King Vol Project
Groundwater Dependent Ecosystem Monitoring Program

Auctus Resources Pty Ltd
# Document Control Summary

**NRA Environmental Consultants**

<table>
<thead>
<tr>
<th>NRA Filepath:</th>
</tr>
</thead>
<tbody>
<tr>
<td>\F:\AAA\401_Auctus Res\401007_GDE\401007.03_KV GDE monit prog\King Vol GDE monitoring pgm_R02.docx</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Status:</th>
<th>Date of Issue:</th>
</tr>
</thead>
<tbody>
<tr>
<td>R02 (Final)</td>
<td>7 December 2017</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Manager:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shannon Wetherall</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title:</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Vol Project Groundwater Dependent Ecosystem Monitoring Program</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Client:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auctus Resources Pty Ltd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Client Contact:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warren Crabb, Project Manager</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Copies Dispatched:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PDF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Info or Requirements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final report supersedes and replaces all previous documentation prepared.</td>
</tr>
</tbody>
</table>

---

## Report Summary

### Key Words

Auctus Resources Pty Ltd, King Vol, Groundwater Dependent Ecosystem, GDE, environmental values, monitoring.

### Abstract

Groundwater Dependent Ecosystems (GDEs) are likely to be impacted by the proposed dewatering activity at King Vol mining project on mining lease (ML) 20658 in north Queensland. This report describes the program proposed to monitoring impacts on environmental values of the GDEs.

---

## Citation

This report should be cited as: NRA 2017, *King Vol Project Groundwater Dependent Ecosystem Monitoring Program*, R02 (Final), prepared by NRA Environmental Consultants for Auctus Resources Pty Ltd, 7 December 2017.

---

## Quality Assurance

<table>
<thead>
<tr>
<th>Author</th>
<th>Technical Review</th>
<th>Editor</th>
<th>Document Version</th>
<th>Approved for Issue by QA Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Megan Grixti</td>
<td>Peter Buosi</td>
<td>-</td>
<td>R01</td>
<td>-</td>
</tr>
<tr>
<td>Shannon Wetherall</td>
<td>BAppSc(Hons)</td>
<td>Kirsty Anderson</td>
<td>R02</td>
<td>7/12/17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BA(Hons)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© Natural Resource Assessments Pty Ltd
This document is the property of Natural Resource Assessments Pty Ltd. Apart from any use as permitted under the Copyright Act 1968 all other rights are reserved. Unauthorised use of this document in any form whatsoever is prohibited.

Certified Integrated Management System
AS/NZS ISO 9001:2008 (Quality)
AS/NZS ISO 14001:2004 (Environment)
AS/NZS 4801:2001 (Safety)
Limitations of this Report

The information in this report is for the exclusive use of Auctus Resources Pty Ltd, the only intended beneficiary of our work. NRA cannot be held liable for third party reliance on this document. This disclaimer brings the limitations of the investigations to the attention of the reader. The information herein could be different if the information upon which it is based is determined to be inaccurate or incomplete. The results of work carried out by others may have been used in the preparation of this report. These results have been used in good faith, and we are not responsible for their accuracy. The information herein is a professionally accurate account of the site conditions at the time of investigations; it is prepared in the context of inherent limitations associated with any investigation of this type. It has been formulated in the context of published guidelines, field observations, discussions with site personnel, and results of laboratory analyses. NRA’s opinions in this document are subject to modification if additional information is obtained through further investigation, observations or analysis. They relate solely and exclusively to environmental management matters, and are based on the technical and practical experience of environmental practitioners. They are not presented as legal advice, nor do they represent decisions from the regulatory agencies charged with the administration of the relevant Acts. Any advice, opinions or recommendations contained in this document should be read and relied upon only in the context of the document as a whole and are considered current as of the date of this document.
Table of Contents

1. Introduction .............................................................................................. 1
   1.1 Scope ................................................................................................. 1

2. Summary of EVs and Impacts Associated with GDEs ......................... 2

3. Monitoring Program ................................................................................. 3
   3.1 Semi-evergreen vine thicket on limestone rock outcrops (RE 9.11.8a) 3
   3.2 Riverine wetland vegetation (RE 9.3.13) ............................................ 5
   3.3 Flora species of conservation significance ......................................... 7
   3.4 Aquatic ecosystems – surface water .................................................. 7
   3.5 Aquatic ecosystems – subterranean ................................................... 9
   3.6 Habitat for fauna species of conservation significance ..................... 10
   3.7 Groundwater levels and water quality ............................................... 11

4. Program Reporting and Review ............................................................ 12

5. References .............................................................................................. 13

Tables

Table 1: Potential impacts on EVs associated with dewatering for the
         King Vol project to 680 m BGL ................................................................. 2

Table 2: Proposed GDE monitoring sites for RE 9.11.8a ............................ 3

Table 3: Proposed GDE monitoring sites for RE 9.3.13 ............................. 6

Table 4: Proposed GDE monitoring sites for surface water ecosystems .... 8

Table 5: Proposed GDE monitoring sites for bat species ......................... 10
1. Introduction

The King Vol project mining lease (ML 20658) is approximately 38 km north-west of Chillagoe and approximately 5 km north-west of the Walsh River. The project is owned and operated by Auctus Resources Pty Ltd (Auctus) for the extraction of metalliferous ore. Auctus proposes to expand the underground mining operations to 680 m below ground level (BGL).

Interference with groundwater occurs at King Vol from dewatering activity. The dewatering activity will continue and expand as part of the proposed ongoing operations at the mine\(^1\). The nature and scale of the potential impacts to Groundwater Dependent Ecosystems (GDEs) associated with the proposed groundwater dewatering activities were assessed by NRA Environmental Consultants (NRA) and hydrogeologists Rob Lait & Associates Pty Ltd (RLA). The assessment identified that the dewatering activity for the mine expansion is likely to affect environmental values (EVs) associated with the GDEs (NRA 2017a, RLA 2017).

The EVs associated with the GDEs are:

- remnant vegetation associated with limestone rock outcrops (RE 9.11.8a) and riparian vegetation (RE 9.3.13)
- aquatic ecosystems in watercourses and potentially in subterranean landforms (e.g., stygofauna)
- flora and fauna species of conservation significance (*Macropteranthes montana*, *Panicum maximum*, Greater Large-eared Horseshoe Bat and Diadem Leaf-nosed Bat), associated with RE 9.3.13 and/or RE 9.11.8a, and caves in the limestone outcrops.

1.1 Scope

This monitoring program, prepared by NRA for Auctus, identifies the approach recommended to monitor potential impacts on EVs that may be affected by the proposed dewatering activity at King Vol. Where an impact is detected, investigations to quantify scale and intensity may be required, and mitigation measures may be implemented where relevant.

---

\(^1\) Subject to an amendment to the environmental authority (EA) for the project (EPML00562913).
2. Summary of EVs and Impacts Associated with GDEs

EVs associated with terrestrial, aquatic and subterranean GDEs at King Vol were identified within the predicted drawdown area of the proposed dewatering activity at King Vol (NRA 2017b). Some of the EVs are directly related to the GDEs, and others are present by association. Potential impacts to the EVs were identified and described in NRA (2017a) and are summarised in Table 1.

Table 1: Potential impacts on EVs associated with dewatering for the King Vol project to 680 m BGL

<table>
<thead>
<tr>
<th>Environmental value</th>
<th>Potential impact</th>
</tr>
</thead>
</table>
| Remnant vegetation associated with RE 9.11.8a (semi-evergreen vine thicket on limestone rock outcrops). | • Degradation/mortality (eg dieback) of deep-rooted canopy species (*Brachychiton* spp., *Gyrocarpus americanus*).  
• Weed ingress due to alteration of community from dieback of deep-rooted canopy species. |
| Remnant vegetation associated with RE 9.3.13 (riparian wetland). | • Degradation/mortality (eg dieback) of the riparian vegetation, which may lead to a change in community or increase risk of bank erosion. |
| Flora of conservation significance (*Macropteranthes montana*, *Panicum chillagoanum*). | • Reduction in extent of, or increase of threat to, flora of conservation significance in RE 9.11.8a due to weed ingress. |
| Aquatic ecosystems (surface water and subterranean). | • Loss of surface water pools during the dry season, reducing habitat availability and quality for surface water fauna.  
• Loss of subterranean water sources, reducing habitat availability for stygofauna. |
| Fauna of conservation significance (Greater Large-eared Horseshoe Bat, *Diadem Leaf-nosed Bat*). | • Loss or degradation of habitat for roosting and foraging (eg change in structure of vegetation at RE 9.11.8a and 9.3.13 communities; change in microclimate of cavities/caves for roosting). |

1 From NRA (2017a).
2 Greater Large-eared Horseshoe Bat (*Rhinolophus philippinensis*); Diadem Leaf-nosed Bat (*Hipposideros diadema reginae*).  
RE denotes Regional Ecosystem.
3. Monitoring Program

The monitoring program has been prepared with reference to relevant guidelines (eg Richardson et al 2011a-b) and consideration of site-specific conditions.

The purpose of the monitoring program is to assess the temporal and spatial scale of potential impacts on GDE EVs that may occur as a result of the King Vol project dewatering activity. This information may be used by Auctus to quantify the scale and intensity of the impact and to initiate mitigation measures where relevant. The information may also be used to quantify the recovery of EVs after dewatering ceases. Where an impact is detected, further investigation may be required, the scope of which would be determined at the time and in consultation with the regulator.

To provide a complete monitoring program, the approach referred to in this section includes monitoring recommended in RLA (2017).

3.1 Semi-evergreen vine thicket on limestone rock outcrops (RE 9.11.8a)

Semi-evergreen vine-thicket on limestone rock outcrops, ie Regional Ecosystem (RE) 9.11.8a, occurs within the predicted groundwater drawdown area. The proposed groundwater dewatering activity at King Vol may directly (eg via air embolism) or indirectly (eg via reduced plant health, which increases susceptibility to disease) impact the deep-rooted canopy trees. If canopy trees are lost from the community, weed ingress may increase and, in the absence of mitigation, may affect the condition of the community over the long-term.

Monitoring sites

Groundwater modelling by RLA (2017) predicts the spatial and temporal scale of change in groundwater levels in response to the proposed drawdown activity. Drawdown contours have been prepared based on this data. Monitoring sites for impacts on RE 9.11.8a should be located across the predicted drawdown contours. Several sites should be located for each of the contour levels, as per Table 2. The exact location of each site needs to be confirmed during the baseline survey, and therefore the co-ordinates are indicative only.

Two reference sites should be established in RE 9.11.8a communities outside of the predicted drawdown area. The location of these sites will need to be confirmed during the baseline survey; potential co-ordinates are listed in Table 2.

Data from monitoring sites may be used as control data for comparison with affected sites until such time as the area around the monitoring site is likely to be affected by groundwater dewatering (to be determined by groundwater levels in monitoring bores).

---

<table>
<thead>
<tr>
<th>Site label</th>
<th>Co-ordinate (GDA94, zone 55k)</th>
<th>Description</th>
<th>Label used in NRA 2017a/b</th>
<th>Drawdown contour range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TerGDEref1</td>
<td>To be confirmed</td>
<td>Reference site to be selected north of the predicted drawdown area, in RE 9.11.8a.</td>
<td>Near WP029</td>
<td>Reference</td>
</tr>
<tr>
<td>TerGDEref2</td>
<td>To be confirmed</td>
<td>Reference site to be selected south of the predicted drawdown area,</td>
<td>-</td>
<td>Reference</td>
</tr>
<tr>
<td>Site label</td>
<td>Co-ordinate (GDA94, zone 55k)</td>
<td>Description</td>
<td>Label used in NRA 2017a/b</td>
<td>Drawdown contour range</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------</td>
<td>-------------</td>
<td>--------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>TerGDE1</td>
<td>207131E; 8125113N</td>
<td>Small limestone outcrop on the King Vol mining lease, south of the mining area.</td>
<td>WP022</td>
<td>0-1 year</td>
</tr>
<tr>
<td>TerGDE2</td>
<td>207780E; 8124487N</td>
<td>Small limestone outcrop on the southern border of the King Vol mining lease.</td>
<td>WP020</td>
<td>0-1 year</td>
</tr>
<tr>
<td>TerGDE3</td>
<td>207475E; 8123940N</td>
<td>At the northern extent of a large limestone outcrop south of the King Vol mining lease.</td>
<td>500 m north of WP019</td>
<td>0-1 year</td>
</tr>
<tr>
<td>TerGDE4</td>
<td>208348E; 8123562N</td>
<td>At the southern extent of a large limestone outcrop south of the King Vol mining lease, and south-east of site TerGDE3.</td>
<td>WP018</td>
<td>1-2 year</td>
</tr>
<tr>
<td>TerGDE5</td>
<td>209059E; 8124375N</td>
<td>Medium limestone outcrop on the eastern side of the Burke Developmental Road and in the south-east corner of the King Vol mining lease.</td>
<td>WP023</td>
<td>1-2 year</td>
</tr>
<tr>
<td>TerGDE6</td>
<td>205719E; 8127155N</td>
<td>Small limestone outcrop north of the King Vol mining lease.</td>
<td>110 m south-east of WP026</td>
<td>1-2 year</td>
</tr>
<tr>
<td>TerGDE7</td>
<td>208883E; 8123120N</td>
<td>Large limestone outcrop south of the King Vol mining lease, on the northern side of Bowler Creek.</td>
<td>350 m north-east of WP016</td>
<td>2-3 year</td>
</tr>
<tr>
<td>TerGDE8</td>
<td>205224E; 8128331N</td>
<td>Small limestone outcrop north-east of the King Vol mining lease, approximately 400 m from the Burke Developmental Road.</td>
<td>-</td>
<td>2-3 year</td>
</tr>
<tr>
<td>TerGDE9</td>
<td>209253E; 8122506N</td>
<td>Large limestone outcrop south of the King Vol mining lease, on the southern side of Bowler Creek.</td>
<td>WP010</td>
<td>3 year-LoM²</td>
</tr>
<tr>
<td>TerGDE10</td>
<td>209606E; 8123500N</td>
<td>Medium limestone outcrop on the eastern side of the Burke Developmental Road and south-east of the King Vol mining lease.</td>
<td>WP024</td>
<td>3 year-LoM</td>
</tr>
<tr>
<td>TerGDE11</td>
<td>205218E; 8128894N</td>
<td>Medium limestone outcrop on the eastern side of the Burke Developmental Road and north-east of the King Vol mining lease.</td>
<td>WP033</td>
<td>3 year-LoM</td>
</tr>
</tbody>
</table>

¹ Co-ordinates are indicative only and need to be confirmed during the baseline survey.
² LoM = life of mine.

**Baseline survey**

A baseline survey should be undertaken to inform the scale and intensity of the monitoring program for impacts to environmental values associated with RE 9.11.8a. This will give a description of the condition of the community prior to groundwater dewatering within the King Vol predicted drawdown area. The baseline survey of RE 9.11.8a communities must occur late in the wet season (nominally March to April) and will record baseline data as follows.

- Confirm the monitoring site co-ordinates.
• Establish a photograph reference point (to allow comparison over time).
• Secondary transects (as per Neldner et al. 2017) quantifying the number of species (native and non-native) and the abundance of those species at the monitoring sites.
• Canopy cover and height of vegetation in each strata layer at the monitoring sites.
• Stem count of canopy species seedlings (to assess canopy recruitment).
• Identification and tagging of trees to be observed in the monitoring program (height >8 m, diameter at breast height (DBH) >30 cm, and nominally 10 individuals per site).2
• Measurement of the canopy diameter and health (eg using DSE 2004 or similar) of the individual tagged monitoring tree(s).

**Annual monitoring survey**

Monitoring must be undertaken annually during the late wet season months (nominally March to April) when the deciduous species of interest (ie Brachychiton spp., Gyrocarpus americanus, Macropteranthes montana), have a full canopy and can be monitored for canopy dieback. The monitoring of RE 9.11.8a will include the following.

• Photograph from the photograph reference point(s).
• Canopy cover and height of vegetation in each strata layer at the monitoring sites.
• Measurement of the canopy diameter and health of the individual tagged monitoring tree(s).
• Abundance of non-native species in each vegetation strata layer (50 m x 50 m plots as per Eyre et al. 2015) and their relative dominance in the community.
• Stem count of canopy species seedlings at the monitoring sites (50 m x 50 m plot).
• General observations (eg presence of pathogens, dieback in sub-canopy or shrub layers).

### 3.2 Riverine wetland vegetation (RE 9.3.13)

The watercourses within the predicted drawdown area contain riverine wetland vegetation RE 9.3.13) along some sections. The dewatering activity has the potential to directly (eg via air embolism) or indirectly (eg via reduced plant health, which increases susceptibility to disease) affect certain tree species in this vegetation community. Loss of vegetation, or degradation of vegetation condition, on the banks of the watercourse may result in weed ingress and/or exacerbated erosion of the stream banks.

**Monitoring sites**

Riverine wetland monitoring sites will be located on Archies and Bowler creeks and the unnamed watercourse on the western side of the King Vol mining lease, which flows into Bowler creek. The monitoring sites (Table 3) selected are consistent with the permanent/semi-permanent pools identified on Archies and Bowler creeks during the GDE field verification survey (NRA 2017b) and with relevant existing surface water monitoring sites at King Vol.

The reference site to be established for the aquatic ecosystem surface water sites (Table 4) should be used as the reference site for monitoring RE 9.3.13.

---

2 The objective is to have 20 to 30 treatments, ie trees, per range of drawdown contours, as identified in Table 2. This is an average of 10 trees per site.
Table 3: Proposed GDE monitoring sites for RE 9.3.13

<table>
<thead>
<tr>
<th>Site label</th>
<th>Co-ordinate (GDA94, zone 55k)</th>
<th>Description</th>
<th>Label used in NRA 2017a/b</th>
<th>Drawdown contour range¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>AqGDEref1</td>
<td>To be confirmed</td>
<td>A reference site located outside of the drawdown area. The site must be located in the geological unit ‘Chillagoe Formation’ and have similar physical attributes as the sites on Archies and Bowler creeks.</td>
<td>-</td>
<td>Reference</td>
</tr>
<tr>
<td>AqGDEArch1</td>
<td>205822E; 8127478N</td>
<td>Located on Archies Creek, between limestone rock outcrops. The site is approximately 950 m upstream of the Burke Developmental Road causeway over Archies Creek.</td>
<td>WP028</td>
<td>1-2 year</td>
</tr>
<tr>
<td>AqGDEBowl1</td>
<td>209043E; 8122724N</td>
<td>Located on Bowler Creek, between limestone rock outcrops. The site is approximately 1.1 km upstream of the Burke Developmental Road causeway over Bowler Creek.</td>
<td>WP015</td>
<td>LoM</td>
</tr>
<tr>
<td>KV05</td>
<td>207868E; 8123242N</td>
<td>Existing surface water site on the unnamed watercourse south-west of the King Vol mining area.</td>
<td>-</td>
<td>1-2 year</td>
</tr>
<tr>
<td>M01</td>
<td>207990E; 8125251N</td>
<td>Existing surface water site on Bowler Creek, east of the Burke Developmental Road and within the King Vol mining lease.</td>
<td>-</td>
<td>0-1 year</td>
</tr>
<tr>
<td>M03</td>
<td>209191E; 8123810N</td>
<td>Existing surface water site on Bowler Creek, east of the Burke Developmental Road and south-east of the King Vol mining lease.</td>
<td>-</td>
<td>2-3 year</td>
</tr>
</tbody>
</table>

¹ Predicted groundwater drawdown 0.2 m contour from RLA (2017) and shown with GDE sites in NRA (2017a).

Baseline survey

The baseline survey of RE 9.3.13 communities should occur in the late wet season (nominally March to April) and will record data to give a baseline description of the condition of the community prior to effects of the groundwater dewatering activity at the monitoring sites. The baseline survey will use a method that assesses the condition of the community, such as the Tropical Rapid Appraisal of Riparian Condition (TRARC) (Dixon et al. 2005). The following type of information will be recorded as part of this assessment.

- Canopy species, cover and condition.
- Non-native (weed) species abundance and dominance.
- Groundcover.
- Animal damage to the riparian vegetation and banks.
- Bank stability and erosion.
- Photographic reference point(s).

Annual monitoring survey

The monitoring sites established during the baseline survey will be assessed annually during the wet season months when the species of interest (ie Melaleuca spp., Cyperus spp. and Paspalum spp.), have a full canopy/ground cover and can be monitored for dieback. The monitoring will follow the same approach applied during the baseline survey (eg the TRARC method (Dixon et al. 2005)).
3.3 Flora species of conservation significance

Within RE 9.11.8a communities, two flora species of conservation significance are known to occur: *Macropteranthes montana* and *Panicum chillagoanum*. The proposed dewatering activities are not expected to directly impact on these species; however, alterations to the RE 9.11.8a canopy species (*Brachychiton* spp. and *Gyrocarpus americanus*) may affect the community in which these plants occur. Monitoring is therefore recommended in the event that potential impacts may need to be quantified during the King Vol operations.

**Monitoring sites**
The monitoring sites for flora of conservation significance will be the same as the RE 9.11.8a monitoring sites (refer to Section 3.1).

**Baseline survey**
A baseline survey will be undertaken during the late wet season (nominally March to April) prior to groundwater decline occurring near the monitoring sites (groundwater levels to be confirmed by bore monitoring). The baseline survey will coincide with the RE 9.11.8a survey, and the following information will be recorded.

- Abundance, extent, and condition of *M. montana* and *P. chillagoanum* populations within a 50 m x 50 m plot at the monitoring site.
- Photographic reference point of the population at each site.

**Trigger response monitoring survey**
Due to the nature of the potential impact on *M. montana* and *P. chillagoanum*, ie indirect impact, monitoring of these species will occur if the RE 9.11.8a monitoring identifies that the habitat is affected by weed ingress and/or dieback/mortality of canopy species. If monitoring is required, the following information will be recorded.

- Abundance, extent, and condition of *M. montana* and *P. chillagoanum* populations within a 50 m x 50 m plot at the monitoring site.
- Photographic reference point of the population at each site.

3.4 Aquatic ecosystems – surface water

Permanent/semi-permanent pools of water occur on Archies and Bowler creeks within the predicted groundwater drawdown area. The pools identified during the GDE field verification survey (NRA 2017b) provide refuge to terrestrial and aquatic species during the dry season and may be connected to groundwater sources. King Vol dewatering has the potential to reduce/remove these pools of water. To monitor the effects of groundwater drawdown on these pools, monitoring of the surface water environment should be undertaken. This includes:

- water levels
- water quality
- aquatic community.

**Monitoring sites**
Monitoring sites for surface water aquatic ecosystems should be located on Archies and Bowler creeks at the pools identified during the GDE field verification survey (WP028 and WP015 in NRA 2017b). A reference site with similar conditions (ie watercourse through limestone rock outcrop with pooled water late into the wet season) should be included in the monitoring program.
The pools identified in NRA (2017b) (ie WP028 and WP015) should be used as the monitoring points because they retain water late in the dry season. The location of the reference site needs to be determined during the baseline survey. The reference site should be located outside the drawdown area, in the Chillagoe Formation, and have physical attributes similar to the Archies and Bowler creeks sites. The co-ordinates for the monitoring sites are listed in Table 4. If a suitable reference site cannot be located, the Archies and Bowler creek sites will be used in Before-After assessments, with the Bowler Creek site results considered ‘control’ until groundwater dewatering is confirmed (by water levels in groundwater bores) to be approaching Bowler Creek.

### Table 4: Proposed GDE monitoring sites for surface water ecosystems

<table>
<thead>
<tr>
<th>Site label</th>
<th>Co-ordinate (GDA94, zone 55k)</th>
<th>Description</th>
<th>Label used in NRA 2017a/b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aq GDE REF1</td>
<td>To be confirmed</td>
<td>A reference site located outside of the drawdown area. The site must be located in the geological unit ‘Chillagoe Formation’ and have similar physical attributes as the sites on Archies and Bowler creeks.</td>
<td>-</td>
</tr>
<tr>
<td>Aq GDE Archies1</td>
<td>205822E; 8127478N</td>
<td>Located on Archies Creek, between limestone rock outcrops. The site is approximately 950 m upstream of the Burke Developmental Road causeway over Archies Creek.</td>
<td>WP028</td>
</tr>
<tr>
<td>Aq GDE Bowler1</td>
<td>209043E; 8127224N</td>
<td>Located on Bowler Creek, between limestone rock outcrops. The site is approximately 1.1 km upstream of the Burke Developmental Road causeway over Bowler Creek.</td>
<td>WP015</td>
</tr>
</tbody>
</table>

1 If a suitable reference site cannot be located, the Archies and Bowler creeks sites will be used in Before-After assessments, with the Bowler Creek site results considered ‘control’ until groundwater dewatering is confirmed (by water levels in groundwater bores) to be approaching Bowler Creek.

### Monitoring parameters

The following parameters should be included in the GDE surface water ecosystem monitoring program.

- Water quality (including analytes listed in the King Vol EA, as well as major ions).
- Water levels (using a reference point each year).
- Rainfall (from the closest rainfall gauge).
- Aquatic macroinvertebrates (in accordance with the REMP, or an alternative program if developed).
- Observations of fish and other aquatic organisms (eg freshwater crocodiles, mussels).
- Condition of the surface water habitat (including observations of water scum/oils, vegetation dieback on the banks).

### Baseline survey

The purpose of the baseline survey is to describe the surface water aquatic ecosystems at the monitoring sites prior to the influence of the groundwater drawdown. It is expected that groundwater drawdown will not affect the Archies Creek site until year 2 of the dewatering activity, and from year 3 onwards for Bowler Creek (NRA 2017a, using groundwater drawdown predictions from RLA 2017).

The baseline survey will be undertaken prior to expected impacts from the dewatering activity. Based on the current mine schedule, this survey will need to occur in 2018. The survey will be conducted twice in the year: once during the wet season (nominally February to May 2018) and once during the dry season (nominally September to October 2018).
Where possible, the survey should coincide with the King Vol Receiving Environment Monitoring Program (REMP)\(^3\) for efficiency and allow for comparison between other monitoring sites on Archies and Bowler creeks.

**Annual monitoring survey**

For each year of the project, and following the cessation of dewatering (until recovery of the system has been confirmed), two sampling events will be undertaken each year at the GDE surface water sites: once during the wet season (nominally February to May) and once during the dry season (nominally September to October). Monitoring will include the parameters listed above and will occur at the sites nominated in **Table 4**. Where possible, the survey should coincide with the King Vol REMP for efficiency and to allow comparison between other monitoring sites on Archies and Bowler creeks.

Data collected each year should be statistically analysed to compare the potentially affected sites (Aq GDE Archies1 and Aq GDE Bowler1) with baseline/control data for these sites and with the reference site (Aq GDE Ref1). Statistical analysis should include appropriate multivariate analyses, using a statistical program such as PRIMER, to allow the identification of significant differences between variables. The use of indices such as SIGNAL and AUSRIVAS on the aquatic macroinvertebrate data should be avoided because these indices have not been derived for the systems being monitored and may provide misleading results in the impact assessment.

### 3.5 Aquatic ecosystems – subterranean

It is not certain if aquatic ecosystems in subterranean environments (eg stygofauna) exist within the predicted drawdown area at the King Vol project. The monitoring program proposes a baseline survey to determine if the community is present, following which an ongoing monitoring program will be prepared and implemented to monitor changes to the subterranean ecosystem.

**Monitoring sites**

Stygofauna monitoring will occur in bores established within the Chillagoe Formation. It is proposed that the existing bores used for the King Vol groundwater monitoring network be selected for stygofauna monitoring. Additional bores proposed by RLA (2017) to expand the monitoring network for GDE impact monitoring will also be included. The selection of bores will be done in consultation with the hydrogeologists to ensure that the integrity of the bores for compliance water quality monitoring is not compromised. The bores will be selected based on their spatial distribution across the predicted groundwater drawdown area. Existing monitoring bores at KVMB002, KVMB003 and KVMB004 should be included in the monitoring program.

**Baseline survey**

Monitoring methods for stygofauna are described in EHP and DSITI (2017). These methods will be referred to when undertaking the baseline survey. The manual identifies two approaches to sampling bores for stygofauna: (i) netting, (ii) pumping. The netting approach samples the community within the bore casing, and the pumping approach samples the community in the surrounding aquifer. It is recommended that the pumping approach is used.

---

\(^3\) A REMP design has been prepared for King Vol (TropWATER 2017), and would require updating to incorporate the GDE monitoring sites, including alteration to the timing of surveys.
for the monitoring program, and this will be confirmed based on the equipment available (some pumps may damage the fauna) and in consultation with the hydrogeologist.

Organisms collected in the samples will be preserved and identified in the laboratory. Statistical analysis of the data will depend on the sample size collected, and should include univariate and multivariate analyses.

**Ongoing monitoring survey**

If stygofauna communities are identified during the baseline survey, an ongoing monitoring program will be established. The program will nominate the sites, frequency and methods of sampling, and the data analysis to be completed.

### 3.6 Habitat for fauna species of conservation significance

Fauna species of conservation significance (Greater Large-eared Horseshoe Bat and Diadem Leaf-nosed Bat) are known to occur in the King Vol area. These bat species may use caves/cavities and large trees in the area to roost and will forage through dense vegetation and creek lines. The dewatering activity proposed at King Vol will not have a direct impact on these species; however, they may be indirectly impacted by loss/degradation of habitat.

Monitoring of habitat attributes, such as condition of the communities at RE 9.11.8a and 9.3.13 sites, will identify if habitat for these species is being degraded (e.g. loss of large trees). The proposed dewatering activity may result in a reduction in moisture levels in caves/cavities, and groundwater level monitoring will indicate where and when groundwater levels are reducing.

To assess impacts on the bat species, acoustic monitoring will be undertaken. This method has been used at King Vol during baseline studies (NRA in prep.) and during contemporary operations (NRA 2017c).

**Monitoring sites**

Monitoring sites for bat species should be located in RE 9.11.8a communities, near potential cave/cavities, and along watercourses. Previous monitoring has been undertaken at RE 9.11.8a sites on the King Vol mining lease and to the south and south-east of the mining lease. Monitoring has not been undertaken to the north of the mining lease, and this area needs to be surveyed. The sites in **Table 5** are recommended for the bat monitoring at King Vol.

**Table 5: Proposed GDE monitoring sites for bat species**

| Site label | Co-ordinate (GDA94, zone 55k) | Description | Label used in NRA 2017a/b | Drawdown contour range
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TerGDEref1</td>
<td>To be confirmed</td>
<td>Reference site to be selected north of the predicted drawdown area, in RE 9.11.8a.</td>
<td>Near WP029 Reference</td>
<td></td>
</tr>
<tr>
<td>TerGDE2</td>
<td>207780E; 8124487N</td>
<td>Small limestone outcrop on the southern border of the King Vol mining lease.</td>
<td>WP020 0-1 year</td>
<td></td>
</tr>
<tr>
<td>TerGDE4</td>
<td>208348E; 8123562N</td>
<td>At the southern extent of a large limestone outcrop south of the King Vol mining lease.</td>
<td>WP018 1-2 year</td>
<td></td>
</tr>
<tr>
<td>TerGDE9</td>
<td>209253E; 8122506N</td>
<td>Large limestone outcrop south of the King Vol mining lease, on the southern side of Bowler Creek.</td>
<td>WP010 3 year-LoM</td>
<td></td>
</tr>
<tr>
<td>Site label</td>
<td>Co-ordinate (GDA94, zone 55k)</td>
<td>Description</td>
<td>Label used in NRA 2017a/b</td>
<td>Drawdown contour range</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>TerGDE10</td>
<td>209606E; 8123500N</td>
<td>Medium limestone outcrop on the eastern side of the Burke Developmental Road and south-east of the King Vol mining lease.</td>
<td>WP024</td>
<td>3 year-LoM</td>
</tr>
<tr>
<td>TerGDE11</td>
<td>205218E; 8128894N</td>
<td>Medium limestone outcrop on the eastern side of the Burke Developmental Road and north-east of the King Vol mining lease.</td>
<td>WP033</td>
<td>3 year-LoM</td>
</tr>
<tr>
<td>BowlerCk</td>
<td>To be confirmed</td>
<td>Active acoustic monitoring along Bowler Creek.</td>
<td>-</td>
<td>0 year-LoM</td>
</tr>
<tr>
<td>ArchiesCk</td>
<td>To be confirmed</td>
<td>Active acoustic monitoring along Archies Creek.</td>
<td>-</td>
<td>0 year-LoM</td>
</tr>
</tbody>
</table>

1 Predicted groundwater drawdown 0.2 m contour from RLA (2017) and shown with GDE sites in NRA (2017a).
2 LoM = life of mine.

**Baseline survey**

Baseline surveys targeting the Greater Large-eared Horseshoe Bat and Diadem Leaf-nosed Bat will be conducted in the wet season and the dry season to account for variability in seasonal distribution within the drawdown area. Active and passive acoustic sampling will be used in the survey.

**Annual monitoring survey**

Results of the baseline survey will inform the sampling regime for the monitoring program. The survey will be integrated into the current bat monitoring program (as reported in NRA 2017c, though extended to the cave areas in the northern drawdown area). It is likely that the annual survey will consist of two sampling events: once during the wet season and once during the dry season. The monitoring will involve passive acoustic recording, and may include active acoustic monitoring.

### 3.7 Groundwater levels and water quality

RLA (2017) identifies monitoring required to assess the impact of the dewatering activity on the groundwater levels at King Vol. The monitoring is summarised in Table 8.2 of RLA (2017) and includes the following.

- Existing monitoring bores (as per the EA) and proposed new bores (NMB-A, NMB-B, NMB-C).
- Monthly water level measurements at all monitoring bores.
- Water level data loggers on the existing KVMB003 and proposed new bores (NMB-A, NVM-B and NMB-C).
- Water quality in the existing and proposed bores quarterly for the parameters listed in Table 8.3 of RLA (2017).
4. Program Reporting and Review

The reporting for the proposed monitoring program will include baseline survey report(s) and annual survey report(s). The annual report may be incorporated into existing Auctus monitoring programs, such as the annual REMP report.

The monitoring program will require review after the baseline surveys have been completed to clarify the ongoing monitoring approach and sites. Ongoing reviews of the program should also occur, as and when needed, to ensure that the program remains suitable for the purpose and is continually improved where required.
5. References


