Surface Water Studies
North Star Magnetite Project
Final Report

301012-01539

Sep 2012
Disclaimer

This report has been prepared on behalf of and for the exclusive use of Fortescue Metals Group and is subject to and issued in accordance with the agreement between Fortescue Metals Group and Worley Parsons. WorleyParsons accepts no liability or responsibility whatsoever for it in respect of any use or reliance upon this report by any third party.

Copying this report without permission of Fortescue Metals Group or WorleyParsons is not permitted.
## CONTENTS

1. **INTRODUCTION** ................................................................................................................ 1
2. **NORTH STAR PROJECT DESCRIPTION** ......................................................................... 2
3. **REGIONAL CLIMATE AND CATCHMENTS** ..................................................................... 4
   3.1 Regional Rainfall ................................................................................................................. 4
   3.2 Evaporation ......................................................................................................................... 5
   3.3 Regional Stream flows and Flooding .................................................................................. 6
   3.4 Climate Change ................................................................................................................ 10
4. **NORTHSTAR PROJECT AREA SURFACE WATER CHARACTERISATION** ............. 14
   4.1 Sub Catchments ............................................................................................................... 14
   4.2 Design Rainfalls ................................................................................................................ 14
   4.3 Design Flows .................................................................................................................... 15
   4.4 Vegetation and Land Systems .......................................................................................... 16
   4.5 Ecology ............................................................................................................................. 18
5. **PREDICTED HYDROLOGICAL CHANGE DUE TO NORTHSTAR** ............................. 20
6. **REFERENCES:** ................................................................................................................ 28
   **FIGURES** ......................................................................................................................................... 29
   **APPENDIX 1: VEGETATION ASSOCIATIONS** ................................................................. 37
   **APPENDIX 2: LAND SYSTEMS WITHIN THE NORTH STAR PROJECT AREA** ............ 39
   **APPENDIX 3: IDENTIFICATION OF ENVIRONMENTAL FACTORS** ............................. 41
1. INTRODUCTION

FMG Iron Bridge Ltd, a subsidiary of Fortescue Metals Group Ltd is planning the development of the North Star iron ore Magnetite mine in the Pilbara, which is located approximately 100km south of Port Hedland, on the boundary between the Turner River and Shaw River catchments. Further references to ‘Fortescue’ refer to both FMG Iron Bridge Ltd and Fortescue Metal Group Ltd.

WorleyParsons were engaged to undertake a high level desktop study to characterise the natural hydrologic regime of the catchments in which North Star development is to be located and to assess the change in the regime due to the development of the mine.

The scope of this work includes:

- Regional surface water characterisation:
  - Identify regional catchments in which the mine and access road is proposed.
  - Describe the regional climate.
  - Describe any surface water dependent ecosystems in the vicinity of the development, particularly those that are threatened or are considered to be regionally significant.
  - Describe the hydrologic regime of the regional catchments (including climate, stream flows if recorded, regional flood levels).
  - Provide advice on climate change.

- North Star project area surface water characterisation:
  - Delineate sub catchments within the proposed project area (mine and haul road)
  - Describe sub catchments and land use pre development.
  - Map land use, soils and vegetation.
  - Provide information on recorded rainfalls and stream flows if available for the sub catchments.
  - Provide design rainfalls and design flows for the sub catchments.
  - Describe changes to design flows.
  - Describe any hydrologic features of environmental relevance, including sheet flow areas and pools/wetlands that have been identified within these sub catchments.
  - Describe changes to the hydrologic regime within, and downstream of the sub catchments and at any pools or sheet flow areas that have been identified.
  - Comment on the change to the regional hydrologic regime as a result of the proposed development.
2. NORTH STAR PROJECT DESCRIPTION

Fortescue proposes to develop a new iron ore mine approximately 110km south of Port Hedland, known as the North Star Magnetite Project (Project). The Project includes a new mine with one mine pit, one waste rock dump (WRD), one tailings storage facility (TSF), one low grade ore stockpile (LGOS), crushing and screening hub, magnetic separation processing plant, roads, and other associated mine infrastructure. The Project is premised on a maximum of 30 Million tonnes per annum (Mtpa) Run of Mine (ROM) feed of magnetite ore with a mine life of 45 years. The ore will undergo crushing and screening, then magnetic separation, with up to 15 Mtpa of product being sent to Port Hedland for export as concentrate. The key characteristics of the Project are summarised in Table 1.

Table 1: Key Characteristics of Proposal

<table>
<thead>
<tr>
<th>Relevant Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Activities</td>
<td>Iron ore mining, crushing, grinding and magnetic separation, transport of magnetite concentrate by slurry pipeline to Port Hedland for dewatering and stockpiling.</td>
</tr>
<tr>
<td>Resource</td>
<td>Up to 2.1 Billion tonnes of magnetite.</td>
</tr>
<tr>
<td>Total Material Moved</td>
<td>Up to 2,500Mt at maximum mining rate of 155Mtpa.</td>
</tr>
<tr>
<td>Tailings</td>
<td>Up to 540Mt of tailings</td>
</tr>
<tr>
<td>Life of Mine</td>
<td>Approximately 45 years.</td>
</tr>
<tr>
<td>Total Disturbance Footprint</td>
<td>Approximately 5000 hectares.</td>
</tr>
<tr>
<td>Pit Size</td>
<td>4.5 km in length, 1 km in width.</td>
</tr>
<tr>
<td>Pit Depth</td>
<td>Maximum depth of 375m below original ground level</td>
</tr>
<tr>
<td>Mining Method</td>
<td>Standard open cut mining proposed. Overburden and waste material will be permanently placed outside of the open pit mining area in a dedicated landform. The opportunity for backfill of the pit will be reviewed during mining operations.</td>
</tr>
<tr>
<td>Waste/Overburden Volume</td>
<td>Approximately 913Mt of hard rock and 180 Mt of dry process rejects.</td>
</tr>
<tr>
<td>Topsoil Volume</td>
<td>Approximately 3Mt to be stored in a temporary stockpile, no more than 2m high for use in rehabilitation.</td>
</tr>
<tr>
<td>Export Tonnage</td>
<td>Up to 15Mtpa.</td>
</tr>
<tr>
<td>Dewatering Requirements</td>
<td>Minimal dewatering will be required from the open pit due to the limited available water within the host rock. An estimated dewatering rate of 0.5Gtpa has been calculated.</td>
</tr>
</tbody>
</table>

Mine Site Infrastructure and Ancillary Services

| Ore Processing           | Processing of magnetite will involve primary and secondary crushing and grinding. Product separation will be through a combination of low intensity magnetic and dry air classification. |
| Power                    | 110MW to be built at the mine site. |
| Fuel Storage Requirements | Up to 4,000 kL stored within a dedicated fuel farm and satellite tanks for major fuel use areas |
| Water                    | Construction: 2.5GLpa supplied by bores located within Fortescue’s rail corridor |
Operations: up to 14GLpa supplied by bores located at the Canning Basin.

Workshops and Administration Facilities
Administrative and maintenance buildings; Product stockpiles and workshops, fuel storage and explosive storage magazine.

Camp
Construction Camp of 2,000 beds
Operations Camp of up to 800 beds

Workforce
Construction approximately 2,000 (drive in drive out from Port Hedland)
Operational Approximately 800 (drive in drive out from Port Hedland)
Operational hours are 24hrs per day, 7 days per week.

Transport
A 600mm buried steel pipeline will be used to transport magnetite concentrate as slurry from site to Pt Hedland for filtering and stockpiling prior to shipping.

The total area of disturbance associated with the Project is approximately 5,000 ha\(^1\). The ore mining methodology employed for the Project will involve conventional drill and blast, followed by hydraulic excavation and haulage to processing facilities and stockpiles by off road haul trucks.

The Project involves the development of a single Mine Pit which will be approximately 4.5km in length and 1km in width. Minimal mine pit dewatering will be required. In-pit sumps may be required to collect any incidental rainfall or seepage during mining activities with sub-surface drainage from the surrounding country rock into the ore body. It is proposed to construct a levee bank around the Mine Infrastructure area to provide flood protection for a 1 in 100 year Average Recurrence Interval (ARI).

Up to 913 Mt of waste rock (410 Million Loose Cubic Metres (MLCM)) will be mined throughout the life of the Project. A waste landform will be required with an approximate area of 991 ha to contain this volume of waste. The waste landform will be a maximum height of 340m AHD, which is the approximate height of the surrounding ridgelines (332m AHD).

Ore will be transported via haul trucks to the run-of-mine (ROM) facility, where it will be stockpiled prior to processing.

A 600mm buried steel pipeline will be used to transport magnetite concentrate as slurry from site to Port Hedland for filtering and stockpiling prior to shipping.

A 38.5 km access road to North Star will be constructed to connect to the Great Northern Highway. The access road will utilise 1.5km of the existing Wittenoom Road and existing level crossings at the BHPB Newman rail mainline. The access road will be suitable for Class 1, 2 or 3 Restricted Access Vehicles (RAV) traffic. A 20m wide constructed road pavement will be required to allow for access of heavy haulage trucks and light vehicles. The total disturbance width of the road will be 30m to allow for road berms, shoulders and drains. The access road basis of drainage design will satisfy a 1-in-5-year ARI rain event.

---

\(^{1}\) The disturbance area has been calculated to provide allowance for construction activities such as gaining access to the designed area and providing sufficient area for shaping and battering of designed slopes.
3. REGIONAL CLIMATE AND CATCHMENTS

3.1 Regional Rainfall

The Pilbara region has a hot semi-arid to arid climate. Average annual rainfalls range from 300 mm to 350 mm within a 100 km radius of the North Star mine. The location of daily rainfall gauging stations in the study area is shown in Figure 1.

Rainfall occurs mainly in the three month period from January to March (refer to Chart 1) with major falls occurring from cyclone, tropical lows and convective thunder storms. Rainfall is highly variable with a mean annual rainfall of 300-360 mm, but annual totals vary from 0 mm to over 1000 mm. Relevant statistics for rainfalls stations in the Pilbara are presented in Table 2. Note that the closest long term rainfall gauge to the site is Wallareenya.

**Chart 1: Monthly Rainfall Statistics for Wallareenya**
Table 2: Annual Rainfall Statistics (based on a water year commencing 1st Oct)

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean Annual Rainfall (mm)</th>
<th>Median Annual Rainfall (mm)</th>
<th>Min Annual Rainfall (mm)</th>
<th>Max Annual Rainfall (mm)</th>
<th>25th Percentile</th>
<th>75th Percentile</th>
<th>Stand. Dev.</th>
<th>Dist. to site (km)</th>
<th>Years of record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mallina (004059)</td>
<td>327</td>
<td>294</td>
<td>0</td>
<td>880</td>
<td>196</td>
<td>419</td>
<td>174</td>
<td>113</td>
<td>1901-2008</td>
</tr>
<tr>
<td>Wallareenya (004038)</td>
<td>319</td>
<td>312</td>
<td>24</td>
<td>706</td>
<td>186</td>
<td>375</td>
<td>140</td>
<td>59</td>
<td>1909-2011</td>
</tr>
<tr>
<td>Strelley (004036)</td>
<td>358</td>
<td>358</td>
<td>13</td>
<td>944</td>
<td>205</td>
<td>464</td>
<td>182</td>
<td>86</td>
<td>1907-2011</td>
</tr>
<tr>
<td>Carindie (004008)</td>
<td>316</td>
<td>302</td>
<td>48.3</td>
<td>994</td>
<td>202</td>
<td>400</td>
<td>167</td>
<td>70</td>
<td>1908-2005</td>
</tr>
<tr>
<td>Marble Bar (004106)</td>
<td>361</td>
<td>315</td>
<td>168</td>
<td>706</td>
<td>250</td>
<td>446</td>
<td>169</td>
<td>74</td>
<td>2001-2010</td>
</tr>
<tr>
<td>Indee (004016)</td>
<td>328</td>
<td>282</td>
<td>33</td>
<td>859</td>
<td>202</td>
<td>428</td>
<td>170</td>
<td>68</td>
<td>1909-2007</td>
</tr>
<tr>
<td>Hillside (004015)</td>
<td>335</td>
<td>306</td>
<td>25</td>
<td>1268</td>
<td>206</td>
<td>393</td>
<td>197</td>
<td>66</td>
<td>1917-2008</td>
</tr>
<tr>
<td>Redmont (004043)</td>
<td>312</td>
<td>304</td>
<td>54.2</td>
<td>553</td>
<td>212</td>
<td>399</td>
<td>124</td>
<td>84</td>
<td>1926-1993</td>
</tr>
</tbody>
</table>

*# Years of record available from Bureau of Meteorology website.*

### 3.2 Evaporation

Evaporation rates in the Pilbara are very high with the mean annual potential evaporation being approximately 3,400 m (WRC 2000), or ten times higher than the mean annual rainfall. Evaporation rates vary seasonally with mean monthly evaporation rates ranging from 2.5 mm/day to 18 mm/day, refer to Chart 2.

**Chart 2: Monthly Evaporation** *(From Surface Hydrology of the Pilbara Region, Water & Rivers Commission, Report No SWH 32 (WRC 2000))*
3.3 Regional Stream flows and Flooding

The North Star mine is located on the boundary between the Turner River and Shaw River catchments. Refer to Figure 1 for a regional locality map which shows the location of the mine and access road in relation to regional catchment areas. The mine layout is shown in Figure 2, key features include:

- The mine pit
- One tailing storage facility to the north of the mine pit
- A stockpile to the west of the pit
- A waste rock dump to the east of the pit

The mine pit runs approximately along the boundary between the Turner River and Shaw River catchments, with the majority of the mine site located within the Turner River catchment. Sub-catchments potentially impacted by the mine are shown in Figure 3. The footprint of the mine disturbance area is relatively small compared to the Turner River and Shaw River catchments, as can be seen from Table 3.

The proposed access road runs directly west from the mine site for a distance of approximately 20 km where it connects to an existing road/rail transport corridor. The access road runs alongside a tributary of the Turner River as well as crossing numerous minor waterways. The catchment areas for these crossings are shown in Figure 4.

The nearest stream flow gauging station to the North Star mine is on the Turner River at Pincunah, which was established in 1985 and has a catchment area of 885 km$^2$. The next closest stream flow gauging stations are located on the Yule River at Kangan Homestead and the Shaw River at Upper North Pole. Refer to Figure 1 for the location of these gauging stations.

Table 3: Relative Catchment Areas

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Total Catchment Area (km$^2$)</th>
<th>Approx. Mine Footprint in Catchment (km$^2$)</th>
<th>Percentage of Mine Footprint in Catchment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strelley River (sub-catchment of the Shaw R)</td>
<td>2805</td>
<td>10</td>
<td>0.36</td>
</tr>
<tr>
<td>Turner River</td>
<td>4802</td>
<td>40</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Streams in the region are ephemeral and flow for only a short duration following rainfall events, typical for streams in the Pilbara. A plot of daily stream flows is provided in Chart 3 for the Turner River at Pincunah showing flows to be intermittent, generally occurring in the wet season (January-March) with long periods of no flow during the dry season. In years with low rainfall there are no flows.

Flow duration curves are provided in Chart 4 for the total period of record (26 years-1985 to 2011), as well as the wettest and driest years. The flow duration curve for the total period shows that flows only occur for 51 days per year and zero flows for 314 days. However, behaviour varies remarkably from
The driest year had 365 zero flow days whilst the wettest year had flow for 277 days.

Key hydrological statistics for the Turner River at Pincunah are provided in Table 4. These statistics characterise the natural flow regime and are found to be relevant for assessing impacts on ecosystems. The statistics show that in the 27 years of record there have been 64 significant flow events, or approximately 2 events per year. However, some years had no flow, whereas others had multiple flow events. The average duration of a flow event is approximately 12 days and the average flow rate during these events is $54 \text{m}^3/\text{s}$. The mean annual flow volume is 33,250 ML, which corresponds to a mean runoff depth of 37 mm. Therefore, runoff represents approximately 10% of the mean annual rainfall.

Chart 3: Daily Flows for Turner River at Pincunah
Table 4: Key Hydrologic Statistics for Turner River at Pincunah (based on daily flow volumes)

<table>
<thead>
<tr>
<th>General Statistics</th>
<th>Whole Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum daily flow (ML)</td>
<td>Min</td>
</tr>
<tr>
<td>Maximum daily flow (ML)</td>
<td>Max</td>
</tr>
<tr>
<td>Mean daily flow (ML)</td>
<td>MDF</td>
</tr>
<tr>
<td>Median daily flow (ML)</td>
<td>Med</td>
</tr>
<tr>
<td>CV</td>
<td>CV</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>STD</td>
</tr>
<tr>
<td>Skewness</td>
<td>Skw</td>
</tr>
<tr>
<td>Zero flow days</td>
<td>Zer</td>
</tr>
<tr>
<td>Zero flow days (%)</td>
<td>Zer%</td>
</tr>
<tr>
<td>Days Less or equal 10 ML/d</td>
<td>Under10</td>
</tr>
<tr>
<td>Days Greater or equal 10 ML/d</td>
<td>Greater10</td>
</tr>
<tr>
<td>High Flow Spell result</td>
<td>HSThld</td>
</tr>
<tr>
<td>Number of High Spells</td>
<td>HNum</td>
</tr>
<tr>
<td>Mean of High Spell Peaks (ML/d)</td>
<td>HSPeak</td>
</tr>
<tr>
<td>Mean Duration of High Spells (days)</td>
<td>HSMeanDur</td>
</tr>
</tbody>
</table>
A flood frequency analysis was applied to the recorded flows (Turner River at Pincunah) in order to provide an estimate of the peak flood discharges for a range of annual Exceedance Probabilities (AEP’s). Since there were four years with zero flow the partial series was applied with a threshold flow of 110 m$^3$/s. This gave 24 events, which equalled to the number of years of record. The 2 parameter Log Normal distribution was found to give the best fit to the data, refer to Chart 5. The estimated peak discharges are provided in Table 5. Peak discharges provided by the Flavell Regional Flood Frequency Procedure (RFFP) are also provided for comparison purposes. The RFFP method is based on flood frequency analysis of stream flow gauging stations across the entire Pilbara region and is typically used to estimate design flows. It can be seen that the RFFP gives higher values than frequency analysis of the Pincunah gauging station. This suggests that flood discharge rates from the Turner River catchment are lower than the average discharge rates for the Pilbara region. The 1 in 100 AEP flood extents in the vicinity of the mine and access road are provided in Figure 4. It can be seen that the access road is not located on the floodplain, but a portion of the mining footprint is within the mapped floodplain. Thus parts of the mining footprint will require diversion drains and flood protection levees.

Table 5: Estimated Peak Flood Discharges for Turner River at Pincunah

<table>
<thead>
<tr>
<th>AEP</th>
<th>Peak Flood Discharges (m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flood Frequency Analysis</td>
</tr>
<tr>
<td>1 in 10</td>
<td>785</td>
</tr>
<tr>
<td>1 in 20</td>
<td>1055</td>
</tr>
<tr>
<td>1 in 50</td>
<td>1472</td>
</tr>
<tr>
<td>1 in 100</td>
<td>1840</td>
</tr>
</tbody>
</table>

# Partial series flood frequency analysis with number of peaks equal to number of years of data (n=24). Threshold flow of 110 m$^3$/s.
3.4 Climate Change

Examination of historical rainfall records shows that there is a slight trend for increasing rainfall in the North Star region of the Pilbara (refer to Chart 6). This is consistent with the results of a study by the Bureau of Meteorology for all of Australia, which showed that the Pilbara has experienced an increase in annual rainfall of between 1-5 mm/annum since 1970 (refer to Chart 7). In contrast to the observed trend, climate modelling by the CSIRO has estimated that mean annual rainfall in the Pilbara is likely to decrease slightly (by 2-10%) by the year 2030 (refer to Chart 8). The impacts of reduced rainfall will be exacerbated by a slight increase (1-1.5°C) in mean annual temperatures (refer to Chart 9), which is estimated to give a 2-4% increase in potential evapotranspiration (refer to Chart 10). Hence, given the resulting drier antecedent soil moisture, the decrease in surface water flows is likely to be more than the decrease in rainfall.

There still remains much uncertainty over the impact of global climate change on the patterns of precipitation in the Pilbara. There are also longer term climate cycles at play which remain poorly understood. While the observed and predicted trends may be considered significant in absolute terms, they are small in comparison to the annual variability in extremes that are characteristic of the...
region (as illustrated in Chart 5). Management of such extremes will continue to be important for water management at mine sites in the Pilbara.

![Annual Rainfalls with Trendline - Wallareenya-(004038)](chart)

**Chart 6: Annual Rainfalls at Wallareenya**

![Annual Rainfall Trends across Australia](chart)

**Chart 7: Annual Rainfall Trends across Australia**
Chart 8: Predicted change in mean annual rainfall by year 2030

Chart 9: Predicted change in mean annual temperature by year 2030
Chart 10: Predicted change in mean annual evapotranspiration by year 2030
4. NORTHSTAR PROJECT AREA SURFACE WATER CHARACTERISATION

4.1 Sub Catchments

A total of 9 sub-catchments have been identified at the mine site, refer to Figure 3. The majority of the catchments drain towards the Turner River, but runoff from the waste rock dump drains towards the Strelley River catchment. The catchments are hilly with slopes ranging from 2%-6%. The dominant vegetation is eucalyptus woodland and hummock grassland, refer to Figure 5.

4.2 Design Rainfalls

Design rainfall intensities for the mine site sub catchments were derived using the Bureau of Meteorology (BOM) online IFD calculator for the location of Latitude 21.250 Longitude 119.050. The design rainfall intensities and depths are provided in Table 6 and Chart 11. Whilst the Pilbara region experiences reasonably low annual rainfall totals, peak rainfall intensities during cyclone and thunderstorm events are relatively high. It is not uncommon for the majority of the rainfall for a given year to occur during one or two intense storm events. Table 6 shows that the rainfall during a 24 hour 1 in 100 Average Recurrence Interval (ARI) event is 300 mm, which approximates the mean annual rainfall.

Table 6: Design Rainfall Intensities (Intensities and depths shown)

<table>
<thead>
<tr>
<th>DURATION</th>
<th>1 in 1</th>
<th>1 in 2</th>
<th>1 in 5</th>
<th>1 in 10</th>
<th>1 in 20</th>
<th>1 in 50</th>
<th>1 in 100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm/hr</td>
<td>mm/hr</td>
<td>mm/hr</td>
<td>mm/hr</td>
<td>mm/hr</td>
<td>mm/hr</td>
<td>mm/hr</td>
</tr>
<tr>
<td>5 mins</td>
<td>80.1</td>
<td>6.7</td>
<td>107.</td>
<td>8.9</td>
<td>151.</td>
<td>12.6</td>
<td>179.</td>
</tr>
<tr>
<td>6 mins</td>
<td>74.3</td>
<td>7.4</td>
<td>99.2</td>
<td>9.9</td>
<td>141.</td>
<td>14.1</td>
<td>167.</td>
</tr>
<tr>
<td>10 mins</td>
<td>61.1</td>
<td>10.2</td>
<td>81.9</td>
<td>13.7</td>
<td>117.</td>
<td>19.5</td>
<td>140.</td>
</tr>
<tr>
<td>20 mins</td>
<td>45.9</td>
<td>15.3</td>
<td>61.9</td>
<td>20.6</td>
<td>90.4</td>
<td>30.1</td>
<td>109.</td>
</tr>
<tr>
<td>30 mins</td>
<td>37.6</td>
<td>18.8</td>
<td>50.9</td>
<td>25.5</td>
<td>75.1</td>
<td>37.6</td>
<td>91.0</td>
</tr>
<tr>
<td>1 hour</td>
<td>24.8</td>
<td>24.8</td>
<td>33.8</td>
<td>33.8</td>
<td>50.8</td>
<td>50.8</td>
<td>62.2</td>
</tr>
<tr>
<td>2 hours</td>
<td>15.0</td>
<td>30.0</td>
<td>20.6</td>
<td>41.2</td>
<td>31.6</td>
<td>63.2</td>
<td>39.2</td>
</tr>
<tr>
<td>3 hours</td>
<td>10.9</td>
<td>32.7</td>
<td>15.0</td>
<td>45.0</td>
<td>23.3</td>
<td>69.9</td>
<td>29.1</td>
</tr>
<tr>
<td>6 hours</td>
<td>6.17</td>
<td>37.0</td>
<td>8.57</td>
<td>51.4</td>
<td>13.6</td>
<td>81.6</td>
<td>17.2</td>
</tr>
<tr>
<td>12 hours</td>
<td>3.55</td>
<td>42.6</td>
<td>4.96</td>
<td>59.5</td>
<td>8.03</td>
<td>96.4</td>
<td>10.2</td>
</tr>
<tr>
<td>24 hours</td>
<td>2.10</td>
<td>50.4</td>
<td>2.96</td>
<td>71.0</td>
<td>4.84</td>
<td>116.2</td>
<td>6.19</td>
</tr>
<tr>
<td>48 hours</td>
<td>1.24</td>
<td>59.5</td>
<td>1.75</td>
<td>84.0</td>
<td>2.87</td>
<td>137.8</td>
<td>3.68</td>
</tr>
<tr>
<td>72 hours</td>
<td>0.87</td>
<td>62.6</td>
<td>1.22</td>
<td>87.8</td>
<td>2.01</td>
<td>144.7</td>
<td>2.58</td>
</tr>
</tbody>
</table>
4.3 Design Flows

Peak flows for the mine site catchments depicted in Figure 3 were estimated using the Regional Flood Frequency Procedure (RFFP) developed by Flavell (2005) and are presented in Table 7. This method was derived using stream-flow and rainfall data sets collected from gauged catchments in the Pilbara, which have areas ranging between 52 and 41,400 km². Given that some of the mine site catchments are considerably smaller, the peak flows estimated by the RFFP may under estimate discharges (because of the lesser influence of storage, which reduces peak flows, in smaller catchments). It may therefore be more appropriate to apply other estimation procedures for the smaller catchments during detailed design of mine site drainage infrastructure such as road culverts, and diversion drains.
Table 7: Estimated peak flood discharges for mine site catchments (using Flavell method)

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Area (km²)</th>
<th>AEP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 in 10</td>
</tr>
<tr>
<td>M1</td>
<td>2.18</td>
<td>23</td>
</tr>
<tr>
<td>M2</td>
<td>3.71</td>
<td>40</td>
</tr>
<tr>
<td>M3</td>
<td>0.46</td>
<td>10</td>
</tr>
<tr>
<td>M4</td>
<td>1.69</td>
<td>30</td>
</tr>
<tr>
<td>M5</td>
<td>3.16</td>
<td>22</td>
</tr>
<tr>
<td>M6</td>
<td>1.34</td>
<td>12</td>
</tr>
<tr>
<td>M7</td>
<td>4.5</td>
<td>30</td>
</tr>
<tr>
<td>M8</td>
<td>20.5</td>
<td>105</td>
</tr>
<tr>
<td>TSF</td>
<td>19.7</td>
<td>102</td>
</tr>
</tbody>
</table>

4.4 Vegetation and Land Systems

Pre-European vegetation has been mapped at a broad scale (1:1,000,000) for the Pilbara region (Beard 1975, Department of Agriculture Western Australia 2005) and is shown in Figure 5 for the North Star project area. Descriptions of the vegetation categories are provided in Appendix 1. Three broad vegetation associations have been mapped within the access road and proposed mine site:

- The vegetation association ‘Eucalyptus camaldulensis woodland’. This association represents riparian vegetation and occurs on major drainage lines and coincides with the River land system.
- The vegetation association ‘Grevillea mixed sparse shrubland’. This association usually occurs on stony plains and low rolling hills.
- The vegetation association ‘Eucalyptus leucophloia open woodland and Triodia open hummock grassland’. This association usually occurs on low hills and ridges.

Land systems mapping of the Pilbara region has been undertaken by Van Vreeswyk et al. (2004) and includes consideration of geomorphology, soils, vegetation, land use and resource condition.

Land systems occurring within the North Star project area are shown in Figure 6. The proposed access road lies across seven land systems (Boolgeeda, Boolaloo, Capricorn, Macroy, Platform, River, Rocklea, Talga), whilst the proposed mine site and infrastructure falls within the Capricorn and Boolgeeda land systems. Descriptions of each land system category are provided in Appendix 2.

The Rocklea, Boolgeeda and Macroy land systems are widely represented throughout the Pilbara region. The Capricorn, Talga and River land systems each represent less than 3% area in the Pilbara region. The Boolaloo and Platform land systems each represent less than 1% of area in the Pilbara region. Very small areas of each of these land systems will be impacted by the proposed North Star access road.
The River land system is characterised by active flood plains and major rivers supporting grassy woodlands, tussock grasslands and soft spinifex grasslands. The proposed access road crosses short sections of these active floodplains.

The River land system is likely to be dependent on surface water and is potentially impacted by the proposed access road. This land system is represented in two small sections of the access road, approximately 2 km in total. It is characterised by active flood plains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands (Van Vreeswyk et al. 2004).

A detailed assessment of the vegetation of the North Star study area was completed in 2011 by ecologia Environment (2012) and 33 vegetation units were described and mapped. Four of these units occurred in rivers, gorges, creeks and floodplains. These are:

- **FpAtCo** – *Ficus platypoda* open woodland over *Acacia tumida* and *Gossypium robinsonii* sparse tall shrubland, over *Cymbopogon obtectus* and *Eriachne mucronata* sparse tussock grassland,
- **ChAbTp** – *Corymbia hamersleyana* open low woodland, over *Acacia bivenosa* mid shrubland, over *Triodia pungens* open hummock grassland,
- **EvCc** (mapped as Cc) – ± *Eucalyptus victrix* ± *Eucalyptus camaldulensis* open mid woodland, over *Cenchrus ciliaris* tussock grassland, and
- **PtTp**–*Pluchea ferdinandi-muelleri* open low shrubland over *Triodia pungens* sparse hummock grassland.

A further five vegetation units were recorded in drainage lines or shrubby drainage lines: These are

- **GwTe** – *Grevillea wickhamii* sparse mid shrubland, over *Triodia epactia* or *Triodia schinzii* open hummock
- **GwTp** - *Grevillea wickhamii* sparse tall shrubland, over *Triodia pungens* open hummock grassland
- **Ap** - . *Acacia pyrifolia*, *Gossypium robinsonii* and *Tephrosia rosea* mid shrubland,
- **ApTp** - *Acacia pyrifolia*, *Acacia acradenia* and *Tephrosia rosea* mid shrubland, over *Triodia pungens* open hummock grassland, and
- **At** - *Acacia tumida*, *Grevillea wickhamii* and *Indigofera monophylla* shrubland.
4.5 Ecology

A preliminary assessment was made of ecological factors such as significant flora species and vegetation communities that may be dependent on surface water and potentially impacted by changes in surface water flows as a result of the proposed North Star mine and access road. Details of the methodology applied to identify these factors are provided in Appendix 3.

Threatened Communities

There are no Threatened Ecological Communities listed as Matters of National Environmental Significance under the Environmental Protection and Biodiversity Conservation Act 1999 located within the region affected by the North Star project. There are no known occurrences of Threatened Ecological Communities (TECs) or Priority Ecology Communities (PECs) within 30 km of the proposed North Star project.

Surface Flow Dependent Ecosystems

Mulga Sheet-flow vegetation communities have not been mapped as occurring within the North Star project area (ecologia Environment 2012, Beard 1975, Department of Agriculture Western Australia 2005). Information from land system and pre-European vegetation datasets indicate that the surface flow dependent ecosystems present in the North Star project area are likely to be the *Eucalyptus camaldulensis* riparian woodlands along major drainage lines.

ecologia Environment (2012) have described nine vegetation units that occur within rivers, gorges, creeks, floodplains and drainage lines (See section 4.4). Of these, two are most likely to be dependent on surface water flows for at least some of the year and represent riparian vegetation (Figure 7). These are:

- FpAtCo – *Ficus* open woodland
- EvCc (mapped as Cc) – *Eucalyptus* open woodland

FpAtCo is restricted to small patches where water cascades over escarpments from areas higher in the landscape and is considered significant (ecologia Environment 2012). This vegetation unit occurs in areas with relatively high levels of moisture and shelter and provides conditions to support habitat specific fauna and flora which may be locally restricted including conservation significant fauna species, such as the Pilbara Olive Python and the Northern Quoll.

EvCc is found on major drainage lines that receive surface water run-off from upstream catchments. This vegetation type was assessed as being in very poor condition by ecologia Environment (2012) as a result of the prevalence of the introduced species *Cenchrus ciliaris* (buffel grass) in drainage lines that have been grazed by cattle.

The other seven vegetation units described by ecologia Environment (2012) whilst occurring within minor drainage lines are not likely to be dependent on surface water flows as they are likely to be
ephemeral and only experience flows during periods of intense rainfall and would quickly dry out and remain dry for most of the year.

**Threatened and Priority Flora**

According to available databases, there are no Threatened Flora records within 30 km of the proposed North Star Mine (DEC 2012a). Ten Priority Flora species have been recorded in this 30 km radius (DEC 2012b) and description records are provided in Table A3.1.

Ecologia Environment (2012) identified a total of eight Priority Flora species within the North Star survey area. These are:

- *Abutilon pritzelianum* (P1)
- *Heliotropium muticum* (P1)
- *Pityrodia* sp. Marble Bar (P1)
- *Euphorbia clementii* (P2)
- *Acacia glaucoacaesia* (P3)
- *Gymnanthera cunninghamii* (P3)
- *Goodenia nuda* (P4)
- *Ptilotus mollis* (P4)

Of these, *Gymnanthera cunninghamii* and *Goodenia nuda* are discussed below:

- *Gymnanthera cunninghamii* was observed by Ecologia Environment (2012) to have high habitat specificity to vegetation unit GwTp, which occurs in sandy drainage channels. These sandy drainage channels are likely to experience flows during high intensity rainfall events, but would quickly dry out and are likely to be dry for most of the year.
- *Goodenia nuda* also showed some habitat specificity for vegetation unit GwTp and ImTp, which correspond to drainage channels and floodplains.
5. PREDICTED HYDROLOGICAL CHANGE DUE TO NORTHSTAR

**Mine Site**

The major impact on flows by the mine is caused by the tailings storage facility, which covers an area of approximately 1500 ha that drains towards the Turner River. The TSF embankment completely cuts-off flow from its catchment to the downstream waterway. However, flow recovers with distance downstream, as additional flow enters from downstream catchments. Figure 8 shows the proportion of natural flows in different reaches of the downstream waterway. It can be seen that the flow proportion recovers to approximately 80% of the natural flow within a distance of approximately ten kilometres from the TSF embankment wall.

The mine pit will also have an impact on flows. However, since the pit lies almost along the catchment divide and is relatively long and narrow the impact on flows will be relatively minor i.e. flows will recover to greater than 80% of the natural flow a short distance downstream of the pit. The stockpile and waste dump will have an impact on the rate of infiltration and the volumes of runoff (which will decrease), but will not materially change the catchment boundaries, therefore impacts on flow will be minor. Drainage associated with the earthworks pads and other infrastructure will only have a minor impact on local flows.

Further, details of surface water impacts are provided in Table 8.

**Regional Pools**

A number of regional pools have been identified as part of the Vegetation and Flora Assessment for the North Star project (ecologia Environment (2012)). The mine is not expected to have a significant impact on the pools. Details are provided in Table 9. Note that the majority of the catchment area for the Site 12 Pool lies to the north, away from the waste rock stockpile.

**Access Road**

The access road crosses a number of minor streams which take the form of defined, incised channels. The largest of these drainage channels are likely to support EvCc vegetation. Dense vegetation can be observed along the banks of these channels. Typical terrain is shown in Photos No's 1-3. The access road is designed for a 1 in 5 year rainfall event with flows up to this event passing through culverts and bridges. Larger events will spill over the road. Impacts on flow behaviour immediately upstream and downstream of creek crossings will be minor and localised.
### Table 8: Potential Impacts on Surface Flows

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Contained Infrastructure</th>
<th>Flow related processes</th>
<th>Potential Impacts on Flow (without any mitigation measures)</th>
<th>Mitigation Measures needed</th>
</tr>
</thead>
</table>
| M1        | - Stockpile              | - stockpile may change rate of runoff due to increased infiltration  
- changes in runoff water quality from disturbed areas with exposed soil surfaces. | - minor decrease in runoff  
- water quality of surface runoff may change. | - sediment control for disturbed areas with exposed soil |
| M2        | - Open pit               | - rainfall on the open pit will be captured and deducted from the outflow from this catchment (surface water in the pit to be used for processing).  
- with diversion drains runoff from east of the pit will discharge into the pit  
- Increased runoff coefficient from cleared/compacted areas (haul roads etc.) due to changes in infiltration properties.  
- changes in runoff water quality  
- reduction in catchment runoff from rainfall on open pit.  
- detention effect of drainage crossings may attenuate the peak discharge rate.  
- increased runoff from cleared/compacted areas.  
- water quality of surface runoff may change.  
- there is no diversion of runoff to/from adjacent catchment. | - diversion bund/drain to the east of the Open Pit to prevent surface water ingress into the pit.  
- drainage crossings for the haul/access roads.  
- sediment control for disturbed areas with exposed soil. |
<table>
<thead>
<tr>
<th>Catchment</th>
<th>Contained Infrastructure</th>
<th>Flow related processes</th>
<th>Potential Impacts on Flow (without any mitigation measures)</th>
<th>Mitigation Measures needed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>from disturbed areas with exposed soil surfaces.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>- Stockpile</td>
<td>- stockpile may change rate of runoff due to increased infiltration - changes in runoff water quality from disturbed areas with exposed soil surfaces.</td>
<td>- minor decrease in runoff - water quality of surface runoff may change.</td>
<td>- sediment control for disturbed areas with exposed soil</td>
</tr>
<tr>
<td>M4</td>
<td>- Processing plant</td>
<td>- increased runoff coefficient from cleared/compacted areas (processing plant and other infrastructure) due to changes in infiltration properties. - changes in runoff water quality from disturbed areas with exposed soil surfaces.</td>
<td>- ponding upstream of roads and other obstructions. - increased runoff from cleared/compacted areas. - water quality of surface runoff may change.</td>
<td>- provide appropriate culverts and diversion structures. - sediment control for disturbed areas with exposed soil surfaces.</td>
</tr>
<tr>
<td>M5</td>
<td>- minor roads and sundry infrastructure</td>
<td>- minor flow obstructions and local changes to infiltration rates - changes in runoff water quality from disturbed areas with</td>
<td>- minor changes to flow rates. - water quality of surface runoff may change.</td>
<td>- provide appropriate culverts and diversion structures. - sediment control for disturbed areas with exposed soil surfaces.</td>
</tr>
</tbody>
</table>
## SURFACE WATER STUDIES
### NORTH STAR MAGNETITE PROJECT

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Contained Infrastructure</th>
<th>Flow related processes</th>
<th>Potential Impacts on Flow (without any mitigation measures)</th>
<th>Mitigation Measures needed</th>
</tr>
</thead>
</table>
| **M6**    | - minor roads and sundry infrastructure | - minor flow obstructions and local changes to infiltration rates  
- changes in runoff water quality from disturbed areas with exposed soil surfaces. | - minor changes to flow rates.  
- water quality of surface runoff may change. | - provide appropriate culverts and diversion structures.  
- sediment control for disturbed areas with exposed soil surfaces. |
| **M7**    | - Admin area | - increased runoff coefficient from cleared/compacted areas due to changes in infiltration properties.  
- changes in runoff water quality from disturbed areas with exposed soil surfaces. | - increased runoff from cleared/compacted areas.  
- water quality of surface runoff may change.  
- there is no diversion of runoff to/from adjacent catchment. | - diversion drains around the northern edge of the Stockpile.  
- sediment control for disturbed areas with exposed soil surfaces. |
| **M8**    | - Waste rock dump | - the waste rock dump may change the rate of runoff due to increased infiltration  
- changes in runoff water quality from disturbed areas with exposed soil surfaces. | - minor decrease in runoff  
- water quality of surface runoff may change. | - sediment control for disturbed areas with exposed soil surfaces |
### Catchment and Contained Infrastructure

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Contained Infrastructure</th>
<th>Flow related processes</th>
<th>Potential Impacts on Flow (without any mitigation measures)</th>
<th>Mitigation Measures needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSF</td>
<td>- Tailings Storage Facility</td>
<td>- TSF covers the site</td>
<td>- No runoff from the site</td>
<td>- Not applicable</td>
</tr>
</tbody>
</table>
### Table 9: Potential Impacts on Regional Pools

<table>
<thead>
<tr>
<th>Water Pools</th>
<th>Easting</th>
<th>Northing</th>
<th>Major River Catchments</th>
<th>Potential Impacts on Water Pools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig Pool</td>
<td>711673</td>
<td>7650631</td>
<td>Turner River</td>
<td>No Project Infrastructure upstream of water pool. No potential impacts expected.</td>
</tr>
<tr>
<td>Cow Spring</td>
<td>711108</td>
<td>7648592</td>
<td>Turner River</td>
<td>No potential impacts expected.</td>
</tr>
<tr>
<td>Gorge &amp; Rock Pool</td>
<td>713227</td>
<td>7644656</td>
<td>Turner River</td>
<td>Located upstream of project area. No potential Impacts expected.</td>
</tr>
<tr>
<td>Central Creek Pool</td>
<td>704366</td>
<td>7646358</td>
<td>Turner River</td>
<td>Located downstream of the project area. Since these infrastructure areas constitute only a small portion of the catchment draining into the water pool, the impact on the water pool is expected to be minor.</td>
</tr>
<tr>
<td>Northern gorge 1</td>
<td>712735</td>
<td>7658183</td>
<td>Strelley River</td>
<td>No project infrastructure upstream of water pool. No potential impacts expected.</td>
</tr>
<tr>
<td>Northern Gorge 2</td>
<td>713545</td>
<td>7658568</td>
<td>Strelley River</td>
<td>No project infrastructure upstream of water pool. No potential impacts expected.</td>
</tr>
<tr>
<td>Echo Pool</td>
<td>714504</td>
<td>7655427</td>
<td>Strelley River</td>
<td>No potential impacts expected.</td>
</tr>
<tr>
<td>Site 12 Pool</td>
<td>716248</td>
<td>7649263</td>
<td>Strelley River</td>
<td>Part of the waste dump at the top edge of the catchment may affect the runoff characteristics (volume and quality). Since this area constitutes a small portion of the catchment area draining into the water pool, the impact on the water pool is expected to be minor.</td>
</tr>
<tr>
<td>Camp Pool</td>
<td>712628</td>
<td>7655633</td>
<td>Strelley River</td>
<td>No potential impacts expected.</td>
</tr>
<tr>
<td>Dirty Water Pool</td>
<td>718242</td>
<td>7655603</td>
<td>Strelley River</td>
<td>No project Infrastructure upstream of water pool. No potential impacts expected.</td>
</tr>
</tbody>
</table>
Photo No 1: Typical terrain for stream crossing access road

Photo No 2: Typical terrain for stream crossing access road
Photo No 3: Typical terrain for stream crossing access road
6.REFERENCES:

Beard, J.S. (1975) Vegetation Survey of Western Australia. 1:100,000 Vegetation Series Map Sheet 5 – Pilbara.

Department of Agriculture Western Australia (2005) Pre-European Vegetation – Western Australia. GIS Dataset.

Department of Agriculture Western Australia (2009) Rangeland Land System Mapping for Western Australia. GIS Dataset.

Department of Environment and Conservation (2012a) Threatened (Declared Rare) Database Search.

Department of Environment and Conservation (2012b) WA Herbarium Database Search.

Department of Environment and Conservation (2012c) Threatened Ecological Communities Database Search.


Water & Rivers Commission (WRC 2000), Surface Hydrology of the Pilbara Region, Report No SWH 32.
FIGURES
Figure 1
Figure 1. Regional locality North Star Mine

LOCATION PLAN

North Star Mine Area

LEGEND

Daily rainfall gauging stations
Streamflow gauging stations
Railways
Major rivers
Roads
North Star Magnetite Project Proposed Infrastructure
Strelley River
Turner River

Copyright © WorleyParsons Services Pty Ltd ABN 61 001 279 812 Datum : GDA94 Map Grid of Australia Zone 50

INFORMATION ONLY
NOT TO BE USED FOR CONSTRUCTION

Figure 1. Regional locality North Star Mine

DATE : 03 Aug 2012
CUSTOMER : FMG
MAP : 201012_00350_019.mxd
AUTHOR : M. Rouse

Produced By: M. Rouse - Geomatics W.A.
Figure 2
Figure 2. North Star mine layout
Figure 3
Figure 3. Mine site catchments
Figure 4
Figure 4. Project area and mine access road

- Mine access road catchments
- 100 year flood extent
- Railways
- Rivers
- Waste Dump
- Stockpile
- North Star Mine Pit
- Tailings Facility
- Access Road
- Accommodation Camp
- Admin, Workshop and Substation
- Canning Basin Pipeline
- Chemical Stone
- Explosives Store
- Go-line Area
- Power Infrastructure
- Process Plant
- Rail Siding
- Stockyard
- Tailings Pipeline

LOCATION PLAN

DATE: 30 Aug 2012
CUSTOMER: FMG
MAP: 201012_00350_022.mxd
REV: A

Figure 4. Project area and mine access road

- Mine access road catchments
- 100 year flood extent
- Railways
- Rivers
- Waste Dump
- Stockpile
- North Star Mine Pit
- Tailings Facility
- Access Road
- Accommodation Camp
- Admin, Workshop and Substation
- Canning Basin Pipeline
- Chemical Stone
- Explosives Store
- Go-line Area
- Power Infrastructure
- Process Plant
- Rail Siding
- Stockyard
- Tailings Pipeline

LOCATION PLAN

DATE: 30 Aug 2012
CUSTOMER: FMG
MAP: 201012_00350_022.mxd
REV: A

Figure 4. Project area and mine access road

- Mine access road catchments
- 100 year flood extent
- Railways
- Rivers
- Waste Dump
- Stockpile
- North Star Mine Pit
- Tailings Facility
- Access Road
- Accommodation Camp
- Admin, Workshop and Substation
- Canning Basin Pipeline
- Chemical Stone
- Explosives Store
- Go-line Area
- Power Infrastructure
- Process Plant
- Rail Siding
- Stockyard
- Tailings Pipeline

LOCATION PLAN

DATE: 30 Aug 2012
CUSTOMER: FMG
MAP: 201012_00350_022.mxd
REV: A
Figure 5
Figure 5. Pre-European Vegetation

Pre-European Vegetation

- Acacia pyrifolia shrubs / Triodia lanigera open hummock grassland
- Grevillea pyramidalis, Hakea loesca, Senna sp. and Grevillea wickhamii shrubs
- Triodia pungens and T. wiseana open hummock grassland
- Eucalyptus leucophloia open woodland Triodia wiseana and T. pungens hummock grassland
- Eucalyptus camaldulensis and Melaleuca leucadendron woodland / Acacia sp. aff. coriacea, Crotalaria cunninghamii, Gossypium robinsonii, Hibiscus panduriformis, Gossypium australis shrubs
Figure 6
Land Systems Impacted by Mine

- Boolgeeda - Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands
- Boolaloo - Granite hills, domes and tor fields and restricted sandy plains
- Capricorn - Hills and ridges of sandstone and dolomite
- Macroy - Stony plains and occasional tor fields based on granite
- Platform - Dissected slopes and raised plains
- River - Active flood plains and major rivers
- Rocklea - Basalt hills, plateaux, lower slopes and minor stony plains
- Talga - Hills and ridges of greenstone and chert and stony plains

Figure 6. Land systems
Figure 7
Figure 7. Vegetation Mapping (FMG) associated with riparian vegetation

06 Sep 2012

CUSTOMER: FMG

SCALE: 1:150,000

AUTHOR: M ROUSE

MAP: 201012_00350_017.mxd

REV: A

LOCATION PLAN

LEGEND

- Ficus - Open Woodland (FpAICo)
- Eucalyptus - Open Woodland (CC)
- Goodenia nuda
- Gymnanthera cunninghamii
- Pityrodia sp. Marble Bar
- PRIORITY FLORA

- Highways
- Roads
- Railways
- Drainage

INFORMATION ONLY
NOT TO BE USED
FOR CONSTRUCTION
Figure 8
Figure 8. Tailings storage facility flow impacts
APPENDIX 1: VEGETATION ASSOCIATIONS
### Table A1.1: Vegetation Associations mapped within the North Star exploration area (Department of Agriculture 2005)

<table>
<thead>
<tr>
<th>Vegetation Association</th>
<th>Original Association Description</th>
<th>Original Mapping Code</th>
<th>NVIS Level 6 (SUB_ASSOCIATION)</th>
<th>Environmental Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>82.1</td>
<td>Hummock grasslands, low tree steppe; snappy gum over <em>Triodia wiseana</em></td>
<td>e16Lr t3Hi</td>
<td><em>Eucalyptus leucophloia</em> open woodland <em>Triodia wiseana</em> and <em>T. pungens</em> hummock grassland</td>
<td>GEORGE RANGES</td>
</tr>
<tr>
<td>93.3</td>
<td>Hummock grasslands, shrub steppe; kanji over soft spinifex</td>
<td>a2Sr t1Hi</td>
<td><em>Triodia pungens</em> and <em>T. wiseana</em> open hummock grassland</td>
<td>ABYDOS PLAIN - Lower slopes on summits</td>
</tr>
<tr>
<td>93.4</td>
<td>Hummock grasslands, shrub steppe; kanji over soft spinifex</td>
<td>a2Sr t1Hi</td>
<td><em>Grevillea pyramidalis</em>, <em>Hakea lorea</em>, <em>Senna</em> sp. and <em>Grevillea wickhamii</em> shrubs</td>
<td>ABYDOS PLAIN - CHICHESTER - Oakover Valley</td>
</tr>
<tr>
<td>619.1</td>
<td>Medium woodland; river gum (<em>Eucalyptus camaldulensis</em>)</td>
<td>e18Mi</td>
<td><em>Eucalyptus camaldulensis</em> and <em>Melaleuca leucadendron</em> woodland / <em>Acacia</em> sp. aff. <em>coriacea</em>, <em>Crotalaria cunninghamii</em>, <em>Gossypium robinsonii</em>, <em>Hibiscus panduriformis</em>, <em>Gossypium australe</em> shrubs</td>
<td>ABYDOS PLAIN</td>
</tr>
<tr>
<td>626.1</td>
<td>Hummock grasslands, shrub-steppe; kanji over soft spinifex &amp; <em>Triodia brizoides</em></td>
<td>a2Sb t16Hi</td>
<td><em>Acacia pyrifolia</em> shrubs / <em>Triodia lanigera</em> open hummock grassland</td>
<td>ABYDOS PLAIN - Mt. Tinstone footslopes</td>
</tr>
</tbody>
</table>
APPENDIX 2: LAND SYSTEMS WITHIN THE NORTH STAR PROJECT AREA
### Table A2.1: Land Systems within the North Star Project Area

<table>
<thead>
<tr>
<th>Land Type</th>
<th>Land System</th>
<th>Description</th>
<th>Area of land system represented in the Pilbara region</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hills and Ranges with spinifex grasslands</td>
<td>Boolaloo</td>
<td>Granite hills, domes and tor fields and restricted sandy plains</td>
<td>1,502 km², 0.8%</td>
</tr>
<tr>
<td></td>
<td>Capricorn</td>
<td>Hills and ridges of sandstone and dolomite</td>
<td>5,296 km², 2.9%</td>
</tr>
<tr>
<td></td>
<td>Rocklea</td>
<td>Basalt hills, plateaux, lower slopes and minor stony plains</td>
<td>22,993 km², 12.7%</td>
</tr>
<tr>
<td></td>
<td>Talga</td>
<td>Hills and ridges of greenstone and chert and stony plains</td>
<td>2,124km², 1.2%</td>
</tr>
<tr>
<td>5. Dissected plains with spinifex grasslands</td>
<td>Platform</td>
<td>Dissected slopes and raised plains</td>
<td>1,570 km², 0.9%</td>
</tr>
<tr>
<td>8. Stony plains with spinifex grasslands</td>
<td>Boolgeeda</td>
<td>Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands</td>
<td>7,748 km², 4.3%</td>
</tr>
<tr>
<td></td>
<td>Macroy</td>
<td>Stony plains and occasional tor fields based on granite</td>
<td>13,095km², 7.2%</td>
</tr>
<tr>
<td>17. River plains with grassy woodlands and shrublands and tussock grasslands</td>
<td>River</td>
<td>Active flood plains and major rivers</td>
<td>4,088 km², 2.3%</td>
</tr>
</tbody>
</table>
APPENDIX 3: IDENTIFICATION OF ENVIRONMENTAL FACTORS
Environmentally sensitive areas (ESAs)

A preliminary assessment was made of environmentally sensitive areas (ESAs) that may be dependent on surface water and potentially impacted by the proposed North Star mine or access road. Environmentally sensitive areas (ESAs) are protected under the Environmental Protection (Clearing of Native Vegetation) Regulations 2004. ESAs are selected for their environmental values at state or national levels. They include:

- Declared World Heritage property sites (Environmental Protection and Biodiversity Conservation Act 1999);
- Areas registered on the Register of the National Estate (Australian Heritage Commission Act 1975);
- Defined wetlands and riparian vegetation within 50 m;
- Areas covered by Threatened Ecological Communities (TECs);
- Areas of vegetation within 50 m of Threatened Flora; and
- Bush Forever sites.

Database Searches

Database searches were centered on the proposed North Star mine at the coordinate; zone 50K 699480mE, 7650849mN, using a 30 km search radius.

The Department of Sustainability, Environment, Water, Population and Communities Protected Matters Search Tool provides guidance on matters of national environmental significance or matters protected by the Environmental Protection and Biodiversity Conservation Act 1999, specifically:

- World Heritage properties
- National Heritage places
- Nationally Important Wetlands
- Wetlands of International Significance
- Threatened Ecological Communities
- Threatened Flora species

The Department of Environment and Conservation’s (DEC) database of Threatened Ecological Communities (TECs) and Priority Ecological Communities (PECs) is used to identify communities...
under threat. The DEC’s Threatened Flora database and the Western Australian Herbarium Specimen
database are used to identify known and predicted locations of Threatened (T) and Priority (P) flora.

The DEC’s interactive on-line map of Environmentally Sensitive Areas (ESAs) is used to identify areas
of native vegetation that are protected under the Environmental Protection (Clearing of Native
<table>
<thead>
<tr>
<th>Species</th>
<th>Cons Code</th>
<th>Site</th>
<th>Vegetation</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia leeuweniana</td>
<td>1</td>
<td>Among granite rocks on granite hill.</td>
<td>Spinifex ground cover.</td>
<td>Ca 120 km S of Port Hedland (27 km N of Woodstock turnoff, then ca 1 km W of Great Northern Highway)</td>
</tr>
<tr>
<td>Acacia leeuweniana</td>
<td>1</td>
<td>On orange-stained granite outcrop. Light orangy-brown gravelly sand</td>
<td>Associates include Acacia retivena, A. pyrifolia and A. acradenia.</td>
<td>7 km N of Obstinate Creek (or 29.1 km N of Woodstock turnoff) on New Great Northern Highway</td>
</tr>
<tr>
<td>Acacia leeuweniana</td>
<td>1</td>
<td>Granitic outcrop and boulder field, skeletal gritty red-grey soil over</td>
<td>Open Scrub of Acacia retivena subsp. clandestina, A. tumida var. pilborensis, Terminalia canescens and Cajanus sp. over scattered open</td>
<td>Obstinate Creek Repeater Tower, 13.9 km E of Mount Francisco, 25.2 km SW of Pincunah Hill, 28.9 km NW of Woodstock Homestead, 18.7 km S of Mount Tinstone</td>
</tr>
<tr>
<td>Acacia levata</td>
<td>3</td>
<td>Narrow granite creek with tors.</td>
<td>Triodia lanigera hummock grassland.</td>
<td>c. 125 km S of Port Hedland on Great Northern Highway</td>
</tr>
<tr>
<td>Acacia levata</td>
<td>3</td>
<td>Granitic sand among granite rocks at base of granite hill.</td>
<td>Spinitex ground cover.</td>
<td>Ca 120 km S of Port Hedland (27 km N of Woodstock turnoff, then ca 1 km W of Great Northern Highway)</td>
</tr>
<tr>
<td>Acacia levata</td>
<td>3</td>
<td>Granite outcrop.</td>
<td>With Acacia stellaticeps, A. orthocarpa (weeping form), Triodia pungens.</td>
<td>ca 13 km W along unnamed track to Telstra Tower junction with Great Northern Highway, 122.8 km N of Auski Roadhouse</td>
</tr>
<tr>
<td>Species</td>
<td>Cons Code</td>
<td>Site</td>
<td>Vegetation</td>
<td>Locality</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Euphorbia clementii</td>
<td>2</td>
<td>Distal colluvium in outwash fans. Very gently inclined slope, aspect 80 degrees. Coarse fragments common to maximum size of 20 mm. No bedrock exposed. Red brown sandy loam, average depth 33.2 cm.</td>
<td>Scattered Low Trees of <em>Corymbia hamersleyana</em> over Scattered Tall Shrubs of <em>Acacia tumida var. pilbarensis</em> over Open Shrubland of <em>Acacia tumida var. pilbarensis</em>, <em>Grevillea wickhamii</em> &amp; <em>Acacia ancistrocarpa</em> over Low Shrubland of <em>Acacia tumida var. pilbaren</em></td>
<td>Site: MBW09, South side of track, 1.8 km west of Great Northern Highway on southern access road to Yandeyarra Community, 7.7 km NNE of Mt Tinstone, 109.1 km W of Marble Bar, Kangan Station, Pilbara IBRA</td>
</tr>
<tr>
<td>Goodenia nuda</td>
<td>4</td>
<td>Drainage line. Mining tenant. Red soil.</td>
<td></td>
<td>Cloudbreak FMG Mine, Pilbara</td>
</tr>
<tr>
<td>Gymnanthera cunninghamii</td>
<td>3</td>
<td>Brown-red sand.</td>
<td>Open Hummock Grassland of <em>Triodia</em> sp.</td>
<td>FMG Stage A Rail Corridor</td>
</tr>
<tr>
<td>Heliotropium muticum</td>
<td>1</td>
<td>Flat. Red silty sand. Low lying floodplain. Burnt &lt;3 years ago.</td>
<td>Hummock grassland with emergent shrubs. Associated species include <em>Acacia stellaticeps</em>, <em>Corchorus</em> sp., <em>Triodia</em> sp., <em>Eriachne</em> sp.</td>
<td>Along FMG northern access track E of Great Northern Highway, 70 km S of Port Hedland</td>
</tr>
<tr>
<td>Nicotiana umbratica</td>
<td>3</td>
<td>Cool shelter with shade under lee of large rocks. Soil friable.</td>
<td><em>Triodia</em> grassland with scattered trees and subshrubs.</td>
<td>Abydos Station, S of Port Hedland</td>
</tr>
<tr>
<td>Nicotiana umbratica</td>
<td>3</td>
<td>Granite outcrops.</td>
<td></td>
<td>Road to Nullagine, 2-5 km from junction with Great Northern Highway, Pilbara</td>
</tr>
<tr>
<td>Phyllanthus hebecarpus</td>
<td>3</td>
<td>Midslope of very steep ironstone</td>
<td>With <em>Triodia</em> spp.</td>
<td>Near the Port Hedland to Newman Highway ca 250 km NW of Newman</td>
</tr>
<tr>
<td>Pityrodia sp.</td>
<td>1</td>
<td></td>
<td></td>
<td>Unallocated Crown Land, ca 7 km S of</td>
</tr>
<tr>
<td>Species</td>
<td>Cons Code</td>
<td>Site</td>
<td>Vegetation</td>
<td>Locality</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------</td>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Marble Bar (G. Woodman &amp; D. Coultas GWDC Opp 4)</td>
<td></td>
<td>hillslope, base of small cliff, SW facing. Skeletal red-brown sandy loam over massive ironstone.</td>
<td></td>
<td>Strelley Station southern boundary, ca 12 km E of Wallareenya Station eastern boundary, E of the Strelley River, ca 90 km SSE of Port Hedland</td>
</tr>
<tr>
<td>Pityrodia sp. Marble Bar (G. Woodman &amp; D. Coultas GWDC Opp 4)</td>
<td>1</td>
<td>Base of very steep sandstone hillslope, S-facing, within gorge. Skeletal brown sandy loam over massive sandstone.</td>
<td>Tall shrubland of <em>Terminalia canescens</em> and <em>Acacia tumida</em> var. <em>pilbarenensis</em> over hummock grassland of <em>Triodia longiceps</em>, with <em>Eriachne mucronata</em>, <em>Sarcostemma viminal subsp. australae.</em></td>
<td>Unallocated Crown Land, ca 5 km S of Strelley Station southern boundary, ca 15 km W of Panorama Station western boundary, just E of the Strelley River. Ca 90 km SSE of Port Hedland</td>
</tr>
<tr>
<td>Tephrosia bidwillii</td>
<td>3</td>
<td>Bedrock and proximal colluvium. Very gently inclined slope, aspect 150 degrees. Coarse fragments common to maximum size of 600 mm. Very slight bedrock outcrop. Red brown loam, average depth 28.4 cm.</td>
<td>Scattered Tall Shrubs of <em>Acacia inaequilatera</em> over Scattered Shrubs of <em>Acacia inaequilatera</em> &amp; <em>Acacia bivenosa</em> over Hummock Grassland of <em>Triodia</em> spp. over scattered sedges of <em>Bulbostylis barbata</em> over Scattered Herbs of <em>Polycarpacea</em> sp.</td>
<td>Site: MBW01, 2 km NE of Pilgangoora Mining Centre, 6.9 km N of Mt York, 87.5 km WNW of Marble Bar, Wallareenya Station, Pilbara IBRA</td>
</tr>
</tbody>
</table>