SYNOPSIS

Background

Mount Grace Resources NL are proposing to develop a magnesium mine and smelter (the Batchelor Magnesium Metal Project) 4km east of Batchelor township approximately 75 km south of Darwin in the NT. The development area is adjacent to and includes poorly draining drainage floors and tributaries of a perennial creek, large water filled pit excavations of a former gold mine, a large disused quarry operation with eroding spoil heaps, and preliminary test pits for the magnesium mine. These features are potential source of mosquitoes.

The Minster for the Department of Lands Planning and Environment (DLP&E) has determined that the project be assessed at the level of an Environment Impact Statement (EIS). The guidelines for the EIS require Mount Grace Resources (MGR) to provide baseline mosquito and other biting insect habitats and populations, and indicate the health impacts of mosquitoes and other biting insects. They are also required to outline actions to prevent the development of mosquito and other biting insect breeding habitats.

The Medical Entomology Branch (MEB) of Territory Health Services (THS) was commissioned by URS, an environmental consultant company, to carry out an investigation of biting insects in the area. The tasks of the commission included;

- Carry out a ground survey of the site for actual and potential mosquito breeding sites.
- Conduct a limited adult biting insect survey of the project area to indicate species present and relative abundance.
- Examine any plans and evaluate existing and potential biting insect problems caused by the development.
- Prepare a report on the results of the surveys and evaluations, outline preventative measures, recommend management procedures, and indicate future monitoring requirements.

Investigation

The MEB undertook the investigation in late July 2001. The initial aspects included an assessment of the potential mosquito breeding sites, possible access, and potential trap positions made from aerial photographs. A site inspection, evaluation of potential mosquito breeding sites, selection of trap positions was made on 24 July 2001. The adult biting insect trapping program was carried out overnight on 24/25 July 2001. The results of the biting midge collections was compared with the seasonal abundance of selected species in the “Fairway Waters Biting Insect Investigations 1996-97” (Whelan et al 1998) carried out at Palmerston near Darwin. The result of the mosquito collections was compared with species present and seasonal abundance of mosquitoes from the “Woodcutters Mine Biting Insect Investigation 1995-96” (Montgomery et al 1996) carried out by MEB at a nearby mine approximately 5 km north of the development area.

Findings

Biting midges

Species present, and pest problems

- *Culicoides marksi*, a species that breeds at the edge of freshwater creeks and swamps will be the predominant pest species.
- *Culicoides marksi* is not likely to occur in sufficient numbers to cause a significant pest problem.

- The other species present are not likely to cause a pest problem.
- The development will not produce a significant increase in biting midge breeding sites to cause a pest problem.

Biting midge control

- There are no specific control measures required for biting midges.

Mosquitoes

Species present and pest problems

- There were 13 species of mosquitoes detected by the current survey. The 33 species of mosquitoes detected in baseline monitoring for the Woodcutters Mine area are also probably present in the mine area.
- The most abundant species during the present trapping were *Culex annulirostris*, *Coquillettidia xanthogaster* and *Anopheles bancroftii*.
- *Culex annulirostris* (the common banded mosquito), is likely to exhibit the highest relative abundance. This species will be present over an extended period from January to July. The population level of this species is likely to be low to moderate and pose only low to moderate pest problems.
- *Culex annulirostris* will pose the greatest potential public health problems, as it is a vector of Murray Valley encephalitis (MVE), Ross River Virus disease (RRV) and Barmah Forest disease (BF).
- Other species likely to occur in relatively high numbers listed in decreasing order of probable relative abundance include *Coquillettidia xanthogaster* (the golden mosquito), *Mansonia uniformis* (the freshwater reed mosquito), *Anopheles annulipes (*the Australian malaria mosquito*), Anopheles bancroftii (*the black malaria mosquito*), Ochlerotatus normanensis* (the floodwater mosquito), and *Ochlerotatus vigilax* (the salt marsh mosquito).
- *Ochlerotatus normanensis* and *Ochlerotatus vigilax* are likely to pose greater pest problems than indicated by their relative abundance due to their persistent biting habits and day biting activity. However they are likely to provide only very brief but intense seasonal pest problems during December to January. These two species also pose a potential public health problem, as they are vectors of RRV and BF.
- The most important vector of malaria in the NT (*Anopheles farauti*) was not detected during the current survey. However it was detected in relatively low numbers at Woodcutters. It is possible that this species could exist in the locality in higher numbers.
- The secondary vector of malaria *Anopheles annulipes* was detected in moderate numbers and results from Woodcutters indicate moderate numbers are likely to occur on a seasonal basis.
- The important domestic pest species *Culex quinquefasciatus* was not trapped at the mine site or at Woodcutters but is known to be present at Batchelor.

Mosquito borne disease

- The most serious potential mosquito borne disease is Murray Valley encephalitis, which is a relatively rare disease.
- The highest incidence of mosquito borne disease is likely to be due to Ross River Virus disease and to a much lesser extent Barmah Forest disease.

- Four recognized vectors for Ross River Virus disease were recorded during this survey or from the Woodcutters baseline monitoring, i.e. *Cx. annulirostris*, *Oc. normanensis*, *Oc. vigilax* and *Verallina reesi*. *Culex annulirostris* was recorded in the highest numbers and is likely to represent a higher risk for arbovirus transmission. It is probable that the other three species will occur seasonally in sufficient numbers to represent risks for arbovirus transmission.
- *Anopheles* species may be present in sufficient numbers seasonally to enable malaria transmission to occur if undetected cases of imported malaria are present in the area, and are exposed to mosquito attack.
- Mt Grace mine should warn personnel and visitors that there will be seasonal mosquito pest problems in the area and appropriate personal protection measures will be required when mosquito numbers are high (Appendix 3).

Mosquito control measures

- *Ochlerotatus vigilax* breeding sites are associated with the tidally affected floodplains and upper tidal sections of the Adelaide River and so will be unaffected by the development. The other species will have breeding sites within the vicinity of the study area.
- The most significant breeding sites at present are vegetated cut off marginal pools and animal or human disturbed areas along creeks and floodways, and in habitats with semi aquatic vegetation within creeks.
- The most significant potential mosquito breeding sites are associated with the Coomalie Creek diversion around the pits, disturbance to the poorly draining drainage floors and seasonal floodways adjacent to the perennial creeks, and discharge of pit water.
- Most of the existing and potential mosquito breeding sites within the development area will be relatively simple to reduce. This reduction will require a combination of rehabilitation, drainage, water impoundment design, and water management.
- The large water filled pits of the former Sundance Gold mine are not currently significant sources of mosquitoes and are not likely to be in the short to medium future.
- There is a potential breeding site associated with a blocked drainage floor by eroding overburden from an adjacent abandoned quarry.
- The incised channels of Coomalie Creek or major tributaries on the lease are not likely to be significant mosquito breeding sites because of perennial water flow and the presence of fish.
- The test pit for the magnesium mine is not currently a source of mosquitoes because of the presence of fish and steep bare margins.
- Soil erosion, silt deposition, pooling of rain in excavations, and disturbance of drainage lines during the construction phase will have a potential to create temporary mosquito breeding sites. Any filling or rectification works in this zone should be closely supervised and follow THS guidelines to prevent the creation of new mosquito breeding sites.
- There is a potential to breed a limited range of pest mosquito species such as *Cx. annulirostris* in artificial impoundments and dams. Design of the ponds with respect to depth and slope, introduction and maintenance of suitable fish in the dams, active management of marginal reeds and grass, and water management within the impoundments can reduce this potential.
- An internal storm water drainage scheme will need to be designed to eliminate potential mosquito breeding sites within the development area.

- A significant potential mosquito problem will be the capacity to breed freshwater mosquitoes, including *Cx. annulirostris* and *Oc. normanensis,* by disturbance to drainage floors and floodways, and in artificially cut off sections of creeks after the creek diversion.
- The storage and discharge of pit water has a very high potential to create new mosquito breeding sites by encouraging the growth of the semi aquatic reeds *Typha* and *Eleocharis.* The volume, period and site of discharge should be assessed for potential vegetation changes in the discharge area that could lead to increases in mosquito breeding.
- Silt deposition in the perennial freshwater creeks may disrupt the free draining nature of the creek channels and create additional mosquito breeding.
- Appropriate silt retention and erosion prevention measures must be installed to prevent silt and gravels entering Coomalie Creek.
- Any septic tanks or other sewage treatment and disposal facilities have the capacity to be very productive mosquito breeding sites. All sewage facilities must be of adequate design to prevent mosquito breeding and contamination of nearby surface water.
- Any borrow pits or artificial depressions should be rectified so that they do not retain water.
- The presence of artificial containers at the mine area will increase the potential for the introduction of *Cx. quinquefasciatus* onto the mine site. The introduction of this species can be prevented by adequate precautions regarding the import and disposal of artificial receptacles.

Recommendations

Biting midges

Pest problems and public health

- There are unlikely to be any biting midge pest problems and any corresponding public health problems. However if biting midge pest problems occur, specimens can be collected and sent to the MEB for identification and advice.

Mosquitoes

Mosquito pest problems and borne disease

- Workforce accommodation and recreation facilities should be mosquito proof with suitable insect screening or sealed buildings with air-conditioning.
- Personnel should be advised of the possibility of seasonal pest and local arbovirus disease risks and be given appropriate advice on the disease risks and personal protection measures from mosquito bites.
- Any personnel recently arrived from overseas with fever should consider malaria as a possible cause and be recommended to seek medical advice.

Mosquito control

- Any impoundments likely to retain water for periods of more than 7 days should be steep and deep enough to prevent semi-aquatic reed growth at the edges and within the impoundments.
- Stormwater drains through the development should all have erosion control structures and silt traps in their lower reaches before they enter the lower tributaries of Coomalie Creek or the main creek.

- Any drains within the development likely to have dry season low flows should convey the low flow in such a manner that it does not lead to mosquito breeding. Stormwater discharge should be via silt retention structures and not direct to the well-defined creek channels. Erosion control structures and silt traps should be in place well before the wet season in new construction areas.
- Pit water discharge should be free of silt and any discharge should have provision to prevent the growth of semi aquatic reeds.
- The spill way overflow from any proposed dam should incorporate erosion prevention structures to prevent the creation of additional mosquito breeding sites.
- The redirection of any creeks or floodways should ensure the former sections are completely rehabilitated or free draining.
- Septic tanks should be completely sealed and absorption trenches positioned such that there is no contaminated surface pooling capable of breeding mosquitoes. Septic and rainwater tanks should be installed to the satisfaction of the regional Environmental Health Officer to prevent the creation of additional mosquito breeding sites.
- Any rainwater filled receptacles such as old tyres and drums, old car bodies and disused machinery should be removed or rendered incapable of breeding mosquitoes.
- An appropriate person should survey the mine at least once in the wet season and dry season to detect any mosquito breeding sites and determine relevant rectification measures. Periodic checks should be made a number of times in a year for mosquito larvae in sewage treatment facilities and other wastewater storage and artificial ponding due to mine operations.
- Mosquito larval control should rely on the larvicide *Bacillus thuringiensis* variety *israelensis* (B.t.i.) or methoprene and only be carried out when breeding sites are detected. The advice of the Medical Entomology Branch of Territory Heath Services should be sought when mosquito breeding is detected or there are pest problems with mosquitoes

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Figure 3: Batchelor Magnesium mine (Mt Grace Resources). Mine development Air Photo. Medical Entomology Branch, THS.

Figure 4: Woodcutters mine. Baseline biting insect survey, Graph of mosquito numbers over 15 month period, Medical Entomology Branch, THS.

Figure 5: Photographs of habitats at Mt Grace mine. Medical Entomology Branch, THS.

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1 INTRODUCTION

1.1 Background

Mount Grace Resources NL are proposing to develop a magnesium mine and smelter (the Batchelor Magnesium Metal Project) 4km east of Batchelor township approximately 75 km south of Darwin in the NT (Fig 1). The development area is adjacent to and includes the floodway and tributaries of Coomalie Creek, large water filled pit excavations of a former gold mine, a large disused quarry operation with eroding spoil heaps, and a test pit for the magnesium mine (Fig 2, Fig 5). These features include potential source of mosquitoes.

The Minster for the Department Land Planning and Environment (DLP&E) has determined that the project be assessed at the level of an Environment Impact Statement (EIS). The guidelines for the EIS require Mount Grace Resources (MGR) to provide baseline studies on the mosquito and other biting insect habitats and populations, and indicate the health impacts of mosquitoes and other biting insects. They are also required to outline actions to prevent the development of mosquito and other biting insect breeding habitats.

The Medical Entomology Branch (MEB) of Territory Health Services (THS) was commissioned by URS, an environmental consultant company, to carry out an investigation of biting insects in the area. The tasks of the commission included;

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- Examine any plans and evaluate existing and potential biting insect problems caused by the development.
- Prepare a report on the results of the surveys and evaluations, outline preventative measures, recommend management procedures, and indicate future monitoring requirements.

The results of the survey and the report are presented here.

1.2 Acknowledgements

We wish to acknowledge the assistance of Susie Williams of URS in providing plans of the proposed development and for assistance with the development figures. We also thank Greg Smith of URS for assisting with the field survey and location of boundaries. The DLP&E provided the aerial photos.

This report is a group effort of the staff of MEB. Peter Whelan and Gisela Lamche carried out the field assessment and mosquito trapping. Gwenda Hayes and Jane Carter carried out the identification of biting midges and Gwenda Hayes prepared and checked the tables, graphs and figures, and collated the report. Allan Warchot, Gisela Lamche and Brett Brogan identified the mosquitoes. Catherine Goody assisted with tables and figures.

2 PROJECT AIMS

2.1 Aims

The aim is to evaluate the mine site for potential mosquito and biting midge pest problems. Additional aims are to identify and avoid potential mosquito breeding sites that could be created by construction activities or mine operations, advise on the management procedures to deal with these problems, and outline future biting insect monitoring requirements.

A brief field survey is to be undertaken to evaluate current adult mosquito and biting midge numbers, and evaluate the site area for current mosquito breeding sites. These results are to be assessed against seasonal patterns from a previous biting insect study at Woodcutters mine near the Stuart Highway approximately 5 km north of the study site.

A report is to be prepared outlining the results of the survey and trapping, the evaluation of current and potential biting insect problems, and the construction and management issues to be considered to reduce potential pest and public health problems.

2.2 Significance and scope of the project

A biting insect evaluation is required under the EIS provisions by the NT government. It is a requirement to consider the impact of development on biting insect populations.

Biting midges can be considerable pests, particularly near the coast and tidal rivers in the NT. These pests can disrupt the work force by causing direct effects due to their painful bites, and indirect effects due to secondary infection and loss of a sense of well being. As there is little available information on biting midges in the area, it was decided to collect and evaluate biting midges at the same time as collections were made for mosquitoes.

Mosquitoes are a serious potential public health issue in the NT, both as pest insects and as vectors of a number of human diseases including the potentially fatal Murray Valley encephalitis, and a number of other diseases caused by Kunjin virus, Ross River virus and Barmah Forest virus. The site includes a number of creeks and seasonally flooded areas, which could be expected to provide breeding sites for a number of mosquito species such as *Culex annulirostris* (the common banded mosquito), *Coquillettidia xanthogaster* (the golden mosquito), *Mansonia uniformis* (the freshwater reed mosquito), *Anopheles annulipes* (the Australian malaria mosquito), *Anopheles bancroftii* (the black malaria mosquito), and *Ochlerotatus normanensis* (the floodwater mosquito).

The timing of the trapping in late July was expected to sample freshwater mosquitoes from the more perennial mosquito habitats after wet season and early dry season temporary habitats had dried.

The fieldwork of this project is limited in scope because of the season when the investigation could be carried out and the limited time frame for an investigation and report. The relative seasonal fluctuation of biting insects in the study area was determined indirectly from seasonal fluctuations from other areas where biting insects had been monitored over a 12-month period.

An evaluation of the plans for development, together with a knowledge of the habitats likely to be created, were used to evaluate potential mosquito breeding sites likely to be created by the development. Preventative measures or management procedures could then be recommended to prevent or reduce the mosquito breeding sites, and reduce potential biting insect problems.

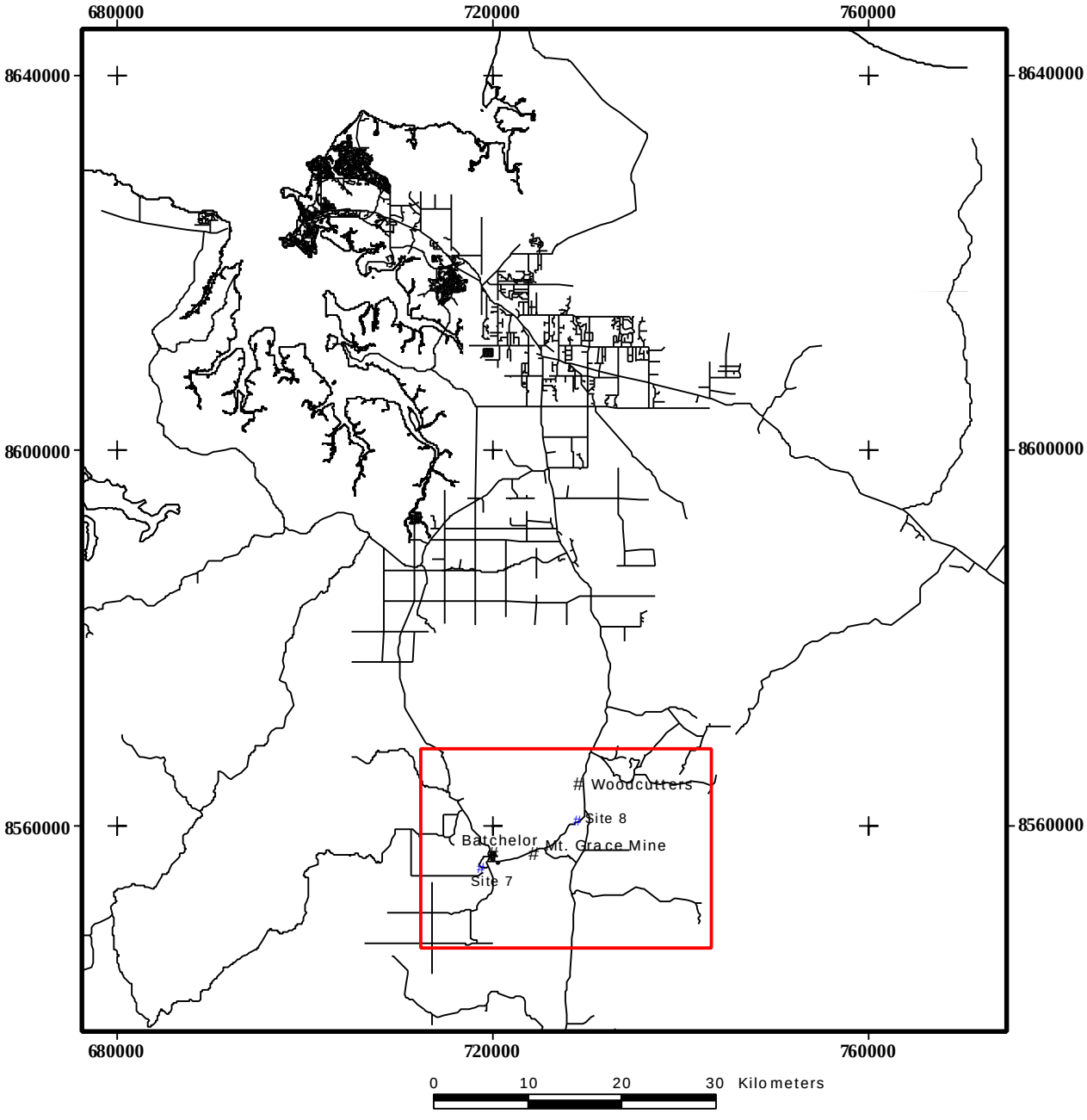
2.3 Study site

The development is planned for a site adjacent to a tributary of Coomalie Creek, which traverses the mine lease and eventually crosses the Stuart Highway and runs into the Adelaide River. The study

locality is outlined in Figure 1. The site has a number of small well-defined perennial freshwater creeks leading to Coomalie Creek, adjacent seasonal floodways, and a number of broad poorly draining drainage floors.

Adjacent features included a large disused quarry and associated tailings, and an old gold mine with large water filled pits. The site area is outlined in Figure 2 and Figure 3.

Figure 1: Study area location.



3 METHODS

3.1 Field inspection

3.1.1 Habitat inspection

A field inspection was carried out in the mid dry season on July 24th 2001. The project area was inspected with the aid of a 4 x 4-wheel vehicle.

No ground inspections were made for biting midge breeding sites.

Inspections were made during the survey to evaluate actual or potential mosquito breeding sites. Prospective mosquito habitats were inspected for the presence of mosquito larvae, aquatic predators, and associated flora. Potential mosquito breeding sites were assessed based on minor topographical features, localized depressions and drainage, and vegetation patterns indicating water logging and pooling.

Photographs were taken of potential mosquito breeding sites or general (Figure 5).

Access and adult trapping sites were located and selected with the aid of 1:20,000 air photos and 1:10,000 topographic map by MGR showing the ore deposit and proposed development (Figure 2, Figure 3).

3.1.2 Trap site selection

All the adult trap sites were selected during the field inspection. All trap sites were located by GPS using a hand held Garmin GPS unit and numbered 1 to 8. The trap sites are indicated in Figure 3. Trap sites were selected based on proximity and at sites where development could lead to significant habitat change and the creation of new mosquito breeding sites.

Two sites off the lease were selected as evaluation traps for different habitats in the region. This included one at the Batchelor sewerage ponds and associated swamp area, and a site adjacent to a large extensive wet rainforest area at another tributary of Coomalie Creek arising north of Batchelor road and crossing the Batchelor road near the Stuart Highway (Figure 1).

3.2 Biting midges trapping

Trapping for the presence and relative abundance of biting midges was carried out overnight using carbon dioxide baited modified EVS traps (Rohe and Fall 1979). The traps consist of an insulated bucket, a battery driven suction fan with a 'grain of wheat' light, and a rigid collection container (4 litre, 220 mm diameter) fitted with a muslin sleeve and very fine wire mesh vents. The traps were set at chest height and baited with approximately 0.8 kg of dry ice.

Traps were set from 1500 to 1700 on 25 July and collected the following day from 0900 to 1000.

Trap collections were taken to the MEB, killed by freezing, sieved to separate the midges from mosquitoes, and the midges were stored in 70 % alcohol in individual tubes for each collection. Each collection was identified with the aid of stereo microscopes using taxonomic references and wing photos.

3.3 Biting midge population and seasonal trends

The seasonal trend in *Culicoides* numbers in the mine vicinity was evaluated from the Palmerston Fairway Waters study (Whelan et al 1998).

No specific biting midge study has previously been carried out in the vicinity of Batchelor. The Fairway Waters study was very different from the present study site and was designed to sample biting midges from tidal areas. However freshwater habitats were present at seepage areas, creeks, dams and swamps around the Fairway Waters area.

Freshwater breeding species of midges at the present study site were present at Fairway Waters and the seasonal trends obtained from that study could be applied to the Mount Grace area. Although the Fairway Waters results will provide an indication of seasonal trends of those species present in this study area, it will not indicate all species likely to be present. The relative abundance and maximum numbers at different seasons can be inferred from a comparison of the seasonal data from Fairway Waters with the results of the present trapping.

3.4 Mosquito trapping

Mosquitoes were sampled by the same traps used above for biting midge sampling. All mosquitoes were identified in each collection.

3.5 Mosquito population and seasonal trends

While maximum numbers and the relative numbers of all species of mosquitoes over a complete year are not known, seasonal trends can be interpreted from the results of the current survey and an evaluation of the Woodcutters results over a 12 month period. The seasonal trends obtained from the Woodcutters study is likely to give a good indication of the seasonal trends for most fresh water species of mosquitoes. However the Woodcutters development created an extensive artificial swamp of *Typha* reeds, which is the favorable habitat of *Coquillettidia xanthogaster* and *Mansonia uniformis.* These species are likely to be over represented in the Woodcutters collections when compared with the present study area.

4 RESULTS

4.1 Habitat survey

The mine development area includes well draining foothills to the south, with a number of poorly draining drainage floors in small catchments leading down to the relatively narrow well-defined perennially flowing creek with associated floodways (Figure 2, Figure 3). This creek arises outside the lease area to the west and flows through a rainforest area, around former gold mine pits, and then through the lease along the northern edge as a wide floodway with a central defined creek. The creek receives extended freshwater flows from a number of tributaries flowing through culverts under the Batchelor road from the northern catchment hills.

The widest and flattest sites in the floodway, which exhibit poor drainage and seasonal flooding, are indicated by *Lophostemon* and *Grevillea* trees or grassland. The floodway contains local natural depressions that are poorly draining and could be mosquito breeding habitats. Where these floodways are subject to artificial disturbance, such as borrow pits and vehicle traffic, isolated pools could be created and produce wet season and early dry season mosquito breeding sites. The flattest topography and the widest zone of flooding occur in the floodway on the south side of Coomalie Creek from just west of the magnesium deposit to the east boundary of the lease.

The floodway is likely to be shallowly flooded in the wet season and dry up in April soon after the wet finishes. There are no large expanses of fresh water reeds in the creek, floodway or adjacent to the study site, compared with those at Woodcutters.

Most of the drainage floors flowing from the steep hills to the south of the lease are from relatively small catchments and will dry out rapidly as the dry season progresses, and hence do not contain significant areas of most freshwater mosquito habitats. However they are potential sources of *Oc. normanensis* during the wet in sites with slow to impeded flow and pooling. New wet season mosquito breeding sites could be created where these drainage floors are subject to artificial disturbance, such as feral pig wallows, borrow pits, access road embankments and vehicle ruts.

Coomalie Creek has a well-defined central channel where rapid stream flow during the wet season can be expected to keep the channel open and enable good access to fish (Photo 1, Photo 8, Figure 5).. Some feral pig activity was observed along the creek and these disturbed sites and hoofprints could provide small local breeding sites along the creek during the dry season. Most of the channel is relatively steep sided and has perennial flow with good populations of rainbow fish (Melanotaenia sp) which are good predators of mosquito larvae, and does not offer a suitable habitat for mosquito breeding. There are some marginal areas along the creek that contain shallow grass or reed habitats that will be potential minor sources of *Cx. annulirostris* and *Cq. xanthogaster.*

The smaller tributaries to Coomalie Creek from the north are relatively more vegetated with grass and Eleocharis reeds near their junction with Coomalie Creek. These sites offer more potential habitats for *Cx. annulirostris* and *Cq. xanthogaster*. These tributaries north of Batchelor road are relatively poor draining and contain seasonally flooded paperbark (*Melaleuca*) forest habitats which could be significant breeding sites for *Cx. annulirostris* and *An. bancroftii.*

The large mine pits of the former Sundance Gold mine has deep water and steep sides (Photo 2, Photo 3, Figure 5) They contain good populations of rainbow fish and there is little marginal vegetation, indicating that they offer little mosquito breeding habitat.

The deep quarry to the east of the mine lease has a large steep pit that retains water in the wet season. It is not likely to be an appreciable mosquito-breeding site because of the steep nature of the sides and lack of vegetation (Photo 9, Figure 5). However the steep overburden around the pit has eroded on the south side and partially blocked a drainage floor (Photo 10, Figure 5). The drainage floor is likely to be shallow flooded grassland in the wet and early dry season and offer a breeding habitat for *Oc. normanensis, Cx. annulirostris* and *Ve. reesi.*

The artificial foothills dam near the southern boundary of the lease is fed by a catchment in the hills to the south. At the time of inspection it was dry but is likely to hold water into the early dry season (Photo 6, Figure 5). There was evidence of *Eleocharis* reeds around the margin and this site is a probable minor source of *Cx. annulirostris, Oc. normanensis* and *An. annulipes*.

The rain forest and associated section of Coomalie Creek is not likely to be appreciably flooded in the wet season or to provide significant breeding sites for mosquitoes. However it will provide a good harborage site of mosquitoes (Photo 7, Figure 5).

The upper reaches of Coomalie creek to the west of the lease area, particularly where there is clearing for development or in the wider paperbark floodways, are expected to offer considerable potential breeding sites for *Cx. annulirostris, Oc. normanensis, An. bancroftii, Ve. reesi,* and *An. annulipes.*

4.2 Biting midge trapping

The biting midge trapping results from all 8 sites are shown in Table 1.

4.2.1 Species present

A total of 395 biting midges were collected, representing at least 9 different species. There were 8 *Culicoides* species, and one *Forcipomyia* species (Table 1).

The majority of the biting midges were *Culicoides marksi,* representing approximately 40 % of all the biting midges recovered. The next most frequently recovered species were *Culicoides narrabeenensis, C. austropalpalis,* and *C. actoni* (Table 1).

The identification of the *Forcipomyia sp.* and *C. dollingi* needs to be verified by additional specimens and further examination.

4.2.2 Spatial abundance

The highest number of biting midges was from Site 3 (168) near the dry artificial dam, followed by Site 8 (57), with most sites (except Site 3) with similar total numbers of midges (Table 1).

The highest total number of *C. marksi* was from Site 3 (107) followed by Site 5 (36). This site also showed the highest number of *C. bundeyensis* and *C. austropalpalis* (Table 1).

Culicoides narrabeenensis numbers were highest in the Coomalie Creek rainforest near the Stuart Highway and the rainforest on the lease area.

4.3 Biting midge seasonal trends

4.3.1 Seasonal abundance from Fairway Waters study

In the Fairway Waters study, traps were set monthly over a twelve-month period at 11 sites ranging from the margin of the mangroves to 1 kilometre inland.

The collections of all species of biting midges are shown in Table 3.

Culicoides marksi showed mid dry season abundance from late April to early August, with the highest in April and July. The individual trap collection showed a July collection of 6160 and an April collection of 5940. Both these collections were relatively close to a large perennial reed edged dam. The early August collections per trap were about a quarter of those in early July, indicating a steep decline after the mid dry season.

Culicoides narabeenensis was only present in appreciable numbers from May to early July and in relatively low numbers.

Forcipomyia sp. was only present in higher numbers during February (86) and March (117) (Table 3) and was absent in August.

4.4 Mosquito trapping

4.4.1 Species present

There were a total of 1851 mosquitoes recorded from the trapping from the 8 sites representing 13 species (Table 2). Most (1835) were females. Of the females *Cx.. annulirostris* (898) was the most frequent species trapped, followed by *Cq. xanthogaster* (694), *An. bancroftii* (98), *Cx. palpalis* (66), and *An. annulipes* (32). *Ochlerotatus normanensis* and *Oc. vigilax* were not recovered. There were relatively few numbers of all species per trap.

4.4.2 Spatial abundance

The results of the collections from the different trap sites are shown in Table 2.

Most mosquitoes were collected at Site 4 (341) (the rainforest site), and Site 3 (292) (the dry dam), with the next highest collections at Site 8 (268) (the Coomalie Creek rainforest). The lowest numbers were at Site 7 (134) at Batchelor sewage ponds.

The highest number of *Cx. annulirostris* females was at Site 4 (170) followed by Site 8 (160) and Site 3 (152), with all sites showing a relatively similar magnitude.

The highest total number of *Cq. xanthogaster* females was at Site 3 (120) followed by Site 4 (114) and Site 6 (102) the creek near the quarry, with again most sites showing a similar order of magnitude. The highest number of *Cq. xanthogaster* males was from Site 8 (6) and Site 1 (5).

Anopheles bancroftii occurred in highest number near dense forest areas along perennial creeks at Site 8, Site 4, Site 1, and Site 6.

4.5 Mosquito seasonal trends

4.5.1 Seasonal abundance from Woodcutters study

A total of 8,033 female mosquitoes were trapped over the 15-month period from January 1995 to March 1996. The most predominant species trapped was *Cx. annulirostris* (30.82 %), followed by *Coquillettidia xanthogaster* (25.69 %), *Mansonia uniformis* (20.71 %), *An. annulipes* (4.48 %), and *An. bancroftii* (3.87 %). The complete species list with relative numbers is provided in Table 4.

The highest total number of mosquitoes from all traps were collected in the post wet to mid dry season with peaks in July (1,811) and June (1,513), (Table 4). Significant secondary peaks also occurred in February 1996 (739), May (608), and January 1996 (588). The July and June 1995 peaks corresponded with large peaks in *Ma. uniformis*, *Cx. annulirostris*, and *Cq. xanthogaster*. The peak in February 1996 was primarily comprised of *Cx. annulirostris* and *Cq. xanthogaster*, while the peak in May was primarily comprised of *Cx. annulirostris* and *Ma. uniformis*.

The total number of *Culex annulirostris* peaked in July (530) and had significant secondary peaks in October (374) and January 1996 (367). Between these peaks, numbers remained at moderate levels,

with the exception of November and December 1995 when the levels were low. The highest number per trap was recorded in July (296).

The total number of *Cq. xanthogaster* peaked in June 1995 (632). Secondary peaks occurred in July and February 1996. The highest number per trap for this species occurred in February 1996 (340/night).

The peak in numbers of *Ma. uniformis* was in July (588). Lower peaks occurred in June (433) and March 1996 (277). The highest number per trap (427) occurred in July. The peaks in *An. annulipes* and *An. bancroftii* occurred in July and generally followed a post wet to mid dry season occurrence. *Ochlerotatus vigilax* showed a late dry season - early wet season pattern, with relatively low numbers. *Ochlerotatus normanensis* showed a sharp early wet season occurrence and was absent during most other months. *Verrallina reesi* showed a sharp post-wet season occurrence (Table 4).

4.6 Evaluation of development plans

The basic development plans are shown in Figure 2. The impact of the development on existing biting insect populations and the capacity to create new breeding sites is discussed under the various heading of biting midges or mosquitoes. Suggested measures to reduce mosquito problems are dealt with separately in section 5.4.

5 DISCUSSION

5.1 Biting Midges

5.1.1 Species present

Thirty-three (33) species of *Culicoides* have been recorded in the Darwin area (A. Dyce pers. comm.). A number of these are marine species and are very unlikely to be recorded in the Batchelor vicinity.

One of the 9 species of *Culicoides* collected in the present survey, only *C. marksi* is a potential human pest species.

Specimens of *Forcipomyia sp*? are being checked. *Forcipomyia peregrinator* and *F. nhulunbuyensis* ? have been recorded in the NT and the species is likely to be one of these.

There are likely to be additional species in the present study area. However they are not likely to include any additional species that will pose a significant human pest problem for this development. The most important common species near Darwin, their biology, and their seasonal prevalence are summarized in Appendix 1.

5.1.2 Probable breeding sites

The actual breeding sites for *C. marksi* have not been located in this area. They breed at the margin of freshwater lakes and streams (Appendix 1). The breeding sites in this locality can be inferred from other areas. In the Fairway Waters study they were in highest number close to a permanent water filled dam edged with semi aquatic *Eleocharis* reeds.

Highest numbers were in the vicinity of Site 3, which is a relatively dry site near the dam. It is possible that this site was a breeding site for this species before it dried. If *C. marksi* proves to be a pest problem this dam is an obvious starting point for investigation. It is more likely that breeding sites exist in the tributaries in the steep hills to the south whenever pools remain long into the dry season. If this is correct, significantly higher numbers should be found in traps placed near these locations. Other sources possibly occur along Coomalie Creek where there are vegetated shallowly flooded sections.

The breeding site of the *Forcipomyia* sp. is not known but is possibly associated with mosses, alga mats or along stream banks (Debenham 1983). Sources here are possibly in the perennial creek. The *Forcipomyia sp.* was only present at Site 4 in the rain forest area and a breeding site is probably associated with a section the creek in this locality.

5.1.3 Spatial abundance and dispersal

The highest collections of *C. marksi* in the study site were from Site 3 (107) and to a much lesser extent Site 5 (36). The low numbers at other nearby sites indicates it does not disperse far and probably in the order of a few hundred metres. Their breeding sites are still unknown but in Fairway Waters they were most numerous in or near thick closed forest areas. Thick forested areas can be seen associated with creeks in the hills south of Site 3 (Figure 3).

5.1.4 Seasonal fluctations

Culicoides marksi are likely to occur in higher numbers from April to early July, as indicated from the Fairway Waters seasonal data. The highest number at Fairway Waters was in the order of 6000 per trap in July, with August numbers approximately a quarter of the July peak. If the present numbers at Site 3 represent maximum August numbers, peaks of 4 times that, i.e. up to 430 per trap, could be

expected in July. If these are the maximum number expected, they will not translate into an appreciable pest problem when it is considered numbers of 6000 odd were recorded from urban areas of Fairway Waters without complaints attributable to this species.

The *Forcipomyia sp.* was at present at very low numbers. In the Fairway Waters study they were present in the mid wet season with peaks in March and February respectively and absent in August.

5.1.5 Pest problems and public health

The highest numbers of biting midges in the development will be from *C. marksi* in the April to July period. However this species primarily feeds on mammals other than humans and only occasionally bites people. It is regarded as only being a minor pest at times. There is unlikely to be an appreciable pest problem in the development from this species.

Forcipomyia peregrinator and *F. nhulunbuyensis?* are potential human pest species in certain locations in the Top End. They are known to attack humans during daylight hours, and were very minor pests in a study at Wickham Point (Whelan et al. 1997c). The biology and available knowledge on these species is very limited. If they occur in any appreciable numbers in the study area, the *Forcipomyia* sp. is only likely to be small to very minor pests in February and March, and only in or near the rain forest areas. The exact pest nature will depend on further information on the nature and extent of their breeding sites.

There are no potential public health threats posed by either of these biting midges. If minor pest problems occur they can be easily reduced and avoided by the use of personal protection measures similar to those employed against mosquitoes. These include the use of protective clothing and repellents and avoiding exposure at locations and times of greatest occurrence.

5.1.6 Limitations

The current trapping at Mt. Grace is very limited and there is no supporting midge data from nearby areas. Although the Fairway Waters results will provide an indication of seasonal trends of those species present in this study area, it will not indicate all species likely to be present.

It is possible that the maximum numbers of *C. marksi* could be higher in June/July than indicated by the current trapping. However even if the maximum numbers were out by an order of magnitude, they are still not likely to be an appreciable pest problem when compared to the 6000 odd recorded from near an urban area at Fairway Waters.

It is also possible that the *Forcipomyia sp.* could be present in appreciable numbers in the wet season. However their probable greatest occurrence in rain forest and thick forest will mean that they are unlikely to be an appreciable pest problem in operational areas of the mine.

5.2 Mosquitoes

5.2.1 Species present, biology and disease significance

There are over 100 species of mosquitoes recorded in the NT. In the Woodcutters study 38 species were recorded. The 13 species recorded in the current survey is a reflection of trapping over a small period when many species may be seasonally absent or not present in sufficient numbers to be recorded. The species recovered however include most of the common or most relevant pest and potential disease vectors in the Top End of the NT (Whelan 1988a), (Appendix 2).

The order of probable abundance at Mt Grace will be *Cx. annulirostris, Cq. xanthogaster, Ma. uniformis, Cx. pullus, An. annulipes, An. bancroftii, Ve. reesi, Ad. catasticta, An. farauti, An.*

meraukensis, Oc. normanensis, and *An. hilli. Culex pullus* and *Ad catasticta* do not bite people and have no pest or public health significance.

The most important potential vectors and pest species in the development area are dealt with below in order of their expected pest numbers or importance as vectors.

5.2.1.1 Culex annulirostris "the common banded mosquito".

5.2.1.1.1 BREEDING SITES

This species exploits temporary ground pools, poorly draining grassy wet season depressions and shallow reed swamps. Potential breeding sites in the development include the seasonal floodways and low-lying areas adjacent to the creeks, as well as the seasonally flooded grassed drainage floors. The perennial sections of creeks are relatively well defined and well drained, and do not contain significant areas of semi aquatic or aquatic vegetation, and hence the productivity of the sites present appears limited. The greatest potential for increased breeding of this species will be in impeded or blocked floodways and drainage floors, cut off sections of creeks and pooling in the internal storm drainage facilities. The capacity of these sites to breed mosquitoes should be rectified by engineering means to reduce numbers of this species in the development and for future development areas within flight range of this species.

Any new dams and ponds have the potential to be colonized with freshwater *Eleocharis* and *Typha* reeds. This includes the proposed settling ponds near the pit (Figure 2). These can provide ideal breeding sites for *Cx. annulirostris.* If these impoundments are not constructed with steep margins and are not maintained free of thick grass and reed growth at the margins, they will become appreciable sources of *Cx. annulirostris* mosquitoes over the medium to long term. The Sundance Gold Mine pits are not sources of mosquitoes except for a few small depressions in the east pit (Photo 4, Figure 5).

5.2.1.1.2 SEASONAL ABUNDANCE

The seasonal abundance pattern of *Cx. annulirostris* in the study area is expected to be similar to that seen in the Woodcutters study with highest numbers in mid dry season (July) and early wet season (January).

The pattern of abundance is expected to be an increase in numbers coinciding with the start of the wet season in temporary wet season filled depressions, followed by a steady post wet season rise to a peak in July. Breeding will occur in longer lasting creeks and floodways as grass growth and receding water levels hinder the impact of aquatic mosquito predators and isolated pools emerge at the margins.

The perennial creek is unlikely to be significant source of mosquitoes by the mid dry season as the water is restricted to a narrow channel with fish.

5.2.1.1.3 DISPERSAL

Although *Cx. annulirostris* can disperse up to 10 km from highly productive sources (Russell 1986), there is a usually a significant drop in *Cx. annulirostris* numbers up to 2 km away from significant sources (Whelan, et al. 1997b). However if new productive breeding sites are created, this species could become a much more important pest problem in the general area.

5.2.1.1.4 PEST NUMBERS

The pest threshold for *Cx. annulirostris* near the Leanyer Swamp area adjacent to the northern residential suburbs of Darwin is approximately 600 per CO_2 trap per night trapped at a point between the urban areas and the breeding sites (DHCS & DCC 1989). *Culex annulirostris* is not as significant a pest as some of the *Ochlerotatus species* due to its habit of biting only after sundown, and being less persistent in the presence of lights, personal protective clothing and repellents.

In the present context, trap collections within the development area of approximately 100 would probably represent a pest threshold for exposed people in the 1-2 hours before sundown.

In the present survey the highest catches do not indicate a significant pest problem from this species at the moment. However the number of this species could reach pest numbers in January to July. After the initial development of the mine, it is possible that there could be higher numbers of this species, and hence a greater pest problem.

5.2.1.1.5 DISEASE SIGNIFICANCE

Culex annulirostris is the most important vector of arboviruses in the NT (Whelan & Weir 1993). It is a recognized and good vector of MVE, Kunjin, Ross River, and Barmah Forest viruses (Merianos et al. 1992, Whelan et al. 1993*)*. Many other arboviruses have been isolated from this species (Whelan & Weir 1993).

The moderate numbers of *Cx. annulirostris* adults recorded during the present survey and the numbers likely to be present from the Woodcutters investigation indicates relatively low population levels. However even relatively small numbers may be responsible for transmitting viruses with the risk primarily a function of suitable vertebrate hosts, reservoirs and vector numbers. Due to relatively low productivity of the habitats in the area, and the lack of swamps and water bird breeding sites, there appears to be only a low to moderate risk for Murray Valley encephalitis transmission. As this species bites primarily after sundown, self protection measures can be relatively easily employed to give a good degree of protection against mosquito bites.

However if new mosquito breeding sites are created by interference with natural drainage patterns and contamination of creeks and floodways with organic wastewater or the disruption of fish populations, a significant increase in vector numbers could increase the disease risk.

5.2.1.2 Coquillettidia xanthogaster, "the golden mosquito".

5.2.1.2.1 BREEDING SITES

Coquillettidia xanthogaster breeds primarily in association with semi aquatic reeds such as *Typha* and *Eleocharis*. There were no areas of *Typha* and only relatively small areas of *Eleocharis* present in the study area. It is possible that this species is dispersing into the area from breeding sites outside the lease area, possibly from further downstream or from reed swamps in the upper tributaries to the north. The *Eleocharis* present occurs primarily along restricted sections of Coomalie Creek and the open lower tributaries from the north. The future extent of these reeds in this area will be dependent on the water management and maintenance of the margins in the creek and impoundments. The extent of these reeds in impoundments will largely be dependent on the depth of water and the inside slope of the impoundments. Any dams or pits should be constructed with steep internal sides to reduce the extent of these reeds.

5.2.1.2.2 SEASONAL ABUNDANCE

This species has a larval stage in the order of three weeks compared to many other species that have a larval duration of 1 week. Adults tend to emerge in a sharp peak around the full moon. This species can be expected to be abundant from February to August with a peak around June and July.

5.2.1.2.3 DISPERSAL

This species can disperse relatively long distances and probably up to 10 km. There are significant breeding sites near Woodcutters but it is unlikely that pest numbers could disperse from there to the present development.

5.2.1.2.4 PEST NUMBERS

This species will bite humans readily. The pest threshold is probably similar to *Cx. annulirostris*, and in the present context would be around 100 per CO2 trap. The pest aspect warrants reduction of its breeding capabilities in and adjacent to the development area.

5.2.1.2.5 DISEASE SIGNIFICANCE

Coquillettidia xanthogaster is not a vector of human disease in the NT.

5.2.1.3 Mansonia uniformis "the water hyacinth mosquito"

5.2.1.3.1 BREEDING SITES

This species is closely associated with semi-aquatic and aquatic vegetation, particularly thick floating aquatic vegetation. It was not recorded in the mine area in the current survey. There do not appear to be significant areas of suitable habitat for this species in the immediate mine area.

5.2.1.3.2 SEASONAL ABUNDANCE

It was detected at significant levels at Woodcutters from March to July and could be expected to follow this pattern if appreciable numbers do occur in the lease area.

5.2.1.3.3 DISPERSAL

This species does not tend to disperse very far from its breeding site and probably less than 500 meters.

5.2.1.3.4 PEST NUMBERS

This species is an appreciable pest species and tends to bite readily in the shade in the day as well as during the evening and night. The pest threshold is probably between 50 to 100 per CO2 trap in the vicinity of people.

5.2.1.3.5 DISEASE SIGNIFICANCE

This species is not a vector of human disease in the NT.

5.2.1.4 Anopheles annulipes "The common Australian Anopheline"

5.2.1.4.1 BREEDING SITES

Anopheles annulipes breeds in open sunlit pools and swamps, often with vegetation. In the NT it breeds primarily in shallow margins of long lasting pools with some or little vegetation. Appreciable breeding sites are likely to exist in the seasonally flooded areas associated with Coomalie Creek or its northern tributaries.

5.2.1.4.2 SEASONAL ABUNDANCE

The July peaks probably corresponded to the period after the water in Woodcutters Creek and associated creeks began to recede, leaving large areas of isolated pools where biological control agents had not persisted. The peaks in September and December occurred after the nearby creeks and tributaries of Woodcutters Creek had probably largely dried up and represent the formation of isolated, longer lasting deeper pools in which larvae were relatively protected from biological control agents.

5.2.1.4.3 DISPERSAL

The effective flight range of this species is from 1.6 to 2 km.

5.2.1.4.4 PEST NUMBERS

The pest threshold is in the region of 100 per CO2 trap in the vicinity of exposed people. It is not likely to be a pest problem in the mine area unless new breeding sites are created.

5.2.1.4.5 DISEASE SIGNIFICANCE

This species is a potential vector of malaria, and productive sites within the development should be eliminated or reduced.

5.2.1.5 Anopheles farauti "The Australian malaria mosquito"

5.2.1.5.1 BREEDING SITES

An. farauti breeds in either brackish or freshwater pooling in vegetated swamps. It was not detected in the current survey, which indicates that there are not likely to be significant numbers in this area. New breeding places could be provided by the development of dams or impoundments, particularly if isolated pooling with dense reed growth occurs.

5.2.1.5.2 SEASONAL ABUNDANCE

It was most numerous from May to July at Woodcutters.

5.2.1.5.3 DISPERSAL
The effective flight range is in the order of 1.6 km.

5.2.1.5.4 PEST NUMBERS
The pest threshold is in the order of 50 to 100 in a CO2 trap. It is unlikely to be a pest problem in the present development.

5.2.1.5.5 DISEASE SIGNIFICANCE
This species is the most important potential vector of malaria. *Anopheles farauti* was however not detected in numbers here or Woodcutters that would be of medical significance if a case of imported malaria occurred in the vicinity.

5.2.1.6 Ochlerotatus reesi
5.2.1.6.1 BREEDING SITES
Ochlerotatus reesi is a floodwater species and breeds in fresh to slightly brackish, vegetated ground pools often in association with *Cx. annulirostris, Ve. funereus* or *Oc. normanensis*. It was not detected during the present survey and the available habitats in the study area are relatively small.

5.2.1.6.2 SEASONAL ABUNDANCE
It was most abundant at Woodcutters in April. It could be locally present but is not likely to be abundant unless new breeding sites are created in floodways or drainage floors.

5.2.1.6.3 DISPERSAL
Probably disperses in the order of 1 to 2 km.

5.2.1.6.4 PEST NUMBERS
Pest threshold is probably in the order of 50 to 100 per CO2 trap. It will probably not be a significant pest here unless new breeding sites are created.

5.2.1.6.5 DISEASE SIGNIFICANCE
It can be a minor pest for humans and is probably capable of transmitting Ross River virus and Barmah Forest virus.

5.2.1.7 Ochlerotatus normanensis
5.2.1.7.1 BREEDING SITES
Ochlerotatus normanensis is a floodwater species and breeds in open ground pools with or without vegetation and sometimes in association with *Cx. annulirostris.* In the present development, breeding sites are likely in the floodways and drainage floors, particularly in blocked drainage floors such as the one near the quarry.

5.2.1.7.2 SEASONAL ABUNDANCE
It has a wet season abundance. At Woodcutters it was most abundant in January.

5.2.1.7.3 DISPERSAL
The effective dispersal distance is in the range of 2 to 4 km. It would disperse from the quarry area to the mine site in sufficient numbers to become a pest.

5.2.1.7.4 PEST NUMBERS
The pest threshold is likely to be around 50 in a CO2 trap. It is likely to be a pest at the mine site in January and could be present for periods up to March.

5.2.1.7.5 DISEASE SIGNIFICANCE
It is a pest for humans and is capable of transmitting Ross River virus and Barmah Forest virus. Personal protection measures will be required when it is present in pest numbers.

5.2.1.8 Ochlerotatus vigilax

5.2.1.8.1 BREEDING SITES

The most extensive and productive breeding sites will be the upper tidal section of the mangrove areas around the coast, in brackish swamps where extensive reed growth occurs, or in flood plains associated with tidal rivers. The larvae are usually absent from the mid wet to the mid dry season in the major habitats, as the habitats are either flooded and have high numbers of aquatic predators such as fish, or are dry. There are no breeding sites near the mine. The nearest breeding sites will be in tidal sections and floodplains of the Adelaide River system.

5.2.1.8.2 SEASONAL ABUNDANCE

Ochlerotatus vigilax is likely to be most abundant in the late dry season and the early wet season (August to January). Generally the numbers increase after each succeeding spring tide from August to December and reach their highest numbers after the early heavy rains in December or January. The pattern and levels of abundance can vary from one year to another, due to the variable height of the spring tides each year and the amount and timing of rain in relation to the tides.

There can be a sudden appearance of adult saltmarsh mosquitoes seeking blood 9 days after flooding of the breeding site. They are likely to pose an appreciable pest problem for 7 to 10 days per month over the late dry season and early wet season. The number at Woodcutters was relatively low but this is probably a reflection of the timing of the trapping and not a true reflection of the periodic pest problems that can be experienced in the Batchelor area.

5.2.1.8.3 DISPERSAL

The dispersal of *Oc. vigilax* from a breeding area is related to the distribution, area and productivity of their specific breeding sites, as well as the specific dispersal characteristics of this species. Large numbers can disperse over long distances to cause a pest problem at remote areas.

Ochlerotatus vigilax has a long flight range. Relatively high populations have been recorded at Katherine in the early wet season, which is up to at least 100 km from the nearest tidally influenced breeding site. They will disperse in pest numbers from the Adelaide River to the mine vicinity.

5.2.1.8.4 PEST NUMBERS

Public complaints regarding *Oc. vigilax* and corresponding collections in CO_2 baited light traps placed between the residential area and the swamp near the suburbs bordering Leanyer Swamp in Darwin indicated that pest numbers occur at levels in excess of 50 *Oc. vigilax* per CO_2 trap per night (DHCS and Darwin City Council 1989, P. Whelan unpublished data).

A CO_2 trap collection of 50 *Oc. vigilax* per night is approximately equal to a biting rate of 50 mosquitoes per hour at the peak biting period on an unprotected person (DHCS and Darwin City Council, 1989, P. Whelan unpublished data). This species is regarded as the most important pest mosquito in the Darwin area because of its aggressive biting habits, its ability to bite during the day as well as the night, and its sudden emergence in plague proportions.

In the Woodcutters investigation, trap collections were very low (less than 10 per trap). Significant higher numbers can be expected in the present development and will represent an appreciable pest problem throughout the development area. As this species bites during the day, it is likely to disrupt unprotected personnel.

5.2.1.8.5 DISEASE SIGNIFICANCE

Ochlerotatus vigilax is a vector of Ross River virus disease in the Top End of the NT (Tai et al. 1993, Whelan & Weir 1993). It is also a vector of Barmah Forest virus disease (Merianos et al. 1992, Whelan, et al. 1993). The greatest potential transmission period of these viruses in the Top End of the NT is in December and January, when *Oc. vigilax* occurs in relatively high numbers, and during humid months when the longevity of the mosquito population is likely to be extended.

Mine personnel may include relatively new arrivals that may be non-immune to these arboviral diseases. The potential disease aspects, together with the probable pest problems, emphasize the need for personal protection when this species is present.

5.2.1.9 Other species of mosquitoes

The pertinent characteristics of relevant species likely to be minor pest species other than those dealt with above are outlined briefly below.

Anopheles meraukensis breeds in similar sites to *An. annulipes*, although often in clearer unpolluted water with reeds and grasses. It occurs in highest numbers in the late wet and early dry season when the water levels are high. Breeding sites may be associated with the flooded grass area in the floodway of Coomalie Creek. There will be other localized breeding areas. It is not likely to be in sufficient numbers locally to be a pest problem.

Anopheles bancroftii breeds in shaded freshwater swamps, often in association with paperbark and *Eleocharis* reeds. It is often in relatively high numbers in the post-wet season near breeding areas. It is a potential vector of malaria but is not as efficient as some of the other species because of its relative short longevity.

Ochlerotatus elchoensis breeds in rain filled tree holes. It is a common species but generally does not reach large populations because of the limited availability of breeding sites. It is highest where there are dense stands of *Eucalyptus* trees that probably includes older individuals with rot hole breeding sites. It is a very minor pest for humans and is only seasonally present. It is not known as a vector of human disease.

Ochlerotatus notoscriptus breeds in artificial containers filled by rain or in natural rain filled tree rot holes. It was only present at very low numbers during the current survey. However if artificial receptacles such as old tyres and drums are filled with rainwater, new breeding places will be provided. It is a suspected minor vector of Ross River virus and Barmah Forest virus. A management plan should be in place to remove or adequately store receptacles so that they do not become breeding places for these mosquitoes.

Ochlerotatus kochi breeds in *Pandanus* leaf axils filled by rain. There are appreciable *Pandanus* areas associated with Coomalie Creek, with other smaller areas within the development area. This species does not disperse far and usually only causes a minor and transient localized pest problem. This species is not known to be a vector of arboviruses in the NT.

5.2.2 Potential Introduced species

There are two species that were not recovered in the current survey or Woodcutters survey that could be present with development and become a pest or present a public health problem.

5.2.2.1 Culex quinquefasciatus "The brown house mosquito"

This species breeds in polluted water and artificial receptacles filled by rain or purposefully filled. Unsealed septic tanks and poorly designed sewage facilities are particularly productive breeding sites. It is probable that this species was not present at Woodcutters Mine due to the absence of the particular breeding sites. Breeding sites of *Cx. quinquefasciatus* may be more productive during, and for the few months following, the wet season depending on wastewater persistence. With adequate precautions this species can be excluded from the Mt. Grace area.

Septic tanks are required to be installed such that they are completely mosquito proof. An inspection of any septic tanks by an Environmental Health Officer is recommended when first installed and then annually to ensure that they remain mosquito proof and do not cause surface pooling of contaminated water.

5.2.2.2 Aedes aegypti "The Dengue mosquito"

Ae. aegypti breeds in artificial receptacles such as tyres, tins, drums, rainwater tanks, wells, pot plant drip trays, roof guttering and anything that will hold rainwater. It is only found in close association with human habitation.

It is a vector of Dengue Fever (*Ae. aegypti*) but is not present in the NT. However it has the potential to be imported from Queensland in tyres or other containers that may have held water that are sourced from areas where *Ae. aegypti* occurs (e.g., Charters Towers, Townsville, Cairns), (Whelan and Tucker 1998). It is therefore recommended that all receptacles that can hold rainwater including old machinery and tyres in particular be stored under cover, holed or filled with sand or soil to prevent the retention of rainwater.

No used tyres should be sourced from Queensland unless they have been super chlorinated or sprayed with a suitable insecticide to kill any dormant *Ae. aegypti* eggs. Additional items that should not be sourced from Queensland include pot plant drip trays and other vessels capable of holding water.

Any mosquito larvae found in receptacles imported from the relevant areas of Queensland should be submitted to the MEB in 70% alcohol or methylated spirits. If *Ae. aegypti* are found, the MEB will then need to initiate elimination measures as a public health measure.

5.2.3 Limitations

The trapping in the present survey only gives a limited idea of the mosquito species present in the study area and their relative abundance. The Woodcutters trapping has missed the maximum *Ochlerotatus vigilax* numbers that may be in the area. Thus the maximum pest problems of *Oc. vigilax* in the study area remains unknown.

Trapping for mosquito species diversity and abundance should be carried out for at least 12 months on a monthly basis. Trapping on a monthly basis will provide a good indication of the presence and relative abundance of most species.

5.3 Potential Mosquito Borne Diseases

5.3.1 Arboviruses

The most important potential endemic mosquito borne diseases in this area are Murray Valley encephalitis, Ross River virus disease and Barmah Forest virus disease (Mackenzie *et al.*, 1994; Russell, 1995; Whelan *et al.*, 1992). As there is no vaccine against these diseases the best method of prevention is self-protection from mosquito bites (Appendix 3).

The period of greatest risk for Murray Valley encephalitis and Ross River virus disease at Mt Grace Mine is when *Cx. annulirostris* increases in the wet season in January and February. The peaks of this species recorded in January and February 1996 may reflect pooling after the first significant rains at the beginning of the wet season. The period of higher numbers of *Cx. annulirostris* in May to August also represents a risk period for Ross River virus disease and Murray Valley encephalitis.

Ochlerotatus vigilax, an important vector of Ross River virus disease and Barmah Forest virus, was not recorded in high numbers at Woodcutters Mine. However this was a function of the timing of the trapping. It is very probable that high numbers of this species occur in this area from October to January. They originate from tidal areas and disperse very widely. They will not breed in the vicinity of the mine, so no engineering measure is relevant for this species. It is at these periods that personal protection against this species is required.

The floodwater species *Ochlerotatus normanensis* and *Ochlerotatus reesi* are potential vectors of Ross River virus disease, Barmah Forest virus and Murray Valley encephalitis. The floodwater species *Ochlerotatus normanensis* was recorded at Woodcutters in highest numbers in January when the first rains flood low lying drainage lines. The first seasonal appearance of large numbers of *Oc. normanensis* may occur approximately 7 - 9 days after significant rainfall.

Ochlerotatus reesi was recorded at Woodcutters at the end of the wet season where it was probably breeding in pools in floodways.

Both floodwater species bite before dusk and in the early evening and night. Personal protection is necessary when moderate to high numbers of this species occur.

5.3.2 Malaria

Malaria is no longer present in the Northern Territory, but mining operations in particular have a relatively high potential to reintroduce malaria into Australia because a relatively high proportion of a mines workforce is mobile and is often sourced from countries where malaria may be present (Whelan 1981). Cases of imported malaria may not be rapidly detected and may subsequently infect the local species of *Anopheles* mosquitoes. *Anopheles* species do not bite until after dusk and do not tend to fly more than a few kilometres from their breeding sites.

The primary potential vector species for malaria in Australia is generally considered to be *An. farauti s.l.* because of its known association with the disease in Papua New Guinea and because it was shown to be a vector in an epidemic in Cairns in 1942 (Russell, 1987). It is the principal potential vector in the Top End of the NT (Whelan 1981). However, Russell (1987) showed that *An. annulipes* in SE Australia was relatively long lived and therefore *An. annulipes* in the NT must also be considered a probable potential vector of malaria. *Anopheles annulipes* was the probable vector of malaria epidemics in some areas of the NT prior to 1962, and this vector must be regarded as a potential vector in this area.

If more than 10 individuals of *An. annulipes* or *An. farauti* females bite a malarious person (with the sexual forms of the parasite in their blood) there is a good chance that at least one will survive the minimum of 10 days necessary before it is capable of transmitting malaria to another person. Malaria transmission is more likely to occur if relatively high numbers of females have bitten the malarious person. If malaria cases occur in the mine area, they will only create a public health risk if there are appreciable *Anopheles* vectors in the area. This may require an assessment of the current situation by MEB. If there are appreciable *Anopheles* vectors present it is important for the malaria patient to be detected and to receive appropriate treatment to eliminate the parasite in their blood.

Woodcutters mine personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria. Only patients exposed after sundown would be at risk of spreading malaria as *Anopheles* species only bite after dusk. Suspected malaria patients should be advised to seek medical advice.

5.4 Evaluation of development and suggested mosquito control measures

5.4.1 Coomalie Creek and associated creek lines

Coomalie Creek retains water well into the dry season in a defined channel through the lease area. In the mid and late dry season, Coomalie Creek and the tributaries are not likely to contain significant areas of mosquito breeding, either because they will be dry or contain only defined relatively deep channels with steep bare margins and numerous aquatic predators of mosquito larvae. The creeks will only breed mosquitoes at specific sites of thick marginal vegetation or isolated pools. Any development that increases the open shallow section of the creeks will increase the marginal vegetation and increase mosquito breeding.

Silt traps should be constructed in the upper arms of the major creek or its tributaries likely to receive silt from development activities, in order to trap and remove silt to prevent disruption to the free draining nature of the central channels of the creeks. This particularly applies to a silt trap at the end of the new diversion channel just before it joins Coomalie Creek east of the proposed settling ponds, and the cut off creek section north of the pit which will receive silt from the pit construction.

The diversion of Coomalie Creek around the mine pit development should recreate the defined nature of the central channel, and the new margins should be revegetated with trees to discourage marginal grass and reed growth. The cut off sections of the creek, both inside and outside the diversion bund on both the north and south side of the pit created by the diversion, should be filled and leveled to prevent pooling, or new channels created to efficiently drain the sites without creating wet season pooling.

5.4.2 Silt Retention and water storage dams

Any development such as silt retention structures, settling ponds, or water storage dams are likely to lead to significant increases in numbers of certain mosquito species, unless they are appropriately designed with steep sides, maintained free of grass and reeds, and the water is appropriately managed to discourage mosquito breeding. The most productive artificial breeding sites will probably be silt retention facilities in drainage lines. These are likely to have increased vegetation growth, including grasses, and lead to the retention of storm water for periods long enough for mosquitoes to complete their larval development. Any silt retention structure should be able to completely drain within four days after rain. This should satisfy the silt retention purpose and prevent additional mosquito breeding.

Any water storage feature that retains water for an extended period of time has the potential to establish marginal reeds and subsequently become a breeding site for *Cx. annulirostris, Cq. xanthogaster* and *Ma. uniformis.* The presence of biological control agents (e.g. fish, aquatic beetle and bugs, dragonfly and damselfly nymphs) serve to dramatically reduce the larval population until the water features dry out during the dry season.

5.4.3 Pooling due to impeded stormwater runoff

Various artificial structures and earth disturbances such as road access could lead to increased mosquito breeding by retaining water in floodways or drainage floors. The site layout plan (Figure 2) does not indicate any access road from the pit to the waste dump. As access may cross the flood channel, it is vital that this access does not restrict flood flows down the floodway and does not create isolated flooded pools. Similarly the access road from Crater Lake road should not block the floodways or drainage in this area. Any site clearing and development that does not allow adequate wet season drainage or leads to minor depressions can produce breeding sites of *An. amictus, An. annulipes, Oc. normanensis, Ve. reesi* and *Cx. annulirostris*. Conversely, any measure that improves the drainage of these areas or the construction of facilities that reduces the area of poorly draining floodways is likely to reduce the numbers of these species.

5.4.4 Foothills dam

The freshwater dam in the foothills is probably only a minor mosquito-breeding site. The capacity of this dam and any similar structures to breed mosquitoes will depend on vegetation growth, the presence of fish, and the rate of draw down of water. A stable dam water level will encourage *Eleocharis* reed growth around the margins and promote mosquito breeding.

If the dam is retained it should be deepened, maintained with steep sides, and stocked at the start of each wet season with native fish.

5.4.5 Sundance Gold Mine pits

These pits in their existing state are not mosquito breeding sites, except for a very minor site on the eastern side of the eastern pit containing a depression that will form an isolated pool as the water level receded in the dry season. This depression could be filled or made free draining. Otherwise these pits do not require any specific mosquito control measures.

5.4.6 Disused quarry

The disused quarry east of the lease is outside the lease boundary and hence probably not Mount Grace Resources responsibility. However the drainage floor blocked by erosion will breed mosquitoes that will disperse into the lease area. The planned access road skirts this blocked floodway. It is suggested that construction of the access road includes rectifying the blocked floodway and preventing further erosion products from the quarry further blocking the floodway. This could be achieved by installing erosion prevention or silt retention structures between the quarry and the floodway. Discussions should be held with the appropriate authorities and the owners of the quarry to rectify the drainage problem and reduce this artificial source of mosquitoes.

5.4.7 Test Pit

The test pit is not breeding mosquitoes because of the presence of fish and the steep bare margins of the pit (Photo 5, Figure 5). However the disturbed areas around the pit could allow silt and gravel to enter Coomalie Creek and disrupt the ecology of the creek. This process has already begun. Any mine activity must ensure that erosion products do not enter the central channel of Coomalie Creek. This will disrupt fish populations and access, and prevent the adequate drainage of adjacent floodways at the start of the dry season, both of which will produce corresponding increase in mosquito numbers. Fish should be able to enter the new flood channel from downstream sections of Coomalie Creek.

5.4.8 Pit dewatering

Water from the pit will need to be pumped into silt settling ponds before discharge. If this discharge is to Coomalie Creek, the quality, volume and periodicity of the water should not disrupt the ecology of the creek. The greatest potential ecological change that will influence mosquito breeding will be the growth of the semi aquatic reeds *Typha* and *Eleocharis*. If large amounts of pit water are continually discharged from the settling ponds, this may alter the ecology of Coomalie Creek including the prolific growth of *Typha* and *Eleocharis* reeds, and create a major mosquito breeding site. If the excess water is only of moderate volume and only for periods up to the mid dry season, there is less potential for ecological change in the creek. If the pit water is allowed to drain directly down the central channel of Coomalie Creek where nearly perennial flow now occurs, it may not significantly increase reed growth and may not create a corresponding mosquito breeding site. This will depend on the volume and period of excess water and the capacity of the banks to contain all the extra flow. The proliferation and large extent of these reeds caused by discharge of pit water to a tributary of Coomalie Creek at nearby Woodcutters mine caused very significant new mosquito problems with *Cx. annulirostris*, *Ma. uniformis,* and *Cq. xanthogaster*.

5.4.9 Stormwater drains

Open unlined stormwater drains particularly those containing organically polluted water have the potential to breed mosquitoes. If there are dry season low flows in these drains from leaking ponds or other wastewater operations, the drains will become appreciable mosquito-breeding sites. Any storm drain likely to have continuous dry season flow will become a breeding site for *Cx. annulirostris* and *Cx. quinquefasciatus*. Problem drains will be characterized by extended grass or reed growth and stagnant pools with green filamentous algae. Any drain that develops these characteristics will need to be formalized with impervious linings and low flow facilities, and discharge the water to a suitable

end point or be investigated to reduce the wastewater flow. The proposed diversion channel from the plant has a potential to become a new mosquito breeding site. It should be constructed with a wide flat base to reduce stream velocity, and incorporate erosion prevention structures to ensure no pooling occurs and no erosion products reach Coomalie Creek.

5.4.10 Septic tanks and waste water

Septic tanks and wastewater from watering or wash down operations have the potential to breed a number of mosquito species including *Cx. quinquefasciatus* and *Cx. annulirostris*. Septic tanks in particular have an enormous capacity to breed mosquitoes because of the high organic content and the lack of any biological control organisms. All wastewater should be correctly collected, stored and disposed of such that it can not breed mosquitoes. Precautionary measures, such as the correct siting and sealing of septic tanks, are recommended to prevent the introduction and proliferation of *Cx. quinquefasciatus* in the mine area.

5.4.11 Artificial containers

Artificial containers such as tyres, drums, disused machinery, and any rubbish items that can collect rainwater are potential mosquito breeding sites. The closer these items are to personnel areas, the greater the potential pest problem is likely to be. Any large machinery tyres in storage yards are a particular problem because of the considerable volume of water that they can hold. In addition, any tyres or other machinery that have been transported from Queensland poses the risk of importing the exotic "Dengue mosquito" *Ae. aegypti.* All disused artificial containers should be stored under cover, disposed of by landfill or otherwise rectified so that they cannot retain rainwater. Large machinery tyres could be filled with earth, holed to prevent the pooling of water, or treated with insecticide.

A survey of any water holding containers is recommended a week after the start of the wet season to identify and eliminate potential sources of mosquitoes. Any containers that can not be emptied, holed, screened or filled and in which mosquitoes are capable of breeding should be treated with larvicide.

5.4.12 Borrow pits or depressions

Borrow pits can be appreciable sources of *Cx. annulirostris* and *Anopheles* species, particularly after a few years and the colonization by grass and reeds. Any sand or gravel borrow pits within the development should be filled to natural surface level or made free draining.

5.4.13 Personal protection and avoidance

There will be a number of instances of high mosquito numbers in the area and hence personal protection against mosquitoes will be sometimes required. They will primarily be required after spring tides in the late dry season or after the first rains cause hatches and subsequent dispersal of *Oc. vigilax* from their breeding sites on the Adelaide River system. They will also be required when initial flooding of drainage floors and floodways cause a hatch of *Oc. normanensis.* There may be other periods in the early wet season or mid dry season when elevated mosquito numbers and the risk of mosquito borne disease occurs. The appropriate personal protection measures against mosquitoes are outlined in Appendix 3.

5.5 Ongoing Mosquito Surveillance and Control

During the construction phase, temporary mosquito breeding sites will be created in the development area. These will generally require mosquito larval control or physical rectification. The principal requirement for control of these areas will be a regular inspection of ponding and a larval survey to detect when and where mosquito breeding occurs. This is seen as the responsibility of the developer

and not the responsibility of the Territory Health Services. However the Department would be available for advice on any monitoring and control.

In general, mosquito larval control should be carried out by engineering measures such as drainage or filling. Insecticide control should be reserved as a temporary measure until the engineering solution is implemented. Any regular insecticide control program runs the risk of overdosing or affecting non-target animals or the pest population developing resistance to the insecticide.

The insecticide of choice for larval control in this area would be *Bacillus thuringiensis* var. *israelensis* (Bti). This insecticide avoids any deleterious effects on non-target organisms. In the development area, with its relative ease of access to the mangrove margin and creeks, a larval inspection and control could be achieved by a small team using ground application equipment. A mosquito surveillance and control program should be part of an ongoing management plan.

Effective engineering design to eliminate mosquito breeding sites and a water management program aimed at reducing mosquito breeding would ensure that an insecticide mosquito control program would rarely be required.

Adult mosquito control measures would not normally be required in the mine area. Adult mosquito control is inefficient because of the dependence on wind and the provision of satisfactory access to ensure adequate dispersal of the insecticide. However if some unforeseen mosquito breeding occurs which cannot be controlled by larval control operations, an adult mosquito control operation may be required. Adult mosquito control may also be required if there are cases of mosquito borne disease and subsequent entomological investigations indicate a further disease transmission risk.

Adult mosquito control by ground based operations would only be successful if the mosquitoes were breeding or harboring in accessible areas relatively close to where they were causing the problem. This is likely to be along the margins of Coomalie Creek. Adequate vehicle access along the margins would be a prerequisite for such control, but they should not be installed at the detriment of the free draining nature of the floodways.

5.6 Future Mosquito Monitoring

The present survey does not form a baseline level that can be used to determine if any additional mosquito species are introduced to the area and can not be used to determine if there are significant rises in the relative numbers of any mosquitoes that could be attributed to the operation of the mine.

The present survey data is limited in that it covers only one day and there will be yearly variations as well as weekly and seasonal variations. The Woodcutters data does indicate expected seasonal mosquito numbers but there could be different mosquito problems in the current mine area or new ones could develop.

It is recommended that periodic mosquito surveys are carried out after the initial development of the mine and particularly in the early wet season and early dry season, to detect any mosquito breeding on the mine lease and to determine the appropriate rectification measures. The construction of the diversion channel for Coomalie Creek around the pit should receive particular attention to verify there is adequate rectification of the former section of the creek and no stagnant pooling has been created. More regular inspections should be carried out on sewage treatment, wastewater conveyance and disposal, and water storage facilities.

6 CONCLUSIONS

6.1 Biting midges

6.1.1 Species present and pest problems

- *Culicoides marksi*, a species that breeds at the edge of freshwater creeks and swamps will be the predominant pest species.
- *Culicoides marksi* is not likely to occur in sufficient numbers to cause a significant pest problem.
- The other species present are not likely to cause a pest problem.
- The development will not produce a significant increase in biting midge breeding sites to cause a pest problem.

6.1.2 Biting midge control

- There are no specific control measures required for biting midges.

6.2 Mosquitoes

6.2.1 Species present and pest problems

- There were 13 species of mosquitoes detected by the current survey. The 33 species of mosquitoes detected in baseline monitoring for the Woodcutters Mine area are also probably present in the mine area.
- The most abundant species during the present trapping were *Culex annulirostris, Coquillettidia xanthogaster* and *Anopheles bancroftii.*
- *Culex annulirostris* (the common banded mosquito), is likely to exhibit the highest relative abundance. This species will be present over an extended period from January to July. The population level of this species is likely to be low to moderate and pose only low to moderate pest problems.
- *Culex annulirostris* will pose the greatest potential public health problems, as it is a vector of Murray Valley encephalitis (MVE), Ross River Virus disease (RRV) and Barmah Forest disease (BF).
- Other species likely to occur in relatively high numbers listed in decreasing order of probable relative abundance include *Coquillettidia xanthogaster* (the golden mosquito), *Mansonia uniformis* (the freshwater reed mosquito), *Anopheles annulipes (*the Australian malaria mosquito*), Anopheles bancroftii (*the black malaria mosquito*), Ochlerotatus normanensis* (the floodwater mosquito), and *Ochlerotatus vigilax* (the salt marsh mosquito).
- *Ochlerotatus normanensis* and *Ochlerotatus vigilax* are likely to pose greater pest problems than indicated by their relative abundance due to their persistent biting habits and day biting activity. However they are likely to provide only very brief but intense seasonal pest problems during December to January. These two species also pose a potential public health problem, as they are vectors of RRV and BF.
- The most important vector of malaria in the NT (*Anopheles farauti*) was not detected during the current survey. However it was detected in relatively low numbers at Woodcutters. It is possible that this species could exist in the locality in higher numbers.

- The secondary vector of malaria *Anopheles annulipes* was detected in moderate numbers and results from Woodcutters indicate moderate numbers are likely to occur on a seasonal basis.
- The important domestic pest species *Culex quinquefasciatus* was not trapped at the mine site or at Woodcutters but is known to be present at Batchelor.

6.2.2 Mosquito borne disease

- The most serious potential mosquito borne disease is Murray Valley encephalitis, which is a relatively rare disease.
- The highest incidence of mosquito borne disease is likely to be due to Ross River Virus disease and to a much lesser extent Barmah Forest disease.
- Four recognized vectors for Ross River Virus disease were recorded during this survey or from the Woodcutters baseline monitoring, i.e. *Cx. annulirostris, Oc. normanensis, Oc. vigilax* and *Ve. reesi. Culex annulirostris* was recorded in the highest numbers and is likely to represent a higher risk for arbovirus transmission. It is probable that the other three species will occur seasonally in sufficient numbers to represent risks for arbovirus transmission.
- *Anopheles* species may be present in sufficient numbers seasonally to enable malaria transmission to occur if undetected cases of imported malaria are present in the area, and are exposed to mosquito attack.
- Mt Grace should warn personnel and visitors that there will be seasonal mosquito pest problems in the area and appropriate personal protection measures are required when mosquito numbers are high (Appendix 3).

6.2.3 Mosquito control measures

- *Ochlerotatus vigilax* breeding sites are associated with the tidally affected floodplains and upper tidal sections of the Adelaide River and so will be unaffected by the development. The other species will have breeding sites within the vicinity of the study area.
- The most significant breeding sites at present are vegetated cut off marginal pools and animal or human disturbed areas along creeks and floodways, and in habitats with semi aquatic vegetation within creeks.
- The most significant potential mosquito breeding sites are associated with the Coomalie Creek diversion around the pit, disturbance to the poorly draining drainage floors and seasonal floodways adjacent to the perennial creeks, and the discharge of pit water.
- Most of the existing and potential mosquito breeding sites within the development area will be relatively simple to reduce. This reduction will require a combination of rehabilitation, drainage, water impoundment design, and water management.
- The large water filled pits of the former Sundance Gold mine are not currently significant sources of mosquitoes and are not likely to be in the short to medium future.
- There is a potential breeding site associated with a blocked drainage floor by eroding overburden from an adjacent abandoned quarry.
- The incised channels of Coomalie Creek or major tributaries on the lease are not likely to be significant mosquito breeding sites because of perennial water flow and the presence of fish.
- The test pit for the magnesium mine is not currently a source of mosquitoes because of the presence of fish and steep bare margins.
- Soil erosion, silt deposition, pooling of rain in excavations, and disturbance of drainage lines during the construction phase will have a potential to create temporary mosquito breeding sites.

Any filling or rectification works in this zone should be closely supervised and follow THS guidelines to prevent the creation of new mosquito breeding sites.

- There is a potential to breed a limited range of pest mosquito species such as *Cx. annulirostris* in artificial impoundments and dams. Design of the ponds with respect to depth and slope, introduction and maintenance of suitable fish in the dams, active management of marginal reeds and grass, and water management within the impoundments can reduce this potential.
- An internal storm water drainage scheme will need to be designed to eliminate potential mosquito breeding sites within the development area.
- A significant potential mosquito problem will be the capacity to breed freshwater mosquitoes, including *Cx. annulirostris* and *Oc. normanensis*, by disturbance to drainage floors and floodways, and in artificially cut off sections of creeks after the creek diversion.
- The storage and discharge of pit water has a very high potential to create new mosquito breeding sites by encouraging the growth of the semi aquatic reeds *Typha* and *Eleocharis*. The volume, period and site of discharge should be assessed for potential vegetation changes in the discharge area that could lead to increases in mosquito breeding.
- Silt deposition in the perennial freshwater creeks may disrupt the free draining nature of the creek channels and create additional mosquito breeding.
- Appropriate silt retention and erosion prevention measures must be installed to prevent silt and gravels entering Coomalie Creek.
- Any septic tanks or other sewage treatment and disposal facilities have the capacity to be very productive mosquito breeding sites. All sewage facilities must be of adequate design to prevent mosquito breeding and contamination of nearby surface water.
- Any borrow pits or artificial depressions should be rectified so that they do not retain water.
- The presence of artificial containers at the mine area will increase the potential for the introduction of *Cx. quinquefasciatus* onto the mine site. With adequate precautions with regard to import and disposal of artificial receptacles the introduction of this species can be prevented.

7 RECOMMENDATIONS

7.1 Biting midges

7.1.1 Pest problems and public health

- There are unlikely to be any biting midge pest problems and any corresponding public health problems. However if biting midge pest problems occur, specimens can be collected and sent to the Medical Entomology Branch for identification and advice.

7.2 Mosquitoes

7.2.1 Mosquito pest problems and mosquito borne disease

- Workforce accommodation and recreation facilities should be mosquito proof with suitable insect screening or sealed buildings with air-conditioning.
- Personnel should be advised of the possibility of seasonal pest and local arbovirus disease risks and be given appropriate advice on the disease risks and personal protection measures from mosquito bites.
- Any personnel recently arrived from overseas with fever should consider malaria as a possible cause and be recommended to seek medical advice.

7.2.2 Mosquito control

- Any impoundments likely to retain water for periods of more than 7 days should be steep and deep enough to prevent semi-aquatic reed growth at the edges and within the impoundments.
- Stormwater drains through the development should all have erosion control structures and silt traps in their lower reaches before they enter the lower tributaries of Coomalie Creek or the main creek.
- Any drains within the development likely to have dry season low flows should convey the low flow in such a manner that it does not lead to mosquito breeding. Stormwater discharge should be via silt retention structures and not direct to the well-defined creek channels. Erosion control structures and silt traps should be in place well before the wet season in new construction areas.
- Pit water discharge should be free of silt and any discharge should have provision to prevent the growth of semi aquatic reeds.
- The spill way overflow from any proposed dam should incorporate erosion prevention structures to prevent the creation of additional mosquito breeding sites.
- The redirection of any creeks or floodways should ensure the former sections are completely rehabilitated or free draining.
- Septic tanks should be completely sealed and absorption trenches positioned such that there is no contaminated surface pooling capable of breeding mosquitoes. Septic and rainwater tanks should be installed to the satisfaction of the regional Environmental Health Officer to prevent the creation of additional mosquito breeding sites.
- Any rainwater filled receptacles such as old tyres and drums, old car bodies and disused machinery should be removed or rendered incapable of breeding mosquitoes.

- An appropriate person should survey the mine at least once in the wet season and dry season to detect any mosquito breeding sites and determine relevant rectification measures. Periodic checks should be made a number of times in a year for mosquito larvae in sewage treatment facilities and other wastewater storage and artificial ponding due to mine operations.
- Mosquito larval control should rely on the larvicide *Bacillus thuringiensis* variety *israelensis* (B.t.i.) or methoprene and only be carried out when breeding sites are detected. The advice of the Medical Entomology Branch of Territory Heath Services should be sought when mosquito breeding is detected or there are pest problems with mosquitoes

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9 APPENDIX 1

TABLE 1: SUMMARY OF THE BIOLOGY OF SELECTED CULICOIDES SPECIES IN THE TOP END OF THE NORTHERN TERRITORY

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Species	Larval Ecology	Adult Ecology
C. ornatus	Mainly breeds in upper neap tide zone and just above neap tide zone in mud at edge of Camptostemon and Rhizophora mangrove forest in small creek lines and in the Sonneratia zone at the mouths of large creeks and around harbours in the mid to late dry season; also at landward edge of Rhizophora-Bruguiera zone in wet season.	Bites people readily and a serious human pest. Bites other mammals; crepuscular; disperses in pest numbers to 2 km and up to 4 km. Emergence around neap tide time with peak dispersal over 3 days around full moon. Disperses readily to higher ground up to 1.5 km from mangroves.
C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. nr. hewitti)	Upper estuary, freshwater influenced extensive mangrove areas.	Crepuscular. Rarely bites people.
C. marksi	Breeds in the margins of freshwater lakes and streams.	Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.
C. narrabeenensis	Breeds at edge of fresh water.	Rarely bites people.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C.?pangkorensis)	Upper estuary.	Occasionally bites people.
C. pallidothorax	Breeds near fresh water.	NT species, rarely bites people.
C. flumineus	Upper estuary, in mid neap tide zone? in extensive areas of mangroves.	Readily bites people but rarely encountered out of mangroves.
C. immaculatus?	Possibly breeds below neap tide zone in mangrove creeks. Spring tide species	Relatively common in lower reaches of mangrove creeks and bites viciously.
C. immaculatus	Sandy wave washed beach sand often with rocks, near neap high tide level. Neap tide species	A relatively rare to minor pest . Found near breeding sites only.
C. ?subimmaculatus (northern form)	Maritime sands in wave sheltered areas often with small crabs between neap and spring tide zone.	Crepuscular. A minor to moderate pest. Bites man readily near breeding sites. Pest range generally up to 0.5 km.

Adapted from information by Allan Dyce and pers com Martin Shivas 1998

TABLE 2: SEASONAL PREVALENCE OF SELECTED CULICOIDES SPECIES IN THE TOP END OF THE NT

Peter Whelan, Medical Entomology Branch, Territory Health Services

Species	Seasonal Prevalence
C. ornatus	The major species near mangroves at coast. High localized populations all year round, with maximum numbers occurring in September to October and minimum in the wet season.
C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)	A major species near extensive areas of mangroves at coast. High numbers in the late dry season and early wet season, and has low populations in the post wet season.
C. marksi	A major species in sub-coastal and inland areas, with only low populations at coast. Low populations in the late dry season and moderate populations in the early wet and post wet to mid dry seasons.
C. narrabeenensis	A minor species with peak numbers in the early to mid dry season.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)	A minor species. Peak numbers in mid wet season.
C. pallidothorax	A minor species. Peak populations during the early to mid wet season.
C. flumineus	An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.
C. ? immaculatus	A serious pest in lower reaches of mangrove creeks
C. immaculatus	A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.
C. ?subimmaculatus (northern form)	An important pest species. Moderate numbers near favored wave sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.

Adapted from information by Allan Dyce and pers. comm. Martin Shivas 1998

wind of accommodation areas. Light proof curtains or similar screening can be very effective in reducing the attraction of biting insects to areas which are illuminated at night.

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area they can be knocked down with pyrethrin aerosols. Care should be taken by reading the label to ensure only knockdown aerosols suitable for spraying in the air are used in proximity to people or food.

Other devices that can be effective at killing and/or repelling biting insects include mosquito coils (Charlwood & Jolley 1984) and electric insecticide pads. These devices are only effective in relatively closed areas such as inside buildings or where there are only slight breezes. They should be backed up with other measures such as suitable protective clothing or repellents

Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are Maldison or Bioresmethrin. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

Application of short term residual insecticides such as Maldison, Permethrin or other synthetic pyrethroids sprayed on surfaces or nearby vegetation can sometimes give short term (1 day) relief when large numbers of mosquitoes or biting midges are present near accommodation or outdoor use areas (Helson & Surgeoner 1985). These can be applied according to label recommendations with the aid of a garden sprayer. There are some aerosol products available as outdoor yard or patio repellents. Control will only be temporary and re-invasion will usually occur within hours or from one to a few days, depending on the species, nearby vegetation, proximity to breeding sites, environmental conditions and times of activity of the pest species.

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilizing an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices can not be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people

11.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Climbing relatively high trees or choosing locations exposed to the wind can offer protection from some species. Other emergency protection measures include coating the skin with mud, rubbing exposed areas with the leaves of certain plants such as eucalypts or ti-trees that contain volatile oils, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best form of protection, and the most comfortable, require an awareness of the potential problems and adequate preparation.

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Figure 4: Woodcutters Mine Adult mosquito monitoring program. Total numbers of selected female mosquito species from all sites. Jan 1995 to March 1996

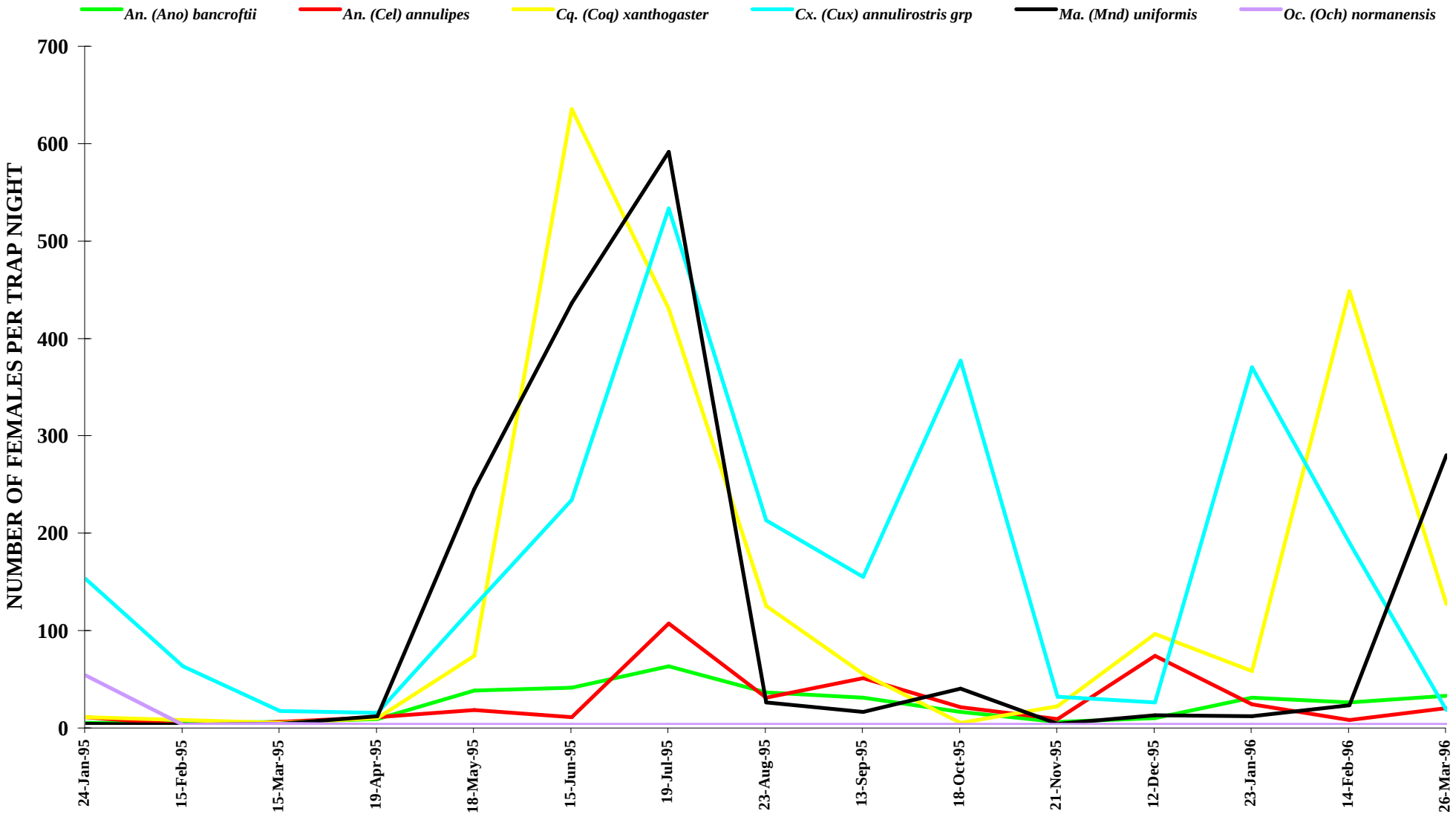

Figure 2: Medical Entomology Branch Adult mosquito trap site positions Mt Grace Batchelor Magnesium Project 25 July 2001

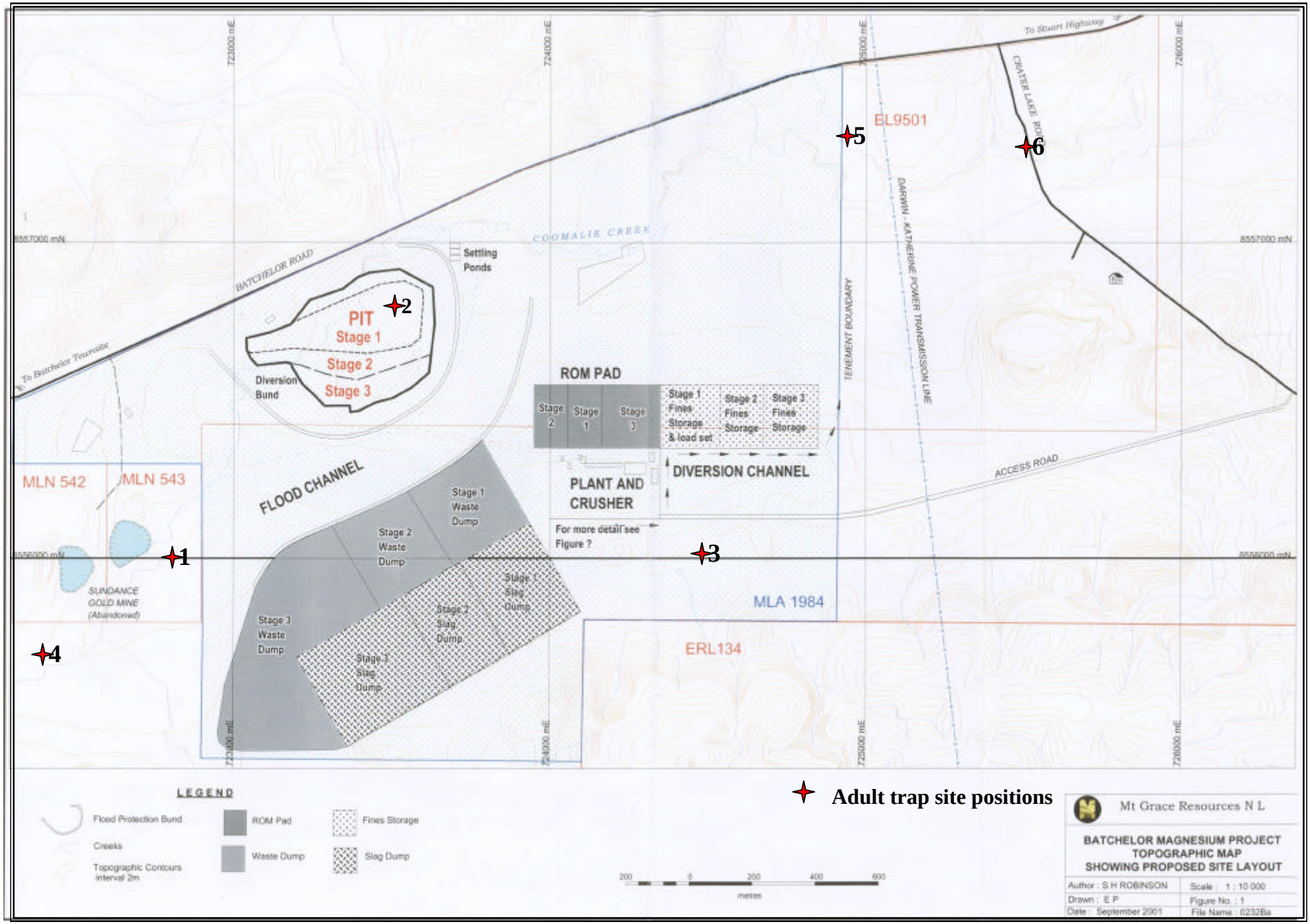

Figure 5: Mount Grace Magnesium Mine. Photographs of habitats 24/7/2001. Medical Entomology Branch

Photo 1: Coomalie Creek - Site 1

Photo 2: Sundance Gold Mine, Western Pit towards outflow.

Photo 3: Sundance Gold Mine, Eastern Pit towards inflow

Photo 4: Sundance Gold Mine, Eastern Pit with margin pooling

Figure 5: Mount Grace Magnesium Mine. Photographs of habitats 24/7/2001. Medical Entomology Branch

Photo 5: Site 2. Test Pit. No margin vegetation.

Photo 6: Site 3. Dry dam, wet season pooling.

Photo 7: Site 4. Rainforest area.

Photo 8: Site 5. Incised creek with fish.

Figure 5: Mount Grace Magnesium Mine. Photographs of habitats 24/7/2001. Medical Entomology Branch

Photo 9: South of Site 6. Disused quarry.

Photo 10: South of Site 6. Quarry overburden erosion and blocked drainage floor.

Photo 11: Site 7. Batchelor sewage ponds.