd (SLR) to undertake a long term health risk assessment which included air monitoring, a series of health impact assessments reports and risk assessments associated with the Woodsreef Mine site as part of the Woodsreef Mine Major Rehabilitation Project.

The Woodsreef Mine is a derelict open cut asbestos mine located approximately 15 km east of Barraba in the Northern NSW Tablelands. The former mine extends over an area of about 290 hectares, comprising predominantly Crown Land.

Open cut mining for chrysotile asbestos first occurred at Woodsreef between 1918 and 1923. The Chrysotile Corporation of Australia carried out large scale mining between 1972 and 1983. The mine closed in 1983 due to high production costs and it is now a derelict mine.

Woodsreef Mine includes a waste rock dump, a tailings dump, both of which are uncapped, and a number of open pits, some containing considerable quantities of water. There were a number of derelict buildings on site which were demolished in October 2014 to June 2015 as part of the Woodsreef Mine Major Rehabilitation Project. These derelict buildings were all substantially un-rehabilitated, and uncontained asbestos fibres can be found throughout the site. An amount of exposed processed asbestos still remains at the site.

The Woodsreef Mine Major Rehabilitation Project broadly consisted of a series of demolition and asbestos removal works, including demolition of the existing mill building, office building, product silos and remaining infrastructure. As the project progressed, five individual reports were prepared that ultimately provided information to guide the project or feed into this long term health risk assessment. These preceding reports were the following:

- Report 1 Hazard Identification Assessment, which investigated hazards associated with asbestos containing materials on the mine site and surrounding the mine site (SLR, 2013a)
- Report 2 Health Impact Assessment Prior Demolition (SLR, 2015)
- Report 3 Health Impact Assessment During Demolition (SLR, 2016)
- Report 4 Health Impact Assessment After Demolition (SLR, 2017a) and
- Report 5 Activity Based Health Risk Assessment, which investigated health risks associated with recreational activities conducted in the vicinity of the mine (SLR, 2017).

The information developed from these preceding reports was used in this current report to determine the long term community health risk associated with the Woodsreef Mine.

2.1.1 Objectives & Outcomes

The overall objective of the Long Term Health Risk Assessment was to determine the public health risk from potential asbestos exposure arising from the abandoned mine site.

The outcomes of the assessment were expected to guide priorities and activities that will be required to most effectively manage and mitigate any identified risk to the community.

This report, under the scope provided by the Woodsreef Taskforce, presents the methodology and findings of the Long Term Health Risk Assessment completed for the Woodsreef Mine Major Rehabilitation Project (Remediation) undertaken by SLR on behalf of the NSW Department of Planning and Environment.

The Health Risk Assessment was conducted as per the recommendations contained in enHealth (2012) and the framework set out in **Appendix A**.

2.2 Background

2.2.1 Naturally Occurring Asbestos

Asbestos refers to a group of six different fibrous minerals (amosite, chrysotile, crocidolite, and the fibrous varieties of tremolite, actinolite, and anthophyllite) that occur naturally in the environment. Chrysotile, belongs to the serpentine family of minerals, the others belong to the amphibole family. Asbestos can be found in a fibrous asbestiform or nonasbestiform state (many diverse forms of nonfibrous crystal shapes). Most amphibole and serpentine minerals in the earth's crust are of nonfibrous forms and are therefore not asbestiform (*ATSDR, 2001*).

Naturally occurring asbestos (NOA) refers to asbestos that occurs naturally in soil or rock and it is present in its natural state in many areas of eastern Australia. It has been estimated that potential asbestos containing rock accounts for approximately 0.2% of the land area of eastern New South Wales, however most deposits are small and commercial scale deposits rare (*Hendrickx, 2009*). **Figure 1** shows areas of naturally occurring asbestos in eastern NSW.

Figure 1 Naturally Occurring Asbestos in Eastern NSW (NSW Department of Planning and Environment, 2017)

Legend

Naturally Occuring Asbestos in NSW

POINT OCCURRENCE DATA

Mineral Occurences - Asbestos Sites

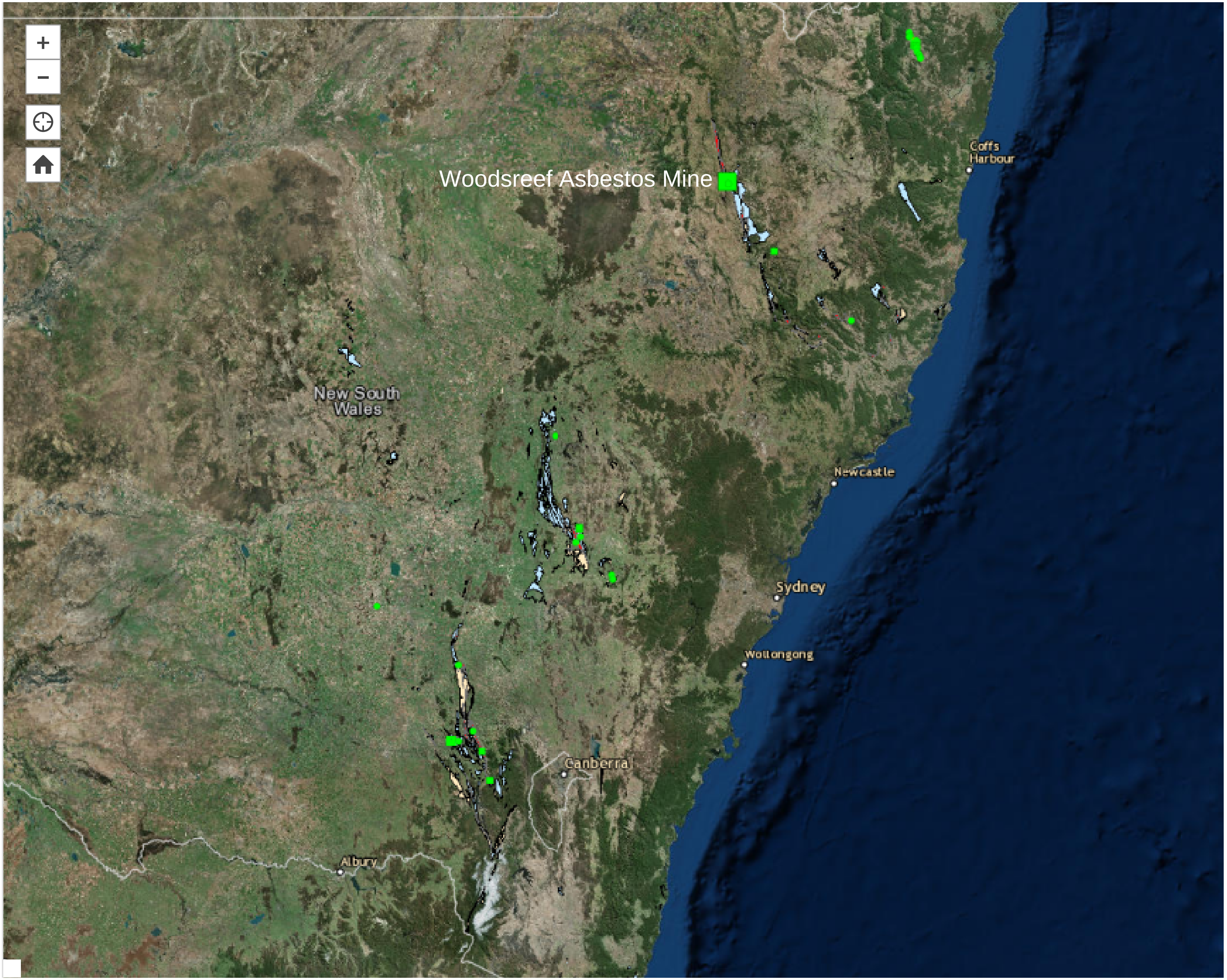
- VLGE
- LGE
- MED
- OCC
- SML

BROKEN HILL - GEOLOGICAL UNITS WITH ASBESTOS POTENTIAL

- Retrograde Ultrabasic Dykes with MEDIUM asbestos potential
- Dykes with HIGH asbestos potential
- Geological Units with HIGH asbestos potential

STATEWIDE - GEOLOGICAL UNITS WITH ASBESTOS POTENTIAL

- Geological Units with HIGH asbestos potential
- Geological Units with MEDIUM asbestos potential
- Geological Units with LOW asbestos potential



2.2.2 Woodsreef Deposit and Mine

The size and composition of the Woodsreef deposit was described by Dames & Moore (1997) as the following:

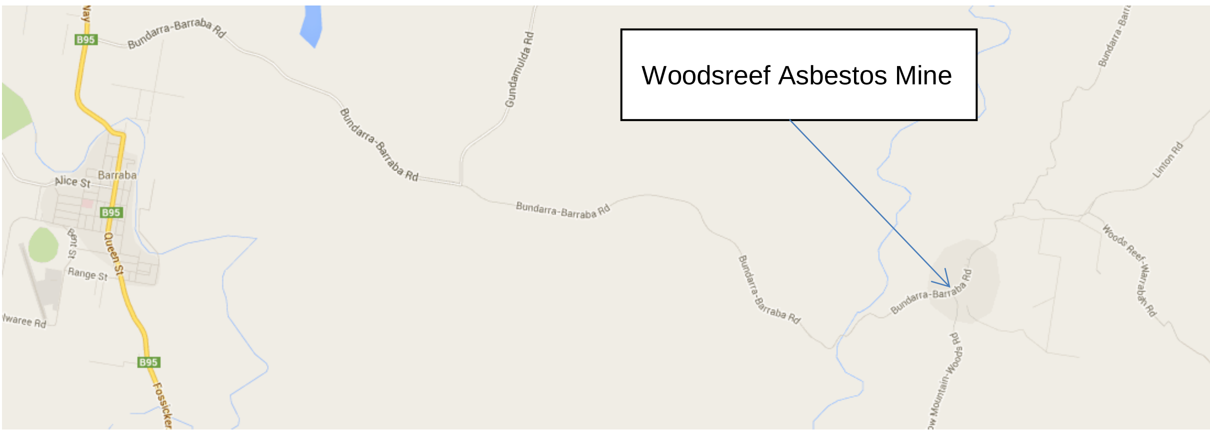
"*The Woodsreef deposit is developed in a massive pod of the Great Serpentine Belt, which is approximately 8 km long and 2 km wide (Brown, et al, 1992).The mineral at Woodsreef occurs as cross fibre to chemically identical host serpentine. The reserve approximates 12.1 million tonnes of proven ore (Brown, et al, 1992). The reserve is only medium in grade averaging 4% (Brown, et al, 1992)*."

The Woodsreef Mine site is situated at the locality of Woodsreef, 15km from Barraba on the Bundarra - Barraba Road (*NSW Department of Primary Industries Soil Conservation Service, 2013*). The mine is situated where The Mine Road (formerly known as Crow Mountain Road) joins the Bundarra - Barraba Road (See **Figure 2, Figure 3 and Figure 4**).

Figure 2 Woodsreef Mine Location

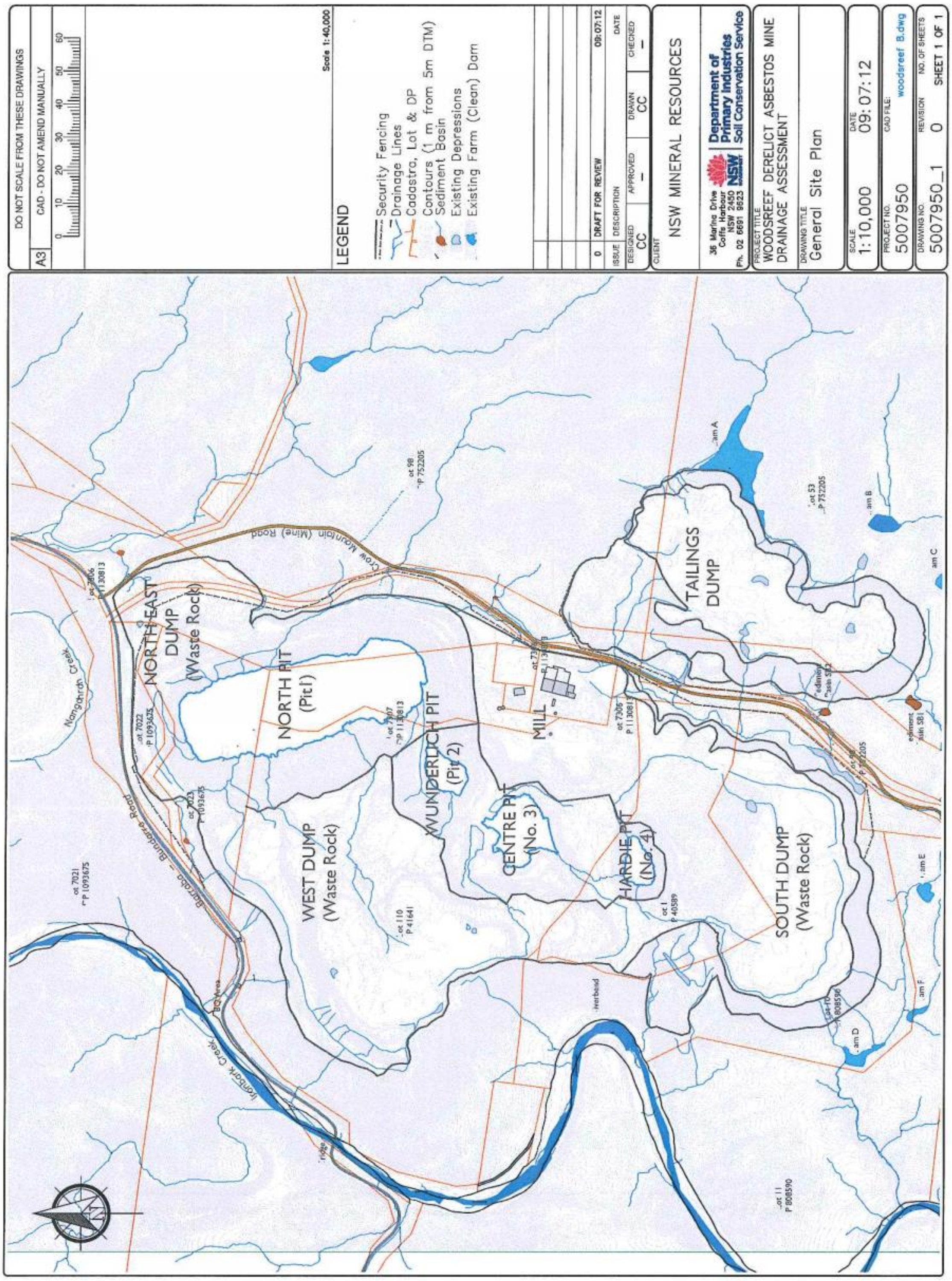
(Source: Google Maps, accessed 18/3/2014)

Figure 3 Woodsreef Mine Location in Relation to Barraba



(Source: Google Maps, accessed 18/3/2014)

Figure 4 Woodsreef Asbestos Mine Site Plan



(Source: NSW Department of Primary Industries Soil Conservation Service, 2013)

Site History

The Woodsreef site has been actively mined for asbestos during three periods. The first from 1919 to 1923 produced 2,500 tonnes of asbestos. After a long hiatus, the second mining period started in 1970 and ceased in 1973. The third and final period of mining commenced in 1975 and continued until 1983. From 1972 to 1983 approximately 550,000 tonnes of chrysotile was produced from 100 million tonnes of mined material (*Dames & Moore, 1997*; *NSW Department of Primary Industries Soil Conservation Service, 2013*). The mine has remained derelict since 1983.

The scale of total asbestos production at Woodsreef, of 552,500 tonnes, dwarfed all other asbestos mines in Australia. The Woodsreef mine accounted for approximately 73% of the total asbestos production in Australia (*Hendrickx, 2009*). Based on the estimates of world production by Virta (2006) the Woodsreef asbestos production equated to approximately 0.3% of the total world production of asbestos up until 2003. In contrast, the next largest Australian asbestos production occurred at the now infamous Wittenoom mine in Western Australia which produced 152,466 tonnes of crocidolite asbestos between 1937 and 1966 (*Gibbons, 2000*).

Current Status

The mine site is approximately 290 hectares in size and is reported to contain a 75 million tonne waste rock dump and 25 million tonne tailings dump. The site also contained two derelict buildings (prior to demolition). There are also four open pits on the site (*Parsons Brinckerhoff, 2012 & NSW Department of Primary Industries Soil Conservation Service, 2013*).

The mine site can be functionally divided into the following areas: Open Pits (four on site), Mill Building Area, Waste Dump (three sites, south, west and northeast), and a Tailings Dump. The Mine Road winds along the eastern perimeter of the mine except for a section of road that runs in-between the South Waste Dump and the Tailings Dump (See **Figure 4** above).

The Mill Building was demolished during remediation works between October 2014 and June 2015. During these works a Containment Cell was dug to the west of the Mill Building. Then the building was demolished and buried in the Containment Cell.

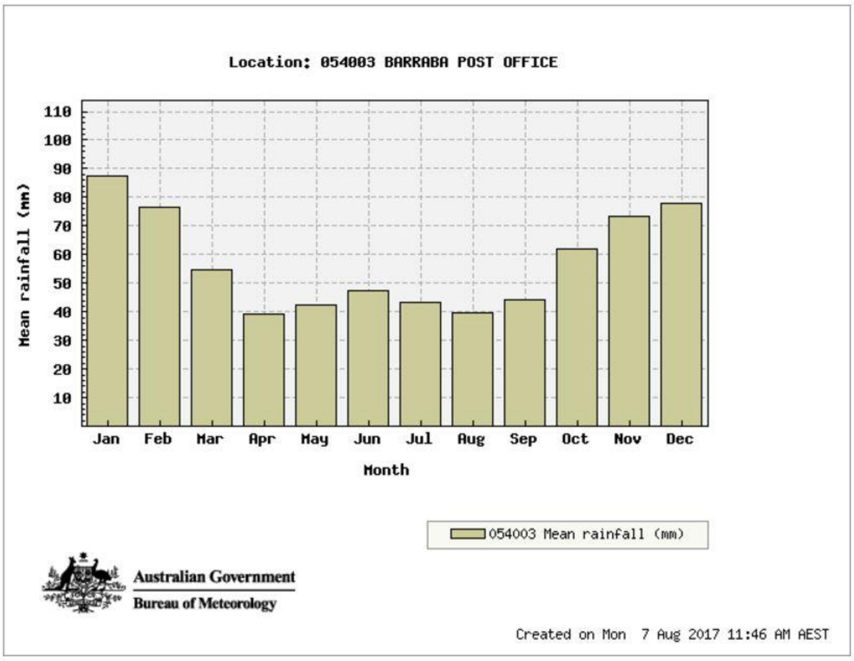
The Waste Dumps consist of processed rocks and overburden. The Tailings have been reported as partially processed ore, understood to be predominately asbestos, stockpiled for later reprocessing that never occurred (*NSW Department of Primary Industries Soil Conservation Service, 2013*).

Site Climate

The climatic conditions at Barraba will be broadly similar to the climate at Woodsreef Mine. Furthermore of the Bureau of Meteorology weather stations operating in the region near Woodsreef Mine, the weather station with the most extensive climate data is the Barraba Post Office (Weather Station Number: 054003 Opened: 1881 Status: Open Latitude 30.38°S, Longitude 150.61°E Elevation: 500m).

Records of rainfall at Barraba indicated the mean annual rainfall to be 687.7 mm, with the heaviest rainfall usually occurred in October to March. Monthly mean rainfall has been set out below in **Figure 5.** Monthly mean maximum and minimum temperatures have been set out below in **Figure 6** and **Figure 7**. Monthly mean wind speeds were less than 15kmph at both 9am and 3pm and have been set out below in **Figure 8** and **Figure 9**.

Figure 5 Barraba Mean Monthly Rainfall 1881-2017

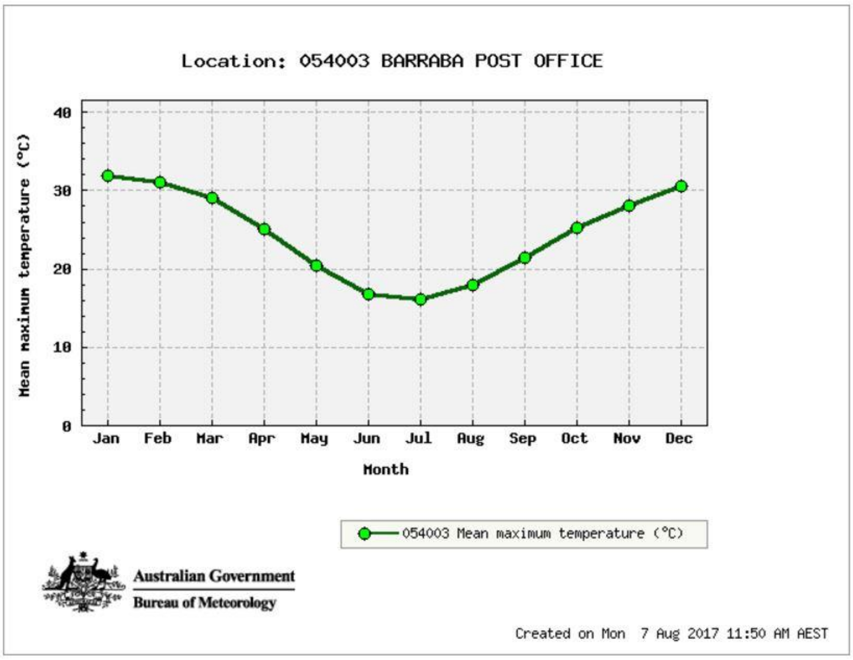


Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1881 to 2017	87.5	76.6	54.9	39.2	42.4	47.3	43.4	39.8	44.2	62.1	73.4	77.9	687.7	136

12.3 = Not quality controlled

(Source: Australian Government Bureau of Meteorology, www.bom.gov.au/climate/data/, accessed 7/8/2017)

Figure 6 Barraba Monthly Mean Maximum Temperatures 1966-2017

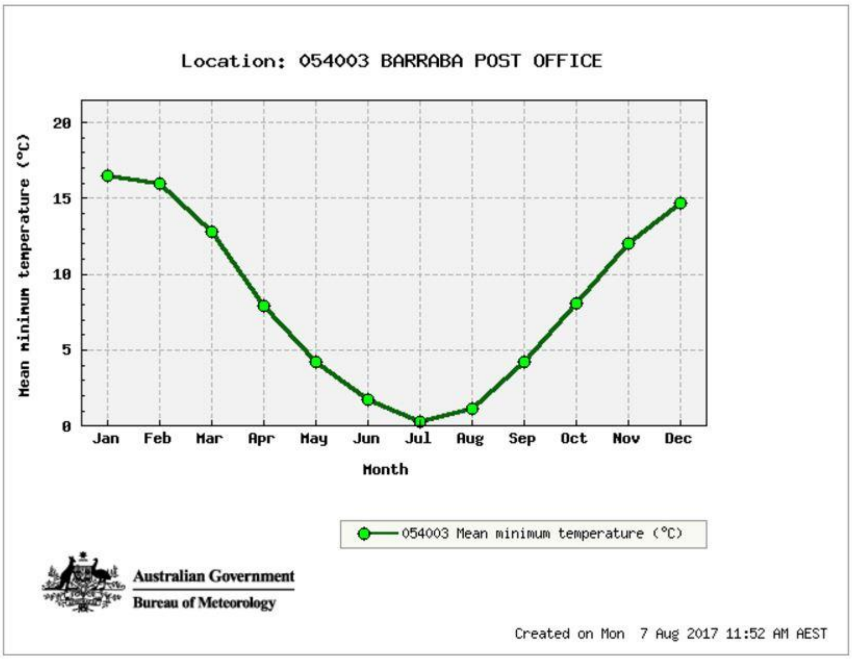


Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean maximum temperature (°C) for years 1966 to 2017	31.9	31.1	29.0	25.1	20.5	16.8	16.2	18.0	21.5	25.2	28.1	30.6	24.5	51

12.3 = Not quality controlled

(Source: Australian Government Bureau of Meteorology, www.bom.gov.au/climate/data/, accessed 7/8/2017)

Figure 7 Barraba Monthly Mean Minimum Temperatures 1966-2017

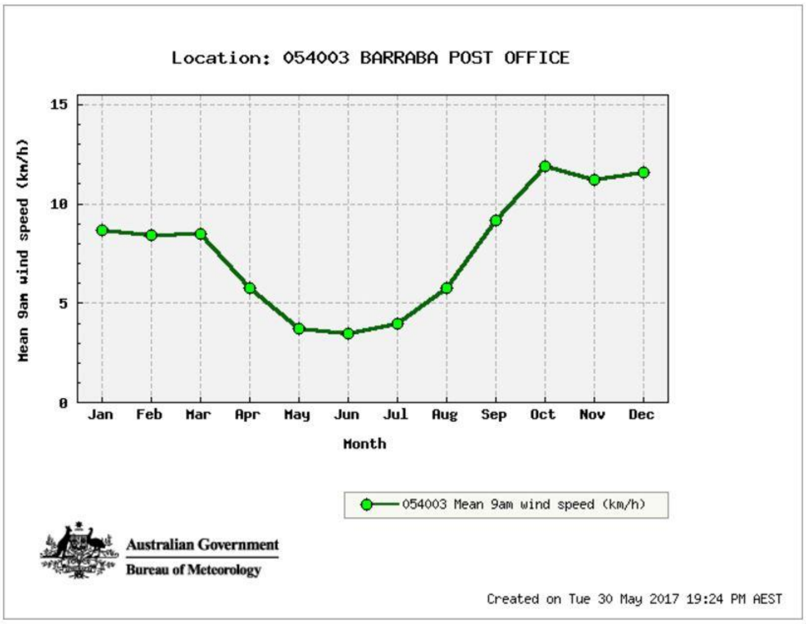


Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean minimum temperature (°C) for years 1966 to 2017	16.5	16.0	12.8	7.9	4.2	1.7	0.3	1.1	4.2	8.1	12.0	14.7	8.3	51

12.3 = Not quality controlled

(Source: Australian Government Bureau of Meteorology, www.bom.gov.au/climate/data/, accessed 7/8/2017)

Figure 8 Barraba Mean Wind Speed, 9am 1966-2010

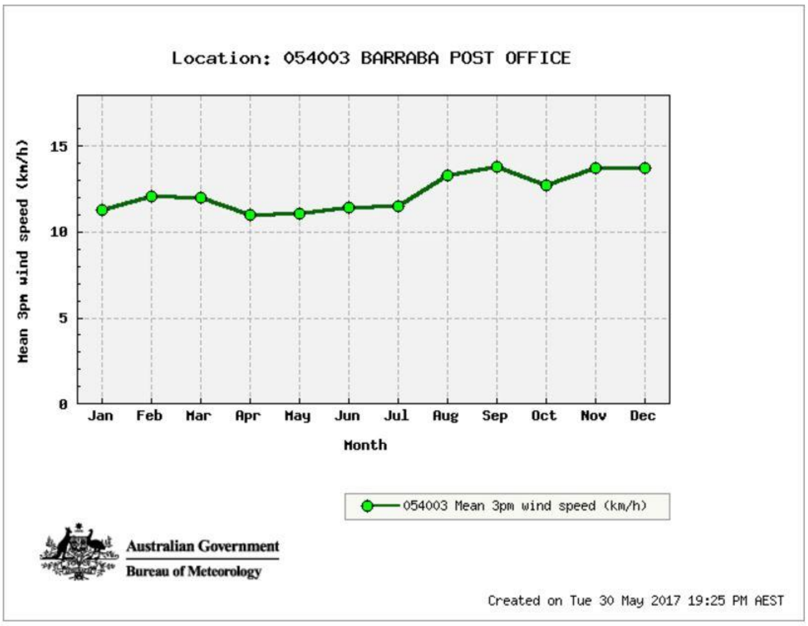


Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean 9am wind speed (km/h) for years 1966 to 2010	8.7	8.4	8.5	5.8	3.7	3.5	4.0	5.8	9.2	11.9	11.2	11.6	7.7	43

12.3 = Not quality controlled

(Source: Australian Government Bureau of Meteorology, www.bom.gov.au/climate/data/, accessed 7/8/2017)

Figure 9 Barraba Mean Wind Speed, 3pm 1966-2010



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean 3pm wind speed (km/h) for years 1966 to 2010	11.3	12.1	12.0	11.0	11.1	11.4	11.5	13.3	13.8	12.7	13.7	13.7	12.3	28

12.3 = Not quality controlled

(Source: Australian Government Bureau of Meteorology, www.bom.gov.au/climate/data/, accessed 30/5/2017)

Geology of the Area Surrounding Woodsreef

The Woodsreef Asbestos mine lies on the Great Serpentine Belt formed by the Peel Fault Line which borders the New England Region and extends from Warialda through Nundle and across to Taree.

The NSW Department of Primary Industries Soil Conservation Service, (2013) describes the geology of the region as the following:

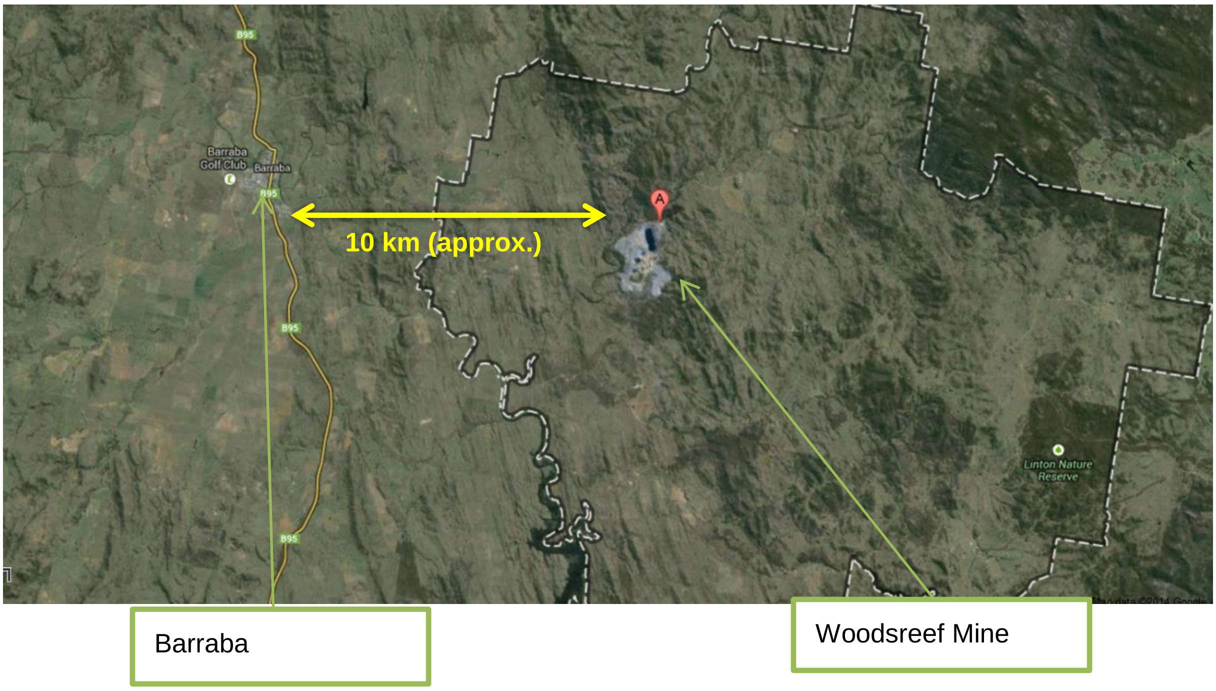
> *"The rock is ultramafic and hence is low in silica but high in magnesium and iron minerals (mafic).*
>
> *At the site, the host rock of the asbestos fibres is from the serpentenite which lies between sandstone and argillite and is often overlain by deep alluvial gravels. All the fibre at the site was chrysotile asbestos of the 'cross fibre' variety and is similar chemically to the host rock. Fibre lengths vary up to 15 mm but are mostly around 4 mm. Percentage in the rock ranges up to a maximum of 10% but averaged around 4%."*

Natural Topography of the Area Surrounding Woodsreef

The Woodsreef topography reflects that formed by the Peel Fault Line. The ridges and valleys generally run in a north south direction. Terrain to the east of the Peel Fault Line is generally higher and steeper, which contrasts with terrain to the west of the Peel Fault Line that is generally lower, "gently undulating valley foothills" (*NSW Department of Primary Industries Soil Conservation Service, 2013*). The town of Barraba lies to the west of the Peel Fault Line.

The natural topography of the area surrounding Woodsreef can be clearly seen in the aerial view shown below in **Figure 10**.

Figure 10 Natural Topography of Area Surrounding Woodsreef Asbestos Mine



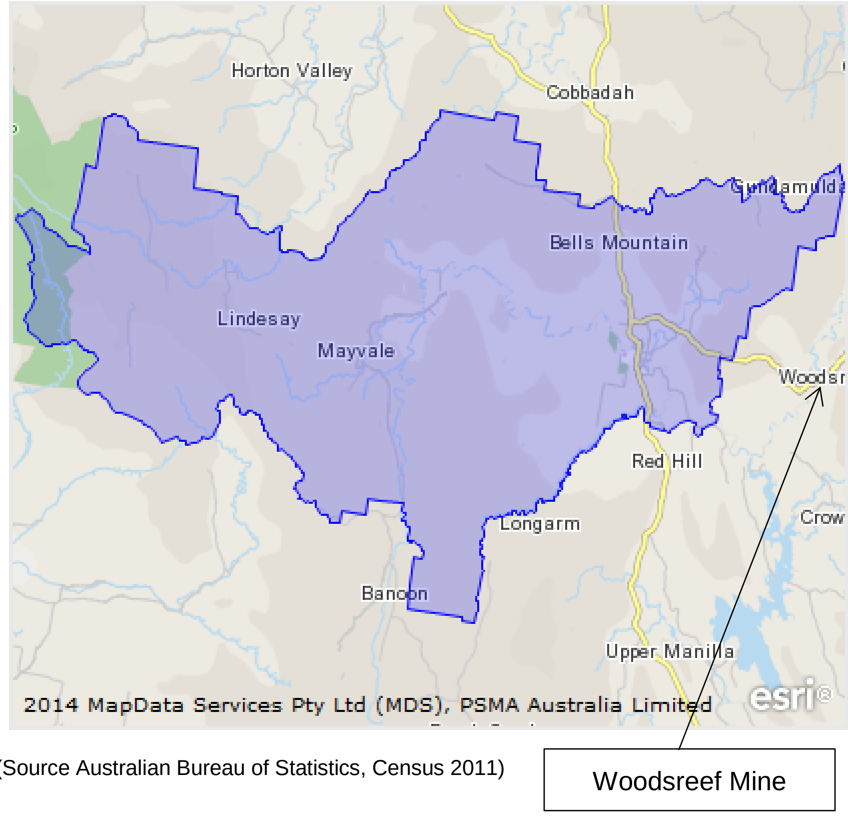
(Source: Google Maps, accessed 18/3/2014)

2.3 Details of Local Communities

The local communities in closest proximity to the Woodsreef mine live in the two state suburb areas of Barraba (SSC 10122) and Woodsreef (SSC 12553). From the 2016 Census, the usual population size for the Barraba state suburb area was 1,410. The majority of who usually resided in the Barraba urban area, with the 2011 Census listing 1,150 people living in the urban area. The population of state suburb area of Woodsreef during the 2016 Census was 74. The area in the immediate vicinity of the Woodsreef mine is rural in nature with scattered houses generally on farmland. From these areas, the main population centre nearest the mine is the township of Barraba.

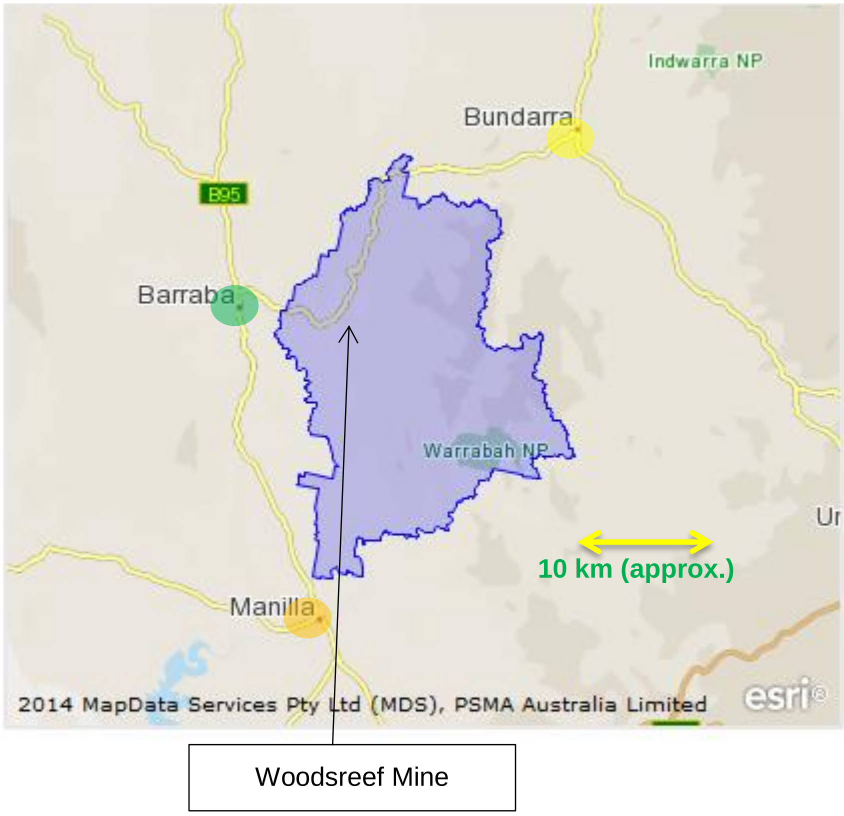
The locations of Barraba and Woodsreef state suburb areas and their proximity to Woodsreef Mine has been set out below in **Figure 11** and **Figure 12**.

Figure 11 Barraba Suburb Area and Location of Woodsreef Asbestos Mine



(Source Australian Bureau of Statistics, Census 2011)

Figure 12 Woodsreef Suburb Area and Location of Woodsreef Asbestos Mine



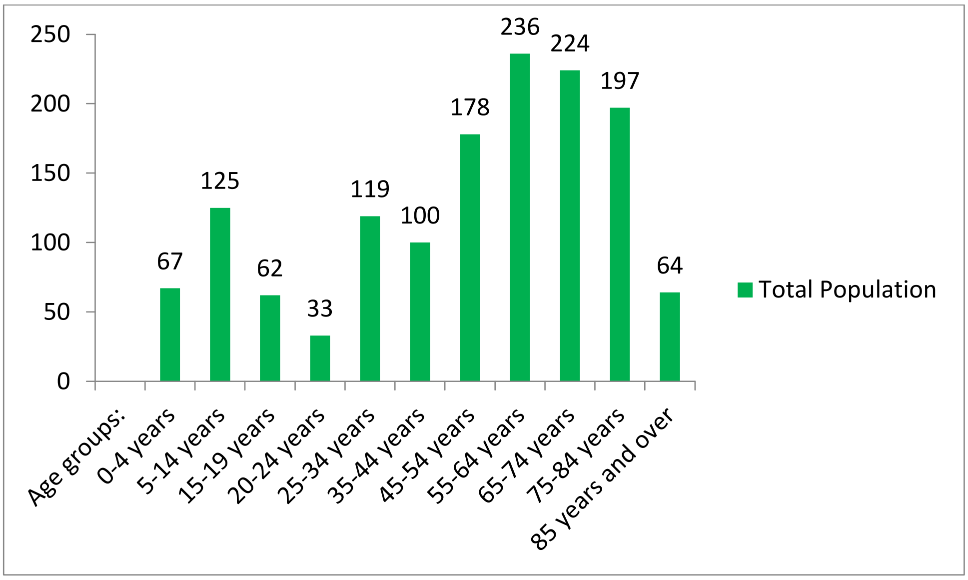
Key	Population Centre	Urban Population
	Barraba	1,410
	Bundarra	381*
	Manilla	2,550

(Source Australian Bureau of Statistics, Census 2016, * = Census 2011)

2.3.1 Community Demographic

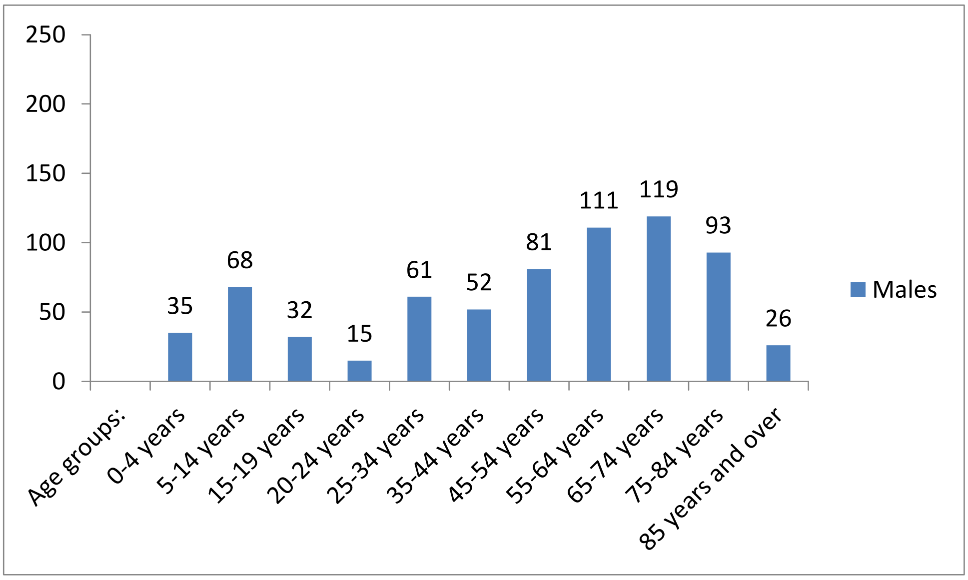
The demographics of Barraba urban area and Woodsreef state suburb area have been set out in **Figure 13** to **Figure 18**. Urban area demographics were available from Australian Bureau of Statistics Census 2011 not the 2016 Census. State suburb area demographics were available from the 2016 Census data.

Figure 13 Barraba Urban Population by Age, 2016



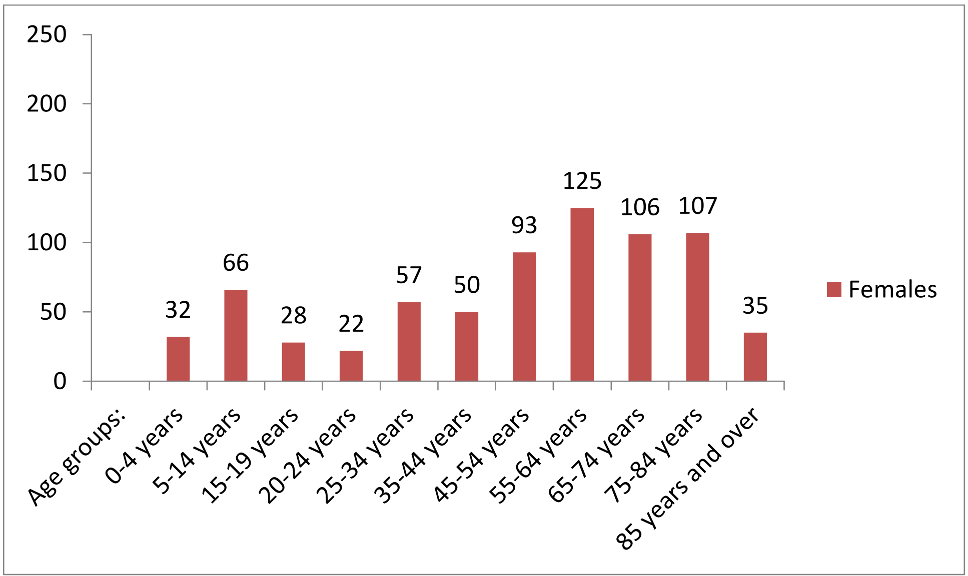
(Source Australian Bureau of Statistics, Census 2016)

Figure 14 Barraba Urban Population of Males by Age, 2016



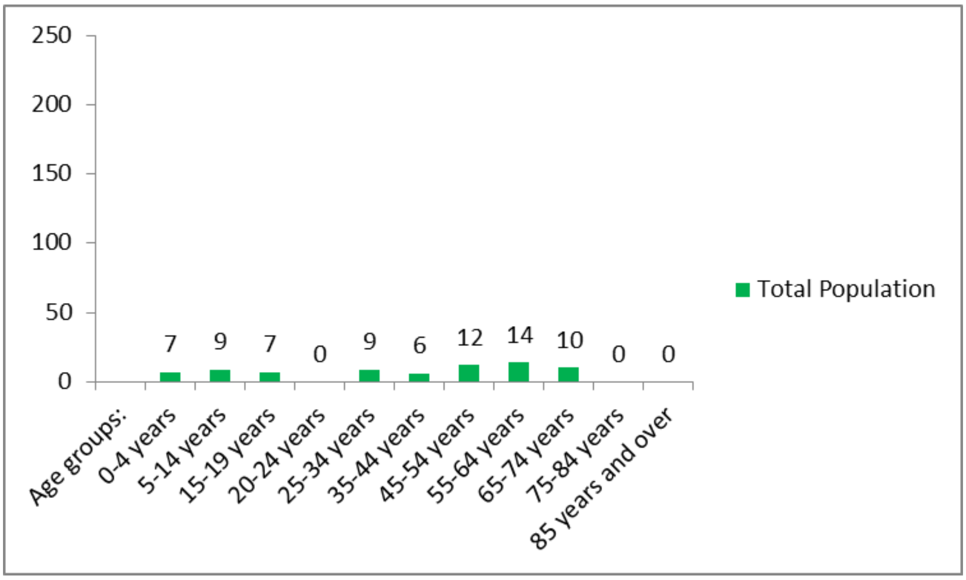
(Source Australian Bureau of Statistics, Census 2016)

Figure 15 Barraba Urban Population of Females by Age, 2016



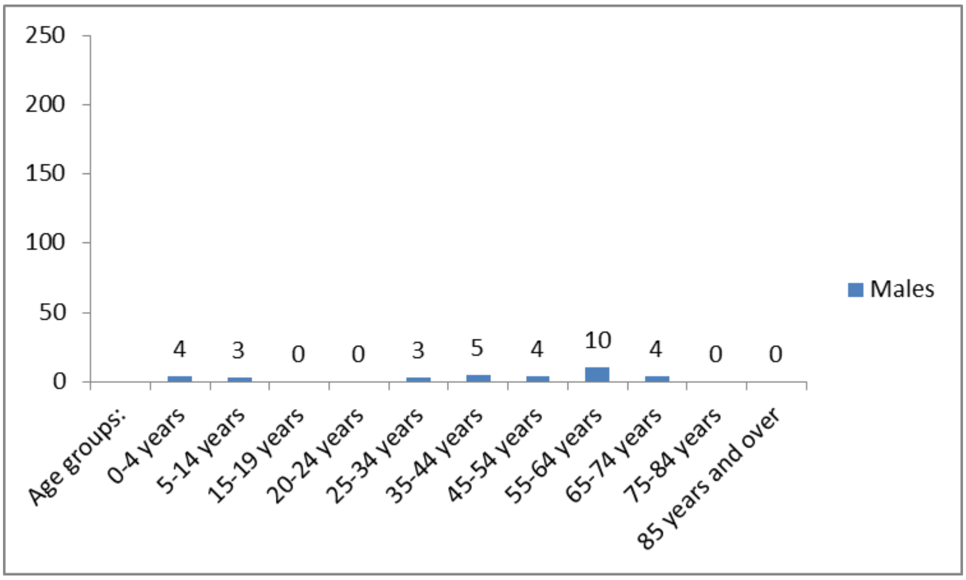
(Source Australian Bureau of Statistics, Census 2016)

Figure 16 Woodsreef Population by Age, 2016



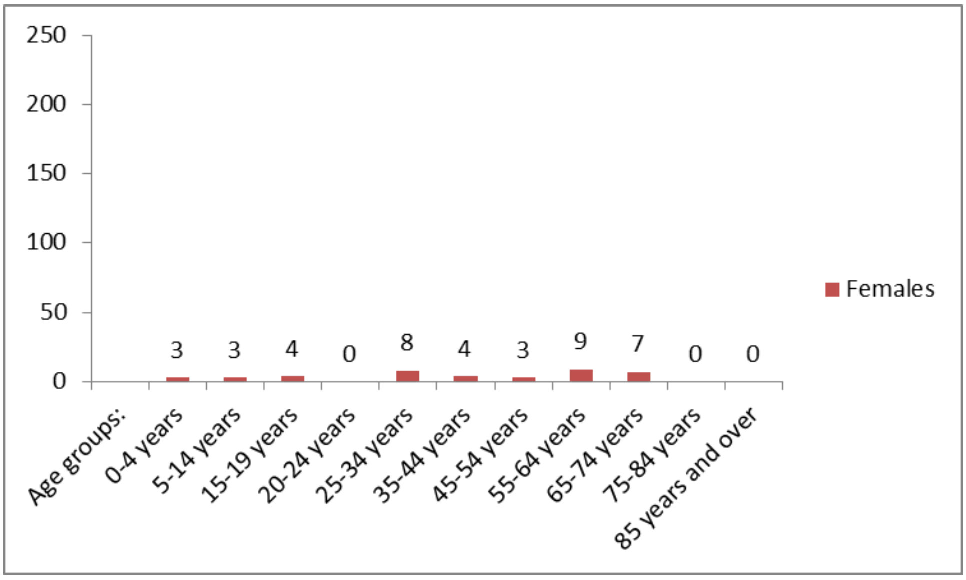
(Source Australian Bureau of Statistics, Census 2016)

Figure 17 Woodsreef Population of Males by Age, 2016



(Source Australian Bureau of Statistics, Census 2016)

Figure 18 Woodsreef Population of Females by Age, 2016



(Source Australian Bureau of Statistics, Census 2016)

2.3.2 Community Socio-Economic Status

To indicate the relative social economic status of the population, this study unitised the Australian Bureau of Statistics (ABS), Socio-Economic Indexes for Areas (SEIFA) 2011. The data in this document was developed by the ABS to rank areas in Australia according to relative social-economic advantage and disadvantage, based on information from the five yearly census (*Australian Bureau of Statistics, 2013*).

The ABS defines relative socio-economic advantage or disadvantage in terms of the "people's access to material and social resources, and their ability to participate in society". The variables used by the ABS in determining in the SEIFA included:

- Income variable
- Education variables
- Employment variable
- Occupation variable
- Housing variables
- Other miscellaneous indicators of relative advantage and disadvantage

(Australian Bureau of Statistics, 2013)

The information available is based on state suburb level information. The lower the SEIFA Score the more socio - economic disadvantaged an area is. For example, the lowest SEIFA Score is in the vicinity of 669, indicating the state suburb with the most socio-economic disadvantage in the Australia. In contrast the highest SEIFA Score is in the vicinity of 1100, indicating the state suburb with the least socio-economic disadvantage in the Australia, or to put it another way the most socio-economic advantaged area in Australia.

The Barraba state suburb area had a SEIFA Score of 876 which indicated Barraba was ranked in the lowest 10% of state suburb areas across Australia. This indicated that the Barraba area was in the bottom 10% of areas for socio-economic advantage.

The Woodsreef state suburb area had a SEIFA Score of 976 which indicated Woodsreef was ranked in the 40% decile of state suburb areas across Australia. This indicated that the Woodsreef area was closer to the middle range of areas for socio-economic advantage across Australia.

The SEIFA Scores above were calculated by the Australian Bureau of Statistics using data from the 2011 Census. As stated previously, the information available is based on state suburb level information. Accordingly within a state area, the socio-economic conditions of individual residents will vary with some individuals more disadvantaged or advantaged than others.

2.3.3 Community Health Data

The current community health data for the township of Barraba was not available at the time of writing. It should be noted that even if the data was readily available, data on small populations such as Barraba may lack epidemiological power to detect health effects. Furthermore it is usually more sensitive and useful to measure hazard directly rather than measure ill health (*enHealth, 2001*).

2.3.4 Special Populations

Special populations are sub groups within the community who may be at greater risk of adverse health effects. The increased risk may be due to factors such as age, ill health or close proximity to an identified hazard, in this case the Woodsreef Mine.

Children or teenagers under eighteen years of age are considered at higher risk than older members of the population. In this age group humans are considered to have not reached maturity. Therefore their bodies may respond differently to adults when exposed to a toxic or carcinogenic threat. In many cases they will be at higher risk from the exposure compared to adults.

In the Barraba Township there are three schools, Barraba Central School which is composed of a Primary School and High School, St Joseph’s Catholic Primary School, and one pre-school, Barraba Pre-School. The approximate student numbers attending each school are set out below in **Table 2.**

Table 2 Approximate Student Enrolments in Schools Located in the Barraba Township

School	Average Student Enrolments 2008-2016*	
Barraba Central School (K-Year 12)	192	
St Joseph's Catholic Primary School	66	
Barraba Pre-School	-	45

Note * Source: ACARA (2017),

As mentioned above other groups considered at potentially greater risk of adverse health impacts include the elderly and those in ill-health. In Barraba there is one retirement facility, Richardson House, which can cater for up to 21 residents. Barraba also has a local hospital Barraba Hospital listed as having less than 50 beds (*NHPA, 2014*). There are also two small health centres, Barraba Medical Centre and Barraba Community Health.

Another special population with potentially higher risk are the residents living in close proximity to the Woodsreef Mine. There are approximately twenty seven houses on properties within an approximate 5 km radius of the Woodsreef mine (*SLR, 2013b*). Of these premises it is anticipated that the majority would be occupied at any one time.

2.3.5 Transient Populations

As well as residents usually residing in Barraba and the Woodsreef area, there will be transient population of visitors to these areas. These visitors are mostly in the area for recreational activities. Examples of these activities include camping, fishing, bird watching, fossicking, visiting the Flora Trail, picnicking, viewing the Woodsreef mine site, etc. The time spent around the Barraba and Woodsreef areas is likely to vary from hours to days, dependent on the activities undertaken during their stay. These recreational activities will be discussed in more detail in the Risk Assessment section of this report.

2.3.6 Transport Routes near Woodsreef Mine

The only transport route in current use near the Woodsreef mine is the Bundarra – Barraba Road. This road skirts the northern edge of the mine site for approximately 1.4 kilometres. There is limited data available on current vehicle movements on the Bundarra – Barraba Road. Observations by the authors when conducting field work near the mine site indicated the traffic on this road is infrequent. Tamworth Regional Council provided data on average daily vehicle traffic in July 2016 of 97 vehicles per day.

Historically The Mine Road ran along the eastern edge of the mine site to join up with the Bundarra – Barraba Road. However, The Mine Road was closed in early 2014 and is no longer considered a transport route near the mine.

2.3.7 Conceptual Site Model

To help understand how persons living in communities near the Woodsreef Mine or visiting the area surrounding the mine may be exposed to asbestos; a Conceptual Site Model (CSM) was developed. Information from various sources was used to determine the CSM. This included information obtained as direct observations and measurements by SLR staff during site visits to the mine site and surrounding lands, field observations and soil sample analysis conducted as part of the Report 1 Hazard Identification Assessment (SLR, 2013a). Information was also obtained through reviews of available documentation, both historic and current, relating to the mine site, surrounding countryside, demographic of local populations and historic local airborne asbestos fibre monitoring records from the mine site. This also included a review of scientific literature relevant to asbestos. Much of the information collected in development of the CSM has been set out in various sections of the current report.

Conceptual Site Model (CSM) uses the concept of the links between source – pathway – receptor to assess risk. This can include the source of Contaminants of Potential Concern (COPC), in this case asbestos, which may impact on the communities in question and transport mechanisms whereby asbestos can be moved to exposure points (human receptors). If any of these links are missing then an exposure pathway in incomplete and human exposure will not occur. If the exposure pathway is potentially complete then likely impact on the receptor may need to be assessed.

The CSM development indicated the following factors:

- The presence of asbestos fibres
- The release mechanism whereby the asbestos fibres may be released into the environment
- The transport pathways moving the asbestos fibres through the environment
- Exposure pathways
- Exposure Routes whereby the a person takes in the asbestos fibres, in this case inhalation
- Location of potential receptors
- Significant pathways by which exposure may occur
- Minimal exposure pathways, considered as less likely to led to human exposure
- Primary exposure pathways considered to be the pathway by which the largest quantities of emissions of asbestos fibres move
- Secondary exposure pathways considered to be the pathway by which lessor quantities (compared to the Primary exposure pathway) of the emissions of asbestos fibres move

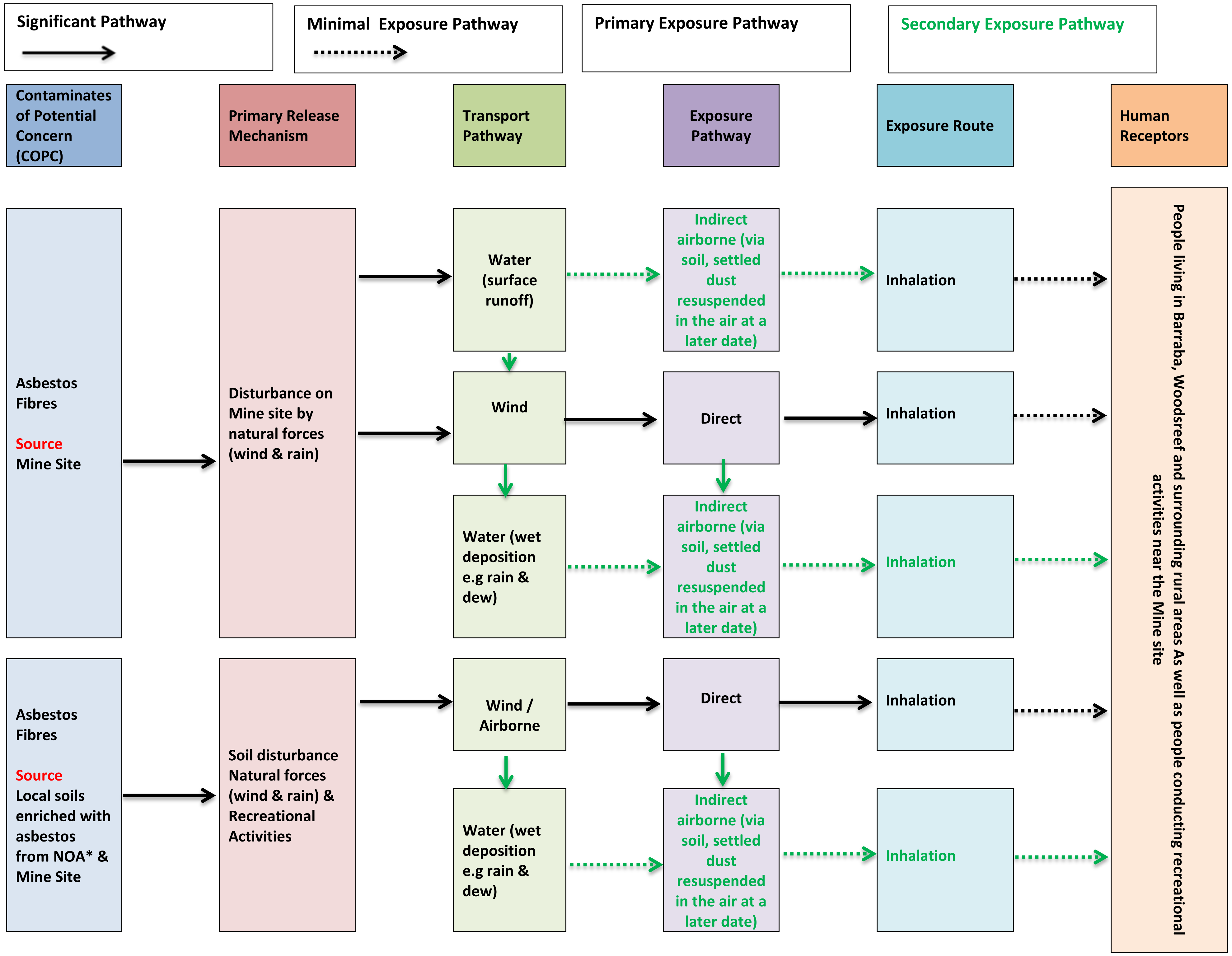
The Primary exposure pathway after completion of remediation works was determined to be via the airborne pathway. The Secondary exposure pathway was considered to be the indirect pathway in which asbestos fibres were transported off site through environmental forces such as wind or water, the asbestos fibres then settle into dusts or soils and at a later date subsequently resuspended in the air when the soil or dusts are disturbed, at which point human exposure via inhalation may take place.

The Primary exposure pathway can be relatively easily quantified through the airborne asbestos fibre monitoring program undertaken during the remediation. Thus any increase in risk associated with the remediation may be quantified.

The Secondary exposure pathways, where asbestos fibres that have previously settled out then are resuspended in the air by natural forces either on the mine site or off the mine site, will form a component of the airborne asbestos fibre concentrations measured during the monitoring program undertaken post remediation.

The Conceptual Site Model showing the proposed links between source of asbestos fibres and pathway to human exposure has been set out in **Figure 19**.

Figure 19 Conceptual Site Model for Potential Asbestos Fibre Exposure to Communities Near the Woodsreef Mine.



* NOA = naturally occurring asbestos

3 RISK ASSESSMENT

3.1 Introduction

3.1.1 What is a Risk Assessment

Risk assessments have been defined in many ways but all share the concept of a process for estimating and characterising the potential risks associated with various agents or activities.

The National Research Council (1983) definition is:

> *Risk assessment is the systematic scientific characterisation of potential adverse health effects resulting from human exposures to hazardous agents or situations.*

A risk assessment is a multidisciplinary process that can involve many scientific disciplines. It may be a simple screening exercise or a complex project over many years.

3.1.2 Risk Assessment Approach

The methodology adopted in the conduct of the Human Health Risk Assessment is consistent with that used to evaluate risks to human health associated with a population's exposure to a hazardous agent, in this case asbestos.

The approach to the assessment of risk to human health is based on the protocols/guidelines recommended by the enHealth Council. These are detailed in the document "Environmental Health Risk Assessment Guidelines for assessing human health risks from environmental hazards, June 2012".

Identification and assessment of the potential risks to human health within the site have been undertaken by implementing four prime tasks. These tasks are:

1. **Issue Identification** - This involves an evaluation of the available information on the potential occurrence and distribution of asbestos transported by natural processes, such as wind and rain, from the Woodsreef Mine to surrounding communities.
2. **Hazard Assessment** - This task provides a review of the current understanding of the toxicity of asbestos to humans and identifies hazards associated with exposure to airborne asbestos fibres.
3. **Exposure Assessment** - This task draws on the evaluation undertaken as part of the "Issue Identification" stage identifying the groups of people who may be exposed to airborne asbestos released during the remediation works and by natural processes, such as wind and rain, from the Woodsreef Mine to surrounding communities and quantifying exposure concentrations.
4. **Risk Characterisation** - This task provides the qualitative evaluation of potential risks to human health. The characterisation of risk is based on the review of toxicity of asbestos fibres and the assessment of the magnitude of exposure.

3.2 Objectives

The objective of the Human Health Risk Assessment is to contribute to the analysis of asbestos released after completion of the remediation works and transported by natural processes, such as wind and rain, from the Woodsreef Mine to surrounding communities and provide an assessment of the risk to human health associated with the presence of asbestos fibres. The risk assessment aims to:

- Identify the groups of people who may be exposed to the asbestos potentially released from the Woodsreef Mine;

- Compare exposure concentrations with contemporary health standards;
- Identify the health risks associated with exposure should it occur; and
- Assess and communicate the identified risks.

Risk assessments of the nature performed here do not provide definitive assessments of the acceptability of risk for specific individuals. Risk assessments should only be applied on a probabilistic basis to a population of exposed persons.

It should be noted that the scope of this Human Health Risk Assessment is limited to asbestos and does not include any other agents of potential concern.

3.3 Issue Identification

3.3.1 Naturally Occurring Asbestos

The Woodsreef Mine is situated in an area where naturally occurring asbestos (NOA) is found in significant concentrations over a broad area. Areas where NOA exists as surface deposits are subject to the usual weathering of the parent material potentially leading to the enrichment of local soils with asbestos fibres. Therefore, the presence of asbestos fibres, released and deposited by natural forces, in local soils is to be expected. However, the extent of natural release of asbestos into soils is unclear. There is a paucity of data on natural background concentrations of asbestos fibres in soils adjacent to asbestos ore bodies. Furthermore, localised asbestos concentrations in soils will be very much dependent on site specific factors relating to natural weathering forces, for example local topography, vegetation cover, whether the area is used for farming or pristine wilderness, rainfall patterns etc.

With regards to the area surrounding the Woodsreef deposit the background soil concentrations of naturally occurring asbestos are unclear. However at least in the area of the Woodsreef mine and immediate surrounds the contribution of asbestos released into soils by natural processes is likely to be dwarfed by the contribution of asbestos released into surrounding soils by prior mining processes.

3.3.2 Woodsreef Mine

The mine site is approximately 290 hectares in size and is reported to contain a 75 million tonne waste rock dump and 25 million tonne tailings dump. The site also contained two derelict buildings and four open pits (*Parsons Brinckerhoff, 2012 & NSW Department of Primary Industries Soil Conservation Service, 2013*). The mine has been derelict since 1983.

The mine site can be functionally divided into the following areas: Open Pits (four on site), Mill Building Area, Waste Dump (three sites, south, west and northeast), and a Tailings Dump. The Mine Road winds along the eastern perimeter of the mine except for a section of road that runs in-between the South Waste Dump and the Tailings Dump (See **Figure 4** above).

The Mill Building was demolished during remediation works between October 2014 and May 2015. During the remediation a Containment Cell was dug to the west of the Mill Building. The building was then demolished and buried in the Containment Cell. The remediation works were done in a controlled manner with the aim of minimising the generation of airborne dusts and the potential for asbestos fibres to become airborne and transported off site towards local communities.

The Waste Dumps consist of processed rocks and overburden. The Tailings have been reported as partially processed ore, understood to be predominately asbestos stockpiled for later reprocessing that never occurred (*NSW Department of Primary Industries Soil Conservation Service, 2013*).

Water drainage studies of the mine site shows on-site drainage flows, that is, back on to the mine site, and off-site drainage flow from the mine site. A siltation / drainage system is in place, partially left over from the mine operations and partially enhanced and expanded by the Soil Conservation Service. These changes were designed to improve drainage and minimise asbestos containing sediments being transported off site with water flows (*NSW Department of Primary Industries Soil Conservation Service, 2013*).

The potential for natural processes, such as rain and wind, to transport materials from the mine site to areas outside the mine boundary will be a major factor in determining the likelihood of the general public being exposed to asbestos from the mine. Wind erosion and transport of asbestos is less significant than waterborne migration in terms of the mass of material that can migrate, although windborne asbestos can be more significant in terms of health risks (*Department of Industry and Resources & Department of Local Government and Regional Development, 2006*).

The ability of the mine site materials and soils to resist these forces of erosion will vary over time. The characteristics of the parent material to form a stable crust will reduce the potential for off-site migration caused by both wind and rain. If the materials do start to migrate under the influence of natural forces such as rain and water movement, then the direction of water drainage from the source materials will determine if the materials leave the mine site. Therefore, the ability of a surface to form a stable crust and the probable water drainage flows from the area of the mine, are primary factors when determining the likely hazard from off-site migration of mine materials.

Ultimately natural forces will be responsible for transporting some materials and soils both off the mine site and within the mine site. However, any potential asbestos hazard coupled with the transport of materials will be dependent on three main factors. This includes the asbestos present in the material, how much asbestos is present in the material and the form of the asbestos.

The presence or not of asbestos in material and how much asbestos is present are both of obvious importance. The form of the asbestos in the materials is extremely important for any hazard assessment. The simple underlying principle being within some limits, the smaller the asbestos fibres present the greater the asbestos hazard.

If the asbestos is present as a natural band encased in rock, with little chance of releasing asbestos fibres, the hazard is negligible. In contrast, asbestos will pose the greatest hazard to humans when present in the form of small fibres or loose bundle of asbestos in a situation where fibre emissions to air can ultimately be generated (e.g. by erosion, weathering, or other physical disturbances).

The asbestos hazard to humans occurs via the respiratory route, the breathing in of asbestos fibres. Asbestos can be present in a material but not in a respirable form. Accordingly, the hazard posed by mine site materials and soils will be dependent on the ability of the material to produce and release respirable asbestos fibres.

The definition of respirable asbestos fibres is those fibres less than 3µm in width, and greater than 5µm in length and with a width length to width ratio of greater than 3:1 (*AS 4964-2004*). The presence or absence of respirable asbestos fibres is determined during laboratory analysis, using Trace Asbestos Analysis, where microscopic asbestos fibres are identified following the procedures set out in *AS 4964-2004.* If Trace Asbestos is reported in a sample it indicates the presence of respirable asbestos fibres (*AS 4964-2004*).

Therefore, materials that pose the highest potential hazard to exposed humans will be materials with relatively high asbestos content, with the asbestos fibres present in the respirable size range and which can be easily disturbed to release respirable asbestos fibres.

3.3.3 Key Points - Woodsreef Mine

- The mine is situated in an area of naturally occurring asbestos
- Background soil concentrations of naturally occurring asbestos around the mine are unclear.

- In the area of the mine and immediate surrounds the contribution of asbestos released into soils by natural processes weathering naturally occurring asbestos is likely to be dwarfed by the contribution of asbestos released into the environment and deposited by mining processes.
- The mine site is approximately 290 hectares in size and is reported to contain a 75 million tonne waste rock dump and 25 million tonne tailings dump. Therefore there remain significant emission sources for asbestos fibres on the mine site.
- The Mill Building was demolished during remediation works between October 2014 and June 2015. The remediation works were done in a controlled manner with the aim of minimising the potential for asbestos fibres to become airborne and transported off site towards local communities.
- Water drainage on the mine site shows drainage flows both back on to the mine site and flows off the mine site. Therefore there is the potential for surface water to transfer asbestos containing materials both around the mine site and off the mine site.
- The potential for natural processes, such as rain and wind, to cause erosion and weathering allowing transport materials from the mine site to areas outside the mine boundary is a major factor in determining the likelihood of the general public being exposed to asbestos from the mine.

3.3.4 Community Chosen for Assessment

The community chosen for the purposes of this assessment was Barraba, the residents who live in or near Woodsreef, and residents between the mine and Barraba. As previously stated, the local communities in closest proximity to the Woodsreef mine live in the two state suburb areas of Barraba (SSC 10122) and Woodsreef (SSC 12553). From the 2011 Census, the usual population size for the Barraba state suburb area was 1,539 of which 1,150 people were listed as usually residing in the Barraba urban area. The population of state suburb area of Woodsreef during the 2016 Census was 74. The area in the immediate vicinity of the Woodsreef mine is rural in nature with scattered houses generally on farmland. From these areas, the main population centre nearest the mine is the township of Barraba.

The demographics, socioeconomic status, etc. of these communities has been previously described above in **Section 2.3**.

There is also a “community” of transient observers and recreational users who use the area near the mine. Some of these people will be local residents and some will be residents from outside the local area, visiting the area for sightseeing or recreational purposes. Transient observers and recreational users have also been included in this assessment.

3.3.5 Recreational Activities Undertaken Near Woodsreef Mine

Recreational activities in the vicinity of the mine cover a range of activities. The activities can be either passive or active in nature. For the purpose of this study, passive activities are taken to include activities that do not involve much movement around a site with little potential to disturb soil or vegetation. Examples of passive activities include observing the mine from the road side or picnicking near the mine. Active activities are taken to include activities that involve greater movement around the site with increased potential to disturb soil or vegetation.

Passive activities tend to occur in proximity to the road around the northern fringe of the mine site, along the Bundarra – Barraba Road.

The following activities have been listed as examples of the main passive activities conducted in the vicinity of the mine.

1. Viewing the mine site - There are a few areas where tourists can park their cars on the road side and walk a few metres to the mine fence for views over the mine site.

2. Picnicking - Areas where tourists can picnic close to the mine are located approximately 200 m to the northwest of the mine where the Bundarra - Barraba Road runs near Ironbark Creek.
3. Attending services at the St John's Woodsreef Church - A small church with services scheduled the second Sunday of each month. The church is approximately 600 m to the north east of the mine site.

Active activities tend to occur mostly on lands outside the mine site area, around the northern half of the mine, including both the western and eastern sides of the mine perimeter. It should be noted that some activities occur approximately 4 km to the south of the mine, at a camping site off the Pera - Linton Road near where Ironbark Creek enters Split Rock Reservoir.

The following activities have been listed as examples of the main active activities conducted in the vicinity of the mine.

1. Camping along Ironbark Creek in the area to the northwest to north of the mine, within 100 metres to 2 km from the mine site.
2. Camping along Ironbark Creek in the area to the south of the mine, at a camping site off the Pera - Linton Road near where Ironbark Creek enters Split Rock Reservoir, approximately 4 km south of the mine site.
3. Fossicking for gold and minerals in the area to the north of the mine, within 2 km of the mine site.
4. Bird Watching in the area to the north of the mine, within 100 metres to 2 km from the mine site.
5. Walking along the Flora Trail in the area to the east of the mine, within 50 metres to 500 metres from the mine site.
6. Fishing along the Ironbark River, near the mine site.
7. Use of off road vehicles including cars and motorbikes, in the areas around the mine.

3.3.6 Key Points - Community & Recreation

- The largest community in proximity to the mine is the town of Barraba with approximately 1,405 people usually residing in town which is located approximately 15 km to the west of the mine. Closer to the mine is the state suburb area of Woodsreef with population of approximately 74 people.
- The lands adjacent to the mine and between the mine site and the town of Barraba are rural in nature and only lightly populated. Vegetation cover ranges from natural scrub and forest, to rural paddocks on properties.
- Recreational activities, both passive and active are undertaken in areas ranging from adjacent to the mine boundary to areas up to 4 km from the mine.
- Recreational activities, both passive and active are undertaken by local residents and tourists.

3.3.7 Asbestos & Land

As would be expected with a derelict un-remediated open cut asbestos mine, the presence of asbestos is widespread on the mine site. Furthermore asbestos present on the site and adjacent to the mine site is in the form of both natural occurring asbestos and mining processed or partially processed asbestos.

Naturally occurring asbestos in the mine site has been reported as averaging 4% of the parent material (*Dames & Moore, 1997*). The naturally occurring asbestos will be largely bound in the rock formation. Therefore the contribution of undisturbed naturally occurring asbestos to the overall release of asbestos from the mine site to the surrounding environment should be minimal compared to the amount of asbestos released from exposed asbestos containing material from mining such as waste rock, tailings etc with large surface areas and high potential for asbestos weathering and erosion.

In the broader regional area surrounding the Great Serpentine Belt the presence of naturally occurring asbestos is likely to have led to areas where weathering processes have released asbestos fibres from the rock into the local soils. Any local enrichment of asbestos in soils from natural processes is likely to be patchy in distribution and very much subject to site specific conditions. Furthermore there is little information available on the likely localised asbestos concentrations in soils as a result of weathering of naturally occurring asbestos in the region. Therefore, the extent of natural asbestos enrichment of local soils is unclear.

The largest source of asbestos in a form that may be easily transported off the mine site into the surrounding environment by natural forces such as wind and water will be the processed and partially processed material on the mine site. As previously stated the mine site is reported to contain a 75 million tonne waste rock dump and 25 million tonne tailings dump. The Waste Dumps consist of processed rocks and overburden. The Tailings have been reported as partially processed ore, understood to be predominately asbestos, stockpiled for later reprocessing that never occurred (*NSW SCS, 2013*).

3.3.8 Asbestos Hazard Assessment of Mine 2013

SLR Consulting conducted a Hazard Assessment of the mine site and adjacent lands in 2013 (SLR, 2013a). This study included a site walk over inspection of the mine site with observations made on the site conditions, including crusting and evidence of ground surface migration noted. Representative soil samples were collected at locations across the area and analysed for asbestos content.

Evidence of current erosion and migration of materials within the mine site and off the mine site were readily apparent in many areas of the mine. It appeared that migration of materials is likely to be intermittent in nature and linked to significant events such as heavy rain or the localised catastrophic collapse of sections of the material such as occurs when water causes erosion to undermine areas leading to collapse of previously stable crusts or materials (*SLR, 2013a*).

All documents reviewed provided historic evidence of significant and ongoing erosion. Dames & Moore (1997) reported that tailings dump erosion and slumping was progressive and ongoing with visible cracking and subsidence around the top of embankments and channel erosion on steeper slopes. This description continues to be valid in 2017.

Control of the ongoing erosion across the mine site appears unlikely in the foreseeable future. The Woodsreef Derelict Asbestos Mine - Drainage Assessment Report (*NSW SCS, 2013*) states that “Erosion control is the lowest priority due to the large area to be addressed and the cost to immediately provide stability.”

SLR (2013a) conducted asbestos analysis on samples of bulk materials collected at forty six locations, representative of the broad areas within the mine site. These areas included:

- Waste/overburden;
- Tailings, Road cuttings;
- Siltation systems sediments;
- Mill Building vicinity;
- Proposed containment cell vicinity; and

- Additional areas likely to have potential for off-site migration of asbestos containing materials.

These additional areas included the following locations:

- Ironbark Creek, adjacent to pumping station; to tyre mount; and floodplain;
- Ironbark Creek, east flood plain, midway; Ironbark;
- Creek, start of walking track north east;
- North of mine central waypoint, north side of Bundarra - Barraba Road;
- Entrance to mine, east of building;
- South end tailings, east road culvert, adjacent to private land;
- Flora Trail adjacent to pit 1, west;
- West of waste dump near pump station; and
- Northwest of overburden.

The hazard assessment identified that sources of asbestos were present in soil or rock throughout almost all sampling sites. The only exceptions were two sites, Ironbark Creek, start of walking track NE and one sample from Siltation Systems Sediments.

The approximate quantity of asbestos present in the soil particle fraction size less than 2 mm in diameter of the collected samples was estimated as part of the analysis by SLR (2013a). The results indicated estimated asbestos concentrations on a percentage volume to volume ratio ranged from less than 0.1% to 95%. These concentrations clearly indicate the potential scale of the asbestos contamination on the mine site and adjacent lands.

Asbestos concentrations varied greatly across the site and also within common functional locations (e.g. Tailings, Road Cuttings, etc) on the site. The broad groupings of sample locations and the estimated asbestos content on the smallest particle size fraction measured (<2 mm) have been set out in **Table 3**.

Further information on sample locations has been set out in **Section 3.4 Risk Mitigation**, **Figure 26**.

Table 3 Estimated Ranges of Asbestos Concentrations in <2 mm Particle Size Fraction of Samples (% vol/vol)

Location	Estimated Range of Concentrations of Asbestos in <2 mm Particle Size Fraction of Samples (% vol/vol)
Waste/overburden	<0.1 to 90%
Tailings	<0.1 to 90%
Road cuttings	<0.1 to 70%
Siltation systems sediments	No asbestos detected to 40%
Mill Building vicinity	<0.1 to 95%
Proposed containment cell vicinity	25 to 70%
Ironbark Creek – land in vicinity of creek	No asbestos detected to 90%
Single Location Samples	
North of mine central waypoint, north side of Bundarra – Barraba Road	2%*
Entrance to mine, east of building	<0.1%*
South end tailings, east road culvert, adjacent to private land	5%*
Flora Trail adjacent to pit 1, west	40%*
West of waste dump near pump station	< 0.1%*
North west of overburden	< 0.1%*

Note * = Locations with one sample only

Critically, respirable asbestos fibres were present at the majority of locations sampled. Asbestos fibres in this size range pose a significant hazard to human health if they are inhaled.

3.3.9 Key Points - Asbestos & Land

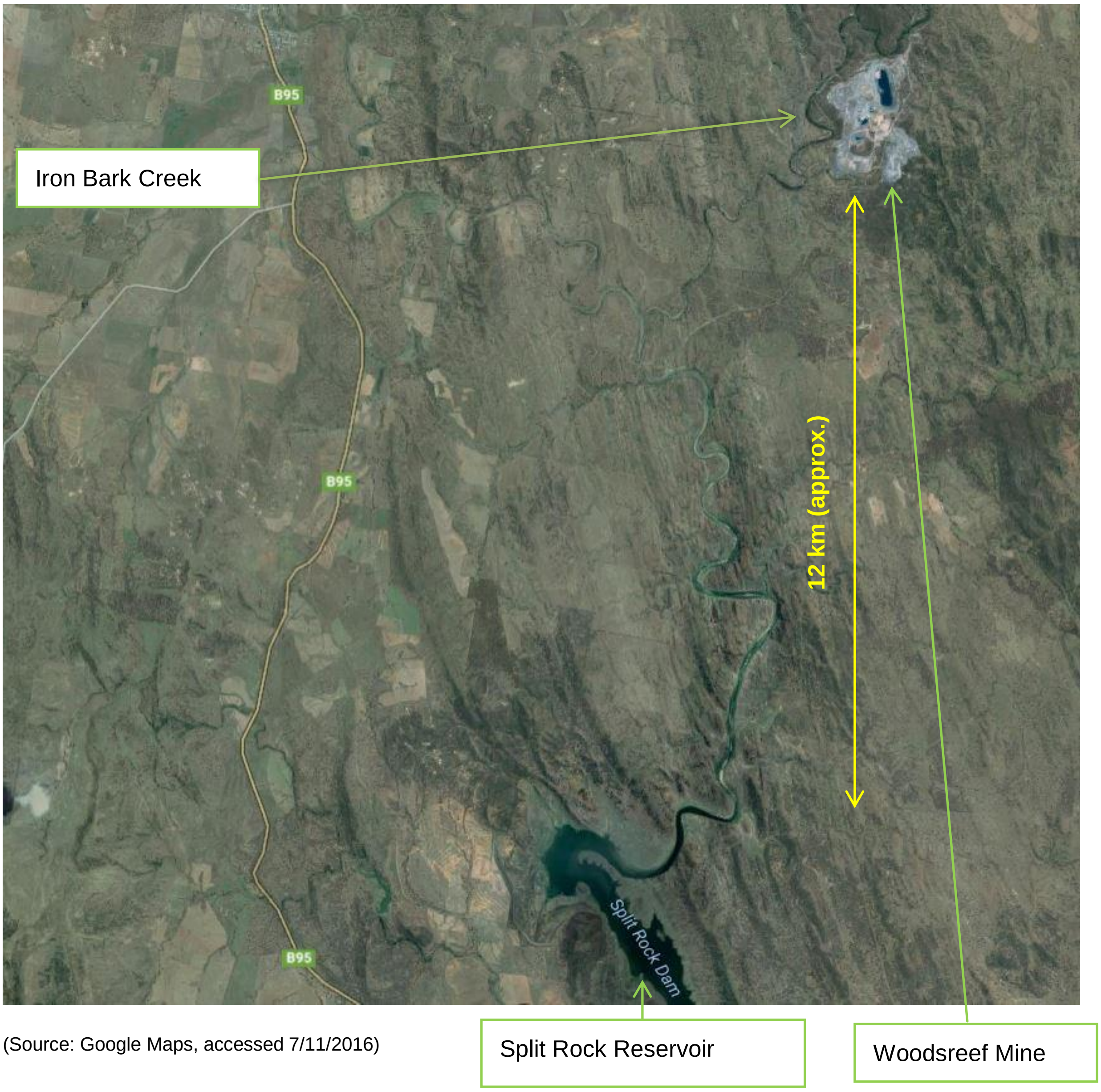
The conclusions that can be drawn in relation to asbestos on the mine site and adjacent lands are the following:

- There is evidence of historic and current erosion and migration of materials within the mine site and off the mine site in many areas of the mine.
- The migration of materials is likely to be intermittent in nature and linked to significant events such as heavy rain or the localised catastrophic collapse of previously stable surface crusts or materials.
- There is significant asbestos contamination across most if not all of the mine site.
- There is evidence of various degrees of asbestos contamination across adjacent lands to the mine.
- The concentrations of asbestos in the particle size fraction less than 2 mm in diameter of material across the site varied greatly from less than 0.1% to 95% (vol/vol).
- Respirable asbestos fibres were present in soils across most of the mine site and in land adjacent to the mine.

3.3.10 Asbestos & Water

Water movement associated with the mine site is important as water has the potential to transport significant amounts of bulk material from the mine site to the surrounding environment and therefore closer to people. The major waterway transporting surface water away from the areas near the mine is Ironbark Creek which is located on the western side of the mine area. Ironbark Creek flows in a southerly direction eventually entering the Spilt Rock Reservoir which is located approximately 14.5 kilometres from the mine site. There are smaller ephemeral creeks and drainage around the eastern and southern sides of the mine area which deposit eroded debris into small alluvial deposits. The location of Ironbark Creek and Split Rock Reservoir in relation to Woodsreef Mine has been set out below in **Figure 20**.

Figure 20 Location of Ironbark Creek and Split Rock Dam in relation to Woodsreef Mine



(Source: Google Maps, accessed 7/11/2016)

Water drainage assessments on the mine site shows drainage flows both back on to the mine site and off the mine site. It has been estimated that for approximately 65% of the mine site area water drainage is retained on the mine site itself. Therefore approximately 35% of the mine site area drains water off site. Of this approximately 12% of the mine area drains uncontrolled off the mine site and 23% of the mine area drains through some form of sediment control.

There is a paucity of information on the amount of asbestos transported off the mine site into the local creeks and Ironbark Creek or the more distant Split Rock Reservoir. The evidence that is available consists mostly of anecdotal, visual evidence of fibrous material or silt observed at drainage points near the mine site. Dames & Moore (1997) quoted a 1978 report (*Toyer & Main, 1978*) in which erosion and movement of mine tailings into Ironbark Creek was observed. The Toyer & Main report also commented on preliminary sampling of asbestos concentration in water in Ironbark Creek and “pits” which ranged from 80,000 to 250,000 asbestos fibres per mL of water. However, it should be noted that in 1978 the mine was in operation and at that time there was little if any sediment control to capture drainage off the mine site. There is currently a siltation / drainage system is in place to capture or impede the movement of materials from the mine site into the surrounding waterways.

Dames & Moore (1997) conducted limited sediment sampling to “update and confirm the results obtained by Toyer & Main (1978)”. The nine sampling sites in streams and creeks replicated sites utilised by Toyer & Main (1978). Asbestos in the form of chrysotile was found in Nangahrah Creek (which flows into Ironbark Creek north of the mine) and Ironbark Creek, both of which receive drainage from the mine site. Chrysotile was also found in sediment of water drainage systems that drain off the Tailings Dump and South Waste Dump into Ironbark Creek. In contrast, chrysotile was not detected in samples taken from the sediments of the Manilla River, the river which Ironbark Creek flows into approximately 6 km southwest of the mine.

It should be noted that asbestos from weathering of naturally occurring asbestos away from the mine area is likely to be entering the local streams. The contribution of this source of asbestos to local waterways is unclear. However, in the immediate vicinity of the mine the natural contribution of background asbestos is likely to be dwarfed by the transport of asbestos from the mine site into the waterways.

The conclusions that may be drawn from the available observations of others and the authors own observations is that asbestos containing material has been transported from the mine site into Ironbark Creek over the years. Once in the Ironbark Creek system, the asbestos would behave in a similar manner to other sediments entering the creek. That is settling out in areas of low flow, being buried over time in the creek bed by incoming sediments, occasionally resuspended and transported with the general sediments during periods of sediment disturbances such as during flooding events. If asbestos containing sediments have been transported along Ironbark Creek and entered the Split Rock Reservoir it would be expected that the asbestos material would settle out into the reservoir sediments and ultimately be buried over time by natural sedimentation processes. Once buried the asbestos should have little or no impact on the environment or end-users of the reservoir water.

3.3.11 Key Points - Asbestos & Water

- Asbestos containing materials have been transported from the mine site into Ironbark Creek over many years.
- The amount of asbestos transported from the mine site into Ironbark Creek in unclear.
- The amount of asbestos from weathering of naturally occurring asbestos transported into Ironbark Creek in unclear.
- Asbestos in the Ironbark Creek system would settle out in areas of low flow, becoming buried over time by incoming sediments.
- Asbestos in Ironbark Creek sediment will occasionally be resuspended and transported with the general sediments during periods of sediment disturbances such as during flooding events.

- If asbestos has been transported into Split Rock Reservoir it would be expected to settle out into the reservoir sediments and be buried over time by natural sedimentation processes. Once buried the asbestos should have little or no impact on the environment or end-users of the reservoir water.

3.3.12 Asbestos & Air Quality

There is limited historical data available on the effects of the mine site on local air quality. The air monitoring for asbestos that had previously taken place was often related to works being conducted on the mine site. Dames & Moore (1997) conducted air dispersion modelling to assess the potential airborne asbestos concentrations “downwind of the tailings dump”. The modelling procedure assumed baseline asbestos concentrations at the tailings of 0.01 to 0.04 fibres/mL air which was based on concentrations recorded during remediation works in 1992. The Dames & Moore (1997) modelling indicated that during high wind velocities (up to 10 m/s) downwind asbestos concentrations would likely decline by 70% within 5 km of the tailings dump and by 90% beyond 15 km from the tailings dump. However there was no monitoring data to support this.

For the current study, a programme of monitoring of airborne asbestos was conducted with the aim of obtaining up to date information on the potential exposures of local communities to airborne asbestos from the mine site in its current state.

Air Dispersion Modelling was used to identify locations that subsequently were used when monitoring airborne asbestos fibres. Data from these two procedures was then used in the estimation of the area likely to be affected, the intensity and duration of the effect and the level of health impact (actual health effects) on the risk population (*SLR, 2013b*).

3.3.12.1 Australian Occupational Exposure Standard for Airborne Asbestos

The Australian Occupational Exposure Standard for airborne asbestos was used to assess results of current and historic airborne asbestos concentrations. The use of this standard was chosen by the Woodsreef Taskforce. The basis being that sampling methodology was standardized and allowed comparisons to a significant body of historic Woodsreef air monitoring data collected over at least 25 years. Comments on the uncertainties associated with the use of this standard can be found in **Appendix E.**

At the time of writing, the Safe Work Australia eight-hour Time Weighted Average (TWA) for asbestos exposure is 0.1 fibres/mL. An eight-hour TWA is translated as the average airborne concentration of asbestos over a normal eight-hour working day, for a five-day working week. Accordingly these standards allow higher exposures than would normally be allowed or expected in the non-occupational environment.

This Safe Work Australia exposure standard is not however, a discriminative dividing line between safe and dangerous concentrations of airborne asbestos fibres but is to be used by appropriately qualified and experienced persons to interpret risk in relation to exposure circumstances.

Furthermore an acceptable level for asbestos exposure has not been determined in the non-occupation environment.

The methodology used by Safe Work Australia for reviewing and updating the national exposure standards involves the use and acceptance of overseas standards from governmental and non-governmental sources. Sources are selected after an assessment against several factors including quality and availability of supporting documentation, integrity of the development process and consistency with the Safe Work Australia philosophies. Sources include the United Kingdom Health and Safety Executive HSE “Occupational Exposure Limits” and the American Conference of Governmental Industrial Hygienists (ACGIH) “Threshold Limit Values”.

3.3.13 Air Dispersion Modelling

Provided below is a brief summary of the modelling assessment conducted to assist with the identification of key monitoring locations that were subsequently utilised in the human health risk assessment.

The air dispersion modelling was based on metrological data and estimates of relative rates of asbestos fibre release from ground surfaces in different regions of the mine site. The dispersion models were not validated for use with asbestos. However the model was used to provide indicative information on ground level impacts associated with site emissions. These limitations of the modelling were due to the limited modelling requirements set out in the project scope.

Details of the dispersion methodology can be found in **Appendix B**.

The objective of this modelling exercise was to identify which of the identified potential monitoring locations were likely to be exposed to lower or greater levels of exposure as compared to other locations, and whether the corresponding relative exposure varies according to changes in seasonal weather conditions.

This was performed to ensure that the locations that were predicted to potentially experience elevated likelihood of exposure were incorporated within the monitoring program, and that the program accounted for seasonal variations in dispersion conditions.

Please note that the results presented in this summary do not represent exposure rates, nor do they represent an assessment of environmental harm or health risk.

The results are presented as a comparison of predicted exposure potential at selected locations relative to the maximum off-site exposure potential that is predicted to occur under a range of meteorological conditions covering a 12 year period.

For clarification, the locations predicted to experience higher exposure potentials should not be interpreted as being ‘at risk’ or associated with environmental harm.

In order to differentiate the comparative exposure potential the following terminology was used:

- **Category A Potential** - areas predicted to have an exposure potential greater than or equal to the maximum exposure potential predicted at the identified receptor locations.
- **Category B Potential** - areas predicted to have an exposure potential greater than or equal to 50% of the maximum exposure potential predicted at the identified receptor locations.
- **Category C Potential** - areas predicted to have an exposure potential greater than or equal to 20% of the maximum exposure potential predicted at the identified receptor locations.
- **Category D Potential** - areas predicted to have an exposure potential greater than or equal to 10% of the maximum rate of exposure potential predicted at the identified receptor locations.
- **Category E Potential** - areas predicted to have an exposure potential less than 10% of the maximum exposure potential predicted at the identified receptor locations.

3.3.14 Receptors

All discrete receptors in proximity to the mine and relevant discrete receptors at distance were identified from available documents and local advice. The location of each discrete receptor was physically checked on the ground. These discrete receptors were used as the key assessment locations in this study and have been set out in **Table 4** and in **Figure 21** to **Figure 25.**

Table 4 Discrete Receptor Locations

Modelling ID	Name	Latitude	Longitude	East (m)	North (m)	Approximate Distance from Mine Boundary
R1	Barraba Central Secondary School	150.6013	-30.3830	269369.57	6636401.28	13km
R2	Barraba Primary School	150.6031	-30.3844	269776.95	6636528.21	13km
R3	St Joseph's Primary School	150.6076	-30.3789	270144.44	6636887.49	13km
R4	Paula McIver	150.6585	-30.3889	274831.06	6635720.16	6km
R5	Gossenbar	150.6861	-30.3814	277427.30	6636884.27	4km
R6	Glenriddle Homestead	150.6896	-30.3899	277947.38	6635914.09	3.5km
R7	The Nuthouse	150.6949	-30.3750	278475.46	6637858.49	4.2km
R8	Ironbark Creek	150.6967	-30.4390	278848.96	6630349.71	3km
R9	Glen Riddle Reserve	150.7093	-30.4422	278086.24	6629158.82	4km
R10	Anglesea	150.7170	-30.3975	280407.91	6635057.99	350m
R11	Picnic Site	150.7255	-30.4021	281265.94	6634550.12	50m
R12	UnID Res 1	150.7333	-30.4503	282557.63	6629300.01	3km
R13	Firnview 1225	150.7345	-30.4440	282638.10	6630029.57	2km
R14	Camping - F&F Trail	150.7404	-30.3907	281940.06	6635693.93	250m
R15	Woodsreef Township	150.7436	-30.3899	283267.54	6635873.89	500m
R16	Wynaroy	150.7465	-30.4051	283583.47	6634792.55	40m
R17	Mr Burgess Property	150.7527	-30.4190	281967.68	6632711.25	116m
R18	UnID Res 2	150.7583	-30.4801	284973.03	6625860.05	7km
R19	Boxpark Station	150.7605	-30.3858	284994.45	6637101.62	2km
R20	Bindaree	150.7605	-30.3858	284599.73	6636922.57	1.9km
R21	Westbank 1708	150.7609	-30.4782	284163.13	6626336.45	6km
R22	Kilpara 1705	150.7609	-30.4782	284903.47	6626763.12	5.9km
R23	Ironbark Station	150.7631	-30.3686	284835.49	6641613.66	6km
R24	UnID Res Prop 1849	150.7703	-30.4822	285766.47	6625871.47	7km
R25	Nangarah Station	150.7732	-30.3784	286351.35	6637740.63	4km
R26	Glenview	150.7778	-30.3719	286746.18	6638658.98	4.5kn
R27	UnID Res Prop Removable House /Perm living	150.7781	-30.4663	286787.24	6627916.35	6km
R28	394 /Coreena	150.7824	-30.4537	286841.79	6628987.26	4.5km
R29	Rimrock	150.8071	-30.3691	289321.63	6638632.20	6.5km
R30	Caernarvon	150.8156	-30.3706	290067.18	6638190.76	7km
R31	Woonoora	150.8178	-30.4305	290581.75	6631405.14	6km
R32	Avondale	150.8190	-30.4314	290328.31	6631555.45	6km

3.3.15 Results

The annual average and seasonal predictions over the years 2001 to 2012 are presented in the following figures:

- Figure 21 Predicted Exposure Potential - Annual Average 2001 to 2012
- Figure 22 Predicted Exposure Potential - Spring 2001 to 2012
- Figure 23 Predicted Exposure Potential - Summer 2001 to 2012
- Figure 24 Predicted Exposure Potential - Autumn 2001 to 2012
- Figure 25 Predicted Exposure Potential - Winter 2001 to 2012

Figure 21 Predicted Exposure Potential - Annual Average 2001 to 2012 (Refer to 3.3.13 for category A-E definitions)

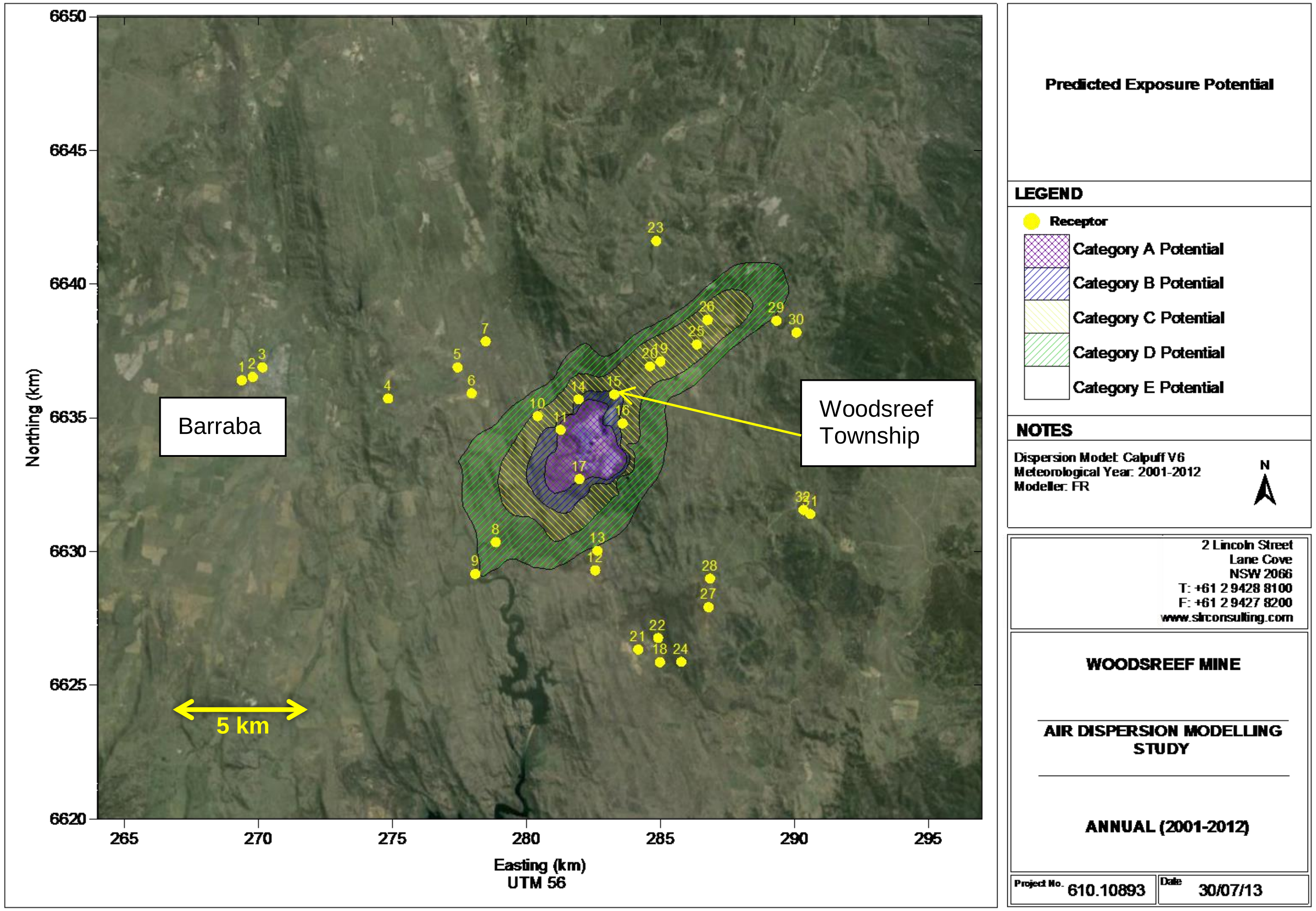


Figure 22 Predicted Exposure Potential - Spring 2001 to 2012 (Refer to 3.3.13 for category A-E definitions)

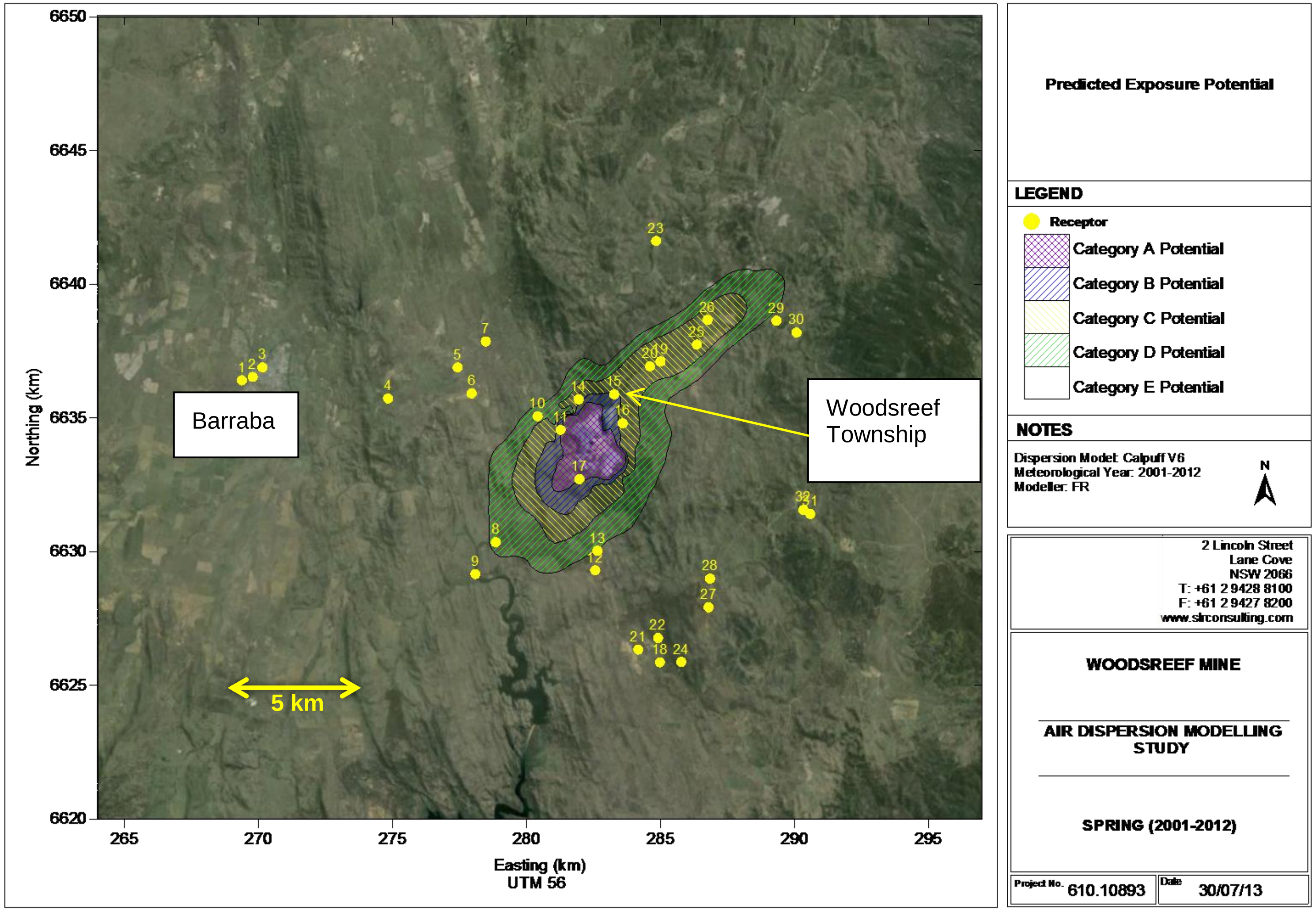


Figure 23 Predicted Exposure Potential - Summer 2001 to 2012 (Refer to 3.3.13 for category A-E definitions)

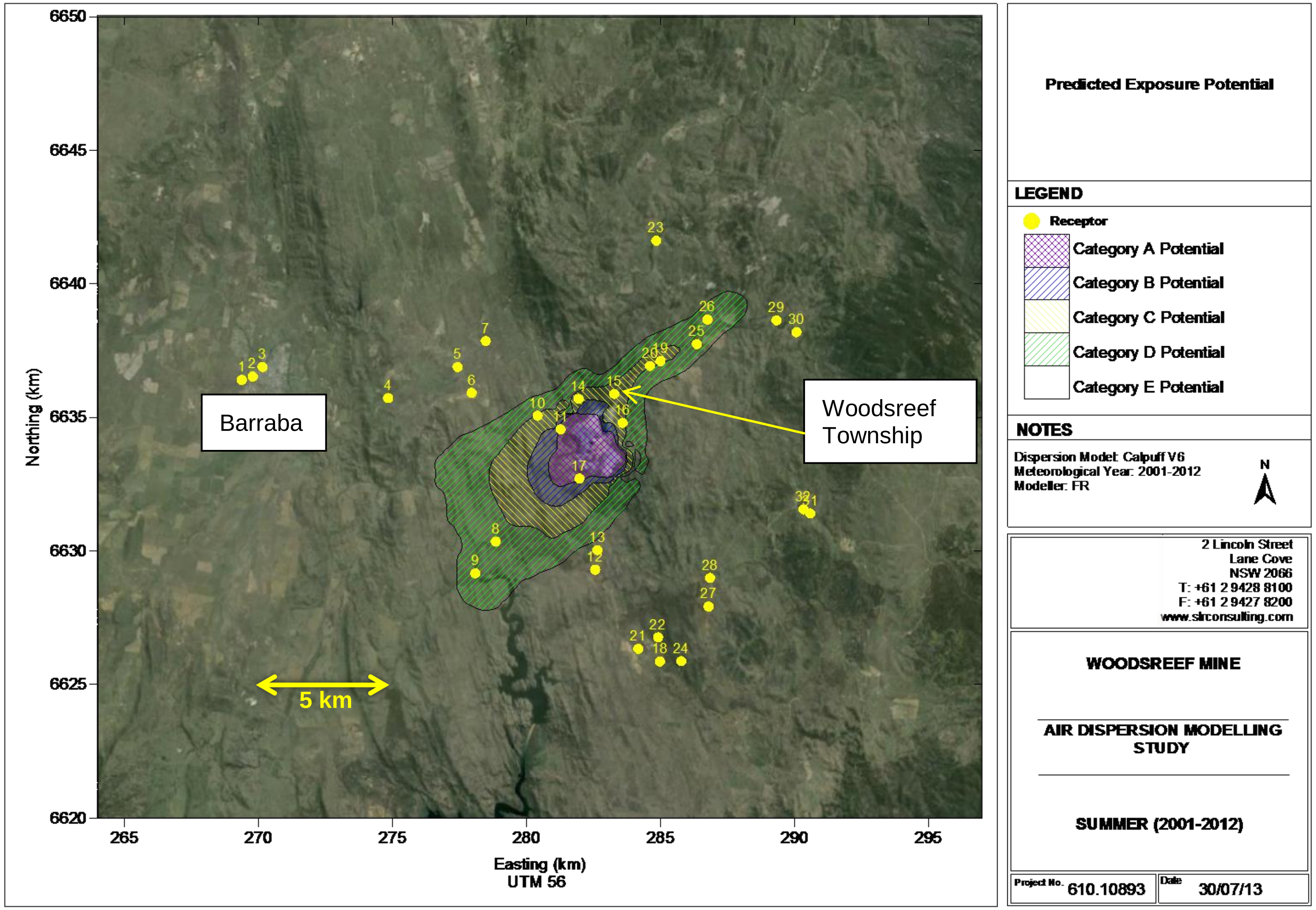


Figure 24 Predicted Exposure Potential - Autumn 2001 to 2012 (Refer to 3.3.13 for category A-E definitions)

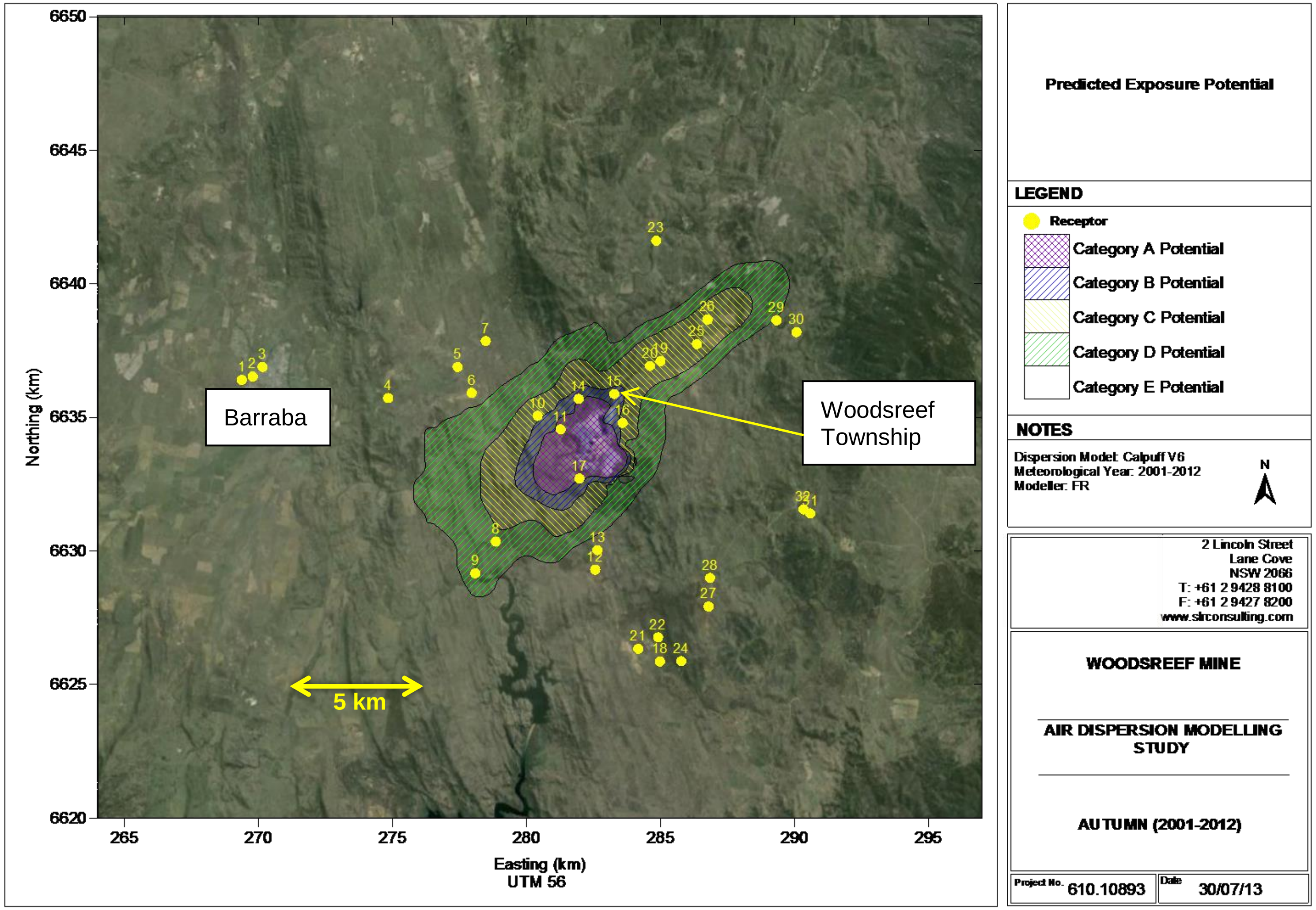
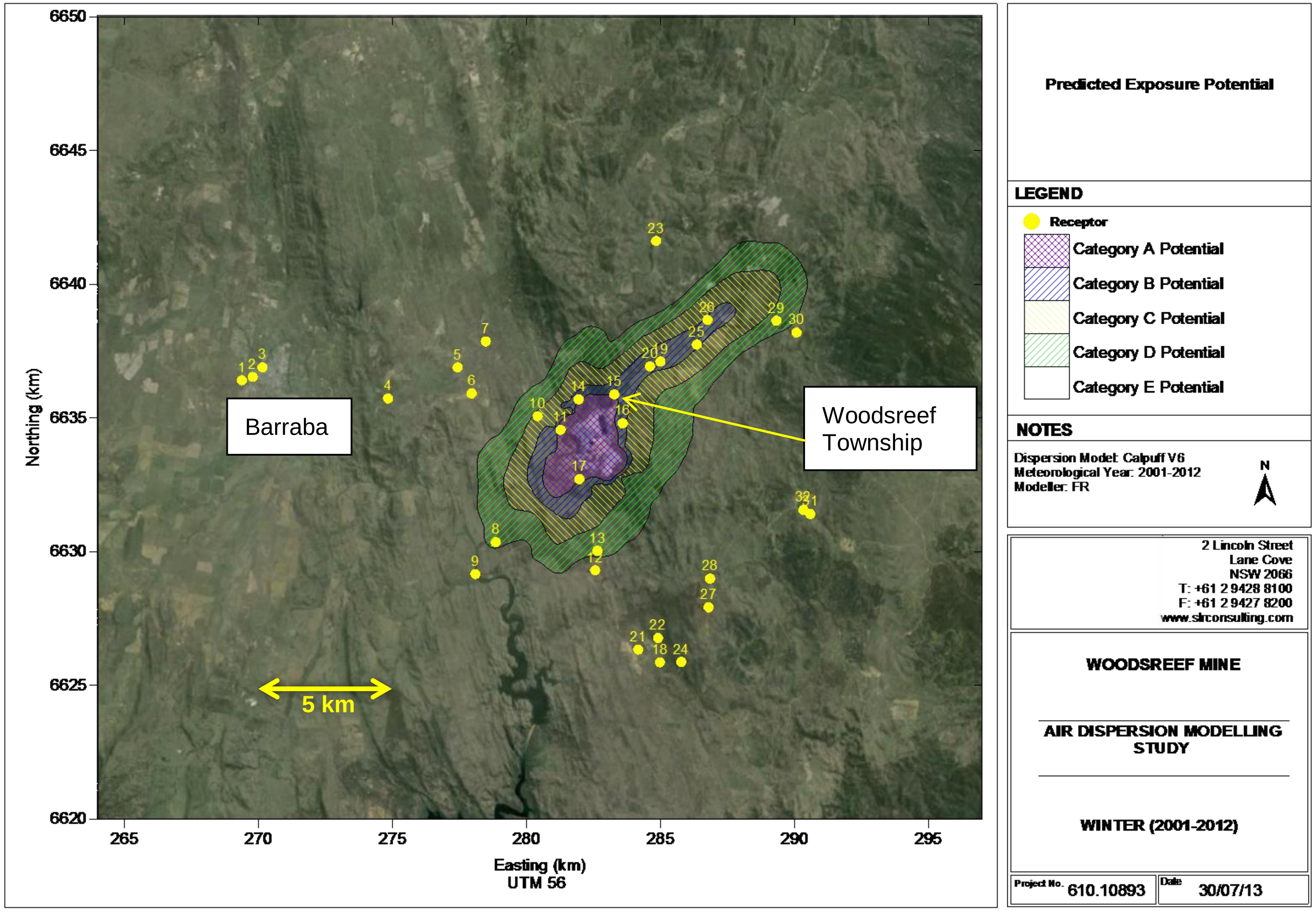


Figure 25 Predicted Exposure Potential - Winter 2001 to 2012 (Refer to 3.3.13 for category A-E definitions)



3.3.16 Air Monitoring Locations

Based upon the exposure potential predictions presented in **Figure 21** to **Figure 25**, the following monitoring stations were recommended. For each season, the monitoring locations were ranked according to their predicted priority (with rank no 1 being the most recommended location) (See **Table 5** below).

Table 5 Recommended Ranked Monitoring Locations (by Season)

Rank	Summer		Autumn		Winter		Spring	
1	R17	Mr Burgess Property	R11	Picnic Site	R17	Mr Burgess Property	R17	Mr Burgess Property
2	R11	Picnic Site	R17	Mr Burgess Property	R15	Woodsreef Township	R11	Picnic Site
3	R15	Woodsreef Township	R14	Camping - F&F Trail	R11	Picnic Site	R15	Woodsreef Township
4	R14	Camping - F&F Trail	R15	Woodsreef Township	R19	Boxpark Station	R19	Boxpark Station
5	R16	Wynaroy	R19	Boxpark Station	R14	Camping - F&F Trail	R16	Wynaroy
6	R19	Boxpark Station	R20	Bindaree	R20	Bindaree	R20	Bindaree
7	R10	Anglesea	R16	Wynaroy	R16	Wynaroy	R14	Camping - F&F Trail
8	R20	Bindaree	R10	Anglesea	R25	Nangarah Station	R25	Nangarah Station
9	R25	Nangarah Station	R25	Nangarah Station	R26	Glenview	R26	Glenview
10	R26	Glenview	R26	Glenview	R10	Anglesea	R10	Anglesea

The final locations chosen for airborne asbestos fibre monitoring were based on the recommended monitoring stations and advice from the Woodsreef Taskforce following consultation with Barraba community. Three locations were chosen at a distance from the mine site, being Tamworth, Barraba and Glen Riddle Reserve. Tamworth was chosen as a control site. Barraba Primary School was chosen as a sensitive site in the urban area closest to the mine. Glen Riddle Reserve was chosen as a distant site (approximately 4 km) to the south west where people conduct recreational activities such as camping.

Six more monitoring locations close to the mine were chosen based on exposure potential predictions over all seasons and professional judgement. As a starting point, locations ranked in the top seven based on exposure potential predictions over all seasons were compared. Air quality modelling predicted that four of these locations, Picnic Site (R11), Woodsreef Township (R15), Mr Burgess Property (R17) and Boxpark Station (R19), were in the area of highest exposure potential predictions for all four seasons. Therefore these four sites were recommended as monitoring locations. For the two final monitoring locations, Wynaroy (R16) was chosen based on proximity to the mine, being around 40 metres from the Mine site and being inhabited. The second location, the Camping - F&F Trail (R14) was chosen based on based on proximity to the mine, being around 250 metres from the Mine site and a location where people conduct recreational activities such as camping and fossicking.

The chosen locations for the air monitoring stations are provided in **Table 6** and can be seen in **Figure 21** to **Figure 25**.

Table 6 Air Monitoring Locations

		Air Monitoring Location
1	-	Control - Residence in Tamworth
2	-	Barraba Primary School, Mower (Cricket Nets)
3	R9	Glenn Riddle Reserve
4	R19	Boxpark Station
5	R16	Wynaroy
6	R14	Camping - F&F Trail
7	R15	Woodsreef Township (Church)
8	R11	Picnic Site
9	R17	Mr Burgess Property

3.3.17 Contemporary Airborne Asbestos Fibre Monitoring 2013 to 2016

Two forms of air monitoring activities were conducted between 2013 and 2016. The first form of monitoring related to the Background Monitoring to investigate the significance of airborne emissions of asbestos fibres, before, during and after the remediation of the mine buildings. The second form of air monitoring was Activity Based Monitoring where SLR conducted personal exposure monitoring while undertaking recreational activities. Monitoring methodology was the same for both Background Monitoring and Activity Based Monitoring and followed the methodology outlined in NOHSC: 3003(2005) Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres 2nd edition. The detection limit for this method was 0.01 fibres per mL of air.

During each of SLR's air monitoring activities from 2013 to 2016, the meteorological conditions were considered likely to be mostly representative of expected weather patterns for the particular time of year. This was based on a review of meteorological data, historic and current, collected by Australian Government Bureau of Metrology from the Bureau's meteorological station located at Barraba Post Office (weather station 054003).

Temperatures (minimum and maximum) were within historic means throughout each year of monitoring.

Rainfall varied with annual rainfalls close to historic annual means in 2013 and 2015, 2014 recording 24% less rainfall and 2016 recording approximately 13% more annual rainfall. Monthly rainfalls were below historic means for 63% of the months between 2013 and 2016.

Some light rainfall was recorded in Barraba on 11 days of the 39 days when asbestos fibre monitoring was conducted. Of the 28 monitoring days with no rainfall, 13 days had rainfall 2 to 3 days preceding the monitoring day.

Wind appeared different to historic mean conditions (1966 – 2010) with wind speeds may have been light at times compared to historic averages. The monthly mean wind speeds, during asbestos fibre monitoring periods, appeared lower than the historic monthly mean wind speeds. The percentage of monitoring days when calm conditions occurred at 9am (45%) were similar to historic means (46% of days). However the afternoon data indicted a higher level of calm days, with the percentage of monitoring days when calm conditions occurred at 3pm (27%) was greater than the historic means (12% of days). It should be noted the afternoon data may not be as representative, compared to the morning data. This may be due to the Bureau of Metrology data set for afternoon wind measurements (3pm) being smaller with less records collected than the morning data.

More details on meteorological data during SLR's air monitoring and comparisons to historic means for weather conditions can be found in **Appendix C**.

3.3.17.1 Background Airborne Asbestos Fibre Monitoring, Before, During and After Remediation of the Mine Buildings

Background airborne asbestos fibre monitoring was conducted at locations set out in **Table 6** above and as shown in **Figure 21** to **Figure 25**.

During each sampling period, rounds of monitoring (a "round" being monitoring conducted on the same day at each sampling location) were conducted at 6 day intervals. The reason for 6 day intervals, being one day less than a full week, ensures that the sequence monitoring days progress through different days of the week. For example, if the first round of monitoring occurs on a Monday then the second round of monitoring will be on a Sunday, the third round on a Saturday, etc.

For all air monitoring including background monitoring from 14 November 2013 to 14 December 2013, background monitoring during remediation monitoring from 20 October 2014 to 12 May 2015 and repeated background monitoring (post remediation) from 22 April 2016 to 27 June 2016, all airborne asbestos fibre concentrations were at levels less than 0.01 fibres per mL of air.

Therefore, the likely concentrations of airborne asbestos during the monitoring period were at least ten times lower than the current the Safe Work Australia Exposure Standard for asbestos (0.1 fibres per mL of air).

Prior to the remediation works, the mine site would have been in equilibrium with the surrounding environment. The combined effects of environmental factors, such as wind, temperature regime and rain, on exposed surfaces of soil and mine wastes across the site would have led to the formation of relatively stable surface crusts. These surface crusts would be a major factor in restricting emissions of airborne asbestos fibres from the mine site to the surrounding areas.

The remediation works was a significant disturbance to the mine site equilibrium. The works consisted of a series of demolition and asbestos removal works, including demolition of all the existing above ground structures including mill building, office building, product silos and remaining infrastructure. Two containment cells were dug on the mine site and demolished buildings and waste were pushed into the containment cells and buried. The works were conducted from 10 September 2014 to 28 May 2015. During this time previously stable exposed surfaces of soils and waste would have been disturbed and some previously unexposed surfaces would have been exposed to the actions of the environment and the works. This breakdown of the previous natural equilibrium of surfaces is likely to have led to emissions of airborne asbestos fibres from the mine site being higher immediately following the remediation works. Over time these emissions would slowly be reduced as the exposed surfaces of soils and mine waste reached a new equilibrium and stabilized.

To obtain monitoring data representative of long term background air concentrations, the mine site was allowed a period of eleven months to let the site reach a more steady state with respect to offsite emission potential prior to repeating background air monitoring. April 2016 was chosen to recommence background airborne asbestos fibre monitoring to minimise the likelihood of rain during the airborne asbestos fibre monitoring. Rainfall during air monitoring period would likely reduce emissions of airborne asbestos fibres from soils and mine waste, potentially leading to measured background levels of airborne asbestos fibres which may not be representative of long term conditions. This decision was based on the historic evidence indicating heaviest mean rainfall for the region occurring in October to March (Barraba mean monthly rainfall 1881-2014, Bureau of Meteorology).

The airborne asbestos fibre results for background monitoring by SLR have been set out below in **Table 7**.

Table 7 Background Airborne Asbestos Fibre Monitoring 2013 to 2016

	Modelling ID	Air Monitoring Location	Approximate Distance and Direction from Mine Boundary	Monitoring Period	Number of Monitoring Rounds Undertaken	Total Number of Valid Samples	Concentrations (fibres/mL)
1	-	Control - Residence in Tamworth #	50 km, south	14/11/13 - 14/12/13 20/10/14 – 12/05/15	6 13	6 13	All <0.01
2	-	Barraba Primary School, Mower (Cricket Nets)	13 km, west	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6 13 12	6 13 12	All <0.01
3	R9	Glenn Riddle Reserve #	4 km, south west	14/11/13 - 14/12/13 20/10/14 – 12/05/15	6 13	6 13	All <0.01
4	R19	Boxpark Station	2 km, north east	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6 13 12	6 13 12	All <0.01
5	R16	Wynaroy	40 m, east	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6 13 12	6 13 12	All <0.01
6	R14	Camping - F&F Trail	250 m, north	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6 13* 12	6 12* 12	All <0.01
7	R15	Woodsreef Township (Church)	500 m, north east	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6 13 12	6 13 12	All <0.01
8	R11	Picnic Site	50 m, west	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6 13 12	6 13 12	All <0.01
9	R17	Mr Burgess Property	116 m, south	14/11/13 - 14/12/13 20/10/14 – 12/05/15 22/04/16 – 27/06/16	6* 13 12	5* 13 12	All <0.01

Notes: * When number of monitoring rounds is greater than number of valid samples it indicates a sample was rejected due to technical issue with sampling;
Monitoring was not undertaken from 22/04 to 27/06/16 as Woodsreef Taskforce advised SLR these site were not considered necessary given the distance from the mine and the results of monitoring in 2013, 2014 & 2105

Based on an evaluation of sampling conditions and other factors (seasonal / meteorological, etc) the monitoring undertaken was considered to provide representative data. Full details of the Background Monitoring have been reported in the health impact assessments prepared at each stage of the remediation project (SLR, 2015; SLR, 2016 & SLR, 2017a).

During the remediation works from September 2014 to May 2015, in addition to the air monition conducted by SLR, air monitoring was also independently conducted by Hygienists engaged by the demolition contractor. This monitoring was designed to ensure asbestos works were conducted in a safe and compliant manner. Their results also indicated that airborne asbestos fibre concentrations were at levels less than 0.01 fibres per mL of air. This monitoring was conducted using the same methodology, NOHSC (2005) as used by SLR. Monitoring was conducted on one hundred and forty one days at up to fifteen locations, mostly on the mine site distributed within and around the remediation works area, with limited off site monitoring (results summarised in **Table 9**).

3.3.17.2 Activity Based Monitoring Airborne Asbestos Fibre Monitoring

Activity Based Monitoring was conducted at locations near the mine site from 9 December 2013 to 12 December 2013 with some activities repeated from 30 May 2016 to 2 June 2016. The aim of this monitoring was to measure personal asbestos fibre exposure of persons undertaking recreational activities near the mine site.

SLR Consultants conducted a range of activities whilst wearing personal monitors using the methodology set out in NOHSC (2005). These activities were chosen by the Woodsreef Taskforce to represent typical recreational pastimes conducted near the mine site. These were based on advice from Barraba community representatives associated with the Woodsreef Taskforce and observations by Taskforce members. Some activities were excluded due to safety concerns, such as off-road driving of cars and motorbikes. However for excluded activities such as off-road driving of cars and motorbikes, it may be possible to infer likelihood of asbestos fibre exposure from other studies. This aspect is discussed further in **Appendix E**.

These activities included the following:

- Fossicking
- Camping (two locations)
- Bird watching
- Walking the Flora Trail (near The Mine Road)
- Viewing the mine from various observation points off the Bundarra - Barraba Road
- Walking along the Bundarra - Barraba Road.

Findings of the Activity Based Monitoring for each activity conducted by SLR in 2013 and 2016 indicated that airborne asbestos fibre concentrations measured on SLR personnel undertaking the activities were at levels less than 0.01 fibres per mL of air.

The airborne asbestos fibre concentrations for the activity based monitoring conducted by SLR in December 2013 and May / June 2016 have been set out below in **Table 8**.

Table 8 Activity Based Airborne Asbestos Fibre Monitoring 2013 & 2016

Activity	Date	Number of Samples	Concentrations (fibres/mL)
Fossicking	9/12/13 & 30/5/16	6	All <0.01
Camping - Iron Bark Camping Area, near Pumping Station	11/12/13 & 1/6/16	7	All <0.01
Camping - Iron Bark Camping Area, north of Bundarra - Barraba Rd, 1km north of mine	10/12/13 & 31/5/16	7	All <0.01
Bird Watching	9/12/13	3	All <0.01
Walking the Flora Trail	11/12/13 & 30/5/16	4	All <0.01
Viewing the mine from various observation points off the Bundarra - Barraba Road	12/12/13	3	All <0.01
Walking along the Bundarra - Barraba Road, near the mine	10/12/13 & 2/6/16	6	All <0.01

Full details of the Activity Based Monitoring have been reported in SLR (2017).

3.3.18 Historic Airborne Asbestos Fibre Monitoring

A review of available data indicated that airborne asbestos fibre monitoring had been undertaken a number of times between 1992 and 2012. Monitoring occurred either off mine site as background monitoring or on the mine site as part of monitoring during site works either during remediation works. The monitoring method used was the NOHSC (2005) method, consistent with the method used in this project.

The majority of the monitoring between 1992 and 2012 indicated that airborne asbestos fibre concentrations were at levels less than 0.01 fibres per mL of air. Therefore the likely concentrations of airborne asbestos during the monitoring periods were at least ten times lower than the current the Safe Work Australia Exposure Standard for asbestos (0.1 fibres per mL of air).

However, concentrations above 0.01 fibres per mL of air were detected during three periods, each time during remediation works on the mine site and at monitoring locations on the mine site only. In these cases the airborne asbestos fibre concentrations were in the range of 0.04 to 0.06 fibres per mL of air. The indicative approximation of samples above the detection limit was 1 sample above the detection limit per 140 samples taken on the mine site.

Dames & Moore (1997) reported that in 1992 monitoring conducted by the NSW Department of Mineral Resources for personnel conducting rehabilitation works on the Woodsreef tailings dump recorded airborne asbestos fibre concentrations in the range of 0.01 to 0.04 fibres per mL air. The second instance occurred during the 2009 remediation of the Mill Building, where monitoring on one day (12 October 2009) at one monitoring location on the mine site recorded airborne fibre concentrations of 0.06 fibres per mL of air. However, this elevated reading can be explained by the monitor location and activity at the time. The monitor was located at the “clean end of decontamination unit” and the report authors commented that the elevated concentration was due to a clothes drier being operated in the vicinity of the monitor. The basis of this claim is that the organic fibres such as from clothing, that conform in size and morphology to the fibre counting criteria set out in NOHSC (2005) are not distinguishable from asbestos fibres under phase contrast microscopy. Accordingly organic fibres will be counted as asbestos fibres leading to an erroneously high calculation of airborne asbestos fibres per mL air.

In the third instance during the 2012 building of the Bat Habitat, monitoring on one day (13 September 2012) at one monitoring location on the mine site recorded airborne fibre concentrations of 0.04 fibres per mL of air. This elevated reading can be explained by the monitor location and activity at the time. The monitor was located on the “Exterior of Mini Excavator” and presumably the Mini Excavator was used to dig trenches for placement of large pipes used for the Bat Habitat. This would have occurred along Mine Road, near the entrance to the Mine site.

Details of the airborne asbestos fibre monitoring undertaken intermittently between 1992 and 2016 have been set out below in **Table 9.**

Table 9 Woodsreef Airborne Asbestos Fibre Monitoring 1992 to 2016

Date		Activity	Number of Samples	Concentrations	Source
1992	Dates not provided	Monitoring of personnel during remediation works on the tailings dump using heavy machinery	Not Provided	**0.01 - 0.04 fibres / ml**	Dames & Moore,1997
2000	26 May - 22 June	Monitoring a combination of properties adjacent to the mine and locations on the mine site			
		Monitoring of properties adjacent to the mine, Wynaroy, Anglesey, Connors Creek	24	All <0.01 fibres/ml	HLA, 2000
		Monitoring locations on the mine site	61	All <0.01 fibres/ml	HLA, 2000
2004	20 October - 4 November	Monitoring of remediation works on mine site	130	All <0.01 fibres/ml	HLA, 2004
2009	6 October - 15 October	Monitoring of remediation works on mine site	51	Majority samples <0.01 fibres/ml **One sample 0.06 fibres/ml**	AECOM, 2009
2011	14 September & 24 November	Monitoring during geotechnical survey of mine site	9	All <0.01 fibres/ml	HAZMAT Services, 2011
2012	19 June	Background monitoring of mine site, included Woodsreef Church, Wynaroy, Mine Gate, 2 km South of mine gate & Fossicking area north west of mine	5	All <0.01 fibres/ml	HAZMAT Services, 2012a
2012	20 June - 21 June	Occupational monitoring on mine site during drainage assessment works	6	All <0.01 fibres/ml	HAZMAT Services, 2012b
2012	20 June - 21 June	Monitoring of mine site, near mine boundary during drainage assessment works	9	All <0.01 fibres/ml	HAZMAT Services, 2012c
2012	20 June - 21 June	Monitoring of mine site, near mine boundary and equipment used during building of bat habitat works	17	Majority samples <0.01 fibres/ml **One sample 0.04 fibres/ml**	HAZMAT Services, 2012d
2013	14 November - 14 December	Background monitoring of locations off the mine site including Barraba and Tamworth control site	48	All <0.01 fibres/ml	SLR, 2015
2013	9 December - 12 December	Activity Based Personal monitoring in the vicinity of the mine including: Fossicking, Camping (two locations), Picnicking, Bird Watching, Walking the Flora Trail, viewing the mine from various observation points off the Bundarra – Barraba Road, walking along the Bundarra – Barraba Road	20	All <0.01 fibres/ml	SLR, 2017

Date		Activity	Number of Samples	Concentrations	Source
2014-2015	20 October 2014 to 12 May 2015	Remediation monitoring of locations off the mine site including Barraba and Tamworth control site	91	All <0.01 fibres/ml	SLR, 2016
2014-2015	10 September 2014 to 28 May 2015	Remediation monitoring of locations on the mine site and occasionally off site	1,793	All <0.01 fibres/ml	Parsons Brinckerhoff, 2015
2016	22 April – 27 June	Background monitoring of locations off the mine site including Barraba	84	All <0.01 fibres/ml	SLR, 2017a
2016	30 May - 2 June	Activity Based Personal monitoring in the vicinity of the mine including: Fossicking, Camping (two locations), Walking the Flora Trail, walking along the Bundarra – Barraba Road	16	All <0.01 fibres/ml	SLR, 2017

In 1974 “dust sampling” was undertaken at properties in the vicinity of the mine. This sampling appears to be of settled dust; therefore, the results were used in a general way to infer airborne transport of asbestos onto the properties with the underlying assumptions that the source of asbestos was the active processes occurring at the mine. Furthermore, the available sources quoting the original works only give qualitative estimations of the amounts of asbestos dust observed. This information may be useful in providing some evidence of how airborne asbestos may have been transported in terms of direction and distance during previous mine operations. This information is of limited value to the current study due to the asbestos source being active mining processes rather than the effects of natural forces on the derelict mine. However, the information has been included below as part of the historic record.

Dames & Moore (1997) quoted from Stewart (1985) that “*Settled dust containing chrysotile was found in very low levels as far as “Black Mountain” (8.5 km) to the southeast of the Mill. Relatively high levels were found at “Fernview” (4 km) to the south and moderate levels at “Box Park” (4 km) to the northeast. Low levels were found at the township of Woodsreef (2 km) to the northeast. The 1974 sampling came only two years after the mine began operation and therefore asbestos levels in neighbouring properties would most likely be attributed to the dispersion of chrysotile fibres from the dryer stack on the Mill only, rather than the tailings dump.”*

3.3.19 Key Points - Asbestos & Air Quality

- There is historic and contemporary air monitoring data available of airborne asbestos fibre concentration in areas surrounding the mine, from 1992 to 2016.
- In the current study, monitoring from 2013 to 2106, 1,807 airborne asbestos samples were collected. All samples recorded of less than 0.01 fibres per mL air.
- Activity Based Monitoring near the mine site in 2013 and 2016 included 36 samples with recorded airborne asbestos fibre concentrations during all activities of less than 0.01 fibres per mL air.
- The activities were chosen to represent typical recreational pastimes conducted near the mine site. These activities included the following: Fossicking, Camping (two locations), Bird Watching, Walking the Flora Trail, Viewing the mine from various observation points off the Bundarra - Barraba Road, Walking along the Bundarra - Barraba Road.
- Airborne asbestos fibres are likely to be only occasionally becoming airborne at detectable concentrations when there is a physical disturbance on the mine site itself.
- Detectable concentrations of airborne asbestos fibres have not been recorded outside the mine site in the surrounding communities and locations.

3.4 Risk Mitigation Measures

The risk mitigation measures set out below are from SLR (2013a) Hazard Assessment Report Woodsreef Mine Major Rehabilitation Project NSW Trade and Investment Division of Resources & Energy Report Number 610.10893.0030. These recommendations were based on information obtained during that study.

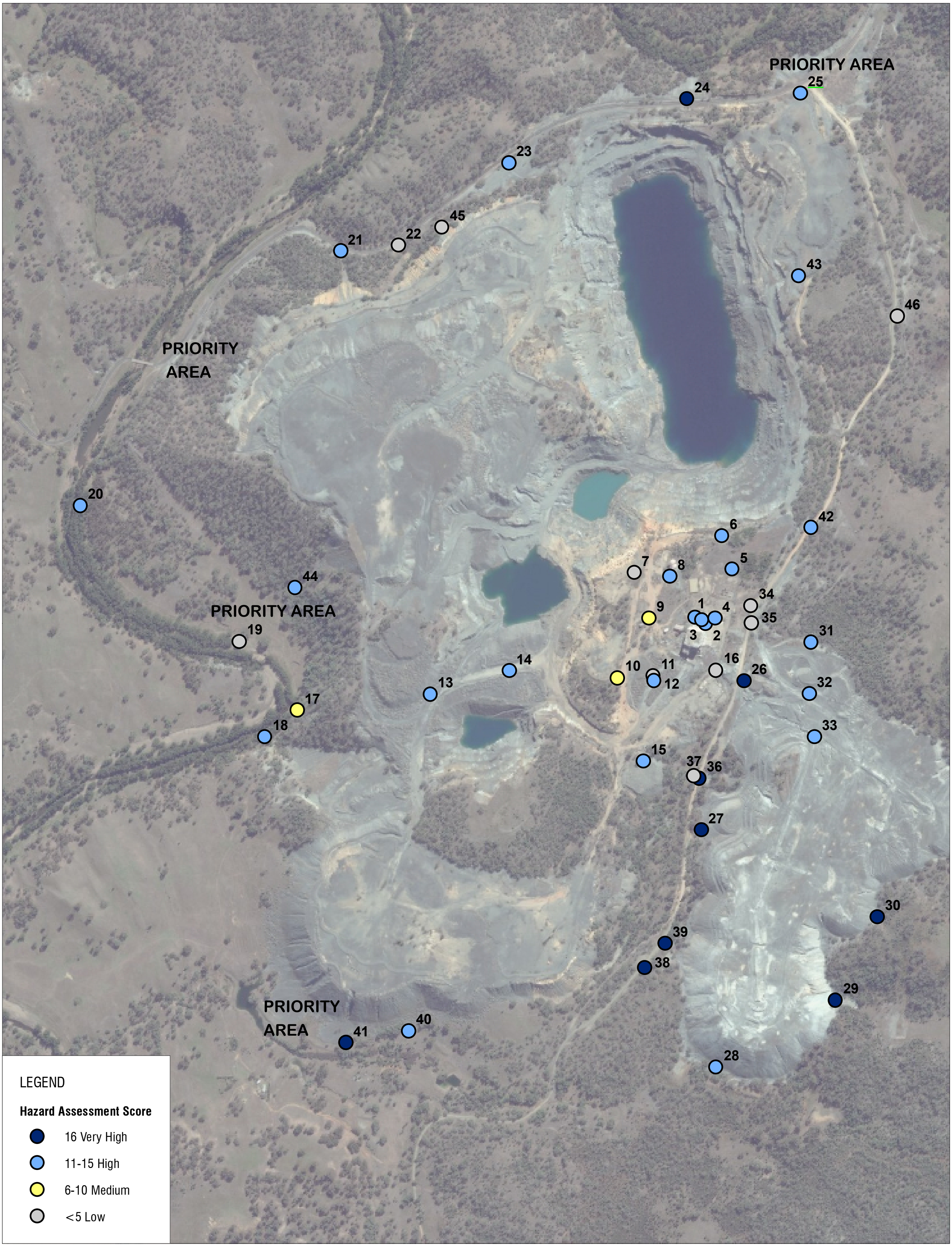
As the mine site is contaminated with significant volumes of naturally occurring and processed asbestos waste and tailings, many high level engineering or large scale asbestos mitigation controls (such as encapsulating and removal) are not feasible. Furthermore the mine is situated in an area of high asbestos mineralisation and accordingly areas beyond the mine would be expected to contain naturally occurring asbestos (NOA).

A mid-level area targeted risk management approach is required in order to implement risk mitigation controls. As there is variability between the different areas within and around the mine (and in some cases within areas themselves) and a number of locations are readily accessible by the public using the Barraba-Bundarra Road, controls need to be tailored in order to provide the best options for members of the public, workers and visitors to the site to control the potential environmental health hazards in and around the mine.

The most effective control is to reduce or limit public access to areas where there is an elevated asbestos hazard present and/or minimise off-site migrating of asbestos materials into publicly accessible areas such as locations where run-off is occurring across roads or is entering upstream creeks. As such the primary focus is on the need to maintain current sediment drains and culverts around the mine site, especially those along the Barra-Bundarra Road as well as preventing drainage into water courses that may lead to extensive off site migration into public areas.

Specific locations of potential notable public risk to areas of elevated asbestos hazard or migration to waterways around the perimeter of the site observed during visits and sampling are also highlighted in the specific controls. In addition they have also been marked as "Priority Area" on the sampling Map in **Figure 26.** These were locations of potential notable public risk to areas of elevated asbestos hazard or migration to waterways around the perimeter of the site. This figure as well as the information and conclusions were reported in SLR (2013a). The figure contains "Sampling Locations" for asbestos analysis and "Hazard Assessment Scores". Factors considered in this scoring included characteristics of soil surface crusting, evidence of material migrations and migration path. Further information on these including the basis for Hazard Assessment Scores can be found in SLR (2013a).

Figure 26 along with the colour coded areas in **Figure 27** have been used to indicate some of the risk mitigation priority areas. **Figure 26** covers the entire mine site whereas **Figure 27** focuses on areas where the public maybe in close proximity to the mine. **Figure 27** is placed here in the text for proximity to **Figure 26** both of which will be referenced later in **Table 11** as will the colour coding in **Figure 27.**



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Woodsreef Mine - Hazard Identification

Sampling Point Locations

FIGURE 26

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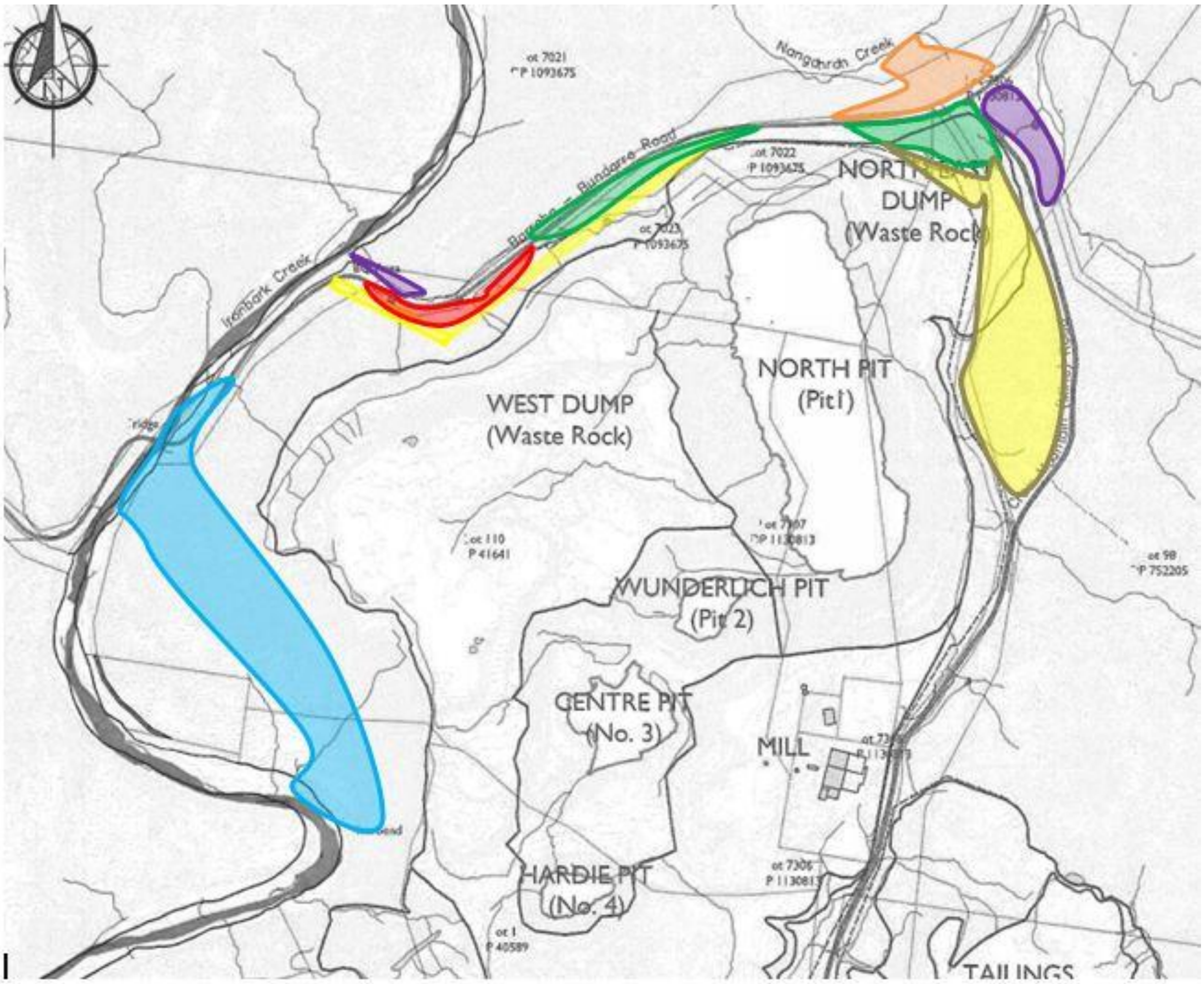
Figure 27 Mitigation Priority Locations – Public Proximity Colour Coding



3.4.1 Locations on and around the Mine Site

3.4.1.1 Air Monitoring

Background air monitoring should be considered in the boundary of the mine site every two (2) years in locations where there is evidence of off-site impacts along perimeters with emphasis on the public access interface. This will provide a method to confirm the adequacy of controls and to document airborne asbestos levels and collate monitoring data. It is suggested that 8 - 10 locations are undertaken and weather conditions noted with sampling undertaken during dry conditions.

Monitoring should be undertaken by a suitably qualified person such as a qualified occupational hygienist or licensed asbestos assessor.

Where there are works or evidence of stability in off-site migration and/or reduction in public access to these areas, the time periods between monitoring should be increased. Conversely, additional air monitoring could be considered following a particular significant event where notable migration of asbestos materials has impacted on publicly accessible areas.

3.4.1.2 Site Boundary Inspections

Table 10 indicates the frequency of recommended inspections around the mine site. Inspections should be carried out by a competent person.

Table 10 Frequency of Site Inspections

Area	Location	Frequency
Waste and Overburden	Barraba-Bundarra Road between the Ironbark Creek Bridge and the Woodsreef Church including sediment basins, siltation and drainage culverts and road cuttings.	Monthly
Public areas of Iron Bark Creek near bridge	A routine inspection is carried out along the publicly accessible areas of Iron Bark Creek to ensure stable condition. This includes picnic areas and access and work points for utilities companies and northern side of road near intersection with Mine Road.	Monthly
Mine Tailings Boundary	As this location is furthest away from the general public, routine inspection should be carried out by a competent person every 6 months or as required to ensure the above mentioned controls are maintained.	Six Monthly

3.4.1.3 On-site Management

In addition to general management controls, there are legislative requirements under the NSW Work Health and Safety Act (2011) for managing an asbestos exposure risk present on and around a site (in this case, the Mine Site). The key requirements for this site include:

- Maintain an Asbestos Register to record authorised site visits that details the purpose of the visit, duration, and any other information deemed necessary. Prohibit any unauthorised activity that will generate dust unless a detailed Asbestos Management Plan is in place which should include monitoring.
- Ensure all authorised personnel that require a site visit are trained in asbestos risk and exposure including the correct use of PPE/RPE and decontamination procedures in association with a Site Specific Asbestos Management Plan or Job Safety Analysis (JSA), as required.
- Maintain a register of unauthorised site visits or security breaches that detail the locations, estimated date, duration and any other information available, insofar as is reasonably practicable.

3.4.1.4 Risk Mitigation Actions

Table 11 provides a list, ranked in order of priority, of engineering and design review based controls for locations around the mine site. Specific time frames are not provided as these should be determined using a risk-based management approach and, where appropriate, from observations through site-boundary inspections. Locations referenced below are indicated on **Figure 26** and **Figure 27**.

Table 11 Risk Mitigation Actions

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
1	Undertake a review of site security and site access in order to restrict unauthorised access around the waste dump and overburden areas and where corresponding drains interface with the public access.	The Waste rock (overburden) forms the largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration.	Barraba-Bundarra Road including sediment basins and culverts and Southern Mine Road entrance.	**Fig 26**	Very High
2	Install security bollards or concrete blocks every 2-3 metres along potential vehicular access points (including access across the Barraba-Bundarra Road and Mine Road intersection) and along deep road verges to discourage vehicles from stopping.	The road cuttings sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. It is also likely that the hazard levels would be highly variable within short distances.	Barraba-Bundarra Road and Mine Road intersection.	**Fig 26**: 21,23,25. **Fig 27**: Green	Very High
3	Removal of tourism signage along Barraba-Bundarra Road as well as restrictions on local government working near mine waste.	The road cuttings sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. It is also likely that the hazard levels would be highly variable within short distances.	Between Bridge over Iron Bark Creek and 100m before Woodsreef Church.	**Fig 26**	Very High
4	Restrictions imposed on building access roads or cuttings through mine waste on the northern side of Barraba-Bundarra Road.	The road cuttings sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. It is also likely that the hazard levels would be highly variable within short distances.	Northern mine area around Mine Road and Nangahrah Creek.	**Fig 26**: 24,25 **Fig 27**: Orange	Very High

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
5	Erecting additional fencing with signage in areas (such as in Figure 26, near sampling point 21) in order to limit public access. The suggested fencing should be constructed of heavy duty rail-less chain link security materials which meet AS1725.1:2010. Appropriate metal asbestos signage should be placed no more than 50m apart or when common accessible points may be.	The siltation system sediments sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. A number of siltation systems are accessible from the Barraba-Bundarra Road.	Western side of the mine waste area along the eastern edge of Barraba-Bundarra Road between Cattle Grid and Mine Road intersections.	**Fig 26**: 21-23,25 **Fig 27**: Yellow	High
6	Prevention of fibre release across the Barraba-Bundarra Road is the most effective option. The laying of blue metal or other similar methods that allow drainage to assist with dust suppression should be considered, especially where there is evidence of occasional run off underneath and/or across the road.	The siltation system sediments sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. A number of siltation systems are accessible from the Barraba-Bundarra Road.	Barraba-Bundarra Road (northern section between Cattle Grid and Mine Road intersections) and the mine boundary where there is evidence or potential for run off.	**Fig 26**: 24,25 **Fig 27**: Orange	High
7	The feasibility of methods to encapsulate or suppress dust release should be considered along identified edges of the road (such as laying blue metal or shotcreting). Where it is not feasible, a risk management approach must be used in determining signage requirements, with the clear intent of informing all on the risk of asbestos contamination and exposure.	Northern mine section (northern side of road) sample taken in this area (**Figure 26**, sample point 24) in the hazard assessment indicates a very high potential to release asbestos fibres. This area has been identified as a site where offsite migration occurs.	Barraba-Bundarra Road (northern section between Sample point 23- 25 (Mine Road intersections) and the mine boundary where there is evidence or potential for run off.	**Fig 26**: 23,24,25 **Fig 27**:Green	High
8	Closure of the trail and fencing-off of the area should be seriously considered. Refer public to other Flora Trails.	The sample taken in this area (**Figure 26**, sample point 43) in the hazard assessment indicates a high potential to release asbestos fibres.	Flora Trail adjacent to Pit 1	**Fig 26**: 43 **Fig 27**:Yellow	High

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
9	Public signage to any trials adjacent to the mine site should be removed and the promotion of tourism activities to locations adjacent to the mine site should be discouraged due to potential risk.	The sample taken in this area (**Figure 26**, sample point 43, 20, 18, 44) in the hazard assessment indicates a high potential to release asbestos fibres.	Flora trail and local maps.	-	High
10	Ensure this section (western side of tailings) is restricted and unauthorised access prevented. A risk management approach shall be used in determining signage and labelling requirements, with the clear intent of informing all on risk of asbestos exposure.	The sample taken in this area in the hazard assessment indicates a very high potential to release asbestos fibres. This area has been identified as an area where offsite migration and run-off occurs. This location can be accessed by off-road vehicles using a track from the Iron Bark Creek picnic area.	Between the West Tailings Dump and the track leading to the Iron Bark Creek pumping station.	**Fig 26**: 18,44 **Fig 27**:Blue	High
11	Stock fencing with gates should be considered in order to limit inadvertent access.	The sample taken in this area in the hazard assessment indicates a very high potential to release asbestos fibres. This area has been identified as an area where offsite migration and run-off occurs. This location can be accessed by off-road vehicles using a track from the Iron Bark Creek picnic area.	Suitable site along main stock route to pumping station.	**Fig 26**: 18,44 **Fig 27**:Blue	High
12	Review the current drainage assessment to ensure it is still appropriate and effective.	Waste and overburden: this area forms the largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration.	Southern end of the South Dump and stock grid area on Barraba-Bundarra Road.	**Fig 26**: 40,41,21 **Fig 27**:Red	Moderate

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
13	Maintain asbestos signage along the fence lines. The signs should conform to AS1319-1994. The display, positioning and numbers of asbestos hazard warning signs shall be determined by a competent person; however, difficulty in removing the signs should be considered given this issue of unauthorised removal or damage in the past. Metal signage placed high behind fencing is preferred where possible.	Waste and overburden: this area forms the largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration.	All the potential entrances, trails, fence-lines, property lines, creek beds and points where there is historical or current evidence of unauthorised access.	**Fig 27**: Yellow	Moderate
14	Information signs on asbestos risk should also be provided in the picnic area, look out areas along the Barraba-Bundarra Road as well as the area along Iron Bark Creek where water sampling is periodically taken by utility companies.	Waste and overburden: this area forms the largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration.	Barraba-Bundarra Road along Iron Bark Creek and access road north of North East Dump waste rocks.	**Fig 27**: Blue, Purple	Moderate
15	Undertake suitable encapsulation along identified edges of the road e.g. laying blue metal, shotcrete or other similar methods to suppress dust and run-off release, especially around the intersection of Mine Road and the current look-out area.	The road cuttings sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. It is also likely that the hazard levels would be highly variable within short distances.	Southern look-out area and verges close to Barraba-Bundarra Road and parking areas for access Roads to Woodsreef Conservation Areas.	**Fig 27**: Green	Moderate
16	Relocate or extend the existing fence boundary towards the Barraba-Bundarra Road to capture as much of this area where permitted under road verge requirements. The suggested fencing should be constructed of heavy duty rail-less chain link security materials which meet AS1725.1:2010. Appropriate metal asbestos signage should be placed no more than 50m apart or when common accessible points may be.	The road cuttings sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. It is also likely that the hazard levels would be highly variable within short distances.	Southern side look-out area and verges close to Barraba-Bundarra Road.	**Fig 27**: Green	Moderate

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
17	Consider a further review of soil and drainage around the immediate vicinity of the Tailings and potential cattle interaction.	The tailings (partially processed ore) area forms the second largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration. This area is primary on the south-eastern areas of the mine site along the southern section of the closed Mine Road.	Southern end of Tailings Dump.	**Fig 26**: 28,38	Moderate
18	A review of site security and site access be undertaken in order to restrict unauthorised access especially where the drainage and sediment basins and culverts interface access paths (including the closed Mine Road).	The tailings (partially processed ore) area forms the second largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration. This area is primary on the south-eastern areas of the mine site along the southern section of the closed Mine Road.	End of Southern Section of Mine Road and the closed Mine Road.	**Fig 26**: 28,38	Moderate
19	Ensure site access is restricted and unauthorised access prevented. A risk management approach shall be used in determining signage requirements, with the clear intent of informing all on risk of asbestos exposure.	The tailings (partially processed ore) area forms the second largest part of the mine site and the hazard assessment indicates a high to very high potential to release asbestos fibres through off site migration. This area is primary on the south-eastern areas of the mine site along the southern section of the closed Mine Road.	Southern end of Tailings Dump.	**Fig 26**: 28,38	Moderate
20	Laying of asphalt to the gate of the land owner off the northern Mine road entrance should be considered to minimise mechanical erosion and disturbance risk and potential contamination of vehicles.	The northeast dump sediments sampled in the hazard assessment indicates a medium to high potential to release asbestos fibres through off site migration.	Barraba-Bundarra Road and Mine Road intersection	**Fig 26**: 25 **Fig 27**: Purple	Moderate

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
21	Further review of the effectiveness of the current drainage system, especially in areas where road run-off is evidence following heavy rain.	The siltation system sediments sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. A number of siltation systems are accessible from the Barraba-Bundarra Road.	Western side of mine on Barraba-Bundarra Road north of stock grid.	**Fig 27**: Red	Moderate
22	Maintain appropriate asbestos signage along the fence lines. The signs should conform to AS1319-1994 Safety Signs for the Occupational Environment. Metal signage placed high behind fencing is preferred where possible.	The siltation system sediments sampled in the hazard assessment indicates a medium to very high potential to release asbestos fibres through off site migration. A number of siltation systems are accessible from the Barraba-Bundarra Road.	All areas where run off or drainage is noted on Barraba-Bundarra Road.		Moderate
23	If closure and fencing off of the area is possible then this approach should be seriously considered as this area has also been known to be impacted by asbestos contamination following heavy rain or a major event. Where it is not feasible, a risk management approach shall be used in determining signage requirements, with the clear intent of informing all on the health risk of asbestos contamination and exposure and ensuring access is minimised insofar as is possible. As Iron Bark Creek is readily accessible from the Barraba-Bundarra Road additional information signage may also be suitable stating recommendations to relocate to alternative camping, fishing and picnic areas.	Iron Bark Creek area in the hazard assessment indicates a range of low to high potential to release asbestos fibres following off site migration. This range also indicates that there is significant variability within a close area making targeted mitigation control difficult.	Public areas of Iron Bark Creek near bridge down to pumping station.	**Fig 27**: Blue	Moderate

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
24	The display, positioning and numbers of asbestos hazard warning signs or labelling shall be determined by a competent person; however, difficulty in removing the signs should also be considered given past issues.	Iron Bark Creek area in the hazard assessment indicates a range of low to high potential to release asbestos fibres following off site migration. This range also indicates that there is significant variability within a close area making targeted mitigation control difficult.	Public areas of Iron Bark Creek near bridge.	**Fig 26**: 17-20 **Fig 27**: Blue	Moderate
25	Signage should be provided for contractor or utility companies of the control measures required if working in this area.	The sample taken in this area in the hazard assessment indicates a very high potential to release asbestos fibres. This area has been identified as an area where offsite migration and run-off occurs. This location can be accessed by off-road vehicles using a track from the Iron Bark Creek picnic area.	Main stock route to pumping station (or gate if 9.2 is implemented).	**Fig 26**: 18,44 g 27: Blue	Moderate
26	Determine if the installation of suitable sediment traps if feasible to reduce migration of asbestos containing materials into Iron Bark Creek.	The sample taken in this area in the hazard assessment indicates a very high potential to release asbestos fibres. This area has been identified as an area where offsite migration and run-off occurs. This location can be accessed by off-road vehicles using a track from the Iron Bark Creek picnic area.	Near pumping station (Iron Bark Creek).	**Fig 26**: 17-20 **Fig 27**: Blue	Moderate
27	Undertake suitable encapsulation along identified edges of the road e.g. laying blue metal, shotcrete or other similar methods to suppress dust and run-off release, especially around the intersection of Mine Road, picnic area and the current look-out area.	The sample taken in this area in the hazard assessment indicates a medium potential to release asbestos fibres. This area has been identified as an area where offsite migration occurs. This location is located near the current fence along Barraba-Bundarra Road and is accessible to the public.	Southern look-out area and verges close to Barraba-Bundarra Road and parking areas for access Roads to Woodsreef Conservation Areas.	**Fig 26**: 45 **Fig 27**: Purple, Green	Moderate

Task	Action	General Area	Detailed Location	Figure Reference	Health Risk Priority
28	Relocate or extend the existing fence boundary towards the Barraba-Bundarra Road to capture as much of this area where permitted under road verge requirements. The suggested fencing should be constructed of heavy duty rail-less chain link security materials which meet AS1725.1:2010. Appropriate metal asbestos signage should be placed no more than 50m apart or when common accessible points may be.	The sample taken in this area in the hazard assessment indicates a medium potential to release asbestos fibres. This area has been identified as an area where offsite migration occurs. This location is located near the current fence along Barraba-Bundarra Road and is accessible to the public.	Southern side look-out area and verges close to Barraba-Bundarra Road.	**Fig 26**: 45 **Fig 27**: Yellow	Moderate
29	Ensure site access is restricted and unauthorised access prevented. Signage requirements will be covered by the signage at the nearby closed road barriers. This location is on the closed section of Mine Road and is not readily accessible to the public.	Mine Road - sample taken in this area in the hazard assessment indicates a medium potential to release asbestos fibres. This area has been identified as an area where offsite migration can occur.	Mine Road (boundary of the mine (northern and southern end).	**Fig 26**: 25,38	Completed

3.5 Toxicity & Carcinogenicity Assessment

Airborne asbestos fibre concentrations are important because asbestos primarily affects the respiratory system (ASTDR, 2001). There is no clear evidence of asbestos causing disease through ingestion such as may occur through eating or drinking asbestos contaminated foodstuff or water.

All types of asbestos are carcinogenic, although there is some debate that amphibole type asbestos is more potent in causing mesothelioma than the serpentine type (chrysotile). However, both types can cause mesotheliomas and are believed to be equally potent in causing lung cancer (*ATSDR, 2001*).

All asbestos-related diseases are dose-related, the higher the concentration and duration of exposure, the higher the prevalence of the disease and mortality. Disease can occur as a result of either high exposure to airborne asbestos fibres for a short time or lower exposure over longer periods of time.

There are numerous reviews of the asbestos related diseases, asbestosis, lung cancer and mesothelioma and a brief summary has been provided in **Appendix D**.

3.6 Exposure Assessment

In general, an exposure assessment aims to provide the magnitude, frequency, extent, character and duration of exposures to a chemical or material of concern, in this case asbestos. An exposure assessment also aims to identify human populations or groups who may be exposed and potential exposure pathways, which in this case is inhalation.

3.6.1 Exposure Pathways and Receptors

An exposure pathway describes the mechanism by which personnel may be exposed to asbestos fibres originating from the Woodsreef Mine. Each exposure pathway must include a source of fibres, mechanism for release of the fibres and a mechanism for fibres to enter the breathing zone. The exposure pathway is incomplete if any of these factors are not present, and therefore no additional risks are associated with that activity.

Receptors

Receptors are similar groups of people from the defined communities. In this assessment, receptors are considered to be individuals who usually reside in the Barraba Township, individuals living in close proximity to the mine, and transient observers who may be in close proximity to the mine.

Based on the community information set out in **Section 2.3** and the information on exposure pathways determined in the Conceptual Site Model in **Section 2.3.7**, members of the communities have been classified into seven (7) exposure categories and a Control group as set out in **Table 12** with accompanying notes.

Table 12 Community Exposure Groupings - Receptors

Exposure Group	Definition
Control Group 0 - Tamworth Residential	Population living approximately 85 km distance from the mine
Exposure Group 1 - Barraba Residents	Population in Barraba and 2 km from Barraba centre, approximately 15 km distance from mine
Exposure Group 2 - Barraba Special Populations	Special population subgroup within community who may be a greater risk of adverse health impacts due to factors such as age or ill health. Includes population under 18 years of age, elderly and infirm
Exposure Group 3 - Rural Residents in immediate vicinity to the Mine	Population living in immediate vicinity to the Mine, approximately 5km to 13km^ from the mine
Exposure Group 4 - Woodsreef Residents	Population living in close proximity to the mine, up to approximately 5 km▫ distance from mine
Exposure Group 5 - Woodsreef Special Populations	Special population subgroup within community who may be a greater risk of adverse health impacts due to factors such as age or ill health. Includes population under 18 years of age, elderly and infirm
Exposure Group 6 - Passive Recreation conducted in proximity to the Mine	Transient observers (general public and visitors) undertaking passive recreational activities (i.e. little or no disturbance of soil and vegetation) in close proximity to the mine, within 4km* of the mine
Exposure Group 7 - Active Recreation conducted in proximity to the Mine	Transient observers (general public and visitors) undertaking active recreational activities (i.e. potential for some disturbance of soil and vegetation) in close proximity to the mine, within 4km* of the mine

Notes:

* Recreational activities are normally undertaken within 4km of the mine site

^ Rural population residing at distances beyond those considered as Woodsreef residents in this study to the edge of Barraba residents (2km from Barraba centre)

▫ The 5km limit is based on encompassing approximately two thirds of the total sensitive receptors identified as closest to the mine as well as modeling of airborne asbestos fibres deposition by both Dames & Moore (1997) and SLR (2013b) which estimated that downwind airborne asbestos concentrations was likely to decline by 70% or 80% within 5km of the mine.

Source of Asbestos Fibres

The original source of asbestos fibres in the current study is the processed materials on the mine site. However, there are also sources of asbestos that have been transported by the forces of nature from the mine site to areas adjacent to the mine site. It is acknowledged that naturally occurring sources of asbestos are also present in the general area however; it is probable that the main bioavailable source of asbestos is overwhelmingly from the mine site.

Notional Mechanism for Release of Fibres

The mechanisms responsible for the release of fibres are many and varied but can be defined in two broad groupings. The first being the release of fibres through natural forces, such as wind, rain, erosion etc, and the second grouping being the release of fibres through man-made forces, such as during the remediation works and when persons or plant disturb the soil/ground.

There is evidence of current erosion and migration of materials within the mine site and off the mine site. The migration of materials and subsequent release of asbestos fibres is likely to be intermittent in nature and linked to significant events such as heavy rain or the localised catastrophic collapse of sections of the material such as occurs when water causes erosion to undermine areas leading to collapse of previously stable crusts or materials (SLR, 2013a).

Release of the asbestos fibres through human activity is in general not currently occurring on the mine site. The exception to this was when remediation works were undertaken or historically when trespassers enter the mine site. However, man-made forces may be disturbing soil containing asbestos fibres in areas where the asbestos fibres have initially been transported off site by natural forces and deposited on lands adjacent to the mine. Examples of soil disturbance off the mine site range from small scale such as a recreational camper or a vehicle disturbing the soil to large scale such as digging up areas for roads works or removal of drainage sediments.

Mechanism for Fibres to Enter the Breathing Zone

Once asbestos fibres have been released then air movement is required for asbestos fibres to enter the breathing zone of a person. This will entail two broad scenarios:

- Air movement will transport airborne fibres over significant distances ranging from hundreds of metres to kilometres (Scenario 1).
- Air movement transporting fibres over limited distances such as metres (Scenario 2).

In Scenario 1, the receptors may be at a distance from the mine and disturbed fibres have to be carried by winds for significant distances. During this distribution the concentrations of airborne asbestos fibres will be diluted from the original fibre suspension from the soil as the winds take the fibres away from the mine site. It is conceivable under the right atmospheric conditions that airborne asbestos fibres may reach receptors at a distance from the mine, such as Exposure Group 1 - “Barraba Residents”; however, the concentration of fibres the receptor may receive in their breathing zone should be significantly diluted compared to the initial airborne fibre concentrations near the mine.

An alternative Scenario 1 example may be a receptor closer to the asbestos source and hence potentially exposed to the higher initial concentrations of airborne fibres before limited dilution in the general air movement. Exposure Group 6 “Passive Recreation” near the mine is an example where people viewing the mine from the mine boundary or picnicking in close proximity to the mine, are potentially exposed to the higher airborne fibres concentrations associated with the initial disturbance.

In Scenario 2, the receptors are very close to the original source of the asbestos when fibres become airborne. The distance from the source of airborne fibres may be less than one metre. The mechanism for the release of fibres may also be due to the activities of the receptor disturbing the asbestos source. These receptors are likely to be potentially exposed to higher concentrations than those in Scenario 1 due to their proximity to the asbestos source. However, the exposure may be of a shorter time period as the airborne fibres disperse into the surrounding air. Exposure Group 7 “Active Recreation” may be exposed to asbestos fibres entering their breathing zone in this manner.

3.6.2 Assessment of Exposure Concentrations

The exposure concentrations for the current study were based on results of historic air monitoring at the mine site and recent monitoring by SLR as set out above in **Section 3.3.18**.

It appears that for all Exposure Groups the airborne asbestos fibre concentrations post remediation works and the general background levels they may be routinely exposed was likely to be less than 0.01 fibres per mL of air. This was based on the review of all available airborne asbestos fibre monitoring from 1992 to 2016, which showed all monitoring data from locations off the mine site have recorded airborne asbestos fibre concentrations of less than 0.01 fibres per mL of air and related information such as air quality modelling.

Airborne asbestos fibre concentrations above 0.01 fibres per mL in air have only been recorded at sampling locations on the mine site itself and only occasionally when remediation activities have been occurring on the mine site. This data fits the assumption that asbestos fibres mainly become airborne during intermittent physical disturbance to the asbestos containing source material. Examples of physical disturbance may be caused by natural forces of erosion or manmade disturbance through remediation works, driving along the now closed section of The Mine Road or recreational activities that disturb the ground structure.

In 1992 monitoring of personnel conducting rehabilitation works using heavy equipment on the Woodsreef tailings dump recorded airborne asbestos fibre concentrations in the range of 0.01 to 0.04 fibres per mL of air (*Dames & Moore, 1997*). The tailings can be considered an area of high asbestos content with a high percentage of respirable size asbestos fibres present in the material, based on current and historic studies as set out in **Section 3.3.7**. Therefore the tailings are in an area where physical disturbance can relatively easily create airborne asbestos fibres. For the purposes of estimating receptor exposure airborne fibre concentrations, the concentration of 0.04 fibres per mL of air recorded during the tailings rehabilitation works may be used to represent airborne concentrations generated by short term physical disturbance on the mine site.

It appears likely that a large percentage of airborne fibres initially generated from the mine, settled back to ground within 5 km of the mine site. Modelling of airborne asbestos fibres deposition by both Dames & Moore (1997) and SLR (2013b) estimated that downwind airborne asbestos concentrations would decline by 70% or 80% within 5km of the mine.

However, the actual distance airborne asbestos fibres generated on the mine site travel before deposition has to date not been verified by field measurements of airborne asbestos fibres. As stated above, all monitoring data from locations off the mine site have recorded airborne asbestos fibre concentrations of less than 0.01 fibres per mL of air.

Therefore, the estimated exposure concentrations, both during the remediation works and the long term background concentrations associated with the mine site are likely to be less than 0.01 fibres per mL of air which is not distinguishable from the background at the control site of Tamworth. The estimated background exposure concentrations have been set out in **Table 13**.

Table 13 Community Exposure Groupings - Background Exposure Concentrations (no disturbance on mine)

Exposure Group	Exposure Concentrations – Remediation Works & Background (asbestos fibres/mL air)
Control Group 0 - Tamworth Residential	< 0.01
Exposure Group 1 - Barraba Residents	< 0.01
Exposure Group 2 - Barraba Special Populations	< 0.01
Exposure Group 3 - Rural Residents in immediate vicinity to the Mine	< 0.01
Exposure Group 4 - Woodsreef Residents	< 0.01
Exposure Group 5 - Woodsreef Special Populations	< 0.01
Exposure Group 6 - Passive Recreation conducted in proximity to the Mine	< 0.01
Exposure Group 7 - Active Recreation conducted in proximity to the Mine	< 0.01

It should be prudent to consider that Exposure Group 7 (Active Recreation conducted in proximity to the mine) may be potentially exposed to localised elevated airborne asbestos concentrations over short time periods, generated by their activities which cause physical disturbance to asbestos containing soils, for example trail bike riding around Iron Bark Creek.

Persons in close proximity to the mine site, such as Woodsreef Residents and persons undertaking recreation activities near the mine (Exposure Groups 4, 5, 6 & 7) may be in close proximity to the asbestos source during the initial disturbance. Asbestos fibre concentrations that persons may be intermittently exposed to are difficult to estimate; however those in closer proximity to a disturbance are more likely to have greater exposure. The only study that attempted to simulate Active Recreation exposure, the activity based air monitoring conducted by SLR in 2013 & 2016, reported airborne fibre concentrations of less than 0.01 fibres per mL (*SLR, 2017*). However this result does not preclude the possibility of exposure to higher airborne asbestos concentrations during active recreational activities or during certain climatic conditions such as periods of strong winds.

As previously stated, short term Exposure Concentrations measured during disturbance on the mine site have been recorded concentrations in the range of less than 0.01 to 0.06 fibres per mL of air with the overwhelming majority of samples showing concentrations of less than 0.01 fibres per mL of air. Airborne asbestos monitoring during the remediation works confirmed the trend in historic data. During the remediation works all concentrations recorded were less than 0.01 fibres per mL of air.

4 RISK CHARACTERISATION

Risk characterisation involves the incorporation of the exposure assessment and the hazard assessment to provide an overall evaluation and assessment of risk. Risk assessment is used extensively in Australia and overseas to assist decision making on project acceptability and chemical use. Risk is the probability of an unwanted event happening and is often expressed as a multiple of its consequences and frequency. Risks can be defined to be acceptable or tolerable if the population will bear them without undue concern. Regulatory limits are set at points deemed "acceptable" by the regulator, taking into account objective evidence of harm and the general views of society. Risks are unacceptable if they exceed a regulatory limit, or cannot be accepted.

As with any risk assessment there is always a degree of uncertainty associated with the assessment. The factors involved in this uncertainty and the implications are discussed in **Appendix E**.

Negligible risks are those so small that there is no cause for concern, or so unlikely that there is no valid reason to take action to reduce them. Humans continually expose themselves to, or have imposed upon them, the risk of injury or fatality. Self-imposed risk is known as voluntary risk and includes everyday events such as smoking, swimming and driving. Each has an associated risk that people voluntarily accept when weighed against the perceived benefits.

Asbestos fibres are ubiquitous in the environment and the population inhales fibres continuously though at generally very low levels (generally below 0.001 fibres per mL in urban environments and lower in rural areas with no naturally occurring asbestos (ASTDR, 2001). The receptor groups identified in the current study in general may not be exposed to airborne asbestos concentrations that vary from background ambient outdoor air levels unless significant disturbance of asbestos sources, either on the mine site or off the mine site occurs. Therefore it is useful to consider the significance of the current incidence rates and the estimated background rate.

4.1 Background Incidence Rate of Mesothelioma

It is suggested that the background incidence rate of mesothelioma (for those not exposed to asbestos fibres occupationally) is estimated to be less than 1 case per million populations per year. Because of the high fatality rate and relatively short survival after diagnosis, incidence and mortality rates are similar (AIHW, 2004). However, it is debated whether this background incidence rate is either due to non-asbestos factors or background exposure to asbestos fibres.

For all exposure scenarios including high level historic occupational exposures, the current incidence of mesothelioma in Australia, as reported by Tossavainen (2004), is 35 cases per million population per year (approximately 490 cases per year) for the population over 15 years of age. This incidence rate reflects the high level occupational exposures occurring between 15 and 40 years ago. A vast majority of people being diagnosed with asbestos-related diseases such as mesothelioma are the workers who worked in the Australian asbestos mines, manufactured asbestos products, unloaded the shiploads of asbestos, worked on construction sites where asbestos was sprayed on the beams and where asbestos products were disrupted aggressively for long periods of time.

With regards to current potential community exposures, if airborne asbestos fibres were at measurable concentrations the exposure risks may be calculated using the US EPA inhalation unit risk factor (US EPA, 2005). Alternately a combined semi quantitative and qualitative based risk assessment including the application of the Safe Work Australia Exposure Standards for airborne asbestos may be used to estimate risk associated with community or worker exposure, such as recreational activities, including activities of less than a day in duration or recreational activities lasting a number of days (such as camping) or when work-related activities are undertaken in the area surrounding the mine.

A simple comparison of an air measurement and a health benchmark can be thought of as a "screening" exercise, that is, the risk assessor is screening for possible problems. If the majority of samples are much less than the benchmark, then in a majority of cases it would be appropriate to conclude that a health impact is unlikely.

The principal benchmark used in this assessment was the Safe Work Australia eight-hour TWA value of 0.1 fibres/mL for asbestos exposure. Details on this benchmark have been set out previously in **Section 3.3.11.1** of the Australian Occupational Exposure Standard for Airborne Asbestos.

As stated above, to classify potential public health risk into groups, a combined semi quantitative and qualitative method was used based on the factors considered to influence the likelihood of asbestos exposure to persons and communities. These factors were broadly divided into primary risk factors and secondary risk factors as set out below:

Primary Risk Factors

Primary risk factors were defined as risk factors where information was easily measured or well known. Such as the quantified data of airborne asbestos concentrations from historic and current airborne asbestos fibre monitoring, how close the Exposure groups are located to the mine or naturally occurring asbestos (NOA) and if the recreational activity undertaken disturbs the soil.

Primary risk factors were considered to be the following:

- Airborne asbestos fibre concentrations recorded at locations near Exposure groups from historic records and monitoring data collected during the remediation works.
- Proximity of Exposure groups to the mine.
- Proximity of Exposure Groups to naturally occurring asbestos (NOA).
- Conducting recreational activities that disturb the soil.

Secondary Risk Factors

Secondary risk factors were defined as risk factors where less information was available or more assumptions needed to be made about a particular risk factor. Such as the possibility of elevated airborne asbestos concentrations occurring near Exposure Groups, the likelihood of Exposure Groups being near the mine or Exposure Groups creating localized disturbances of asbestos contain soils, estimating frequency of Exposure Groups visits to the area or estimating time Exposure Groups spent near the mine during each visit.

Secondary risk factors were considered to be the following:

- Possibility for airborne asbestos fibre concentrations exceeding 0.01 fibres/mL air during short term disturbances (due to either natural or man-made forces) of asbestos contaminated soils at locations near Exposure Groups.
- Likelihood of Exposure Group being near mine site during short term disturbances of potentially asbestos contaminated soils by forces of nature.
- Likelihood of Exposure Group creating short term disturbances of potentially asbestos contaminated soils near the mine.
- Frequency of visits to mine site vicinity.
- Time spent near mine vicinity during each visit.

Table 14 below provides definitions for each Risk Level, based on the factors listed above.

Table 14 Definitions of Risk Ratings

Risk Level	Definition
Negligible	Health risk is **unlikely** given the combination of all known primary and secondary risk factors listed above being unlikely to lead to exposure to airborne asbestos fibres concentrations above normal background concentrations, thereby indicating no increased health risk.
Low	Health risk is **low**, but clearly possible given the potential combination of risk factors described above, leading to increased exposure to airborne asbestos fibres
Medium	Health risk is **possible** given the potential combination of risk factors described above, leading to increased exposure to airborne asbestos fibres
High	Health risk is **likely** given the potential combination of risk factors described above, leading to increased exposure to airborne asbestos fibres

In the current study, both historic and monitoring data collected during the remediation work and background monitoring before and after remediation, at locations both close to the mine and at distance from the mine including the Control at Tamworth, indicated airborne asbestos fibre concentrations below the detection limit of the monitoring method of less than 0.01 fibres/mL air.

Therefore the degrees of risk posed by exposure post the remediation works and as background exposure have been assessed as negligible when there is no major disturbance to the mine or surrounds.

However, the above exposure assessment indicated that during a disturbance within or near the mine site, persons in close proximity to disturbance, such as Woodsreef Residents and persons undertaking recreation activities near the mine (Exposure Groups 4, 5, 6 & 7) may have greater short term exposures than other groups. This determination was based on prudent observations and logic rather than air monitoring data due to the intermittent nature of site disturbances, the likelihood or not of air monitoring capturing this data, and the limitations of the air monitoring methodology such as the uncertainty associated with measurements and limits of detection.

Assessing the risk of short term exposures depends on the frequency of exposure, length of individual exposures and the exposure concentration. An isolated exposure to asbestos fibres of a short duration is extremely unlikely to result in the development of an asbestos - related disease, as fibre concentrations are likely to be insufficient to increase cumulative lifetime exposure (*enHealth, 2005*). At the other extreme, a short term exposure to high concentrations of asbestos or repeated short term exposures may be sufficient to increase cumulative lifetime exposure and hence increase the risk to an individual.

Persons in close proximity to disturbance on the mine site or in the surrounding area may be exposed to localised, short term increases in airborne asbestos fibre concentrations. The frequency and magnitude of these short term exposures is unclear and will be dependent on the specific circumstances at the time.

Even though the general background risk from asbestos fibres maybe considered negligible based on available current and historic ambient airborne asbestos fibre concentrations, for persons in close proximity disturbances, such as Woodsreef Residents and persons undertaking recreation activities near the mine (Exposure Groups 4, 5, 6 & 7) there is currently unquantified potential for short term exposure. The risk to people in these Exposure Groups have been classified as negligible to low rather than add an “unknown” or “unclassified” category, based on information gained during the current study.

4.2 Risk Characterisation Findings

It appears that for all Exposure Groups that the airborne asbestos fibre concentrations they may be routinely exposed is less than 0.01 fibres per mL of air, that is, below the minimum detection limit of the measurement technique. However, for Exposure Groups in close proximity to the mine and naturally occurring asbestos it would be prudent to assume these groups may additionally be potentially exposed to localised higher airborne asbestos concentrations possibly produced over short time periods, generated by their activities or events causing physical disturbance to asbestos containing soils. The current site containment activities and restrictions to access the mine site and The Mine Road are designed to minimise these potential disturbance activities.

The estimated exposure risks of each group have been set out below in **Table 15**.

Table 15 Community Exposure Groupings - Estimated Long Term Risks from Exposure to Airborne Asbestos Fibres Associated with the Woodsreef Mine and Surrounds

Exposure Group		Estimated Long Term Exposure Risk from Airborne Asbestos Fibres
Barraba Residents	Groups 1&2^	Negligible*
Rural Residents in immediate vicinity to the Mine	Group 3	Negligible
Tamworth	Control Group	Negligible
Woodsreef Residents	Groups 4&5	Negligible to Low#
Passive Recreation conducted in proximity to the Mine	Group 6	Negligible to Low
Active Recreation conducted in proximity to the Mine	Group 7	Negligible to Low

Notes

^ As defined in Table 10

* Health risk is unlikely given the combination of all known factors described above

Health risk is unlikely to be low, but clearly possible given the expected combination of factors, including proximity to both the mine and naturally occurring asbestos.

5 CONCLUSIONS

Asbestos fibres are likely to only become airborne at detectable concentrations when there is a physical disturbance on the mine site itself.

Furthermore, detectable concentrations of airborne asbestos fibres have not been recorded outside the mine site in the surrounding communities and locations.

Airborne asbestos fibre concentrations above 0.01 fibres per mL air, that is the detection limit of the method, have only been recorded during three periods, 1992 (0.04 fibres per mL, sample numbers unknown), 2006 (1 sample, 0.06 fibres per mL) and 2012 (1 sample, 0.04 fibres per mL). These occurred when remediation activities have been occurring on the mine site and only at sampling locations on the mine site itself. The indicative approximation of samples above the detection limit is 1 sample above the detection limit per 1,825 samples taken on the mine site.

For Exposure Groups that may be routinely exposed to airborne asbestos fibres, concentrations would likely be below the minimum detection limit of the measurement technique (less than 0.01 fibres per mL of air).

The current report outlines suggested and prioritised mitigation measures that should be undertaken as part of the future planning for the site. Several controls are proposed that are considered critical in minimising potential long term asbestos exposure health risks (refer **Section 3.4**).

Ultimately, maintaining site containment and restricting access, alongside routine inspection and monitoring is considered the most effective method in minimising potential long term health risks to the surrounding.

Health risk communication through education and information sharing to the local community will be an important factor to prevent inadvertent exposure risk.

It is concluded that the long term public health risk is likely to be negligible to low, for potential asbestos exposure arising from the abandoned mine site for adjacent communities and to members of the public that may have intermittent access to areas adjacent to the mine site.

This was based on assessment using the chosen Primary and Secondary Risk factors which included measured airborne asbestos fibre concentrations, as well as estimates of relevant factors such as long and short term background airborne asbestos fibre concentrations, a person's proximity to the mine and time spent near the mine.

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SCOPE OF A HEALTH RISK ASSESSMENT

A Health Risk Assessment has been defined as "the process of estimating the potential impact of a chemical, physical, microbiological or physiological hazard on a specified human population or ecological system under a specific set of conditions and for a certain time frame" (enHealth, 2012). As such a Health Risk Assessment takes into account both positive and negative impacts on the population highlighted in the assessment.

The enHealth sets out in its publication, Environmental Health Risk Assessment, a general framework for Health Risk Assessments (enHealth, 2012). These include:

- Phase I: Problem formulation and scoping.
- Phase II: Stage 1 – Planning
- Phase II: Stage 2 – Risk Assessment including Hazard identification, Dose – response assessment, Exposure assessment, Risk characterisation
- Phase II: Stage 3 – Confirmation of utility e.g has the risk assessment addressed the issues identified in Phase 1?
- Phase III: Risk management - Prevention or minimisation of risk of harm. Managing of consequences and specific risk communications.

Summary of Methodology

Provided is a summary of the modelling assessment conducted to assist with the identification of key monitoring locations that will be subsequently utilised in the human health risk assessment (HRA).

The air modelling was intended purely as a semi qualitative undertaking only. After discussions with representatives of the Woodsreef Taskforce the current method was approved by these representatives and used. This has in turn provided guidance to monitoring locations (etc) for the remainder of the study.

The objective of this modelling exercise was to identify which of the identified potential monitoring locations are likely to be exposed to lower or greater levels of exposure as compared to other locations, and whether the corresponding relative exposure varies according to changes in seasonal weather conditions.

This has been performed to ensure that the locations that are predicted to potentially experience elevated likelihood of exposure are incorporated within the monitoring program, and that the program accounts for seasonal variations in dispersion conditions.

Please note that the results presented in this summary do not represent exposure rates, nor do they represent an assessment of environmental harm or health risk.

The results are presented as a comparison of predicted impacts at selected locations relative to the maximum off-site impact that is predicted to occur under a range of meteorological conditions covering a 12 year period.

For clarification, the locations predicted to experience higher exposure potentials should not be interpreted as being ‘at risk’ or associated with environmental harm.

In order to differentiate the comparative exposure potential the following terminology is used:

- Category A Potential – areas predicted to have an exposure potential greater than or equal to the maximum exposure potential predicted at the identified receptor locations.
- Category B Potential – areas predicted to have an exposure potential greater than or equal to 50% of the maximum exposure potential predicted at the identified receptor locations.
- Category C Potential – areas predicted to have an exposure potential greater than or equal to 20% of the maximum exposure potential predicted at the identified receptor locations.
- Category D Potential – areas predicted to have an exposure potential greater than or equal to 10% of the maximum exposure potential predicted at the identified receptor locations.
- Category E Potential – areas predicted to have an exposure potential less than 10% of the maximum exposure potential predicted at the identified receptor locations.

Dispersion Modelling Approach

The effect of meteorology upon the rate of emission of asbestos containing materials from the site was performed using TAPM and CALMET. The dispersion of this material was performed using CALPUFF. All of these models are routinely used in Australia to predict the rate of dispersion of air pollutants.

Variable Emission Rate

The rate of asbestos fibre emission across the site was not assumed to be constant, as various factors would affect the relative rates of emission, including:

- The asbestos content of the surface materials.
- The erosion-potential of the surface materials, such as the degree of surface crusting and weathering.

Assuming a constant rate of emission was considered to be limiting the potential for asbestos containing materials giving rise to off-site impacts. This may lead to an under-evaluation of the ranking of those locations and potentially underestimate their exposure potential especially under certain meteorological conditions.

The relative rate of release of asbestos fibres from the active surfaces of the study area was predicted through the use of a constant nominal emission rate ($1g/s/m^2$), an arbitrary value used only for comparison and ranking of locations, that was factored to account for:

- The asbestos content of the surface materials in each discrete area; and
- Highly crusted surfaces that would offer significant emission attenuation and mitigation.

Site specific information used in the modelling such as asbestos content of surface materials and surface crusting was sourced from the previous study by SLR (2013a).

Meteorology

To account for the effect of variable weather patterns, meteorological observations over the period from 2001 to 2012 were used in the assessment from the following Bureau of Meteorology (BOM) monitoring stations. The BOM monitoring stations used has been set out **Table 16**.

Table 16 Bureau of Meteorology Monitoring Data used in TAPM Modelling

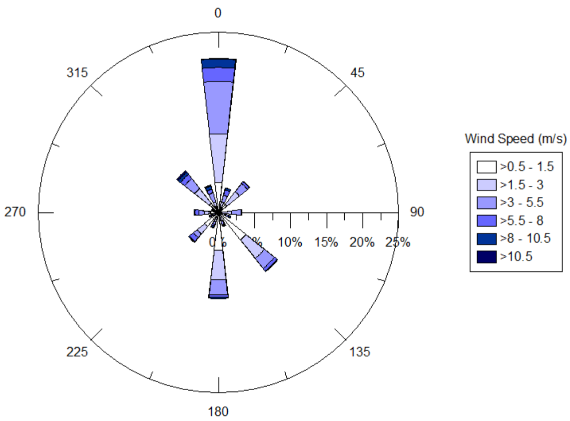
Station	Station Number	Latitude	Longitude	Height (m)	Year Opened	Status	Data Collected
Barraba Post Office	054003	-30.3781	150.6096	500	1881	Open	Surface
Narrabri Airport AWS	054038	-30.3154	149.8302	229	2001	Open	Surface
Gunnedah Resource Centre	055024	-31.0261	150.2687	307	1948	Open	Surface
Tamworth Airport AWS	055325	-31.0742	150.8362	395	1992	Open	Surface
Glen Innes AG Research Stn	056013	-29.6953	151.6936	1060	1910	Open	Surface
Inverell Research Centre	056018	-29.7752	151.0819	664	1949	Open	Surface
Armidale Airport AWS	056238	-30.5273	151.6158	1079	1993	Open	Surface

The output of the TAPM / CALMET modelling was validated against the 9am and 3pm observations at Barraba Post Office.

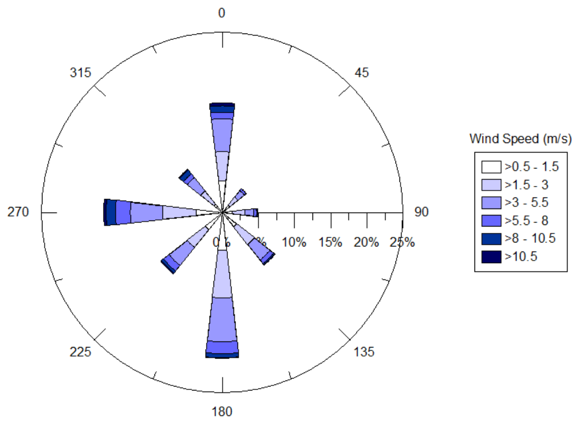
Figure 28 presents summary wind roses at 9am and 3pm for observations at Barraba Post Office for the period 2001 to 2012 and the corresponding CALMET predictions. Overall, the CALMET predictions show a good comparison with the observations.

Figure 28 Comparison of Barraba Observations and Barraba CALMET Predictions 2001-2012

Barraba Post Office Observations (2001-2012)

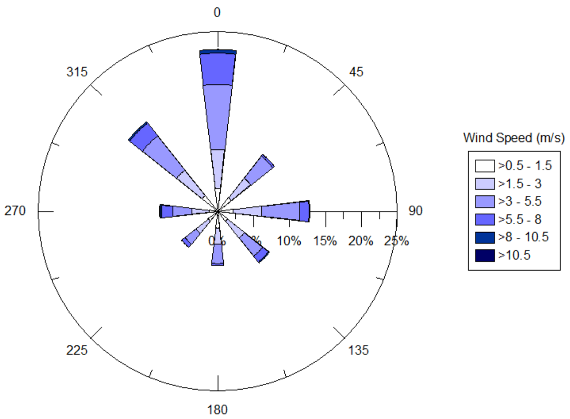


Barraba Wind Data (2001-2012)
9 AM Data

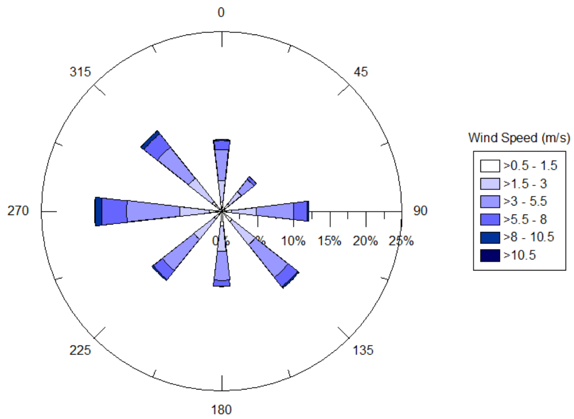


Barraba Wind Data (2001-2012)
3 PM Data

Barraba Post Office CALMET Predictions (2001-2012)



Barraba Wind Data (2001-2012)
9 AM Data



CALMET_Barraba Wind Data (2001-2012)
3 PM Data

Receptors

The following discrete receptors have been used as the key assessment locations in this study, see **Table 17**.

Table 17 Discrete Receptor Locations

Modelling ID	Name	Latitude	Longitude	East (m)	North (m)	Approximate Distance from Mine Boundary
R1	Barraba Central Secondary School	150.6013	-30.3830	269369.57	6636401.28	13km
R2	Barraba Primary School	150.6031	-30.3844	269776.95	6636528.21	13km
R3	St Joseph's Primary School	150.6076	-30.3789	270144.44	6636887.49	13km
R4	Paula McIver	150.6585	-30.3889	274831.06	6635720.16	6km
R5	Gossenbar	150.6861	-30.3814	277427.30	6636884.27	4km
R6	Glenriddle Homestead	150.6896	-30.3899	277947.38	6635914.09	3.5km
R7	The Nuthouse	150.6949	-30.3750	278475.46	6637858.49	4.2km
R8	Ironbark Creek	150.6967	-30.4390	278848.96	6630349.71	3km
R9	Glen Riddle Reserve	150.7093	-30.4422	278086.24	6629158.82	4km
R10	Anglesea	150.7170	-30.3975	280407.91	6635057.99	350m
R11	Picnic Site	150.7255	-30.4021	281265.94	6634550.12	50m
R12	UnID Res 1	150.7333	-30.4503	282557.63	6629300.01	3km
R13	Firnview 1225	150.7345	-30.4440	282638.10	6630029.57	2km
R14	Camping - F&F Trail	150.7404	-30.3907	281940.06	6635693.93	250m
R15	Woodsreef Township	150.7436	-30.3899	283267.54	6635873.89	500m
R16	Wynaroy	150.7465	-30.4051	283583.47	6634792.55	40m
R17	Mr Burgess Property	150.7527	-30.4190	281967.68	6632711.25	116m
R18	UnID Res 2	150.7583	-30.4801	284973.03	6625860.05	7km
R19	Boxpark Station	150.7605	-30.3858	284994.45	6637101.62	2km
R20	Bindaree	150.7605	-30.3858	284599.73	6636922.57	1.9km
R21	Westbank 1708	150.7609	-30.4782	284163.13	6626336.45	6km
R22	Kilpara 1705	150.7609	-30.4782	284903.47	6626763.12	5.9km
R23	Ironbark Station	150.7631	-30.3686	284835.49	6641613.66	6km
R24	UnID Res Prop 1849	150.7703	-30.4822	285766.47	6625871.47	7km
R25	Nangarah Station	150.7732	-30.3784	286351.35	6637740.63	4km
R26	Glenview	150.7778	-30.3719	286746.18	6638658.98	4.5kn
R27	UnID Res Prop Removable House /Perm living	150.7781	-30.4663	286787.24	6627916.35	6km
R28	394 /Coreena	150.7824	-30.4537	286841.79	6628987.26	4.5km
R29	Rimrock	150.8071	-30.3691	289321.63	6638632.20	6.5km
R30	Caernarvon	150.8156	-30.3706	290067.18	6638190.76	7km
R31	Woonoora	150.8178	-30.4305	290581.75	6631405.14	6km
R32	Avondale	150.8190	-30.4314	290328.31	6631555.45	6km

WEATHER CONDITIONS DURING SLR AIR MONITORING

Airborne asbestos fibre monitoring (background monitoring or activity monitoring) was conducted by SLR during three periods between November 2013 and June 2016 as set out below in **Table 18**.

Table 18 Dates of SLR's airborne asbestos fibre monitoring between November 2013 and June 2016 & Weather (source: BOM Weather Station Barraba Post Office 045003)

Air Monitoring Type	Year	Date	Temperature (min) °C	Temperature (max) °C	Rainfall mm	Wind 9am direction / kmh	Wind 3pm direction / kmh
Background Monitoring	**2013**	14/11/13	6.9	30.7	0	Calm	N 7
		20/11/13	12.5	31.0	0	Calm	S 4
		26/11/13	Not available	29.0	0	Calm	E 2
		2/12/13	Not available	28.6	0	Calm	SE 2
		8/12/13	Not available	31.0	0	Not available	Calm
		14/12/13	13.0	34.0	0	N 9	S 7
Activity Based Monitoring	**2013**	9/12/13	12.0	33.0	0	Calm	Calm
		10/12/13	20.0	30.5	1.0	W 2	SSE 4
		11/12/13	12.0	31.6	0.6	Calm	SW 6
Remediation Monitoring	**2014-2015**	20/10/14	6.8	31.0	0	Calm	S 2
		6/11/14	10.5	27.6	9.4	N 2	S 2
		23/11/14	20.0	40.5	0	NNW 4	Calm
		10/12/14	16.5	34.8	0	Calm	NE 2
		13/01/15	20.0	29.5	2.2	Calm	NE 4
		30/01/15	10.0	29.0	0	Calm	S 2
		10/02/15	16.5	32.8	0	Calm	SE 4
		05/03/15	17.0	32.0	0	Calm	E 7
		16/03/15	11.0	29.8	0	SSE 2	SSE 4
		23/03/15	12.5	30.0	0	SSE 2	Calm
		8/04/15	5.0	18.0	0	E 2	Calm
		25/04/15	Not available	24.5	0	Calm	W 4
		12/05/15	Not available	21.0	0	E 2	Calm
Post Remediation Monitoring	**2016**	22/04/16	8.1	Not available	0	S 2	Not available
		28/04/16	6.9	27.2	0	Calm	Not available
		4/05/16	8.1	24.2	0	NNW 2	Not available
		10/05/16	13.0	22.1	1.6	W 2	Not available
		16/05/16	6.0	26.7	0	NNW 2	Not available
		22/05/16	3.0	26.1	0	Calm	Not available

WEATHER CONDITIONS DURING SLR AIR MONITORING

Air Monitoring Type	Year	Date	Temperature (min) °C	Temperature (max) °C	Rainfall mm	Wind 9am direction / kmh	Wind 3pm direction / kmh
		28/05/16	0	15.0	0	Calm	Not available
		3/06/16	8.0	20.0	0.6	S 2	Not available
		9/06/16	7.0	20.2	0	W 4	Not available
		15/06/16	0	19.0	0	S 2	Not available
		21/06/16	7.5	14.5	2.0	NNW 2	Not available
		27/06/16	1.0	8.5	2.6	W 2	Not available
Activity Based Monitoring	2016	30/05/16	-3.0	16.5	1.0	S 2	Not available
		31/05/16	-1.0	19.1	8.2	SSE 2	Not available
		1/06/16	0	19.2	0	NNW 2	Not available
		2/06/16	3.0	18.5	2.0	Calm	Not available

2013 Temperature and Rainfall Comparisons to Historic Records

In 2013 both temperature minimums and maximums were within historic means (1966-2016) as set out in **Figure 29** and **Figure 30**.

Annual rainfall in 2013 appeared likely to be slightly above historic means (1881-2016). Data was not available for December 2013.To allow for this missing data, SLR subtracted the historic average for December (77.9mm) from the historic annual mean rainfall (688.2mm) to get a corrected historic annual rainfall of 610.3mm for comparisons. The available monthly rainfall for 2013 were then added together to get total rainfall for 11 months in 2013 of 630.3mm. Thus by subtracting the corrected historic annual mean rainfall of 610.3mm, from total rainfall for 11 months in 2013 of 630.3mm it can be seen an extra 20mm of rain fell in 2013 over the 11 month period, a 3% increase compared to historic mean rainfall.

Rainfall in 2013 was below historic monthly means (1881-2016) for most of the year. The exceptions were January, March, June and November when above average rainfall occurred (See **Figure 31**).

Figure 29 Minimum Temperatures Comparison 2013 to Historic Means 1966-2016

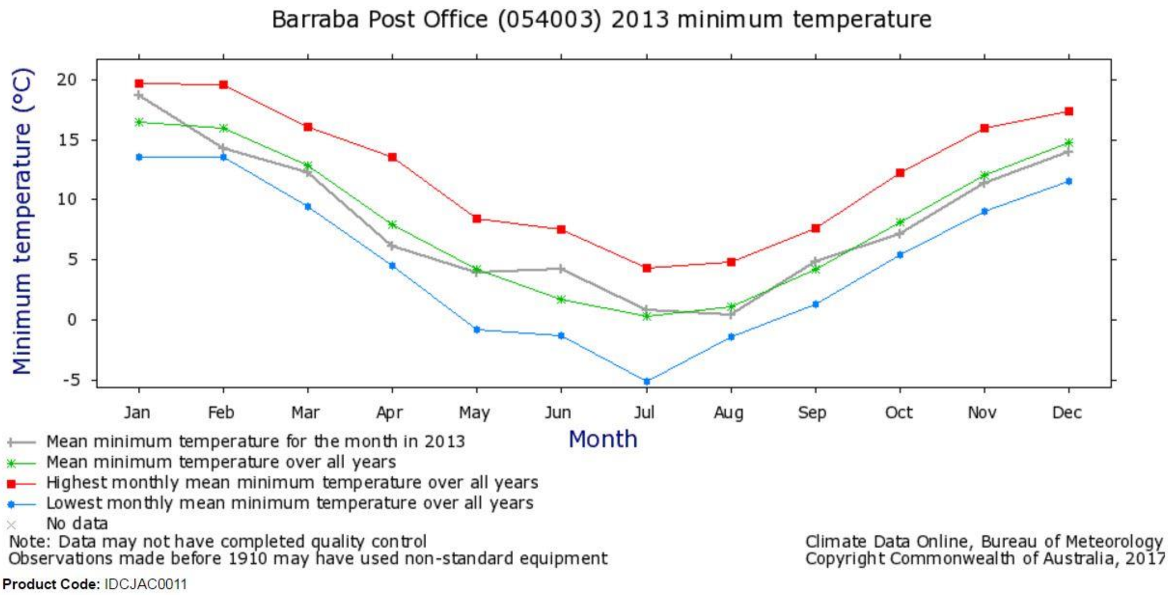


Figure 30 Maximum Temperatures Comparison 2013 to Historic Means 1966-2016

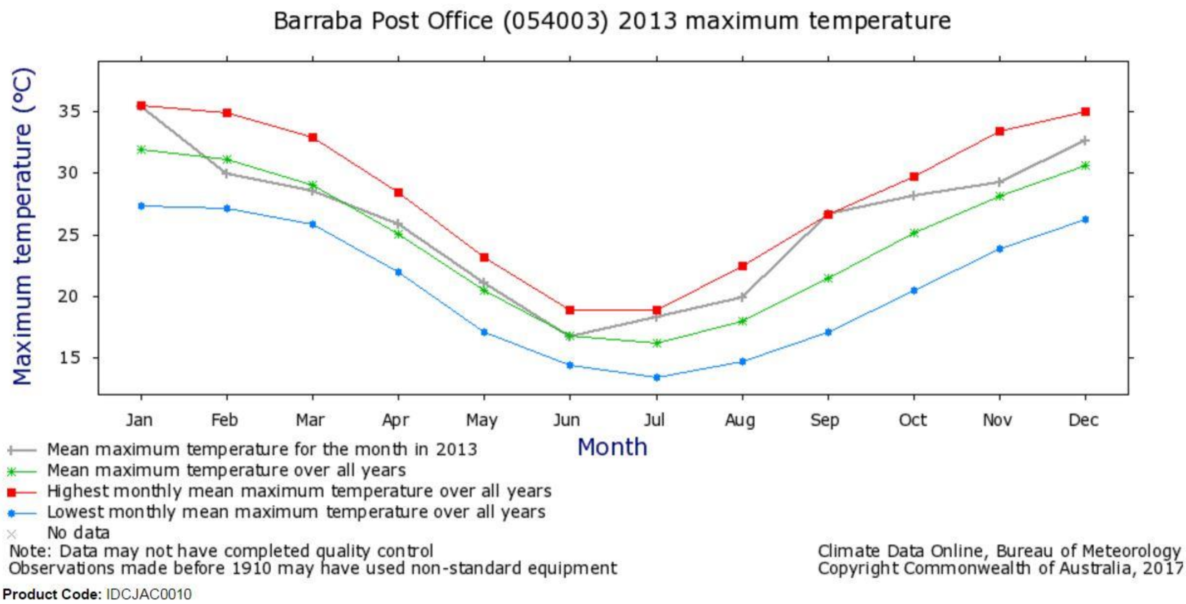
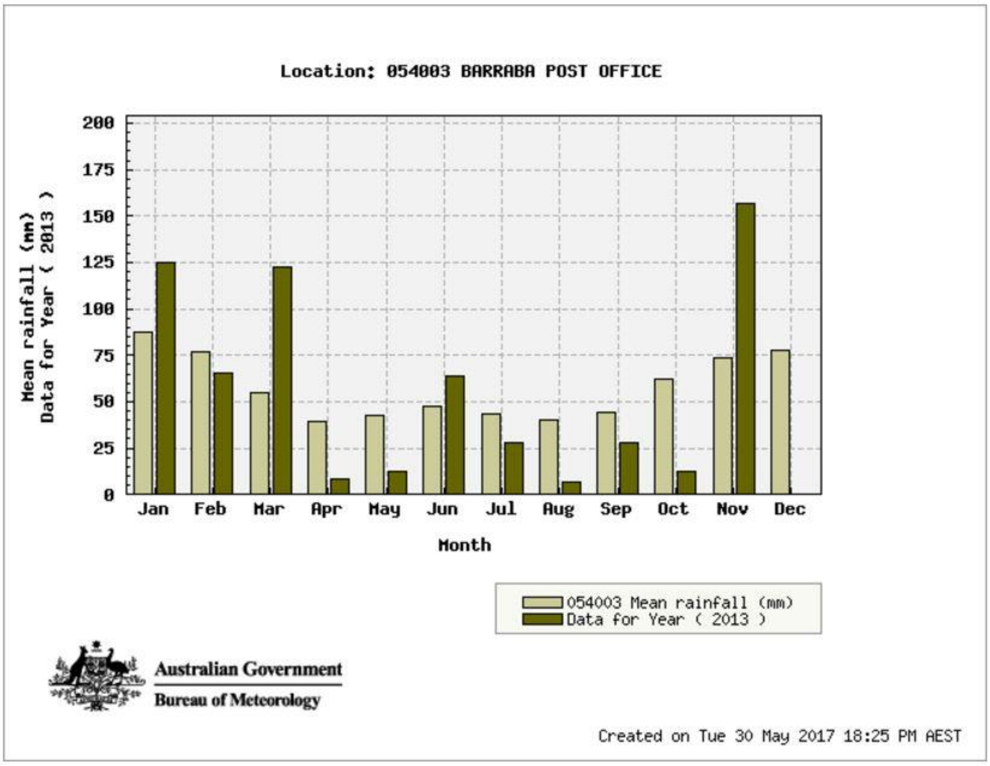


Figure 31 Rainfall Comparison 2013 to Historic Means 1881-2017



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1881 to 2017	87.5	76.6	54.9	39.2	42.2	47.4	43.6	39.8	44.2	62.1	73.4	77.9	688.2	136
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2013	124.9	65.1	122.8	8.6	12.8	63.8	27.5	7.0	28.2	12.8	156.8			1

12.3 = Not quality controlled

WEATHER CONDITIONS DURING SLR AIR MONITORING

2014 Temperature and Rainfall Comparisons to Historic Records

In 2014 both temperature minimums and maximums were within historic means (1966-2016) as set out in **Figure 32** and **Figure 33**.

Annual rainfall in 2014 was lower than historic means (1881-2016). 2014 annual rainfall was 24% below historic mean rainfall.

Rainfall in 2014 was below historic monthly means (1881-2016) for most of the year. The exceptions were March, August and December when above average rainfall occurred (See **Figure 34**).

Figure 32 Minimum Temperatures Comparison 2014 to Historic Means 1966-2016

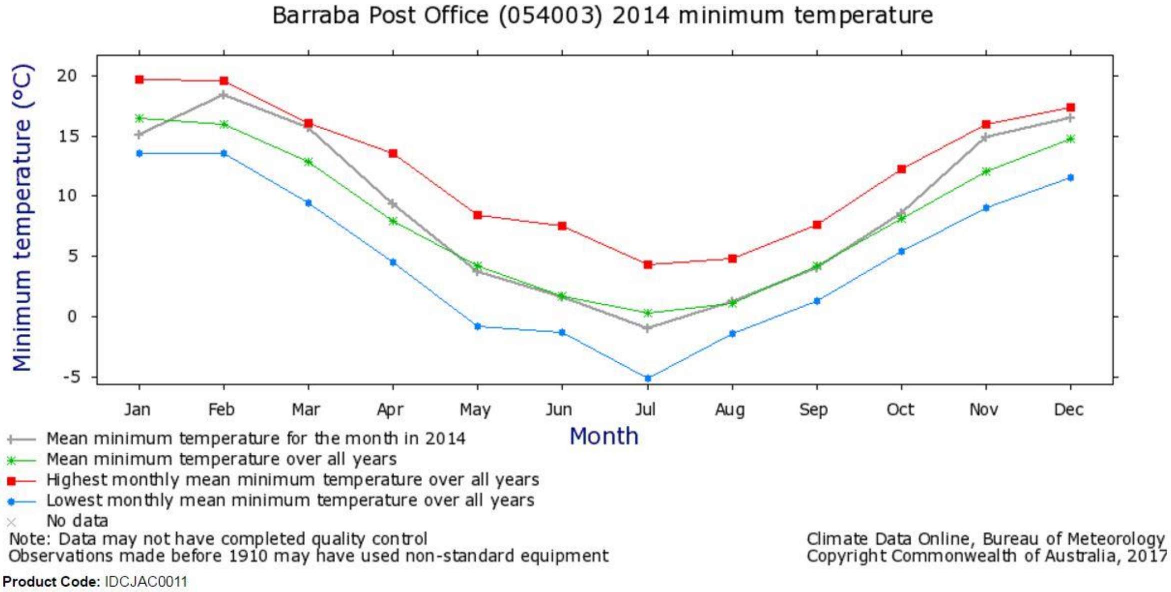


Figure 33 Maximum Temperatures Comparison 2014 to Historic Means 1966-2016

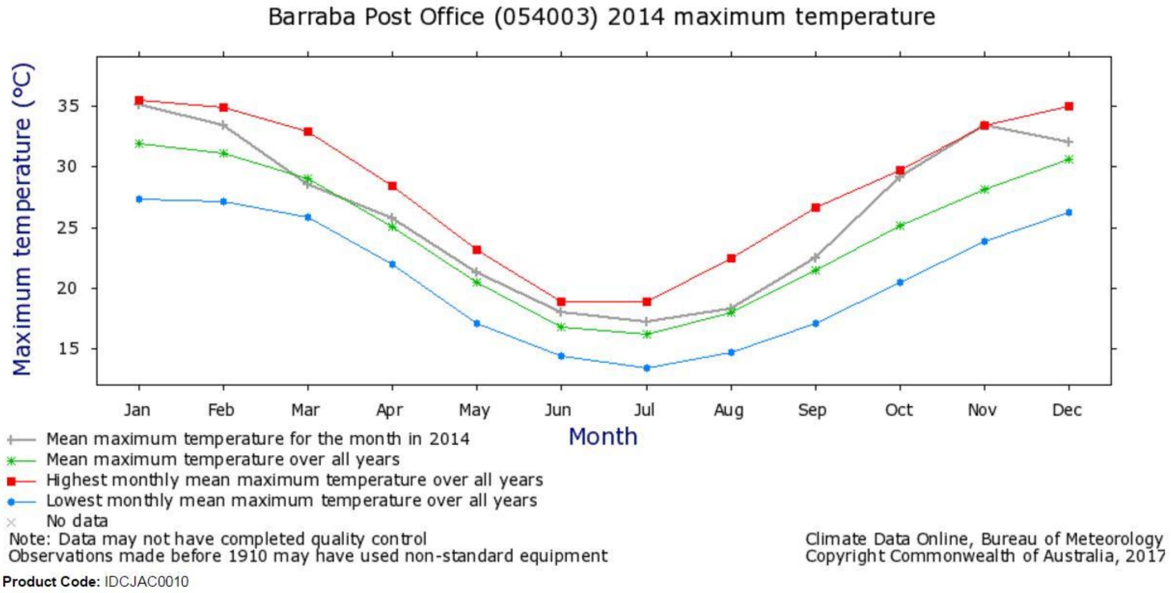
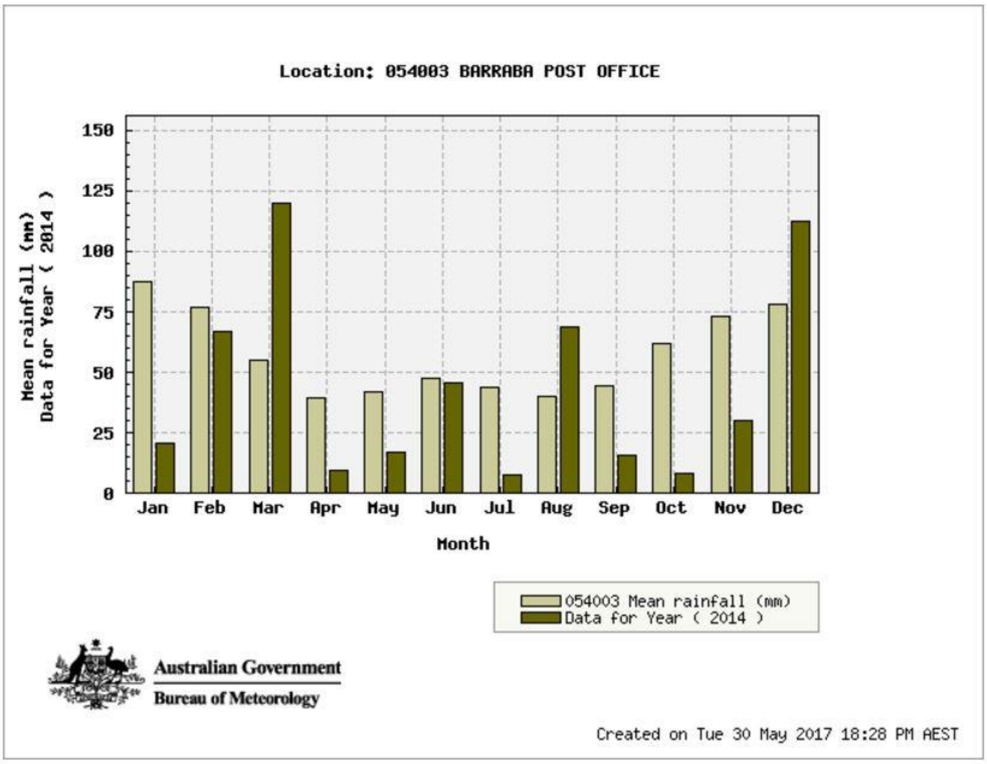


Figure 34 Rainfall Comparison 2014 to Historic Means 1881-2016



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1881 to 2017	87.5	76.6	54.9	39.2	42.2	47.4	43.6	39.8	44.2	62.1	73.4	77.9	688.2	136
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2014	20.8	67.2	120.0	9.2	17.0	46.0	7.6	68.8	15.6	8.0	30.4	112.4	523.0	1

12.3 = Not quality controlled

WEATHER CONDITIONS DURING SLR AIR MONITORING

2015 Temperature and Rainfall Comparisons to Historic Records

In 2015 both temperature minimums and maximums were within historic means (1966-2016) as set out in **Figure 35** and **Figure 36**.

Annual rainfall in 2015 was slightly lower than historic means (1881-2016). 2015 annual rainfall was 3.5% below historic mean rainfall.

Rainfall in 2015 was below historic means (1881-2016) for most of the year. The exceptions were April, August, June and November when above average rainfall occurred (See **Figure 37**).

Figure 35 Minimum Temperatures Comparison 2015 to Historic Means 1966-2016

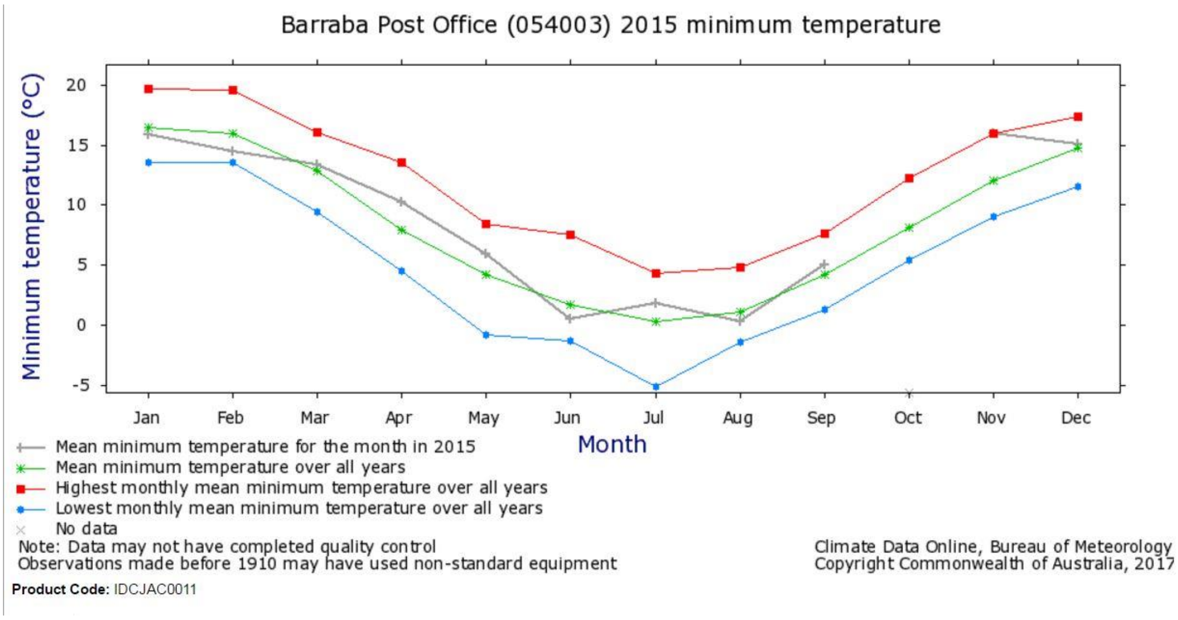


Figure 36 Maximum Temperatures Comparison 2015 to Historic Means 1966-2016

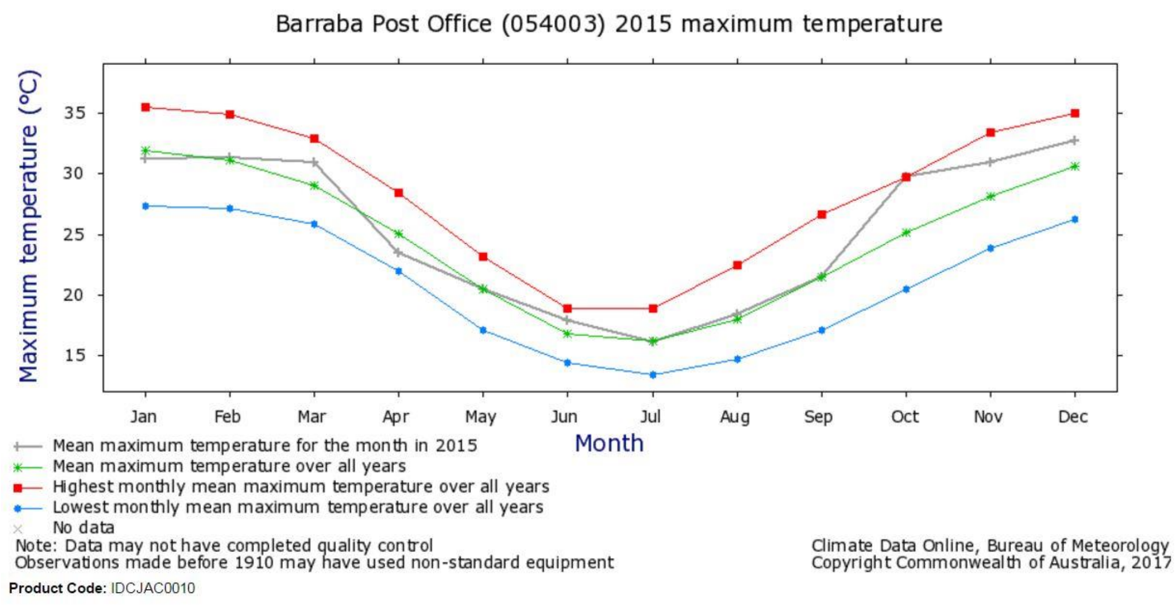
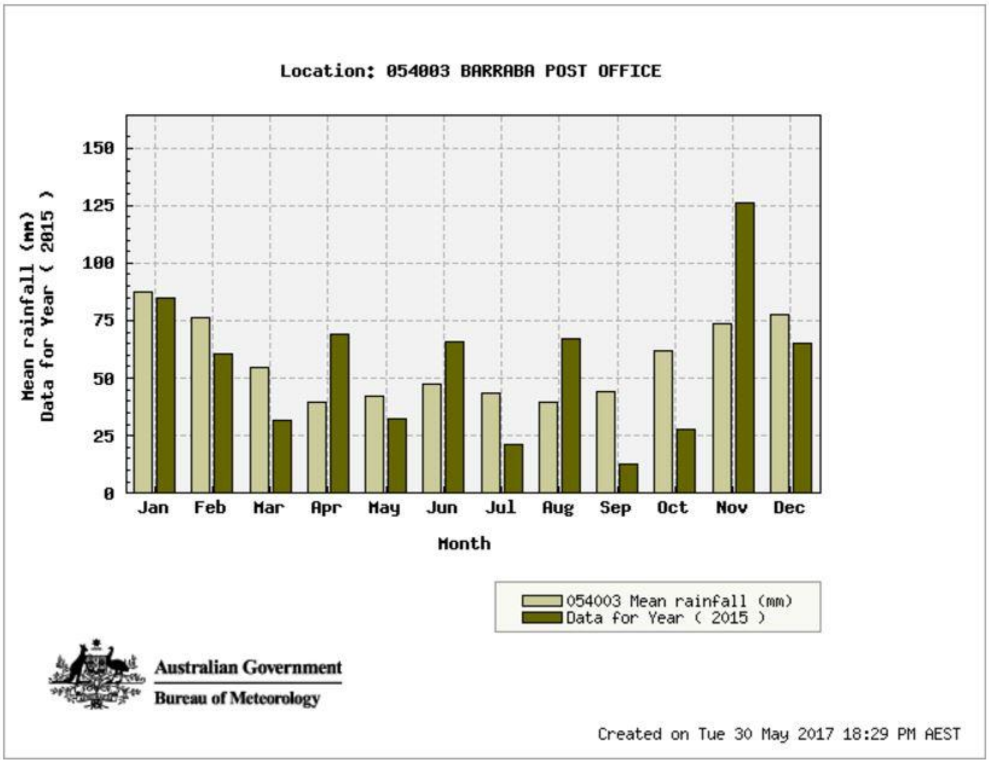


Figure 37 Rainfall Comparison 2015 to Historic Means 1881-2016



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1881 to 2017	87.5	76.6	54.9	39.2	42.2	47.4	43.6	39.8	44.2	62.1	73.4	77.9	688.2	136
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2015	84.8	60.4	31.8	69.0	32.6	65.9	21.2	66.8	12.4	28.0	126.2	65.4	664.5	1

12.3 = Not quality controlled

2016 Temperature and Rainfall Comparisons to Historic Records

In 2016 both temperature minimums and maximums were within historic means (1966-2016) as set out in **Figure 38** and **Figure 39**.

Annual rainfall in 2016 appeared likely to be above historic means (1881-2016). Data was not available for August 2016.To allow for this missing data, SLR subtracted the historic average for August (39.8mm) from the historic annual mean rainfall (688.2mm) to get a corrected historic annual rainfall of 648.4mm for comparisons. The available monthly rainfall for 2016 were then added together to get total rainfall for 11 months in 2016 of 739.2mm. Thus by subtracting the corrected historic annual mean rainfall of 648.4mm, from total rainfall for 11 months in 2016 of 739.2mm it can be seen an extra 90.8mm of rain fell in 2016 over the 11 month period, a 13% increase compared to historic mean rainfall.

Rainfall in 2016 was below historic monthly means (1881-2016) for half of the year. The exceptions were January, May, June, July, September and October when above average rainfall occurred. However, it was only January, June and September when monthly rainfall significantly exceeded historic means (See **Figure 40**).

Figure 38 Minimum Temperatures Comparison 2016 to Historic Means 1966-2016

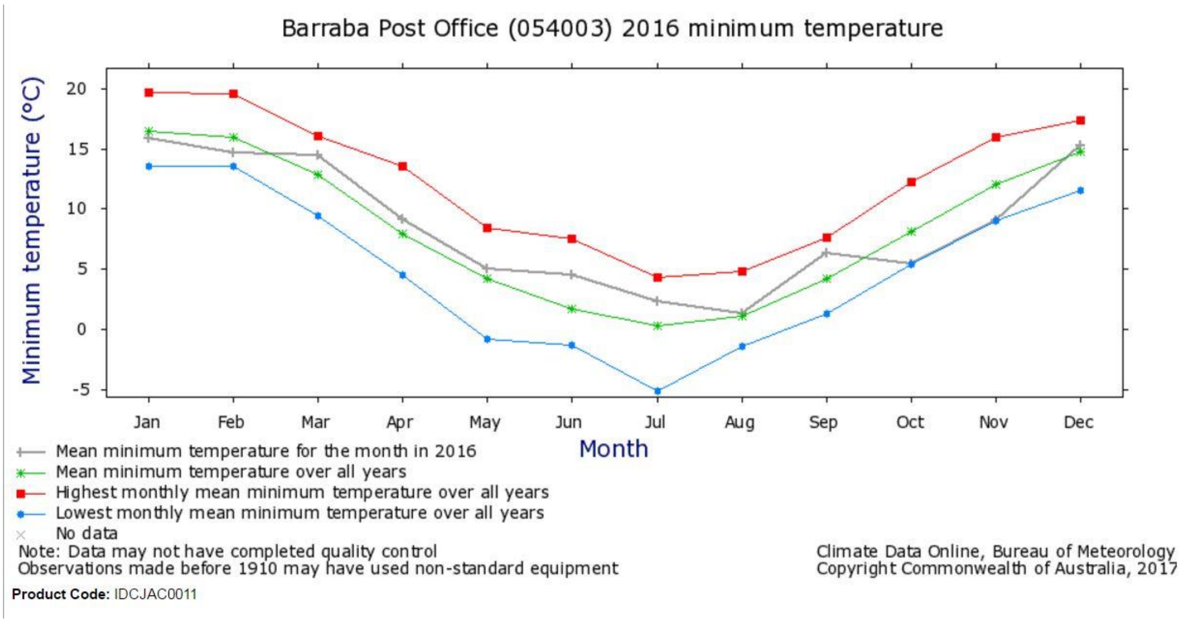


Figure 39 Maximum Temperatures Comparison 2016 to Historic Means 1966-2016

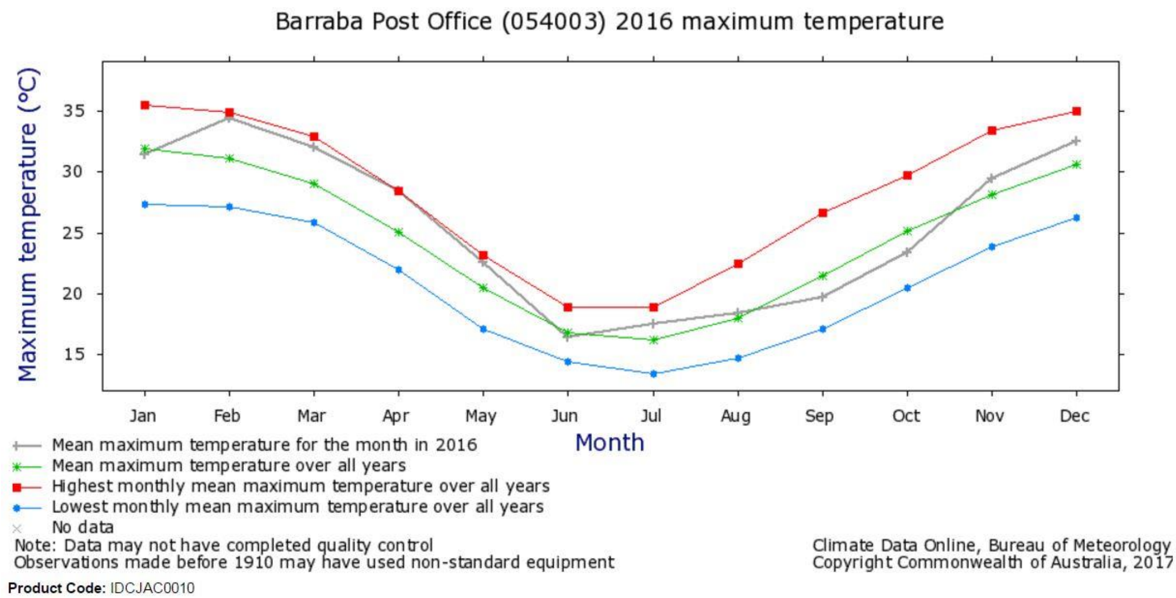
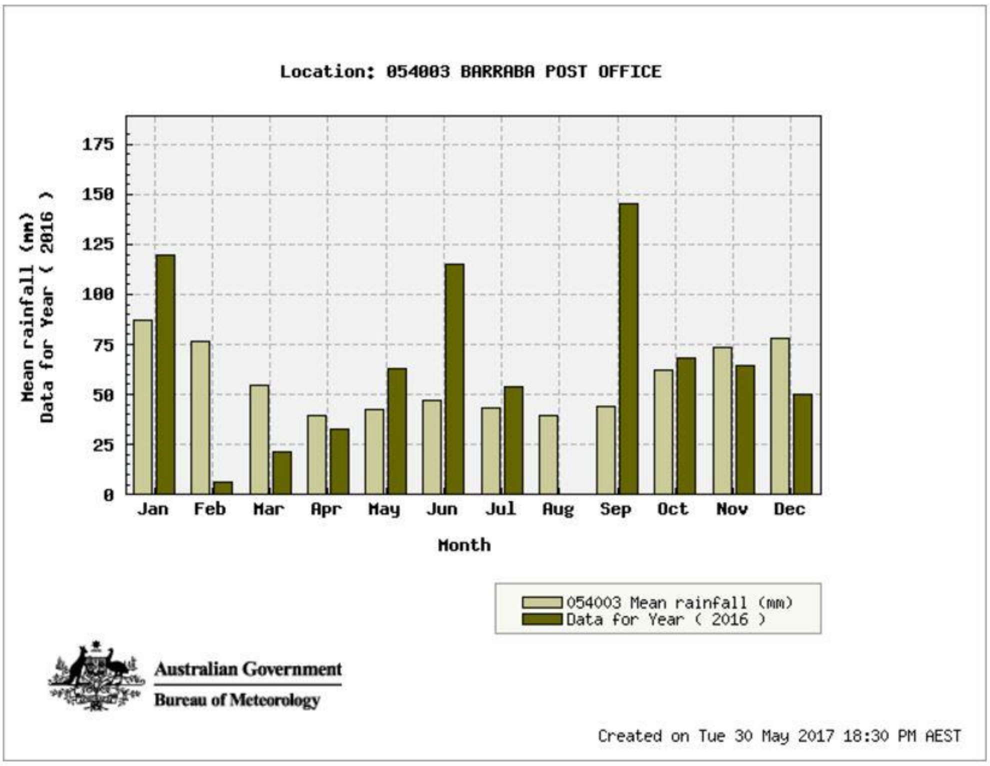


Figure 40 Rainfall Comparison 2016 to Historic Means 1881-2016



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1881 to 2017	87.5	76.6	54.9	39.2	42.2	47.4	43.6	39.8	44.2	62.1	73.4	77.9	688.2	136
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2016	*119.7*	*6.0*	*21.1*	*32.5*	*63.0*	*115.2*	*53.5*		*145.4*	*68.4*	*64.1*	*50.3*		1

12.3 = Not quality controlled

Wind Direction and Speed – Historic Means

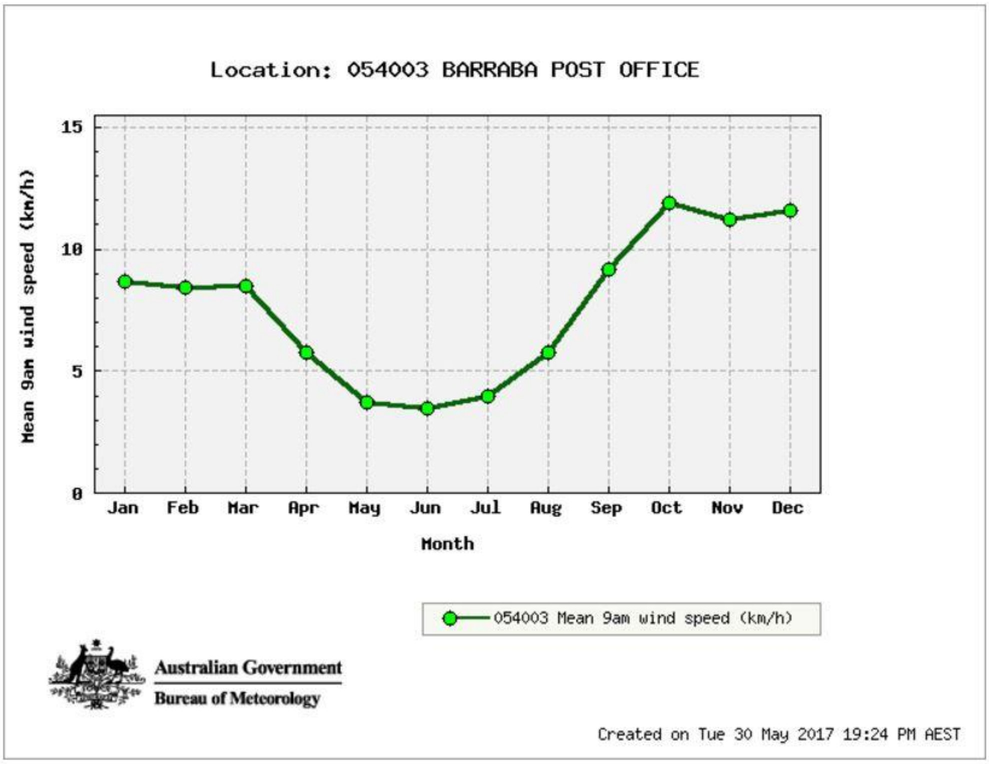
For the months in which airborne asbestos monitoring was conducted the mean monthly wind speeds were lower than the historic monthly means (1966-2010) as set out below in **Table 19** and **Figure 41** to **Figure 44**.

Table 19 SLR's airborne asbestos fibre monitoring between November 2013 and June 2016 – Mean monthly wind speed compared to historic data (source: BOM Weather Station Barraba Post Office 045003)

Air Monitoring Type	Year	Month	Mean Monthly Wind Speed kmh 9am	Historic Monthly Mean Wind Speed kmh 9am 1966 -2010	Mean Monthly Wind Speed kmh 9am	Historic Monthly Mean Wind Speed kmh 9am 1966 -2010
Background Monitoring	**2013**	November	0	11.2	2	13.7
		December	1	11.6	2	13.7
Activity Based Monitoring	**2013**	December	1	11.6	2	13.7
Remediation Monitoring	**2014**	October	1	11.9	3	12.7
		November	2	11.2	4	13.7
		December	1	11.6	4	13.7
	2015	January	0	8.7	3	11.3
		February	0	8.4	4	12.1
		March	1	8.5	2	12.0
		April	1	5.8	4	11.0
		May	1	3.7	5	11.1
Post Remediation Monitoring	**2016**	April	1	5.8	Not available	11.0
		May	1	3.7	Not available	11.1
		June	2	3.5	Not available	11.4
Activity Based Monitoring	**2016**	May	1	3.7	Not available	11.1
		June	2	3.5	Not available	11.4

The mean wind speed and wind directions from 1966 to 2010 in Barraba have been set out below in **Figure 41** to **Figure 44**.

Figure 41 Mean wind speed all observations 9am 1966 -2010



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean 9am wind speed (km/h) for years 1966 to 2010	8.7	8.4	8.5	5.8	3.7	3.5	4.0	5.8	9.2	11.9	11.2	11.6	7.7	43

12.3 = Not quality controlled

Figure 42 Rose of wind direction versus wind speed all observations 9am 1966 -2016

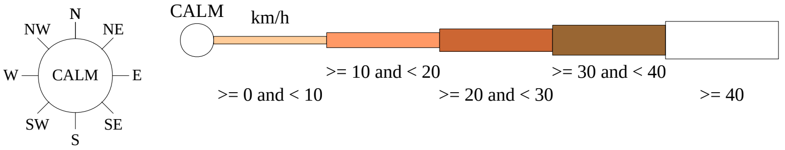
Rose of Wind direction versus Wind speed in km/h (04 Mar 1966 to 30 Sep 2010)

Custom times selected, refer to attached note for details

BARRABA POST OFFICE

Site No: 054003 • Opened Jan 1881 • Still Open • Latitude: -30.3781° • Longitude: 150.6096° • Elevation 500m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



9 am
15575 Total Observations

Calm 46%

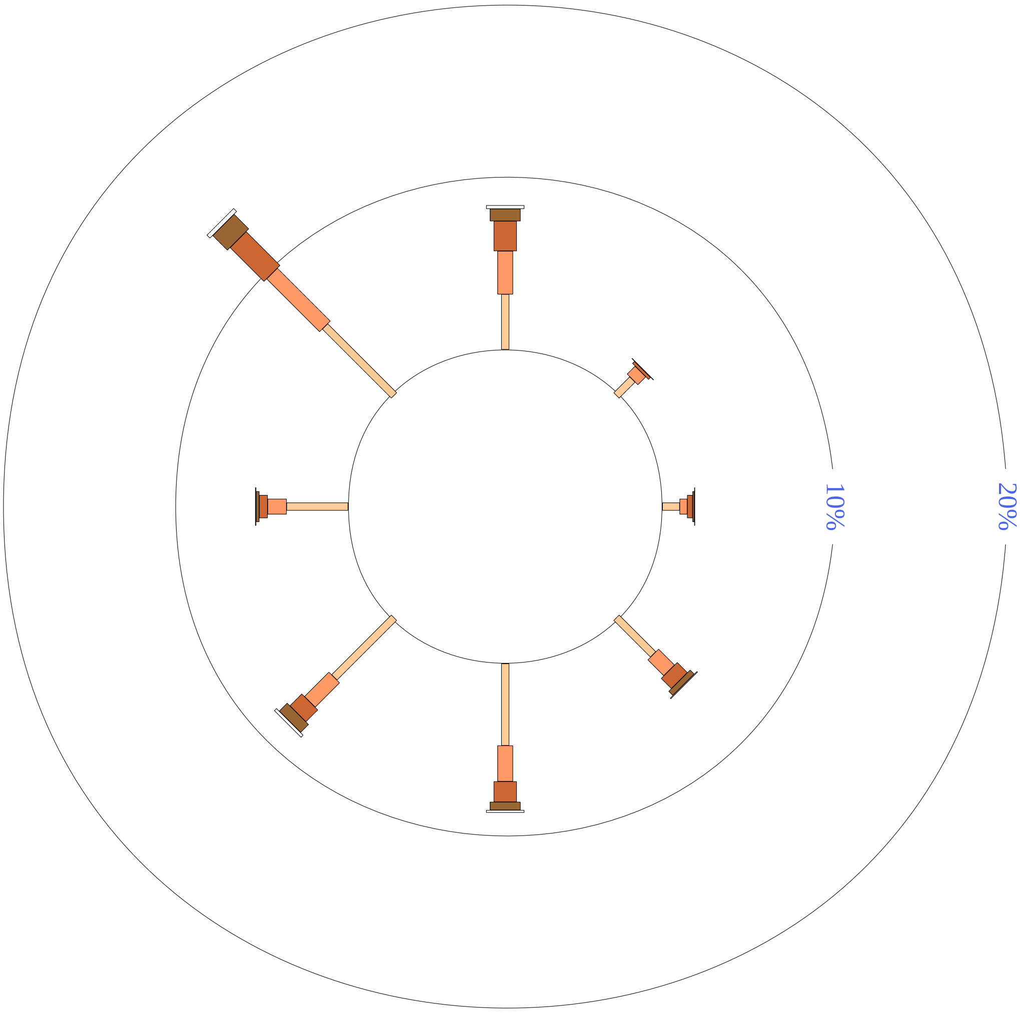
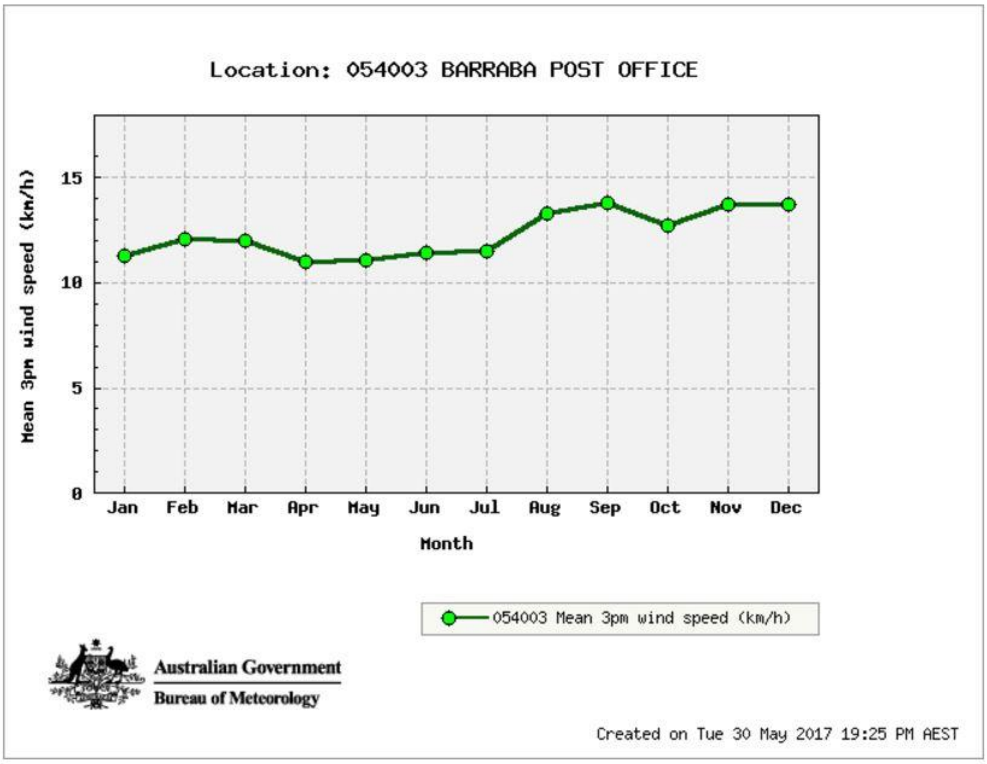


Figure 43 Mean wind speed all observations 3pm 1966 -2010



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean 3pm wind speed (km/h) for years 1966 to 2010	11.3	12.1	12.0	11.0	11.1	11.4	11.5	13.3	13.8	12.7	13.7	13.7	12.3	28

12.3 = Not quality controlled

Figure 44 Rose of wind direction versus wind speed all observations 3pm 1966 -2016

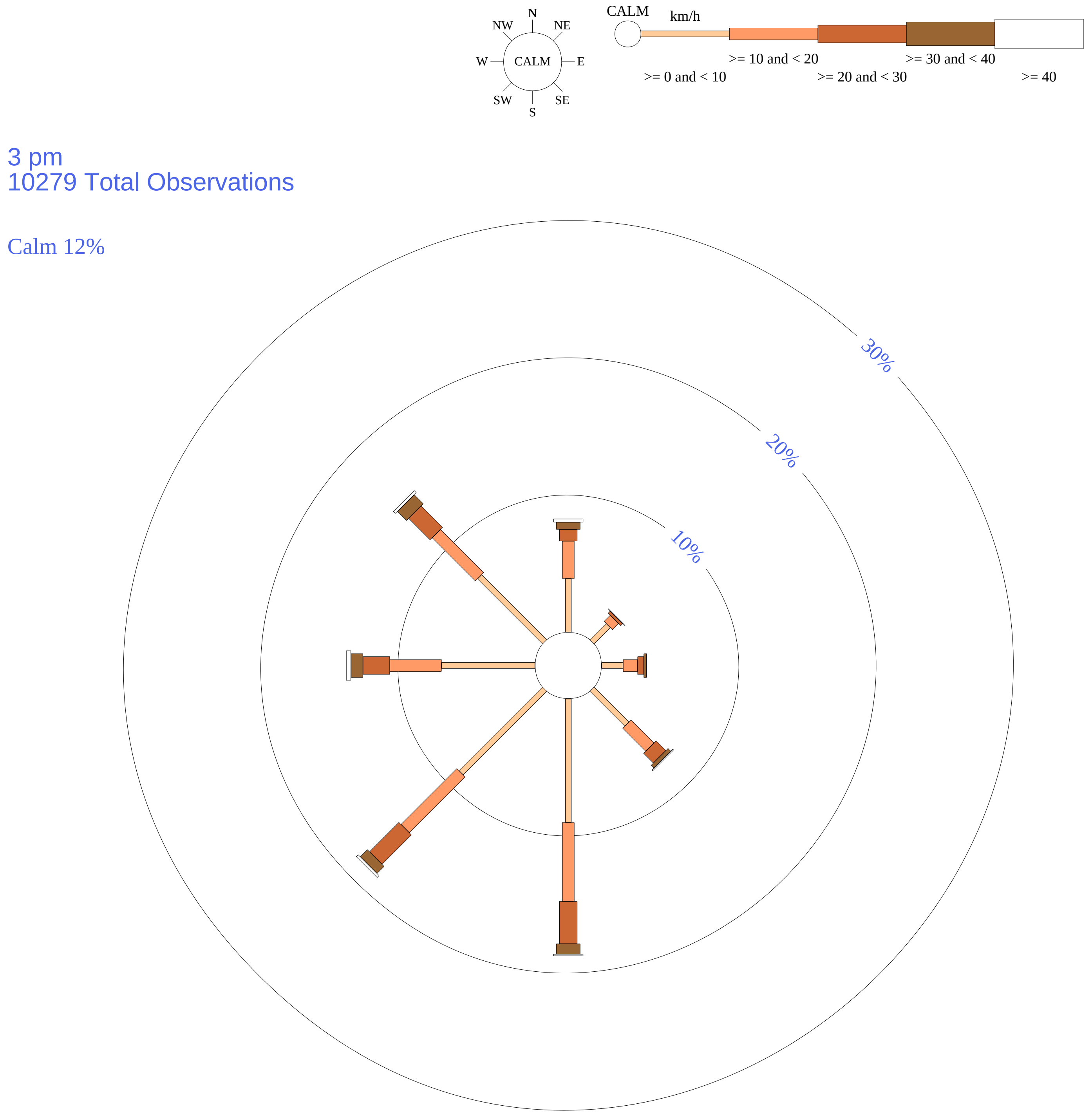
Rose of Wind direction versus Wind speed in km/h (04 Mar 1966 to 30 Sep 2010)

Custom times selected, refer to attached note for details

BARRABA POST OFFICE

Site No: 054003 • Opened Jan 1881 • Still Open • Latitude: -30.3781° • Longitude: 150.6096° • Elevation 500m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



Summary of Diseases

Asbestos related disease can occur as a result of either high exposure to airborne asbestos fibres for a short time or lower exposure over longer periods of time.

There are three primary disease associated with the inhalation of asbestos fibres. These are:

- **Asbestosis**
- **Lung Cancer**
- **Mesothelioma**

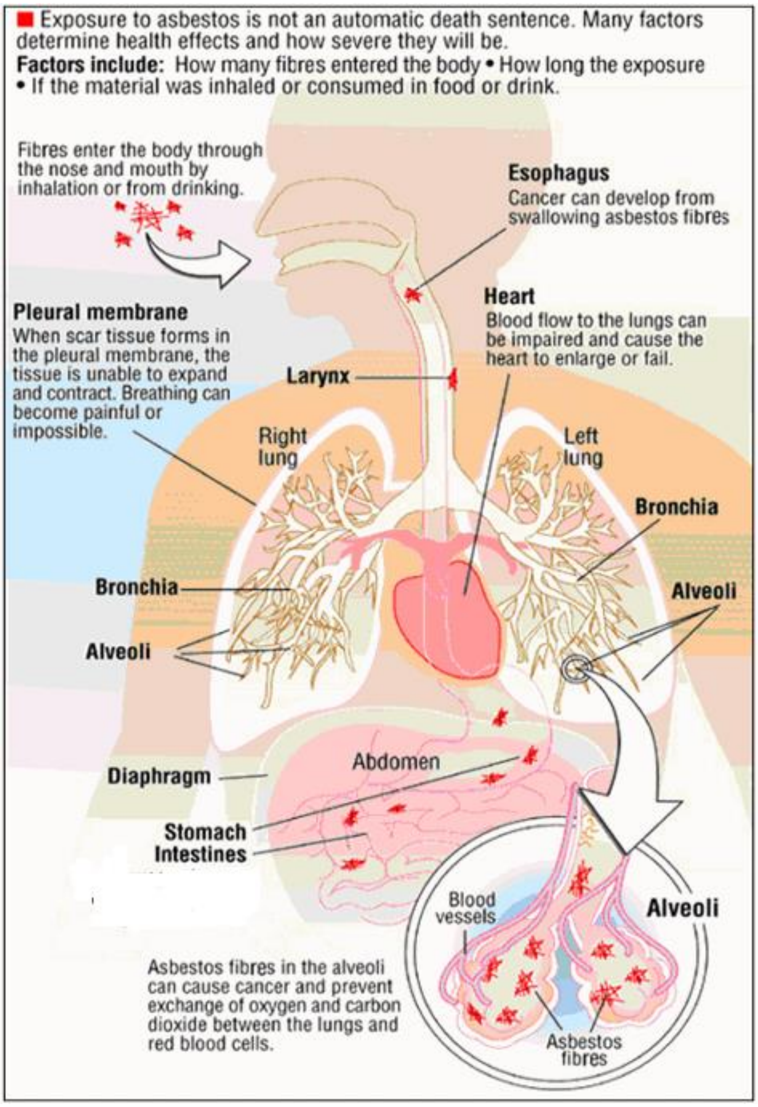
Asbestosis and lung cancer are associated primarily with high level occupational exposures.

Mesothelioma has been associated with exposures below those causing asbestosis and increased risk of lung cancer. Mesothelioma is considered to be the critical effect endpoint for inhalation exposure to asbestos fibres for the purpose of this study. (Safe Work Australia, 2010)

All asbestos-related diseases are dose-related: the higher the concentration and duration of exposure, the higher the prevalence of the disease and mortality. However, the form of the dose-response curve at low doses, typical for the exposure of general population, is not known. There are contradictory opinions as to whether the dose-response relationship in the region of low doses is linear or not. It is difficult to measure the effects at such low doses either epidemiologically or experimentally.

The asbestos exposure routes and sites of impact in the human body can be seen below in **Figure 45**.

Figure 45 Asbestos Exposure Routes and Impact Sites in the Human Body (modified from Worksafe NZ, 2015)



Asbestosis and Pleural Disease

Asbestosis and asbestos pleural disease are non-malignant asbestos diseases that are slowly progressive. Asbestosis is a slowly progressive, fibrotic (scarring) lung disease caused by a cascade of responses to inhaled asbestos fibres. The development of asbestosis is directly associated with both multitude and duration of asbestos exposure. The onset of visible fibrosis rarely occurs earlier than 15–20 years from first exposure. Not all individuals exposed to high levels of asbestos fibre develop asbestosis (*enHealth, 2005*).

Asbestos pleural disease is a non-malignant disease caused by inhalation of asbestos fibres that scar the pleura. The pleura is the thin membrane lining the lung and chest cavity. If the scarring is diffuse and extends along the chest wall, it is called pleural thickening. If the scarring is more focused and well–defined, it is called pleural plaques. Asbestos pleural disease results in a similar scarring process as the one that occurs inside the lung with asbestosis; however, it occurs in the lining of the lungs rather than in the lungs (*ATSDR, 2001*).

Asbestosis occurs in individuals exposed to large quantities of asbestos fibres over long periods of time and is recognised to result from exposure to all forms of asbestos (i.e. chrysotile and amphiboles). There is evidence to suggest a threshold effect associated with asbestosis with a threshold fibre dosage, that is the dose or exposure below which an adverse effect is not expected, of between 25 to 100 F/mL/year (F/mL/year is also referred to as fibre years and is used to describe the cumulative exposure to asbestos fibres). However, this is an area of some debate (*ATSDR, 2001*). In a review of the epidemiologic evidence for an asbestosis exposure response relationship, the World Health Organization Task Group on Environmental Criteria for Chrysotile Asbestos concluded that “the risk at lower exposure levels is not known” (*WHO, 1998*).

There is evidence of an increased incidence of asbestosis in smokers which may be due to a number of issues such as smoking effects on lung function and defence mechanisms, however, no specific ‘dose’ of tobacco that caused this enhanced incidence could be determined (*ATSDR, 2001*). Lung fibre retention is expected to play a role in the development of asbestosis with trapped asbestos fibres having a prolonged lung residence time. Therefore, the progression of asbestosis may continue for many years after exposure (*ATSDR, 2001*).

In regards to pleural plaques enHealth (2005) provides the following:

The relationship between dose and response for pleural plaques is much weaker than for asbestosis. A good correlation has been shown between pleural plaques and asbestos fibres in the lungs; however, there is large variation.

Lung Cancer

National and international health agencies have classified asbestos as a known human carcinogen. There is a long latency period of up to 40 years between the initial exposure to asbestos fibres and the development of lung cancer. The combination of tobacco smoking and asbestos exposure synergistically increases the risk of developing cancer (*enHealth, 2005; ATSDR, 2001*).

There is general agreement that a dose response relationship exists, that is, higher risks occur with higher exposure to asbestos fibres. It is, however, unclear whether a threshold asbestos dose exists for lung cancer. This depends not only on cumulative asbestos exposure, but also on other underlying lung cancer risks (*ATSDR, 2000*). The incidence of lung cancer from all causes is high in the general population, so asbestos as a causative factor is difficult to prove in an individual patient (*ATSDR, 2000*).

Mesothelioma

enHealth (2005) provides the following description:

> *Mesothelioma is a cancer of the lining of the chest cavity (the pleura) or, less commonly, the lining of the abdominal cavity (the peritoneum). It is generally, but not always, associated with continued occupational or other high exposure to respirable asbestos. Fairly consistent and strong epidemiological evidence indicates that approximately 70% to 90% of mesothelioma cases can be related to asbestos exposure and hence it is accepted that asbestos exposure is the cause.*
>
> *The ability to link asbestos exposure to the development of mesothelioma is subject to sufficient time elapsing since the exposure occurred, to permit the disease to have initiated and developed. Mesothelioma generally does not occur until 20–50 years after exposure. Mesothelioma has been associated with all types of asbestos. However, the evidence for causality is strongest for amphiboles. Mesothelioma occurrence does not appear to be affected by smoking history*.

The following is taken from ATSDR (2000):

> *Mesothelioma can occur with low asbestos exposure; however, very low background environmental exposures carry only an extremely low risk. The dose necessary for effect appears to be lower for asbestos-induced mesothelioma than for pulmonary asbestosis or lung cancer.*

A characteristic of mesothelioma is that there is a long latency period (20–30 years) before the signs and symptoms of the disease become apparent. In addition, diagnosis of the disease can be difficult. Mortality from malignant pleural mesothelioma is a function of past exposure to asbestos.

The incidence rates of malignant mesothelioma have been increasing in Australia since 1965 and it is suggested that these rates of mesothelioma are related to the use and production of asbestos in Australia in previous decades. There is no indication of when the incidence rates of mesothelioma will start to decline. Mesothelioma incidence rates are higher in males than females, possibly because of a higher exposure in male-dominated industries that produced or used asbestos (e.g. construction and manufacturing) (*NOHSC, 2002*).

The Australian mesothelioma register data ranked the risks of mesothelioma according to the following groups listed from highest to lowest (*Leigh and Driscoll 2003*). It should be noted that the risks presented in **Table 20** reflect high historical exposures and do not represent the level of risk associated with current exposure.

Table 20 Mesothelioma Risks in Occupational Groups in Australia

Occupation	Lifetime Risk (%)
Power station worker	11.8
Railway labourer	6.4
Navy/merchant navy	5.1
Carpenter/joiner	2.4
Waterside worker	2.1
Plasterer	2.0
Boilermaker/welder	1.9
Bricklayer	1.8
Plumber	1.7
Painter/Decorator	1.2
Electrical fitter/mechanic/electrician	0.7
Vehicle mechanic	0.7
All Australian men	*0.39*
All Australian women	*0.05*

Extrapolation from epidemiological studies provides an estimated background incidence of non-occupational mesothelioma of one to two per million per year (*Hillerdal, 1999*). Case data suggest a dose response relationship with risk increasing with increasing dose; however, a threshold concentration below which mesothelioma will not occur has not been demonstrated (*ATSDR, 2000; Hillerdal, 1999*).

Historic Exposures to Asbestos

In most evaluations, asbestos-related disease rates are predicted to peak sometime during the next few decades. This can be attributed to long latency periods of asbestos-related disease and high historic exposures. Exposure to asbestos has been found in many occupations, the major contributions coming from the primary asbestos production or manufacture industries, from the building industry generally and from shipping-related activities. Numerous other occupations may also involve asbestos exposure, albeit to a lesser degree. Such occupations include the staff of coal powered power stations, mechanics repairing motor vehicles (brakes, clutch), carpenters and woodworkers, electricians, welders, etc (*Hillerdal, 1999; Niklinski, 2004*)

With few exceptions, little or no sampling was conducted prior to the 1950s when exposure concentrations were thought generally to be higher than those monitored more recently, due to lack of use of dust control equipment at the time and procedures to reduce dust levels that were introduced only later. However, airborne fibre concentrations within workplaces in the 1950's were estimated and recreated to be within tens to thousands of fibres/mL. Measurements from workplaces in the 1960s often showed peak doses of 20 fibres/mL and much less in more recent years. Due to long latency periods, current mesothelioma rates are likely due to these 'high' historical occupational exposures.

UNCERTAINTIES AND LIMITATIONS

Uncertainties are present in all risk assessments and this reinforces the need for a systematic and rigorous approach. While the enHealth human health risk assessment process attempts to estimate risk as accurately as possible, there are various sources of uncertainty in the process that should be examined. Understanding these uncertainties places the risk estimates in a proper perspective allowing them to be applied in practice with an appropriate level of confidence.

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Personnel exposure assessment.
- Toxicological assessment.
- Risk characterisation.

Various sources of uncertainty are briefly discussed below.

Uncertainty related to Exposure Assessment

The uncertainties that may exist in exposure assessment include the estimation of concentrations in the air and the use of PCM analytical techniques:

- Uncertainties relating to air modelling.
- Uncertainties relating to the use of historic data.
- Random error in sample analysis may produce erroneous data.
- PCM cannot distinguish between asbestos and non-asbestos conforming fibres, which causes uncertainty about the actual asbestos fibre concentration for a given area and artificially boost the asbestos fibre counts.

Uncertainty related to Airborne Asbestos Monitoring

The uncertainties that may exist in relation to the airborne asbestos fibre monitoring undertaken as part of the project.

Some uncertainty is based on the limited sampling undertaken under the project scope.

To capture information on likely background airborne asbestos fibres concentrations near the mine site, the project scope allowed for six rounds of monitoring (equivalent to 6 days) prior to the remediation works and 12 rounds (equivalent to 12 days) post remediation works. The uncertainty related to whether this number of monitoring days would capture representative background conditions around the mine site.

It seems likely that these two monitoring periods may have captured representative conditions. This is based on firstly the results of monitoring being similar to the historic air monitoring data from 1992 to 2012 and the results of remediation monitoring conducted daily between October 2014 and May 2015. Secondly, the meteorological data indicating weather patterns during monitoring were broadly similar to historic weather patterns.

A longer term monitoring programme may have removed some of the uncertainty in determining background concentrations of airborne asbestos fibres. This comment also applies to the air monitoring undertaken during recreational activities.

Some uncertainty was associated with ensuring post remediation background monitoring was representative on long term background and not short term conditions due to the mine site "settling down" after the remediation project. Remediation works were completed in May 2015. The remediation works was a significant disturbance to the mine site. Accordingly, the mine site was allowed time to settle into the new state prior to repeating background air monitoring. April 2016 was chosen to recommence background airborne asbestos fibre monitoring. An April start was chosen to minimise the likelihood of rain during the airborne asbestos fibre monitoring. This decision was based on the historic evidence indicating heaviest mean rainfall for the region occurring in October to March (Barraba mean monthly rainfall 1881-2014, Bureau of Meteorology).

Uncertainty related to Asbestos Content of soils

There is a general lack of information on asbestos content of soils in areas where recreational activities may be occurring. Accordingly estimating potential exposure through indirect pathways such surface contamination from contact with asbestos containing soils is unclear.

Uncertainty related to Releases of Asbestos fibres from Naturally Occurring Asbestos in the Woodsreef Area

There is a paucity of site specific information on release of asbestos fibres from naturally occurring asbestos in the Woodsreef area. However it is likely that the mine site provides the dominate source of mobile asbestos fibres in the local environment. As such the contribution of fibres from naturally occurring asbestos outside the mine site to the total amount of mobile asbestos fibres in the local environment is unclear.

Uncertainty related to Toxicity Assessment

In general, the available scientific literature is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals or materials to which humans may be exposed. It is necessary therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. This may introduce two types of uncertainties into the risk assessment, as follows:

- Those related to extrapolation from one species to another.
- Those related to extrapolating from high exposure doses, usually in experimental animal studies, to the lower doses usually estimated for human exposure situations.

For asbestos, epidemiology studies used to derive toxicity information often involve high exposure concentrations in an occupational setting.

Safety factors are introduced to compensate for these uncertainties. The use of safety factors and extrapolating from high exposure concentrations typically leads to a conservative over-estimation of dose response relationships.

Uncertainty in Risk Characterisation

The methods available for the estimation of cancer risk do not account for the increased lifetime risk of lung cancer due to prior lung disease. Cancer risks could therefore be underestimated for susceptible subpopulations with prior lung disease.

There is a degree of uncertainty in estimating the risk of contracting cancer (lung cancer or mesothelioma) at low doses. As exposure response data are derived mainly from high occupational exposures scenarios, there is difficulty in estimating risk for short-term exposure at low levels over long periods of time. Additionally, no risk estimates are calculated for non-cancer risks due to the unavailability of any method.

In this study, measured asbestos fibre concentrations were used to estimate risks from exposure and this approach may conservatively over-estimates the risks involved.

Uncertainty related to the use of Australian Occupational Exposure Standards

There is uncertainty associated with using occupational standards for assessing exposure in the non-occupational environment. Occupational standards are determined for work place exposures over the working life of an adult, for example 40 hours per week over a working life of 30 to 40 years. Accordingly, these standards allow higher exposures than would normally be allowed or expected in the non-occupational environment. Nor do occupational standards consider more sensitive subsets of a population such as children.

However, an acceptable level for asbestos exposure has not been determined in the non-occupation environment.

As such the use of an occupational standard, while imperfect, at least provided the basis for standardized sampling methodology and allowed comparisons to a significant body of historic Woodsreef air monitoring data collected over at least 25 years.

Moreover, occupational exposure standards are based on the best available information from industrial experience, human exposure data and animal studies.

Uncertainty related to Site Visits for Recreational Purposes

There is uncertainty associated with the frequency at which persons will repeatedly visit the area to conduct recreational activities. In many cases, it is likely that recreational users will only visit the area once or few times. Local residents of Barraba, Woodsreef and surrounds may conduct repeated recreational activities more often than visitors. However there is no information currently available on the frequency of repeat visits to the area.

In the current report, assumptions were made that recreational users will only visit the area for short periods, such as a day or two on a weekend, once to a few times per year.

If a person is conducting recreational activities repeatedly over many days during each year, then their exposure risk may be greater than Negligible to Low.

The recreational activities chosen for monitoring under the project scope were based on advice from Barraba community representatives associated with the Woodsreef Taskforce and observations by Taskforce members. Most known recreational activities were covered in the monitoring. Some activities were excluded due to safety concerns, such as off-road driving of cars and motorbikes and pig hunting. However, for excluded activities such as off-road driving of cars and motorbikes, it may be possible to infer likelihood of asbestos fibre exposure from other studies.

A similar study of recreational exposure was conducted by the US EPA in an area of naturally occurring asbestos in the Clear Creek Management Area in central California (USA EPA, 2008). The methodology for sampling and analysis, used in the US EPA study was different to that used for the Woodsreef study. Furthermore the detection limits for each study are different. US EPA (2008) reported a detection limit of 0.0005 fibres per mL of air. In contrast, the Woodsreef study reported a detection limit of 0.01 fibre per mL of air (SLR, 2017), making the results of the two studies not directly comparable.

However the US EPA study can be used to indicate broad differences in exposures of various activities include off-road driving of cars and motorbikes as well as hiking. These differences can then be used to provide an indication of possible differences in exposures relating to different recreational activities in other areas of naturally occurring asbestos such as the Woodsreef area.

A simple way to do this using the US EPA data is to relate asbestos fibre exposure concentrations to people hiking in that study to concentrations reported during off road driving of recreational vehicles such as cars and motorcycles. This will then give general indications of possible increase in exposure when conducting an activity such as off road driving compared to hiking in the same area.

For example, the US EPA (2008) reported motorcycle riders were exposed to a mean asbestos fibre concentration of 0.3071 fibres per mL of air but hikers were only exposed to a mean asbestos fibre concentration of 0.0183 fibres per mL of air. To indicate the possible increase in exposure when conducting an activity such as off road driving compared to hiking, the motorcycle rider exposure concentration can be divided by the hiking exposure concentration to give a simple number indicating magnitude of increase in exposure. An example is set out below:

Motorcycle rider mean exposure concentration (adult) = 0.3071 fibres per mL

Hikers mean exposure concentration (adult) = 0.0183 fibres per mL

0.3071 ÷ 0.0183 = 16.8

Therefore, in the US EPA study, an adult motorcycle rider was possibly exposed to asbestos fibre concentrations in the order of 17 times greater than what an adult hiker may be exposed to.

It should be noted that this 17 times increase in exposure between motorcycle riders and hikers will be specific to conditions of the US EPA study. However, the comparison can be used for persons undertaking activities in in other areas of naturally occurring asbestos, to indicate rough magnitude of difference between exposures when riding motorcycles compared with hiking. Therefore, this information can be used to indicate recreational users conducting off road motorcycle riding in the area surrounding Woodsreef mine, will likely be exposed to significantly higher airborne asbestos fibre concentrations than users hiking in the same area.

This concept of magnitude of change based on data from US EPA (2008) may then be used to indicate possible increasing order for potential asbestos exposure for recreational activities in the Woodsreef area including for activities excluded from the Woodsreef monitoring.

That would be the following from likely lowest exposure to highest exposure:

Hiking < camping < washing off road vehicles after use < off-road driving of cars < motorbike riding

Examples of difference in magnitude of asbestos fibre exposure from the Clear Creek Management Area in central California have been set out below in **Table 21** (USA EPA, 2008).

Table 21 CCMA Exposure Activity Air Sampling - Comparison of Asbestos Fibre Exposure during Recreational Activities to Exposure during Hiking (Mean data extracted from US EPA, 2008)

Activities	Magnitude of Increase in Exposure to Airborne Asbestos Fibres Compared to Exposure During Hiking
Adult Activities	
All-Terrain Vehicle	17 x
Motorcycle	17 x
SUV (Jeep Cherokee or similar)	10 x
Vehicle Wash (after use)	8 x
Camping	5 x
Fence Building	3 x
Hiking	-
Child Activities	
All-Terrain Vehicle	17 x
Motorcycle	14 x
SUV (Jeep Cherokee or similar)	10 x
Camping	2 x
Hiking	-

Recreational activities undertaken illegally by trespassers onto the mine site were not considered in this study. It was considered such activities provided high risk of asbestos exposure to the persons trespassing. Furthermore, management goals are to keep trespassers out of the mine site.

Uncertainties Conclusion

While a number of parameters used within the risk assessment have a moderate degree of uncertainty associated with them, values used to define these parameters have been selected to be conservative. This has resulted in estimates of risk which tend towards a conservative overestimation.