RISK ASSESSMENT STUDY
MINE TAILINGS SITE AT
MOUNT EGERTON, VICTORIA
for
Environment Protection Authority
Department of Health & Community Services
Department of Agriculture, Energy & Minerals
Department of Conservation and Natural Resources

1. INTRODUCTION

This report relates to the Consultant Agreement between the Environment Protection Authority and Dames & Moore Pty Ltd dated 15 January 1995 in relation to completion of a Risk Assessment Study for the Paddock Creek area north of the Town of Mount Egerton, Victoria. This agreement encompassed information supplied in a brief prepared by the EPA dated 16 August 1995 titled "Risk Assessment Study Proposal - Arsenic and Mercury Contaminated Mine Tailings, Mount Egerton, Victoria", and Dames & Moore proposals of 1 September 1995 and 14 November 1995.

The study was carried out on behalf of the following Victorian Government agencies:

- Environment Protection Authority (EPA);
- Department of Health and Community Services (H&CS);
- Department of Agriculture, Energy and Minerals (DAEM); and
- Department of Conservation and Natural Resources (DCNR).

Since the study started, some agencies have amalgamated and/or have had changes of name. For consistency, the names of the agencies that applied at the start of the study have been used in this report.

1.1 THE SITE

The area of the study is a former mining area in the vicinity of Mount Egerton approximately 80km west of Melbourne, where mining activity was at its peak in the 1890s. A mining company, Tech-Sol Resources Pty Ltd (Tech-Sol), has started to rework mine tailings in the area for the recovery of gold from the waste stockpiles.

The study site covers part of the course of the Paddock Creek, a tributary of the East Moorabool River, from the township of Mount Egerton northwards towards the Bostock Dam, in an area approximately 20km to the south east of Ballarat. The location of the study area is indicated in Figure 1.

The contaminants of concern on the site were indicated by the brief to be arsenic and mercury associated with the mine tailings. The tailings are present on Crown land comprising the mining site and have also spread onto surrounding private land and into the local Paddock Creek Gully.

1.2 THE AIMS OF THE STUDY

The brief required the study to:

- Define the potential risks to human health and to environmental receptors (including grazing animals) presented by arsenic and mercury in the tailings material.
- Propose management measures to minimise or eliminate unacceptable risk identified by the study.

1.3 SCOPE OF WORK

The study is a theoretical/desk based study utilising information already available. Further testing has not formed a part of this study. The information provided included data from the recent assay of the tailings material associated with the new mining activities, and the results of some soil and water analyses conducted by the Government agencies. Additional information was obtained from various sources during the study. The sources of information are listed in the references section at the end of this report or are referenced with background information contained in Appendices of this report.

It was understood that, any further data required to clarify the results of the assessment would be the subject of additional stages of work following consultation with the EPA after completion of the risk assessment.

Specific issues addressed by the study included:

- Literature search - bioavailability of arsenic and mercury.
- Exposure of residents.
- Exposure of persons using tailings as a construction material.
- Exposure of stock animals and pets.
- Potential environmental impacts on the Paddock Creek and other water bodies.
- Dispersion of contaminants and potential environmental impacts on other receptors.

In order to comply with the brief and to achieve the aims of the study set by the Victorian Government Agencies, a number of tasks were completed.

Task 1: Literature Survey and Risk Assessment

A literature survey was conducted to review available data, analysis of exposure routes and potential doses, toxicity assessment, health and ecological (animal) risk characterisation.

For this preliminary study, which has limited data input, a risk analysis focussed on those receptors and exposure routes considered most likely to be an issue on the site, for example, humans, large grazing animals such as horses, etc.

Task 2: Dispersion of Contaminants and Potential Impacts on Water Bodies

In order to establish the likely extent of dispersion of tailings and the associated contaminants within the study area and into the Paddock Creek Gully, local dams and the Bostock Reservoir, historic plans and air photos of the area were researched and reviewed followed up by a site inspection on the properties affected.

Task 3: Identification of Management Measures

At this stage of the study, identification of the management issues has primarily been based on previous experience with similar sites, this report discusses the possible available range of management options that could be considered.

Task 4: Liaison and Reporting

This report covers the methodology and calculations used to derive the risk based criteria for arsenic and mercury for the site. It covers the likely extent of the tailings and contamination based on the air photo study, site inspections, and review of data supplied by the EPA and others.

The report also discusses management measures and strategies that may be feasible for the minimisation or elimination of exposure pathways that result in potentially significant exposures and risk.

The findings of this study included in this report are specific to the valley of Paddock Creek at Mount Egerton, and involve a history and set of circumstances that are unique to that area. The key features of the study appear to have resulted from a long history of gold mining in the area [1] that has left a legacy of deposits of sandy tailings material located in various parts of the valley of the Paddock Creek.

The conclusions drawn by this study, whilst being specific to the group of properties located along Paddock Creek in the Mount Egerton area, may also have some wider significance in the context of other similar sites where there has been similar historical gold mining activity, and where similar gold extraction processes were undertaken resulting in a build up of mine tailings. At Mount Egerton itself, there are other valleys and watercourses that may also contain mine tailings that may be of a similar nature to those in Paddock Creek. However, the results of this study can only be considered in such wider contexts with a great degree of caution and each should be reviewed on a case by case basis.

2. GEOLOGY

The geological history of the Mount Egerton area has been interpreted from the 1:50,000 Ballan Sheet of the Geological Survey of Victoria, Sheet 7722-4 Zone 55 published in 1986 by the Department of Industry, Technology and Resources (DITR) [3]. This was supplemented with the information contained in Geological Survey Report No 76 titled "Explanatory Notes on Bacchus Marsh and Ballan 1:50,000 Geological Maps" prepared by P S Roberts of the Geological Survey Division of the Victorian Department of Minerals and Energy in 1984 [2]. Roberts' mapping took into account earlier publications by various authors, dating back to 1866 when the first geological maps of the area were published by Daintree and Wilkinson.

Based on Roberts' notes and the Ballan geological map, the portion of the Mount Egerton area that is the subject of this assessment appears to be underlain mainly by Ordovician aged sedimentary bedrock comprising interbedded sandstone, siltstone, shale and slate. The sediments have a slatey cleavage and are tightly folded on axes that trend approximately north/south in the range 0o to 15o. The axial planes of the folds and cleavage are near vertical and generally dip at a high angle, mostly to the east. Quartz reefs, not usually more than a few hundred metres in length, intrude the bedrock. The quartz reefs are also steeply dipping, are generally parallel to the strike of the slatey cleavage and have been worked historically for their gold content. Mining reached a depth of 610 metres at the Blackhorse Mine in a gold reef that trends approximately 10o and dips at a high angle to the west.

Overlying the Ordovician bedrock in the valleys in the Mount Egerton area are also Quaternary aged shallow colluvial or alluvial sediments comprising poorly sorted gravel, sand, silt and clay. Further down the course of the Paddock Creek, towards Bostock Reservoir, the alluvial deposits spread out into swampy areas underlain by Quaternary aged alluvium that includes clay, silt, sand, gravel and possibly some peat.

The Ballan Sheet also indicates that historical mine waste dumps comprising sandy tailings materials overlie the alluvial sediments and Ordovician bedrock in the valley of the Paddock Creek immediately to the east of the Gordon/Mount Egerton Road.

The geology of the area is summarised on the geological map, Figure 2.

3. HISTORY AND EXTENT OF TAILINGS

3.1 BACKGROUND

The history of the Mount Egerton area is well documented both in published local histories, on historic maps, plans and photographs and in government mine surveyors records, and is mostly interlinked with the history of gold mining in the area.

The Bungal Run was established and first occupied for agricultural use in about the late 1830s to 1840s. Gold was discovered in 1852 at Mount Egerton, originally named after George Egerton who owned the Bungal Run property on which it was located. As indicated in the establishment of allotments on a map of the Parish of Bungal dated July 1856, mining was well established soon afterwards, with several dams and crushing mills shown on the 1856 map (Appendix A). Early mining was for alluvial gold which petered out at an early stage. The main quartz reef was discovered in 1854 and surface outcrops were first mined by open cut in the that is now the town refuse tip [1].

The major mines on the Mount Egerton Goldfield are the Blackhorse, the Egerton (Main and Quarry Shafts), Sister Rose and Rose which are all on one line of reef trending at about north 10 degrees east northwards from Mount Egerton or southwards on the same line [2]. The approximate location of shafts associated with these mines are indicated on the site plan, Figure 3.

The first quartz crushing battery of 5 stampers is recorded as having been built in the early 1860s to the south of the Mount Egerton Gold Mine Co [1]. The crushing mills shown on the 1856 Bungal map (Appendix A) may have used more primitive methods such as the "Chilean Mill" which are known to have been used at two locations on Woollen Creek to the west of Mount Egerton, on the East Moorabool River (of which Paddock Creek is a tributary) and on the West Moorabool River at a location now covered by Lal Lal Reservoir [1]. The output from the Chilean mills would have been modest and the gold extracted from the crushed rock by panning techniques.

With the construction of private stamping mills in the 1860s, a considerable quantity of ore was crushed at the Mount Egerton and Blackhorse mines. The output from the Egerton Mine was fed through a 100 stamp battery, with the wash water taking the residue through to a drain that fed into Bungal Creek that flows southwards from Mount Egerton and away from Paddock Creek [1]. The sand and rock waste residues from these mills are shown on the geological map Figure 2. The gold residues within the sand tailings from the Egerton Mine were later re-worked by the cyanide process at a number of cyanide plants set up at different sites down Bungal Creek [1].

The Blackhorse mine (Plate 1) was worked from 1860 to 1905, reaching a depth of 610 metres with a yield up to 1895 of 152,000ozs of gold. The mine battery was set up on the current site of the State Government Battery (Figure 3) and the residues and tailings washed into Paddock Creek [1]. The extent of the sandy tailings residues are clearly visible in a photo taken before the end of the 19th century (Plate 2) as a broad white "river" disappearing into the distance past the Blackhorse mine workings in the foreground. Plate 3 is the same area today showing the flat bottom of the valley of Paddock Creek filled with mine tailings. Figure 4 shows the approximate course of Paddock Creek and its tributaries derived from the 1856 map (Appendix A) that have been largely obliterated by the mass of tailings allowed to flow into and over it. The presence of other shafts (The Blackhorse North shaft, New Discovery and Egerton Consolidated shafts) immediately to the east of Paddock Creek would also have contributed to the flow of tailings and residues into the creek.

The now restored government battery is a much smaller five stamp battery that was set up on the site in 1912 after the Blackhorse mine had closed. Local historians have also suggested the presence of another large battery sited near to the recreation oval that produced the sand residues in that area (although no maps were found to confirm this), the resultant large heap of sand being derived from the Blackhorse mine and also from the North Black Horse and New Discovery shafts. The local history reported that these mines also used the Egerton Mine crushers to which a tramway was constructed.

The large mullock heap (unprocessed waste rock) visible in Plate 1 in 1909 adjacent to the Blackhorse mine headgear is reported to have been crushed for use in the rebuilding of the Mount Egerton - Gordon road in the 1930s [1]. The remaining mullock heaps and large sand heap adjacent to the recreation oval, were investigated in 1952 by Spencer Jones [4] (see plan in Appendix A) as potential sources of road and building material. Local historians have indicated it took another 30 years to use it up [5].

Later mining operations in the area include small scale fossicking with shafts and tunnels driven in various areas around Mount Egerton during the 1930s depression era. The results of these can be seen in the small shafts that dot the valley at intervals. A small circular shaft on Lot 2 of the study area may date from this period (Plate 4). Local historians also report the operation of numerous small scale cyaniding operations during the depression era to extract gold from the tailings [1]. It is reasonable therefore to assume that some of the cyanide extraction operations also took place on the tailings in the Paddock Creek Valley, and old cyanide vats were discovered during recent exploratory work on the mining lease by Tech-Sol Resources at a location near to the existing government battery.

Tech-Sol have occupied the Mining Lease for about 8 years, being engaged on feasibility studies to re-process the tailings by a vat leach process to extract the remaining gold. Several large lined vats have recently been completed and reprocessing started in July 1996 in the area immediately downstream of the government battery (Plate 5).

Local residents have reported that the main tailings dam in the valley failed, possibly at sometime during the 1930s although the date is not clear, allowing water and tailings from the dam to spread out down the valley, filling the course of the Paddock Creek for some distance downstream. The 1933 topographic map of the area does not show any of the dams, but indicates the course of Paddock Creek to where it joins the East Moorabool River at "Blackfellows Flat" (the site of early aboriginal settlement [1]), now covered by Bostock Dam (Appendix A).

3.2 SUB-DIVISIONS IN PADDOCK CREEK VALLEY

The mine township at Mount Egerton was first established on an ad-hoc basis, with the first sub-divisions to the east of the township being laid out in 1856 (Appendix A). Later sub-divisional plans show the progressive sub-division of the area around the mines themselves. The 1967 map of Township of Mount Egerton and surrounding Parish of Bungal, shows the area north along Paddock Creek to be sub-divided into several crown allotments numbered 1 to 12 of Section 3A.

Crown Allotments 2, 3, 4, 8, 11 and 12 of Section 3A were re-organised and sub-divided in 1986 as rural sub-divisions numbered 1 to 6 of slightly more than 8 hectares each, as shown on the plan of sub-division prepared for the Shire of Ballan by G Bishop, Ref. SB 3051 dated 18/12/1986 (Appendix A). These sub-divisions are indicated in Figure 3. A number of mine shafts are shown on the 1986 geological map located on the new Lots 3 and 4 of 3A.

The owners of Lot 5 purchased the property in 1988 and have reported that horses and cattle with which they stocked the property, have exhibited many signs of ill health, two horses ultimately having to be destroyed. They also reported health problems with their pet dogs. This was brought to the attention of the Department of Agriculture in Ballarat and subsequently to the Department of Health and Community Services and the EPA which has lead to this current study. The health status of residents or of animals raised on adjacent properties is generally not known. However, the owners of Lot 5 reported witnessing deaths of cattle on the neighbouring property to the north and health problems of some residents have been reported to the Department of Health and Community Services.

A history of the animals on Lot 5, as reported to Dames & Moore by the owners of Lot 5, is included in Appendix C for reference. The results of laboratory analyses on the soils, water, horses, vegetables, crustaceans and fish in the affected area are discussed further below.

3.3 EXTENT OF TAILINGS

Part of the study brief was to define the potential extent and distribution of contamination within the study area. As the main potential source of contamination appeared to be most likely related to the distribution of the mine tailings and any seepage from the tailings dams, a review of available maps, plans and airphotos was completed to assist in the process. Historical maps reviewed for this study are presented in Appendix A for reference. A laser print copy of a representative airphoto reviewed is included in Appendix B.

The outcome of the review of historic photographs is limited and discussed in detail above. The location of "Battery Sand" derived from earlier investigations by the geological survey is indicated on the geological map, Figure 2 [2]. The approximate outline of the "battery sand" as shown on the geological map, has also been indicated on the site plan Figure 3.

A historic set of airphotos was examined for the site, taken in 1970. Stereo pairs of these airphotos and also of a recent set of colour airphotos taken in 1990, were examined under a high power stereographic viewer. The potential location of the tailings and/or alluvial soils was recorded onto the Darley 10 000/1.7 sheet of the 1981 provisional 1:10,000 series base topographic maps produced by the Division of Survey and Mapping of Victoria (unpublished).

The possible boundaries of the tailings as derived from the airphoto review are indicated on Figure 3. It is difficult to distinguish naturally occurring sandy alluvial soils known to be present from the geological map, from the sandy tailings material based solely on the airphoto review. The interpreted boundaries indicated in Figure 3 therefore should be confirmed by physical investigation on site including shallow boreholes.

Fieldwork and other studies have been carried out on the site by the EPA and others during 1995. The site was also inspected by Dames & Moore in 1996. Sandy and silty soils characteristic of the tailings material were found to be exposed at numerous locations along the course of Paddock Creek during a field inspection carried out by Mr Ken Mival of Dames & Moore during February 1996. Tailings and sandy soils that are potentially derived from the tailings were also reported in auger boreholes by the EPA during fieldwork on the site in July 1995 [8] and in samples collected by the Department of Agriculture vet, Dr John Larsen, during his visit to Lot 5 in March 1995 [9]. The presence of mine tailings in the upper part of the valley has also been reported by Tech-Sol Resources in information made available to the EPA and to Dames & Moore [6 and 10].

From the various studies and visits indicated above, mine tailings have been found to be present in the upper part of the Paddock Creek covering the flat bottom and full width of the valley and covering the former course of the creek and underlying natural soils to a depth of up to 4.5m. To the north of the last tailings dam at the northern extremity of the mining lease, sandy soils with the general appearance of tailings are also visible partly covering the flat floor of the valley through the new sub-divisions - Lots 2, 5 and 6, and the adjacent former Lot 1 of Section 3A and Lot 1c of Section 3. The inferred extent of these tailings areas is indicated on the site plan Figure 3.

The sandy soils examined by Dames & Moore on Lot 5 of Section 3A and soils examined from adjacent to the dams on Lots 5 and 6 of 3A were found to be similar in appearance to the tailings in the mining lease dam. The dam on Lot 1c of Section 3, appears to be excavated in a clayey loam and therefore is outside of the spread of tailings material. Little evidence of tailings was visible in the alluvial areas further to the north except for some sandy deposits within the course of Paddock Creek.

Although there was little indication of tailings in the alluvial areas at the northern limit of the study area, the presence of some tailings material to the north of Lot 1c of Section 3 cannot be ruled out on the basis of the limited visual inspection and few auger borings completed, and may also extend further downstream.

The owners of Lot 5 reported that during digging of post holes for fencing they encountered sandy soils similar to the tailings present beneath a wide area of the central part of Lot 5. The residents indicated that some bulldozing was done to level the area during establishment of the property for horses. This could have also spread the suspect tailings material over a wider area, and some tailings like material is still visible at the surface, having been left around some of the trees (Plate 6). The residents reported that, before they were excluded from this area, their horses used to be attracted to this material and would chew at it. Tailings like material is also clearly visible in the banks of Paddock Creek, downstream of this area (Plate 7) and in the dam excavation on Lot 6, the property to the north (Plate 8).

The main dam on Lot 5 is constructed in the tailings material and the horses were washed in this dam and would also drink the water until the area was fenced off (Plate 9). The horses are now only allowed to drink from rainwater supplies held in a large tank on the property. A small circular dam or waterhole is located near the southern boundary in the path of the creek. The surface of the soils is heavily stained a deep red colour which may represent precipitation of iron oxide from the water (Plate 10). The owner's dogs regularly swim in this water (Plate 11). The origin of this waterhole, which pre-dates the occupation by the present owners, is uncertain and the owners have speculated that it is mining related, although it is unclear what purpose it may have had. It is visible in the 1970s airphotos and therefore pre-dates recent sub-divisions.

Water flow in Paddock Creek was reported by the residents to be intermittent, with major flows only occurring during heavy rainfall. The owners have a video of heavy rainfall overflowing from the valley tailings dams during late 1995 and a steady seepage from the last dam on the mining lease was observed by Dames & Moore during the February site visit (Plate 12). It is clear that this seepage is absorbed into the sandy tailings material covering the bottom of the valley. At the time of the visit, no flow was observed in Paddock Creek either on or further downstream below Lot 5 (Plate 13).

3.4 POTENTIAL FOR CONTAMINATION

The potential contamination of the properties in the Paddock Creek area of Mount Egerton and downstream to the Bostock Reservoir is dominated by a number of key contaminants that are likely to have resulted from the mining processes of which there is a 140 year history described above.

The early process for the extraction of gold involved the use of mercury. The crushed gold bearing sand was mixed with mercury for which gold has an affinity. The mercury was recovered with a retort for re-use whilst the gold and other metals extracted from the sand were heated in a furnace with Borax flux. The gold flowed to the bottom in the mould and could be recovered at about 99.4% purity. Contaminants also released by the process into the wastes included arsenic, lead and iron. The waste stream of sand tailings washed out of the battery therefore contained varying proportions of these contaminants, trace quantities of other metals, together with some remaining un-recovered gold and a small proportion of the mercury not reclaimed for re-use.

The arsenic in the tailings is most probably derived from the breakdown of naturally occurring arseno-pyrite mineralisation associated with the gold. The later re-processing of the tailings at various sites along the valley appears very likely from the site history and this would add potential for the presence of cyanide. However, as the last of the cyaniding processes probably took place more than 50 years ago, the cyanide is likely to have largely broken down in the environment.

The modern vat or column leaching processes proposed by Tech-Sol Resources is only just starting and is understood to be a closed process and therefore is not expected to add to any contamination that may be present in the valley. It may ultimately remove potential sources of contamination by re-processing the tailings material.

There is a potential for the presence of naturally occurring metals in the alluvial sediments, such as arsenic due to the naturally occurring mineralisation of the rocks of the area. In particular, arseno-pyrites are frequently associated with gold ores.

4. AVAILABLE DATA AND SOURCES OF CONTAMINANTS

4.1 SOIL

4.1.1 Results of Soil Sampling - Mining Lease Area

The main source of information available as to potential contaminants within the tailings material is derived from laboratory testing undertaken by Australian Laboratory Services on behalf of Tech-Sol Resources. This was reported to the EPA [6] in a letter dated 18 February 1995, and is summarised in Table 1A.

This information was primarily put together for gold assay and the quality of the results is not known as no quality assurance (QA) information or testing is reported with the test results, although this should be traceable depending on the original reports provided to Tech-Sol.

The tailings samples were composites collected from 1 hectare blocks within the mining lease. The location of these blocks are indicated on Figure 3 and labelled B3, B4, B5, B8, B9, B11 and B12. The results summarised in Table 1A are therefore representative of the tailings type material at the southern end of the lease. Analyses were undertaken for gold, silver, arsenic, antimony, cadmium, copper, iron, lead, manganese, mercury, calcium and magnesium. The selection of analytes is related to the areas of economic significance in the re-processing of the tailings and therefore does not necessarily relate to particular health or environmental risk concerns.

A preliminary review of contaminant concentrations, as indicated in test results made available for this study, was made in relation to threshold investigation levels as published in the Australian and New Zealand Environment and Conservation Council (ANZECC) and National Health & Medical Research Council (NH&MRC) "Guidelines for the Assessment and Management of Contaminated Sites" published in January 1992.

The ANZECC Guidelines propose a range of "environmental investigation levels" and "health investigation levels" which would protect the entire population with few exceptions, and are intended only as "trigger values" or thresholds above which further investigation into potential adverse ecological or health effects is warranted.

The test results summarised in Table 1A indicate the presence of modest levels of copper in the range 25 to 50mg/kg (ppm) and lead in the range 95mg/kg to 160mg/kg, both of which are below ANZECC environmental investigation levels of 60mg/kg for copper and 300mg/kg for lead [18]. Antimony and silver were found to be below detection limits, which was set at 5mg/kg for antimony which is also below the environmental investigation level of 20mg/kg for antimony. Iron levels are high being in the range 1.08 to 2.27 per cent, which may account for the dark red discolouration and precipitation observed in dams and the Paddock Creek downstream of the tailings. No investigation levels for iron have been set by ANZECC.

Arsenic levels in the tailings assays summarised in Table 1A range between 480mg/kg and 720mg/kg with a median of 590mg/kg, which substantially exceeds the environmental investigation level of 20mg/kg and also the proposed health investigation level for arsenic of 100mg/kg. The mercury content of the tailings ranges between 1.6mg/kg and 6.6mg/kg with a median of 2.5mg/kg which also substantially exceeds the environmental investigation level of 1mg/kg. The levels found for mercury were, however, below the health investigation levels of organic mercury (10mg/kg) and inorganic mercury (15mg/kg) as reported in the Health-based Soil Investigation Levels: National Environmental Health Forum Monographs: Soil Series No1, 1996.

On the basis of these test results, assessments subsequently have focussed primarily on the metals arsenic and mercury, and these are the primary contaminants of concern covered in this health risk assessment as requested in the brief. However, the potential for adverse health effects from other contaminants either singly or in combination has not been ignored and is discussed further below.

Gold residues have been found to be present in tailings up to the northern boundary of the lease with the associated arsenic levels shown in further assay information supplied by Tech-Sol in the range 45mg/kg up to 1350mg/kg of arsenic with a depth of tailings of up to 4.5 metres in places [10]. The information is recorded directly onto a plan and the source of the original data is not known. The plan of the mining lease on which this information is based is not included here as it was made available in confidence by Tech-Sol and contains information that may be commercially sensitive.

Table 1B summarises the results of analysis of progressive cyanide extracts carried out by Tech-Sol on a composite sample from Block B5 and the concentration of copper, lead and arsenic after elutriation of the residues left in the tailings after the extraction process has been completed [6].

4.1.2 Soil Samples - Downstream in Paddock Creek Valley

Soil samples have also been collected from the area downstream of the tailings dams in the area of the sub-divisions on section 3A. These comprised samples collected by the EPA at a number of locations, by the Department of Agriculture on Lot 5, and by the Ballan Shire Council (now Moorabool Shire) from tailing sands from the mining lease. These results are discussed in the following sections.

4.1.3 EPA Soil Samples - July 1995

The EPA samples were collected on Lots 2 and 5 of section 3A, and on former Crown Allotments 1 of 3A, and 1c of 3 in material that appeared either to be tailings or was sandy and appeared potentially to be tailings. These locations are numbered 1 to 14 in Figure 3 as reported in EPA report of 26 July 1995. All of these samples were collected from areas that were considered potentially to be underlain by tailings by the EPA staff. The airphoto review also indicates these areas are likely to be underlain by tailings or similar alluvial materials.

The EPA samples were tested for arsenic, mercury and selenium. The results of these tests are summarised in Table 2. Except for samples 11, 13 and 14, all of the samples were found to contain arsenic in the range 113mg/kg to 1140mg/kg with a median of 550mg/kg which is very similar to the median for the tailings summarised in Table 1A. The mercury concentrations are in the range 0.71 to 8.4mg/kg with a median of 4.8mg/kg, somewhat higher than indicated in the tailings assays.

It is understood that the selenium analyses were carried out to examine the potential for low selenium resulting from displacement by arsenic, potentially leading to selenium deficiencies within the stock held on the properties. Selenium was found to be present in the range 3mg/kg to 17mg/kg with a median of 6mg/kg. There is currently no ANZECC or Dutch environmental investigation threshold for selenium. However, these levels are comparable to the concentration of selenium of 10mg/kg permitted in "Fill Material" in EPA publication 448 "Classification of Wastes" of September 1995. The available information on the interaction of mercury and selenium, and arsenic and selenium is discussed in Appendix E Sections III and IV.

QA test results for blanks, trip blanks, spikes and split samples are reported with the testing completed by Probe Analytical. The results of the QA analyses appear to be within acceptable ranges for these analyses.

4.1.4 Department of Agriculture Samples - March 1995

At the request of the residents of Lot 5, the soils were sampled on Lot 5 by the Department of Agriculture Veterinarian, Dr John Larsen, in March 1995 when investigating possible causes of ill health of the horses on that property. These samples are numbered L1 to L5 on Figure 3 and the results of analyses for arsenic, cadmium, copper, iron, lead and zinc are summarised in Table 3.

Cadmium levels in these samples are below detection limits and therefore do not appear to be of concern. The lead (1.9mg/kg to 205mg/kg) and copper (1.5mg/kg to 45mg/kg) levels are similar to those found in the tailings assays, and the zinc levels are also modest (17mg/kg to 85mg/kg) and all are below the ANZECC environmental investigation levels of 300mg/kg, 60mg/kg and 200mg/kg respectively. Iron was recorded at a high concentration in the range 0.23 to 2.06%. Mercury was not analysed, but arsenic was found to be in the range 80mg/kg to 825mg/kg with a median of 315mg/kg for all the results. This is substantially above the ANZECC health investigation level of 100mg/kg and of the same order of magnitude as for the tailings material on the mining lease.

4.1.5 Ballan Shire Sand Samples

Sand samples were collected by an environmental health officer of the Shire of Ballan (now Moorabool) from the remaining sand stockpiles on the recreation reserve at the south end of the mining lease. The results of tests on these samples are summarised in Table 4. Lead, arsenic and mercury were analysed with similar results to those described in Section 4.1.1 - 4.1.4, except for mercury. The concentrations of lead were below 100mg/kg, and the concentration of arsenic was 260mg/kg and 290mg/kg. The mercury concentrations were found to be below detection limits set at 0.1mg/kg.

4.2 SURFACE WATER & GROUNDWATER

A number of organisations have conducted water sampling and testing relevant to water quality on the site. This includes samples of water in dams on the mining lease collected by Tech-Sol; groundwater samples from domestic bores and domestic tank water supplies on Lot 5, sampled by the Department of Health and Community Services; and a single water quality sample included in the samples collected from Lot 5 by the Department of Agriculture. The locations of all the samples are indicated on Figure 3.

The water samples tested for Tech-Sol were collected on 18 October 1990 from the dams and water courses on the mining lease and then analysed by Australian Laboratory Services. As for the tailings assay data, no QA data or sampling methodology is reported with the test results and therefore no assessment of the quality of the results can be made [6]. The test results as reported by Tech-Sol are summarised in Table 5A. The results for analysis of the single water sample collected by the Department of Agriculture from the dam on Lot 5 is summarised in Table 5B.

It was reported by Tech-Sol that the sampling carried out on their behalf was following a heavy rainfall period resulting in heavy surface run-off down the valley which may have resulted in lower than normal concentrations due to dilution. Samples were taken from the dams and from the intervening run-off areas and one surface run-off area below the tennis courts on the recreation reserve (SW1). There is no indication whether samples were filtered to remove suspended solids.

Lead, arsenic and mercury were analysed on behalf of Tech-Sol. Copper analyses were only carried out on the leachates derived from the tailings residues after cyaniding tests and not on the dam water. Lead was detected at several points exceeding the detection limit of 0.01mg/L and ranging up to 0.03mg/L in the central valley dam (VD1R). These results exceed the ANZECC guideline of 0.01mg/L to 0.05mg/L of lead for protection of aquatic ecosystems depending on water hardness, but does not exceed the ANZECC guidelines for raw waters for drinking purposes for lead of 0.05mg/L, for irrigation waters (0.2mg/L) for livestock watering (0.1mg/L) or the SEPP Waters of Victoria limit of 0.1mg/L.

Arsenic was detected in all but one of the samples tested for Tech-Sol in concentrations ranging from 0.01mg/L to 2.7mg/L. The higher concentrations of arsenic, measured in the drain immediately downstream of the central valley dam (VD1R) substantially exceed all of the relevant ANZECC guidelines for drinking water (0.05mg/L), aquatic ecosystems (0.05mg/L), livestock watering (0.5mg/L). All of the test results indicate concentrations many orders of magnitude above the ANZECC guideline to protect consumers of fish of 0.02mg/L for arsenic, which is indicated to be based on carcinogenicity.

The levels measured in the dam on Lot 5 (Table 5B) in the tests carried out by the Department of Agriculture in March 1995 included a concentration for arsenic of 0.58mg/L which is more than ten times the ANZECC criteria for raw water for drinking purposes and for aquatic ecosystems, and also slightly exceeds the livestock guideline and SEPP limit of 0.5mg/L, as well as far exceeding the ANZECC guideline for the protection of consumers of fish. These levels also far exceed the NH&MRC and WHO drinking water criteria of 7μg/L and 10μg/L respectively for arsenic.

As there is potential for water seepage from the dams to have entered the groundwater aquifer and for other drinking water supplies to have been affected, the Department of Health & Community Services also sampled two local groundwater boreholes on Lot 1 of the recent subdivision, and Lot 7 of 3A, and the water supplied from a rainwater tank on Lot 5 to assess the potential for contamination with metals. The results of these tests are summarised in Tables 5C and 5D.

In addition to testing for arsenic and mercury, the groundwater bores were tested for total cyanides as a cyanide process appears may have been used in the valley previously. In all three cases, the results were below the detection limits set. The detection limits for arsenic and mercury were set well below the ANZECC guidelines for raw water for drinking purposes and also below the ANZECC criteria for aquatic ecosystems.

The water sample from the Dam on Lot 5 was analysed for arsenic (discussed above), cadmium, copper, iron, lead and zinc by Centaur Diagnostics. Mercury, although requested, was not reported. The results of the analyses are included in the Department of Agriculture report summarised in Table 5D. Cadmium, copper and lead levels were reported to be below detection limits, whilst the concentration for iron of 7.22mg/L exceeds the ANZECC guidelines for Raw Water for drinking purposes of 0.3mg/L, for aquatic ecosystems and irrigation waters of 1mg/L and the SEPP Waters of Victoria limit of 5mg/L. The concentration of zinc of 0.003mg/L is within all the ANZECC guidelines and the SEPP "Waters of Victoria" limit.

The various water quality criteria discussed above in the context of the quality of water samples from the mining lease, properties downstream and groundwater samples from the vicinity, are summarised for the analytes discussed in Table 6 for reference.

Background water quality in the Moorabool River system should be assessed for comparison with the above test data. However, information on background water quality in the Moorabool River Catchment is of limited extent. Central Highlands Water checks arsenic and mercury levels every 6 months in the Bostock, Lal Lal and Moorabool Reservoirs. Data for the last two years up to October 1996 indicates mercury was below the detection limit of 0.05µg/L for all the reservoirs, whilst arsenic was found to be below detection limit of 1µg/L at Lal Lal and Moorabool (except for April 95 when it was at 1µg/L in the latter). At Bostock Dam the results have varied in the range of below the detection limit of 1µg/L up to 4µg/L [61].

No data is available for background levels in the rest of the Moorabool System. However, a study done by a student (Isobelle Lamb) for an MSc thesis in collaboration with staff at the University of Ballarat was summarised in a paper to the First International Convention on Contamination in the Soil Environment "Dispersion of Arsenic in Soil and Water of the Ballarat Goldfield, Victoria" by I A Lamb, M J Hughes and C E Hughes [54]. This study indicated that concentrations of arsenic in the Barwon river system, fed by run off from the vicinity of Ballarat initially into the Yarrowee Creek, is highly influenced by run off from gold mine sites, being of the order of 70µg/L above, to several hundreds of micrograms per litre immediately below the mine de-watering point into the Yarrowee. The concentration in the Yarowee reduces to less than 50µg/L where it leaves the goldfields, to 24µg/L in the Leigh river, and 14µg/L and less in the Barwon River. This is attributed by Lamb & Hughes to a dilution effect as all feeder tributaries are at background concentration levels below the detection limit of 5µg/L.

The results discussed by Lamb and Hughes would appear to be consistent with the levels indicated by Highlands Water for the reservoirs in the adjacent Moorabool system that is fed from tributaries sourced in the Mount Egerton Area (Paddock Creek) and from the Gordon and Ballan goldfields area.

4.3 LOCAL FISH & AQUATIC BIOTA

Analyses were carried out by Department of Health & Community Services on fish samples recovered from dams located in the study area, the tailings dam "near the mining lease" and also from the property dam on Lot 5 as described by the H&CS. The fish samples were collected by H&CS and sent for analysis on 4 July 1995. The results of the analyses are summarised in Table 7 and are discussed below.

Arsenic is most toxic in its inorganic form and analyses of concentrations report both inorganic and organic forms of arsenic. Concentrations of arsenic in tissues of the yabbies taken from the dam (downstream from the tailings dam), and in fish stomachs (presumably the stomach contents of the fish) were approximately 50% in inorganic form. In both yabbies and fish stomach contents, concentrations exceeded The Australian Food Standards code (1µg/g). Arsenic concentrations in fish tissue were below the food standard. Thus arsenic may be accumulating in crustacean and insect tissue (assuming stomach contents of the fish tested were insects) but not necessarily taken up by the fish.

The data are too limited to draw any firm conclusions and it must be remembered that there is no information to assess whether the levels observed are elevated above background (due to mining) or not. We know of no background levels in fish relevant to this area. However, concentrations of arsenic in water and yabby tissue indicate that there are risks to aquatic ecosystems and to livestock regardless of source, and also risks to human health from consumption of yabbies.

Data from "Water Victoria - an Environmental Handbook" indicates that fish in Bostock Reservoir include brown trout, English Perch (redfin), roach, goldfish, tench. If trout are fished for food, samples should be tested for arsenic.

The levels of mercury in the fish flesh tested are marginally above the Australian Food Standards Code (0.5μg/g). However, these levels are not infrequently encountered in fish (Nicholson et al. 1992) and unless redfin are consumed regularly, risks to humans from consumption of the fish at these concentrations of mercury is likely to be low. This is discussed further in Section 5 on the results of the risk assessment.

Cyanide was not detected in the tissues tested. Since it does not normally accumulate, there does not appear to be any current problem related to cyanide.

In assessing the potential for other adverse effects to eco-systems, it must be noted that at a concentration of 0.048mg/L of arsenic, levels for toxicity to algae would be well exceeded. The arsenic seems to be picked up by crustaceans and insects (assuming that fish stomach contents comprise mainly insects) but is not necessarily transferred to fish flesh. This may result if it is converted to the non-toxic organic form.

If the arsenic is associated with old gold tailings, it is most likely in the form of arsenopyrite (Fe As S). The arsenic speciation depends on pH, oxidation and organic content. If soils and river sediments are clay, this can help to bind and immobilise the arsenic and therefore reduce bioavailability. However, construction of dams across the stream or dredging could re-mobilise the available arsenic in the sediments as indicated by the leachate tests performed on behalf of Tech-Sol.

No data was made available for this investigation that could indicate whether biota are affected further downstream in Paddock Creek or in the Bostock Reservoir, and review of the information in the "Arsenic in the Environment" report did not list any fish data for the East Moorabool River. As the Bostock Dam does fluctuate in arsenic concentration and forms a water supply for Geelong, some consideration should be given to upstream and downstream sampling to assess the potential for wider off-site adverse environmental effects.

4.4 HORSE & CATTLE DATA LOT - 5

The detailed histories of some of the horses that have been located on Lot 5, before the tailings type soils were fenced off, as related by the owners of Lot 5 are indicated in Appendix C. This history is presented as supplied by the owner of Lot 5 and has not been independently verified or confirmed.

A summary of analyses completed on behalf of the Department of Agriculture on specimens from the horses from the property is summarised in Table 8. Tests carried out for the H&CS on meat samples preserved by the owners of Lot 5 from a slaughtered calf (1 year old) are also discussed.

The analytical results for the horses were reported by the Department of Agriculture from tests completed by Centaur Analytical [9]. All of the horses, except for one, indicated significant levels of arsenic in hair samples, which tends to indicate long term exposure to arsenic. However, the horses were also washed with water from the dam and external contamination from contaminated water and dust from the paddock is also possible.

Two horses on the property had to be destroyed. The autopsy on the first horse appears to have been inconclusive as heavy metal poisoning was not suspected at that time and therefore not assessed. The stomach and other organs of the second horse to be destroyed (Princess - a 12 month old foal) were tested on behalf of the owners by Centaur International for arsenic. Approximately 0.5mg/kg of arsenic was detected in the stomach content but none in the kidney or liver. Histological slides were also examined and discussed in the report. It is understood that the second horse was isolated from the affected area for some time prior to being destroyed. If this was the case, then the residual levels in the stomach contents may not fully represent previous levels of exposure.

The results of tests on meat from the calf slaughtered recently initially indicated a presence of mercury in muscle tissue and kidney. The arsenic levels were below detection limits. As the accuracy of these results was in doubt, they were repeated by H&CS on new samples. The repeated tests showed mercury levels were at below detection limits in meat from the same animal, which tended to confirm the initial conclusion that the first results were doubtful.

It must be noted that various dietary supplements had been added to the horses feed during the period when the possible causes of their illness was not fully known and also when selenium deficiency was suspected. Various fertilisers were also added to the soils on the Lot 5 property. These materials and supplements are also indicated in Appendix C as presented by the owners of Lot 5.

4.5 VEGETABLE DATA (LOT 5)

Samples of vegetables grown in a vegetable garden on Lot 5 were analysed for arsenic by Dunn Son & Stone on behalf of the H&CS. The vegetable samples were washed and homogenised before testing. No other details were supplied. Only arsenic was analysed and was found to be below the detection limit set at 0.1mg/kg. This must be seen in the context of the soils from the vegetable garden having the lowest arsenic content (80mg/kg) of those tested on behalf of the Department of Agriculture. The results of vegetables analyses are included with the fish data in Table 7.

4.6 HUMAN DATA

During the course of the study by the Department of Health and Community Services, some data on human samples were also collected. An adult female living on one of the properties was found to have blood mercury level of 0.03µmol/L, and arsenic was below the set detection limits set. However, hair samples in the adult female and a male subject were found to contain 0.03 and 0.07 ppm of arsenic respectively. Both subjects have reported various medical problems.

The blood mercury level of 0.03µmol/L, however, compares with the biological exposure index (defined as the concentration of mercury in blood that is likely to result from inhalation exposure to the time weighted average TLV (TLV - TWA)) for workers in the US of 15µg/L or 0.07µmol/L. This NOAL is not much greater than the blood level recorded at Mount Egerton, but is a conservative measure frequently exceeded in asymptomatic workers in the US.

For comparison, a typical blood level of mercury in people consuming low-fish diets is 6µg/l or 0.03µmol/L (the same as was observed at Egerton). People consuming a moderate amount of fish have around 50µg/L (0.25µmol/L), and those eating a large amount of ocean fish have around 200µg/L (1µmol/L). Thus, it appears that the Mount Egerton sample does not indicate excessive mercury exposure (Baselt R C, 1988) [62].

Arsenic levels in hair for non-occupationally exposed people have been quoted as follows:

- WHO — <1ppm
- International Agency for research on Cancer — <3ppm
- Casarett and Doulls toxicology — <5ppm
- Amcosh — <2.25ppm

(Source Vic Department of Health)

Arsenic levels in the hair of non-occupationally exposed people are usually less than 2mg/kg (two orders of magnitude higher than reported for Mount Egerton). Thus, the observed levels do not appear to indicate excessive As burdens. It should be noted that hair measurements, which are indicative of historical rather than recent exposure, are difficult to interpret due to their lack of distinction between internal and external sources (Valentine J L, 1979)]63].

4.7 ANIMAL INGESTION RATES

As part of the literature survey into bioavailability of arsenic and mercury in the contaminants, it was also necessary to research and assess likely ingestion rates for water and soils in animals that are located on affected properties.

4.7.1 Water Ingestion Rates

Daily intake of water for cattle and horses, as indicated in the ANZECC water quality guidelines, are summarised in Table 9 and have also been reported from other sources reviewed for this study.

4.7.2 Ingestion of Soils by Grazing Animals

Daily intake of soil by horses is not well known although there are a number of sources of information about intake of soil during feeding by cattle and sheep from various parts of the world. This is summarised in Table 10. The owners of Lot 5 reported that the horses also deliberately ate the exposed tailings in a form of equine PICA.

The Department of Agriculture (Dr John Larsen) has indicated that it is feasible for up to 4kg or 5kg per day to be ingested by horses or cattle at some times of the year [22]. No references have been found to substantiate this figure for horses, however a number of sources make reference to sand colic due to direct ingestion of sandy soils during grazing being a familiar problem with horses in some parts of the world.

As part of this study, in addition to the literature survey on the toxicity and bioavailablity of arsenic and mercury in humans and animals, a further review and literature survey was carried out for available information on the ingestion of soils by grazing animals and the associated potential for absorption of metals from the soil.

Direct ingestion of metals in the soils is a potentially significant exposure route in stock animals on contaminated properties. Research in this area is relatively sparse with regard to horses, but is relatively extensive for sheep and cattle, and experimental techniques for estimating soil intake in sheep and cattle were pioneered in the 1960s and 70s by W B Healey in New Zealand (1965, 70, 73) [references 24, 25, 27). Subsequent work has been completed on ingestion of soils by both sheep and cattle in a variety of climates; by Mayland et al (1975 and 1976) in USA [31, 32]; Suttle, Thornton & Abrahams (1981 & 1983) in the UK [28, 29]; McGrath et al in Eire (1982) [26]; Langlands et al in Australia (1979) [33]; Statham & Bray in Tasmania (1975) [34] and by Vaithiyanathan and Singh (1994) in Rajput in India [36] and others listed in the references attached. Ingestion rates for sheep and cattle reported by these authors are summarised in Table 10.

From the studies reviewed, the total soil ingested by large grazing animals was found to be highly variable depending on many interrelated factors including, climate, seasonal factors, pasture quality, stocking rates and management. However, a number of common factors are apparent in all these studies. In all cases the ingestion of soils was found to be highly seasonal. In some studies soil ingestion was found to peak over a relatively short period of time or in a single month.

Ingestion Rates quoted include the following:

- Cattle & Horses - [22] Dr John Larsen - up to 4kg/day to 5kg/day during dry weather, seasonally variable.

- Cattle - [24] Healy & Drew - New Zealand - 1970 - 0.4kg to 1.8kg per cow per day - seasonally variable.

- Sheep - [26] McGrath et al - Eire - 1982 - up to 400g total ingestion of soil per kilogram of bodyweight over the period from May to early November (presumably the drier summer period in Ireland therefore possibly similar to a Victorian summer climate).

A summary of ingestion rates is included in Table 10.

The foregoing appears to be confirmed from available veterinary texts (Hungerford 1990 [40]) where a long history of poisoning of animals by arsenic in Australia is discussed. Although these cases refer to acute cases of poisoning and usually relate to animals gaining access to arsenical chemicals used for dipping or for protecting timber, Hungerford does report that, "on the coastal belt of NSW, cattle generally suffer from mineral deficiency and relish the taste of arsenic. Many cattle inland also seem to relish the taste. As a result, poisoning in cattle is very common. Sheep are less frequently but often affected, and horses occasionally."

The residents of Lot 5 indicated that their animals appeared to be attracted to the mine tailings for some reason and would eat it in quantities.

Hungerford also indicates that, in chronic cases of poisoning with arsenic, "there may be emaciation, loss of appetite, swelling of joints, increasing weakness and death". These are symptoms that could describe those experienced by horses on Lot 5 (see Appendix C).

The reason for a high season of ingestion of relatively short duration is thought by various authors to result from the attraction of animals to fresh new shoots of grass that appear after the first rains following dry periods. With grazing otherwise in short supply, the new grass is pulled out roots and all together with the shallow soil. This appears to be more prevalent in sandy soils than in clay.

Hungerford [40] in discussing colic in horses refers to sand colic as a serious and recurring problem in sandy areas and refers to an article by McErlean (1986) which he quotes: "Our sand colic season starts 7 to 10 days after the first winter rains, when new grass is emerging, is poorly rooted, and half starved horses are eagerly pulling up roots and all. The season lasts six weeks and that's it! Occasional cases appear in spring and summer or after summer rain".

5. HUMAN HEALTH RISK ASSESSMENT

5.1 APPROACH

The human health risk assessment methodology generally follows the Australia and New Zealand Environment and Conservation Council (ANZECC) and Australian National Health and Medical Research council (NHMRC) approach, based on:

- World Health Organisation (WHO) toxicological parameters. These are the Maximum Tolerable Daily Intake (TDI) or Maximum tolerable Weekly Intake (TWI), as published by WHO (WHO/IPCS, 1981, 1990, 1991) and defined in the Draft Australian Drinking Water Guidelines (NHMRC/AWRC, 1994).

- ANZECC & NHMRC Guidelines for the Assessment and Management of Contaminated Sites (1992) and the documents entitled The Health Risk assessment and Management of Contaminated Sites (Saadi & Langley, 1991 [41] and Langley & Van Alpen, 1993 [42] and Langley, Markey & Hill, 1996 [44]).

Due to data limitations, and the relatively poor statistical base, a range of assumptions concerning the exposure of the population and individuals has been examined, and the sensitivity of these assumptions has then been assessed and discussed.

5.2 CHEMICAL CONCENTRATIONS

Chemical concentrations have been assessed from sampling results where available, and as set out in Tables 1 to 8. The concentrations adopted for risk assessment are summarised in Tables 11 and 12.

Tailings Material

Sampling data for chemical concentrations in tailings material are available from a variety of sources as set out in Tables 1 to 4. The data provided in Table 1A (Tailings Assay) and Table 2 (EPA Samples) are consistent, and appear to provide a reasonable statistical base. As discussed in Section 4, these tables indicate that only Arsenic and Mercury concentrations significantly exceed ANZECC (B) Environmental Investigation Levels, and are the principal chemicals of concern. A statistical summary of the Tailings Assay and EPA sampling results for tailings material is given in Table 11. Results for samples likely to be non-tailings material have been excluded from the statistical analysis.

The EPA samples covering the widest area are located on the residential properties, and are therefore judged to be most representative of the range of conditions in the residential area. the arithmetic mean concentrations of the EPA sampling results have been accepted as representative of concentrations of arsenic and mercury in tailings material for the risk assessment as follows:

- Arsenic 495mg/kg
- Mercury 4.3mg/kg

Health risks associated with contamination in mine tailings will be influenced by the land areas covered by tailings material within individual properties, types and patterns of activity and the amount of time spent in tailings affected areas by individuals living and working on those properties.

Figure 3 shows the estimated distribution of tailings material in the area. As would be expected, this shows that the areas affected by tailings are confined to the vicinity of the old mining areas and Paddock Creek downstream. Individual properties in the vicinity of the mine areas and creek contain some areas of tailings, but these generally do not exceed 25% of the total property area.

Since there is no control over the possible current and future locations of houses or facilities on the properties, for a conservative worst case scenario, the distribution of tailings on individual properties was neglected. This provides for the situation in which children might consistently play in a favourite area - which could be the tailings sands.

Drinking Water

Concentrations of arsenic and mercury in waters are set out in Tables 5A to 5D. Although concentrations in dams and ponds significantly exceed guidelines, arsenic and mercury were not detected in samples of groundwater from bores, or in drinking water on Lot 5. It is considered that human consumption of water from dams would be unlikely or occasional. Therefore, in order to assess the sensitivity for risk assessment purposes, the following small finite concentrations equal to the relevant guidelines in drinking water have been assumed:

- Arsenic 0.002mg/L
- Mercury 0.0005mg/L

Local Fish and Yabbies

Limited sampling of local fish and yabbies from ponds and dams has been undertaken, and indicates concentrations of both arsenic and mercury in excess of NH&MRC standards. Available data are summarised in Table 7, although the data are too limited to indicate source. In assessing this information, data values for the stomach contents of fish which would not normally be consumed are excluded Similarly, in the case of arsenic, the organic form is neglected due to its limited toxicity.

Based on this limited information, the following concentrations in local fish and yabbies have been adopted for risk assessment purposes:

- Arsenic (inorganic) 0.3mg/kg
- Mercury 0.5mg/kg

These values allow for consumption of about 80% fish to 20% yabbies in a typical diet as indicated by the Fisheries Research and Development Corporation (FRDC, 1992). However, it should be noted that the database is very limited, and inquiries suggest that local yabbies may be regularly consumed by some individuals or families in different proportions.

Cyanide

Although cyanide has been used in mine processing, it has not been detected from limited sampling. Significant degradation of any cyanide residues is likely to have occurred over the 30 years since the mines were active. Cyanide toxicity has not therefore been quantified in the risk assessment.

5.3 QUANTIFICATION OF EXPOSURE

5.3.1 Exposure Pathways

The following exposure pathways have been considered for quantification of exposure:

- Ingestion of contaminated soil through contact when in areas of tailings material.
- Ingestion of water from drinking water supplies, excluding contaminated dams and ponds.
- Inhalation of contaminated particulates in dust.
- Ingestion of arsenic and mercury in the normal diet, excluding local fish and yabbies.
- Ingestion of local fish and yabbies.

Absorption of arsenic and mercury through the skin has not been quantified due to absence of objective data on dermal absorption. Normally, dermal absorption of heavy metals in soil is not a significant risk factor relative to other pathways.

5.3.2 Quantification of Exposure

The parameters involved in quantification of exposure are listed in Table 12, and the methodology is described below.

Soil Ingestion

Quantification of exposure by soil ingestion is based on ANZECC/NHMRC guidelines for the management of contaminated soils of 25mg of soil per day for adults and 100mg of soil per day for a child in the age range 1 to 5 (ANZECC & NHMRC, 1992). A small proportion of young children may ingest considerably larger quantities of soil (a condition known as PICA). This is an exceptional case which has not been quantified. The calculation of exposure by soil ingestion is based on the following equation:

$$I = \frac{CS \times IS \times BA \times 10^{-6}}{BW}$$

where

I = Intake of contaminant chemicals (mg/kg/day)
CS = Chemical concentration in soil (mg/kg)
IS = Soil ingestion rate (mg soil/day)
BW = Body weight (kg)
BA = Bioavailability factor

The bioavailability factor is subject to uncertainty General evidence suggests that binding of chemicals to soil particles will reduce absorption in the gastro intestinal tract depending on soil characteristics and chemical speciation. In this case, the sandy tailings soils are anticipated to provide some degree of chemical binding to the soil structure. The setting of bioavailability factors for this study is discussed in Appendix D and summarised as follows:

Arsenic

Results from animal studies using monkeys indicate arsenic bioavailability in soil ranging between 9% to 28% (Freeman et al, 1993 and Groen et al 1994). Based on these results, a conservative oral bioavailability factor of 20% has been used for this risk assessment.

Mercury

There is less information available regarding the bioavailability of mercury in soil. A recent study to determine the bioavailablity of mercury in floodplain soils indicated a value of 5.3% (Barnett and Turner, 1996). Based on this result a conservative oral bioavailability of 10% has been used for this risk assessment.

Water Ingestion

Quantification of exposure by water ingestion is based on ANZECC/NHMRC guidelines of 2L of water per day for adults and 0.66L of water per day for a child in the age range 1 to 5 (ANZECC & NHMRC 1992).

The calculation of exposure by water ingestion is based on the following equation:

$$I = \frac{CS \times IW \times BA}{BW}$$

where I = Intake of contaminant chemicals (mg/kg/day)
CS = Chemical concentration in water (mg/L)
IW = Water ingestion rate (L water/day)
BW = Body weight (kg)
BA = Bioavailability factor, assumed to be 100% for water

Inhalation of Particulates

Quantification of exposure by inhalation of particulates in dust is based on ANZECC/NHMRC guidelines of 20m3 of inhaled air per day for working adults and 5m3 of inhaled air per day for a child in the age range 1 to 5 (ANZECC &NHMRC, 1992). Data on average dust levels in the air in the study area are not available. An assumed maximum value of 0.02mg/m3 has been used to assess the significance of dust inhalation as a risk factor.

The calculation of exposure by inhalation of particulates in dust is based on the following equation:

$$I = \frac{BR \times IP \times CS}{BW}$$

where I = Intake of contaminant chemicals (mg/kg/day)
BR = Breathing Rate (m^3/day)
IP = Dust concentration in air (mg/m^3)
BW = Body weight (kg)
CS = Chemical Concentration in Dust (mg/kg)

Ingestion in Fish and Yabbies

There is some evidence that some local people regularly supplement their diet from yabbies and fish in the dams. Quantification of exposure by ingestion in local fish and yabbies is based on USEPA average recreational fish consumption rates of 30g of fish/yabbies per day for adults and assumed value of 5g per day of fish/yabbies for a child in the age range 1 to 5.

The calculation of exposure by ingestion of fish/yabbies is based on the following equation:

$$I = \frac{CS \times IF}{BW}$$

where I = Intake of contaminant chemicals (mg/kg/day)
CS = Chemical concentration in fish/yabbies (mg/kg)
IF = Consumption rate of fish/yabbies (kg/day)
BW = Body weight (kg)

Ingestion in Normal Diet

Quantification of exposure by ingestion in normal diet is based on data for average Australian dietary intake obtained from the Market Basket Survey (NHMRC/NFA, 1990). The survey data indicate the following dietary intakes:

- Arsenic   Adult - 0.04mg/day   Child - 0.012mg/day
- Mercury   Adult - 0.004mg/day   Child - 0.0005mg/day

The calculation of exposure in normal diet is based on the following equation:

$$I = \frac{DI}{BW}$$

where I = Intake of contaminant chemicals (mg/kg/day)
DI = Dietary intake (mg/day)
BW = Body weight (kg)

As the occupants of Lot 5 indicated that they are reliant on home grown produce for much of their intake, this was also researched for this study. However, the data on vegetables grown on Lot 5 and meat samples, did not indicate additional potential exposure above the Australian average, although this could vary if cattle grazed and vegetables were grown in the tailings affected areas.

The calculation of intakes of arsenic and mercury for a range of exposure assumptions are presented in Appendix F.

5.4 TOXICITY ASSESSMENT

The toxicity assessment determines the relationship between the magnitude of exposure to a chemical and the probability of adverse health effects. The magnitude of exposure to chemicals present in the tailings material is discussed in Section 5.3. Toxicity assessment evaluates the types of toxic effects and the magnitude of adverse health effects potentially associated with those chemicals. The results of the exposure assessment and toxicity assessment are then combined to characterise the likely health risks associated with the chemicals present. The risk characterisation is presented in Section 5.5.

Health effects have been evaluated using World Health Organisation (WHO/IPCS, 1981, 1990, 1991 [47 - 49]) toxicological parameters, in line with Australian practice as defined by NHMRC. The key WHO parameter is the Preliminary Tolerable Weekly Intake (PTWI), from which, the Tolerable Daily Intake (TDI) is derived by dividing by seven. For this assessment, the values of PTWI or TDI are taken from the Australian Drinking Water Guidelines (NHMRC/AWRC, 1996 [45]). In general the PTWI is an estimate (with uncertainty spanning perhaps an order of magnitude) of an aggregate weekly exposure to the human population that is likely to be tolerated without appreciable risk of adverse effects during a lifetime. PTWI values are estimated where possible from human epidemiological studies, or otherwise by applying a safety factor (ranging between 10 and 1,000) to a No Observable Adverse Effects Level (NOAEL) derived from animal studies.

The TDIs for arsenic and mercury are summarised in Table 13, and the human toxicology of each chemical is briefly summarised below. Further details of the toxicology of arsenic and mercury are given in Appendix D.

Arsenic

- Arsenic is difficult to characterise toxicologically because its chemistry is complex and there are many different compounds which affect its toxicity. The inorganic forms are generally more toxic than the organic forms.

- The carcinogenic nature of arsenic has not been confirmed by animal studies, but arsenic has shown tumour promoting activities in animals. It did not exhibit mutagenic activity in tests with bacterial or mammalian cells, but chromosome damage has been reported. The International Agency for Research on Cancer (IARC) has concluded that arsenic is carcinogenic to humans (Group 1, sufficient evidence)

- A number of epidemiological studies have looked at the effects of drinking water with high concentrations of arsenic. These showed the principal health effects of long term exposure to arsenic to be skin lesions, skin cancer, vascular disease, effects on the nervous system and possibly cancer of other organs.

- Arsenic is concentrated by many species of fish and shellfish, and is present in poultry and livestock. Concentrations in vegetables are usually an order of magnitude lower than those found in fish and meat. A major portion of the arsenic in fish is present in highly complexed forms that are biologically unavailable, or as simple organic compounds which are essentially non-toxic.

- The average Australian dietary intake of arsenic is 0.04mg/day.

Further discussion on Arsenic is included in Appendix F.

Mercury

- Mercury compounds fall into two categories: inorganic mercury salts, and organic mercury compounds, notably methyl mercury. Inorganic mercury can be converted to methyl mercury in natural systems, where it readily enters the food chain.

- Inorganic mercury compounds accumulate in the kidney. Many studies have reported health effects including tremors, mental disturbance and gingivitis. The main toxic effects are to the kidney, leading to kidney failure. In animal studies, the principal target organs are the kidney and central nervous system. Various reports indicate that inorganic mercury may damage mammalian DNA. There is some evidence of carcinogenicity in rats.

- Organic mercury compounds are more toxic than the inorganic compounds. Methyl mercury compounds are almost completely absorbed by the gastro-intestinal tract and have greater lipid solubility than the inorganic compounds, allowing them to cross biological membranes. The main effects of methyl mercury are severe neurological disorder and mental disability.

- In Japan, two major epidemics of methyl mercury poisoning, known as Minamata disease were caused by industrial release of methyl mercury and other mercury compounds into Minamata Bay. The compounds accumulated in fish which were then eaten by humans.

- Data are insufficient to determine the carcinogenic effects of methyl mercury. However, it is active in inducing chromosomal aberrations in vivo.

- The maximum tolerable daily intake from all sources to ensure no adverse health effects is 0.00033mg/kg/day. This guideline is based on the toxicity of methyl mercury, which is the most toxic form. This guideline value should be sufficient to protect pregnant women and nursing mothers, who are at greatest risk from the adverse effects of methyl mercury.

5.5 RISK CHARACTERISATION

Characterisation of risks involves combining the results of toxicological and exposure assessments to provide numerical estimates of health risk. These estimates are comparisons of exposure levels with the recommended maximum tolerable intakes. Risk characterisation also considers the nature and weight of evidence supporting these risk estimates, as well as the magnitude of uncertainty surrounding such estimates. The risk calculations are shown in Appendix F and the results are summarised in Table 14. The results are discussed below.

There has been no allowance in these calculations for the difference between contaminated and uncontaminated portions of the properties. This is because future land use could change along with house positions, fence lines, etc. and some future occupants could therefore be exposed to the contaminated areas up to 100% of the time.

Sensitivity Analysis

Due to the relatively weak database, and uncertainty with regard to the possible variability of exposure between individuals, health risks were assessed for a two scenarios covering a spectrum of conditions which could apply in the area:

Scenario A (Cases 1 to 4)

Scenario A represents the highest range of combined risk factors. This scenario combines the arithmetic mean concentrations of arsenic and mercury in tailings material with regular consumption of contaminated local fish.

Scenario B (Cases 4 to 8)

Scenario B represents a medium range combination of risk factors. This scenario combines the arithmetic mean concentrations of arsenic and mercury in tailings material but no consumption of contaminated local fish.

Each scenario requires risk estimates for four separate cases - arsenic and mercury, and for adult and child receptors respectively. The risk calculations are presented in Appendix F. No separate scenario for residents exposed to tailings exported from the site has been considered as each such situation should be considered on its own merits depending on individual circumstances. Current evidence is that the contaminated tailings have been taken as construction or landscaping materials and could have been used for children's sandpits. It is therefore possible to assume that some children under 5 could be consistently exposed to tailings material removed from the site.

Risk Calculations

The top section of each calculation in Appendix F lists the exposure parameters and assumptions, and the applicable toxicity value (tolerable daily intake) for each case. The lower section of each calculation details the calculated risk in terms of chemical intake by each exposure route, intake as a proportion of total intake, intake as a proportion of tolerable intake, and corresponding totals.

The key risk parameter, is the calculated ratio of total intake to tolerable daily intake (TDI) indicated at the bottom of each calculation. Calculated ratios significantly in excess of 1.0 are indicative of potential health risks.

5.6 RESULTS

The results of the calculations are summarised in Table 14. The results show that for the parameters adopted for the assessment, no health risks are indicated for adults or children in any of the cases considered. Consumption of local fish and yabbies is not indicated as a significant risk factor.

Soil Contamination Hazard Threshold

Threshold concentrations of arsenic and mercury in soil which would be acceptable for children (the most sensitive receptor) were assessed by trial and error calculations, to obtain a ratio of intake to tolerable intake of 1.00. This gave soil concentrations figures of 650mg/kg for arsenic and 350g/kg for mercury.

Uncertainty Factors

There is a high degree of uncertainty in several of the parameters used in the assessment. These include:

- Variability in Arsenic Concentrations

The arsenic concentration of 495mg/kg used for the assessment is based on the arithmetic mean of 11 EPA samples. Concentrations in some individual samples were over 1,000mg/kg, considerably exceeding the estimated threshold hazard concentration of 650mg/kg. Local hot spots could present health risks.

- Bioavailability Factors

Bioavailability is critical in determining the absorption of metals from soil in the gut. This assessment used factors of 20% for arsenic and 10% for mercury. These factors are based on limited animal studies and are likely to be site specific depending on local chemical speciation and soil types.

- Arsenic in Fish and Yabbies

Based on the parameters used in this assessment, consumption of local fish and yabbies does not appear to be an important risk factor. However, the database is extremely limited. One yabbie sample showed a concentration of arsenic three times higher than the value adopted for this assessment, and consumption patterns of fish and yabbies are not known.

5.7 HUMAN HEALTH RISK CONCLUSIONS

1. The assessment indicates that the average arsenic and mercury contamination in tailings material is unlikely to present health risks to adults or children.

2. Arsenic hot spots (if any) with concentrations exceeding 650mg/kg could present health risks to children.

3. The assessment is subject to a degree of uncertainty with respect to the following main factors:

   - variability in arsenic concentrations in the tailings;
   - bioavailability factors; and
   - limited information on arsenic concentrations in fish and yabbies

Further sampling of arsenic concentrations in tailings material, and in fish and yabbies from local dams, is recommended to improve the reliability of these factors and define their variability.

6. ANIMAL HEALTH RISK ASSESSMENT

6.1 APPROACH

The animal health risk assessment generally follows a similar methodology to the human health risk assessment discussed in Section 5, and is based on a range of international references with emphasis on the USA and Australasia. This approach involves:

- Estimation of the intake by animals of the chemicals of concern through various routes and media, including ingestion of soil, food and water

- Research on toxicological parameters for farm animals defining the maximum tolerable daily intake of those chemicals

- Comparison between estimated intakes of chemicals, and tolerable intakes, to assess potential health risks.

By comparison with the human health risk assessment, the parameters required for the assessment of the animal health risk are poorly defined. Consequently, there is considerable uncertainty in the results. Further studies are suggested to improve the reliability of the animal health risk estimates.

6.2 CHEMICAL CONCENTRATIONS

Chemical concentrations in soil and water adopted for animal health risk assessment are the same as those used for the human health risk assessment and are summarised in the human health risk report (Tables 1 and 2).

Tailings Material

Sampling data for chemical concentrations in tailings material are available from a variety of sources as set out in Tables 1 to 4. The data provided in Table 1A (Tailings Assay) and Table 2 (EPA Samples) are consistent, and appear to provide a reasonable statistical base. As discussed in Section 4, these tables indicate that only Arsenic and Mercury concentrations significantly exceed ANZECC (B) environmental investigation levels, and are the principal chemicals of concern. A statistical summary of the Tailings Assay and EPA sampling results for tailings material is given in Table 11. Results for samples likely to be non-tailings material have been excluded from the statistical analysis.

The EPA samples cover the widest area and are judged to be most representative of the range of conditions in the area. The arithmetic mean concentrations of the EPA sampling results have been accepted as representative of concentrations of arsenic and mercury in tailings material for the risk assessment as follows:

- Arsenic 495mg/kg
- Mercury 4.3mg/kg

For animal health risk assessment, no area weighting factors were applied to chemical concentrations in tailings material. The animal risk assessment therefore only applies to animals which spend the majority of their time in tailings affected areas. This is justified where the farms are small and grazing is generally more abundant in the lower lying areas next to Paddock Creek.

Water Supplies

Concentrations of arsenic and mercury in surface water are set out in Table 5A and 5B. The Tech-Sol results (5A) show the majority of arsenic concentrations in the range 0.01mg/L to 0.10mg/L, with an average of 0.06mg/L excluding one exceptionally high value for sample VD1R of 2.7mg/L. Mercury concentrations for the same samples averaged 0.001mg/L. One water sample from a dam in the Lot 5 property (5B) showed a higher arsenic concentration of 0.58mg/L.

Due to the relatively small data base, peak concentrations were used to represent potential water sources for farm animals:

- Arsenic 0.58mg/L
- Mercury 0.0012mg/L

The potential effects of high concentrations of arsenic in water, as detected on the Lot 5 property and in the tailings dams, are discussed in Section 6.5. The higher concentrations detected in sample VD1R from the tailings dam outlet have been discounted for the risk assessment due to the reasons given in Section 6.5.

6.3 QUANTIFICATION OF EXPOSURE

6.3.1 Exposure Pathways

The following exposure pathways have been considered for quantification of exposure to farm animals:

- Ingestion of contaminated soil in areas of tailings material. This occurs either when animals consume grass with fragments of adhering soil, or during reported licking of tailings material which may be related to the development of a taste for arsenic.

- Ingestion of water from drinking water supplies including dams and ponds.
- Ingestion of arsenic and mercury in the normal diet of grass and other natural or cultivated vegetation due to uptake of heavy metals from the soil, in the vegetation.

Possible other exposure pathways include inhalation of contaminated dust, and absorption of arsenic and mercury through the skin. These pathways are considered likely to be of minor influence in comparison to the other pathways and have not been quantified.

6.3.2 Quantification of Exposure

The parameters involved in quantification of exposure are listed in Table 15, and the methodology is described below.

Soil Ingestion

- Rates of Ingestion

  Table 10 summarises the data from various references concerning ingestion of soil by farm animals. For horses, reports indicate rates as high as 5kg/day for short periods typically during early spring when the grass is short. The patterns for other farm animals are reported to be similar. Based on the data in Table 11, the following typical average ingestion rates (over the year) have been adopted for the quantification of exposure by soil ingestion:

–	Horses	1.0kg/day
–	Cattle	0.7kg/day
–	Sheep	0.1kg/day

- Bioavailability

  The bioavailability of heavy metals in the soil significantly reduces the rate of absorption through the gut. Based on limited available references and professional judgement, the values of bioavailability for arsenic and mercury in soil used for this assessment are :

–	Arsenic	11%	(Davis et al, 1992)
–	Mercury	10%	(based on Barnett & Turner 1996)

  Calculation of exposure by soil ingestion is based on the following equation:

$$I = \frac{CS \times IS \times BA}{BW}$$

where
- I = Intake of contaminant chemicals (mg/kg/day)
- CS = Chemical concentration in soil (mg/kg)
- IS = Soil ingestion rate (kg soil/day)
- BA = Bioavailability factor
- BW = Body weight (kg)

Further details on the derivation of bioavailability factors and associated references are provided in Appendix E. It is important to note that bioavailability depends on chemical speciation which will be controlled by local environmental factors, and is likely to be highly site specific.

Water Ingestion

Quantification of exposure by water ingestion, from figures provided in Table 9 (ANZECC), is based on the following daily water consumption rates:

- Horses 60L/day
- Cattle 70L/day
- Sheep 5L/day

The calculation of exposure by water ingestion is based on the following equation:

$$I = \frac{CS \times IW}{BW}$$

where
- I = Intake of contaminant chemicals (mg/kg/day)
- CS = Chemical concentration in water (mg/L)
- IW = Water consumption rate (L water/day)
- BW = Body weight (kg)

This equation assumes conservatively that the bioavailability of dissolved arsenic and mercury in water is 100%.

Ingestion in Normal Diet

Contaminants are ingested in the normal diet of grass and other natural or cultivated vegetation due to uptake of heavy metals from the soil, in the vegetation. Quantification of exposure by ingestion in normal diet includes a factor for the uptake of chemicals from the soil. For this assessment, an uptake factor of 4 % has been adopted (Baes et al, 1984).

The calculation of exposure in normal diet is based on the following equation:

$$I = \frac{DI \times U \times CS}{BW}$$

where I = Intake of contaminant chemicals (mg/kg/day)
DI = Dietary intake (kg/day)
U = Factor for uptake of contaminants by vegetation
BW = Body weight (kg)
CS = Concentration in soil(mg/kg)

This equation also assumes that the bioavailability of arsenic and mercury in vegetable matter is 100%. The plant uptake factor remains uncertain. A study conducted by Thorton & Abrahams in Great Britain (1981) [29] concluded that uptake of arsenic in the aerial parts of plants is very low, and in some cases would therefore constitute a relatively minor exposure factor in farm animals.

6.4 TOXICITY ASSESSMENT

The toxicity assessment determines the relationship between the magnitude of exposure to chemical and the probability of adverse health effects in the animals. The magnitude of exposure to chemicals present in the tailings material is discussed in Section 6.3. Toxicity assessment evaluates the types of toxic effects and the magnitude of adverse health effects potentially associated with those chemicals. The results of the exposure assessment and toxicity assessment are then combined to characterise the likely health risks to the animals associated with the chemicals present. The risk characterisation is presented in Section 6.5.

Health effects on animals have been evaluated using toxicological parameters for horses obtained from a literature search. Different equivalent terms are used in the literature including the Reference Dose (RfD) and Toxicity Reference Value (TRV). For purposes of simplicity in this report, these toxicity parameters are referred to collectively as the Maximum Tolerable Daily Intake (TDI), using the WHO human health risk terminology. In general the TDI is an estimate (with uncertainty spanning perhaps an order of magnitude) of an aggregate daily exposure to the animal that is likely to be tolerated without appreciable risk of adverse effects during a lifetime.

The TDIs for horses in respect of arsenic and mercury are summarised in Table 16. The same values have also been applied to the assessment of cattle and sheep, since no TDIs specific to cattle and sheep have been found. Further details, derivations and references concerning toxicity factors are summarised in Appendix E.

6.5 RISK CHARACTERISATION

Characterisation of risks involves combining the results of toxicological and exposure assessments to provide numerical estimates of health risk. These estimates are comparisons of exposure levels with the recommended maximum tolerable intakes. Risk characterisation also considers the nature and weight of evidence supporting these risk estimates, as well as the magnitude of uncertainty surrounding such estimates. The risk calculations are shown in Appendix G and the results are summarised in Table 17. The risk calculations for farm animals were conducted for eight separate risk cases as follows:

Cases 1, 2 and 3 Estimate health risks due to arsenic for horses, cattle and sheep respectively for animals which spend the majority of their time in tailings affected areas.

Cases 4, 5 and 6 Estimate health risks due to mercury for horses, cattle and sheep respectively for animals which spend the majority of their time in tailings affected areas.

Cases 7 and 8 Estimate the threshold soil concentrations of arsenic and mercury respectively, which would be acceptable for horses.

Risk Calculations

The risk calculations for animals are presented in Appendix G and follow the same format as the calculation for human health risk. The top section of each calculation lists the exposure parameters and assumptions, and the applicable toxicity value (tolerable daily intake) for each case. The lower section of each calculation details the calculated risk in terms of chemical intake by each quantified exposure route, intake as a proportion of total intake, intake as a proportion of tolerable intake, and corresponding totals.

The key risk parameter, is the calculated ratio of total intake to tolerable daily intake (TDI) indicated at the bottom of each calculation. Calculated ratios significantly in excess of 1.0 are indicative of potential health risks.

6.6 RESULTS OF ANIMAL HEALTH RISK ASSESSMENT

The results of the calculations are summarised in Table 17. The results show that for the parameters adopted for the assessment:

1. Health risks to horses, cattle and sheep are indicated in respect of arsenic, for which estimated intakes typically exceed tolerable values by between 40 and 50%. This is consistent with the elevated arsenic levels reported in samples of hair from horses on the Lot 5 property assuming that this was not caused by dust contamination or washing from the dam.

2. Based on the parameters selected for this assessment, the principal risk factor appears to be uptake of arsenic by local vegetation which is then cropped by the animals in their normal diet. The assessment suggests that soil ingestion is a relatively minor factor, contributing typically 15 to 20% of the total intake of arsenic.

3. Health risks to animals due to consumption of dam water containing elevated levels of arsenic (0.58mg/L) and mercury (0.0012mg/L) are small. Consumption of water containing of arsenic at 0.58mg/L, as observed in the dam on Lot 5 property, could contribute up to about 20% of the tolerable daily intake. The peak value on the site of 2.7mg/kg is considered to be too remote from the farm subdivisions to be of great concern. It also possibly reflects some incorporation of suspended solids in the sample as it was taken at a time of high flow and is inconsistent with samples from adjacent water bodies taken at the same time.

4. For the parameters selected for this assessment, no significant health risks to animals are indicated for mercury.

5. For the parameters selected for this assessment, threshold concentrations of arsenic and mercury in soil which would be acceptable for horses are estimated to be :

    - Arsenic 317mg/kg
    - Mercury 8.4mg/kg

Uncertainty Factors

There is a high degree of uncertainty associated with almost all of the factors and parameters used in the assessment. These include:

- Soil Ingestion Rates
  Although soil ingestion rates are extensively documented, considerable local and seasonal variability is apparent. Ingestion rates of up to 5kg/day have been reported for short periods during early spring. However, annual average rates are less certain. The significance of deliberate licking of arsenic contaminated soil at Mount Egerton, a form of equine pica, is also unclear. This assessment is based on a typical annual average ingestion rate for horses of 1kg/day. If equine PICA is important, this value may be low.

- Bioavailabilty Factors
  Bioavailability is critical in controlling the absorption of metals from soil in the gut. This parameter is very poorly documented, and in any case the value will be site specific

depending on the local chemical speciation and soil type. This assessment used values of 11% for arsenic and 50% for mercury. These values are highly uncertain.

- Plant Uptake Factor

  Plant uptake influences the intake of metals from vegetation in the normal diet. A factor of 4% was selected for this assessment (Baes et al, 1984), implying typical arsenic concentrations in local grass exceeding 20mg/kg. No analysis of grass at Mount Egerton appears to have been conducted. This assessment suggests that consumption of arsenic contaminated grass is a major factor. However, this is in conflict with the conclusions of other studies. Thornton and Abrahams 1981 [29] conducted a study of soil ingestion in heavy metal contaminated areas of Great Britain which involved sampling of soil, vegetation and animal faeces for heavy metals. They concluded that direct soil ingestion was the principal intake route, and that plant uptake was a minor factor. Reducing the plant uptake factor to 2% would bring the total intakes for horses at Mount Egerton to just within the tolerable intake.

  Further study of plant uptake by sampling of local grass at Mount Egerton, is suggested to reduce the uncertainty in this element of the assessment.

- Toxicity Factors

  The toxicity parameters for farm animals are poorly documented and uncertain. The values used for this assessment are considered to be conservative.

6.7 ANIMAL HEALTH RISK CONCLUSIONS

1. This assessment indicates that arsenic contamination in tailings affected soil is likely to affect the health of farm animals due to a combination of soil ingestion and particularly, the uptake of arsenic in local vegetation.

2. The present assessment is subject to a high degree of uncertainty with respect to several key parameters which are not reliably defined. These include:

   - soil ingestion rates;
   - bioavailability factors;
   - plant uptake factors; and
   - toxicity parameters.

In particular, further studies along the lines of the paper by Thorton and Abrahams are recommended to improve the reliability of some of these factors. This should include sampling of local vegetation and stock faeces to better assess rates of soil ingestion and the content of arsenic being consumed in soil and vegetation by farm animals at Mount Egerton.

7. DISCUSSION

Potential receptors of contaminants from within the valley of the Paddock Creek include human residents of the area, farm animals, and wildlife and plants downstream of the mining area. The potential human receptors include adults and children living on properties downstream of the former tailings dams and on the adjacent properties. It also includes adults and children who access the sports oval at Mount Egerton, both for recreation and to obtain sand from the remaining small stockpiles which are understood to be being used on gardens and other domestic purposes at other locations off-site.

Other potential receptors include any humans who use the Bostock Dam either for recreation, or for water consumption downstream (Geelong). Others include humans who ingest food derived locally either from the raising of livestock, crops or vegetables on the affected land or from fauna and flora from aquatic sources in the creek, ponds and dams, and for any non-local receptors who may receive livestock or produce from livestock and vegetables raised on the affected properties.

In this context the consumption habits of people resident on the affected properties includes those who rely up to 100% on their home grown produce for their vegetables and for a large percentage of their meat intake.

Animal receptors potentially include horses, cattle and sheep raised commercially on the agricultural properties downstream, and other associated farm animals including dogs, cats, and may include birds (including fowls).

Ecological receptors include fish and crustaceans, insects and other aquatic life and plants in Paddock Creek aquatic eco-system and downstream in the Bostock Dam, and the animals that feed on the insects, fish, etc., including local birds.

Hewitt and Miller [37] from studies in Arkansas on uptake of arsenic in a population set 30mg/kg as a soil concentration target level - but also reported that there was no observable difference in people exposed to 140mg/kg of arsenic in soil compared to people exposed to 14mg/kg background levels.

With regard to bioavailability of arsenic from soils, other available data indicates that soil adsorption can limit the bioavailability of arsenic to both plants and animals (including humans).

For example, an epidemiological study conducted by the USEPA, CDC, and State of Montana determined that children living near the former copper smelter in Anaconda, showed no elevation of urinary arsenic levels despite average arsenic soil concentrations of greater than 100mg/kg (Binder *et al.*, 1987) [51]. The authors concluded that "the lack of demonstrable exposure in children in the town of Anaconda suggests that mean soil arsenic levels of about 100 ppm are not associated with excess exposure in young children," and established a "**no epidemiologically detectable exposure level" (NEDEL) of 100mg/kg** (Binder *et al.*, 1987).

At levels above those investigated by Binder, this assessment has indicated that, although there are unlikely to be health risks to adults or children residents on the affected properties, "hot spots" of arsenic contamination in excess of 650mg/kg may constitute a health risk to children in some circumstances. The animal health risk assessment has also indicated that there are health risks to grazing animals on the affected properties. Therefore some form of management of the contamination would appear to be prudent.

8. MANAGEMENT MEASURES

8.1 BACKGROUND

In assessing appropriate management measures for the site, it must be appreciated that there are still a large number of assumptions that have been incorporated into the risk assessments and these could change if more information is obtained or made available.

Much of the available soil data is dependant on the information from the assays of the tailings on the mining lease and a small number of samples on the affected properties. Although some of the test results could be considered to be reflective of background levels, there are insufficient data points to allow a reasonable assessment of what background levels may also be relevant in areas not affected by the tailings themselves. Residents have also raised concerns as to the presence of contaminants in bore water, in seepage and surface run-off from the adjacent hillsides for which there is sparse or no information.

Background concentrations in surface waters range up to 2.83mg/L of arsenic in Bendigo [23], but data is limited in the Ballarat area to the Lamb & Hughes study [54] which indicated levels in the Barwon River catchment of up to "hundreds of micrograms per litre" There is no information available on water quality for the Moorabool River system or the Mount Egerton area, except for the Lal Lal, Moorabool and Bostock dams. This indicated mercury levels below detection limits and arsenic in the Bostock dam only in the range 1 to 4 micrograms per litre. The concentrations in the dams in the mine lease on Paddock Creek were taken during heavy rainfall and may have been diluted and therefore management of the run-off and seepage down Paddock Creek should assume that higher concentrations as recorded from Lot 5 may be the norm for the area. There is also no knowledge of the concentration of contaminants in any deeper seepage through the sandy alluvial or tailings soils.

The concentration of contaminants in vegetation routinely grazed by the animals on the properties is also unknown. The test results of below detection limits for vegetables relate to a soil concentration of 80mg/kg of arsenic which is much less than the peak concentrations detected in the tailings, and therefore the result might be considerably greater if they were grown directly in the tailings material.

The risk assessment has indicated that peak soil concentrations for arsenic are such that there are potential health risks to individuals living on the properties particularly to children; potentially also to people who are exposed to soils removed from the mine site and used for construction, on gardens etc; to cattle, sheep, horses and other animals raised on the properties; and by implication, to native animals that may also graze on the properties or catch contaminated fish, etc.

The risk assessment has also indicated that the surface water contributes to the above risks and there are also risks to fish, crustaceans and other species inhabiting the dams, and potentially to some humans if they eat significant quantities of fish/crustaceans from the dams to supplement their diet.

The risk assessment has indicated that assumptions as to the chemical species, toxicity and bioavailability of the main contaminants is crucial in assessing the level of risk that applies to both human and animal receptors. Refinement of the applicable factors could radically change the results of this assessment.

8.2 OPTIONS

In assessing options for management of the contamination on the site, a number of courses of action may be considered. Possible options relate to measures that secure reduction or removal of the potential for exposure by interrupting the exposure pathway. This may include any of the following objectives:

- Remove the sources of contamination (contaminated tailings, water etc).
- Remove access to the contaminated soils/water.
- Remove the affected people/animals from the area.

To achieve the above objectives, management measures could include any or a combination of the following:

- By further investigation, confirm identification of areas of contamination that exceed threshold levels to define exclusion areas.
- Further investigation to define areas of uncertainty in the species, toxicity and bio-availability of the chemical species of concern on the site.
- Undertake a public consultation and information program including typically letter drops, public notices, advertising, and meetings to explain the situation.
- Manage the potential for exposure to the contamination by isolating people and/or animals from affected soils and water bodies.
- Establish warning signs along boundaries of affected soils and water bodies to inform and promote awareness of locals and casual visitors.

- Limit potential access for residents, visitors and animals to the affected soil areas and contaminated water bodies by security fencing both on the residential sub-divisions and around the affected mining lease areas.
- If feasible, removal of worst affected residents from affected sub-divisions.
- Provide alternative sources of water for drinking purposes for residents and stock. For example rainwater tanks, dams in areas not affected by tailings, borehole water from unaffected areas, or piped water.
- Fill in dams located in tailings material to prevent continued use by stock.
- Alternative management of contaminated soil by covering of affected areas to sufficient depth to limit potential for future exposure to humans and animals.
- Alternatively, excavate and remove affected soils from residential and farming areas.
- Identify and remove tailings materials from other residential properties around Mount Egerton where they have been taken for landscaping and building in the past.
- Divert surface run-off around the mine lease area and contain contaminated dam water within the mine lease area.
- Construct a cut off and leachate interception trench at the northern limit of the mine lease to intercept contaminated groundwater and use it for process water on the lease or treat it before disposal.
- Remediate affected soils by leaching or biological methods to remove high arsenic concentrations if technology available.
- Remediate surface waters (and any leachates) by conventional water treatment methods to precipitate metals.

It is clear that any management system must deal with all potential adverse human health and ecological effects and may require a combination of some of the measures indicated above implemented in a structured manner which may be split into a series of stages.

For example, the management of lead contamination in the suburb of Ardeer in the early 1990s went through a number of stages which included: compensation of people and their removal from the worst affected blocks; fencing and warning signs to reduce access to those blocks; community consultation with local residents; clean up of other less contaminated blocks in the surrounding areas without removal of residents; and the final stage of clean up of the original site.

8.3 POTENTIAL MANAGEMENT MEASURES

Currently at Mount Egerton the management measures are restricted to isolation of the affected areas on one property only. Cattle still graze and have access to potentially contaminated water on other properties. Therefore, until more information as to the extent and level of contamination in both the soil and water media is available, a public information program should be implemented. This should firstly be directed at the affected properties discussed in this report, and then on to the wider community, setting out what minimum measures would be necessary to isolate people from the affected areas and to reduce potential for casual exposure through eating of vegetables, meat and fish sourced from the affected areas.

It is considered that a minimum interim measure that should be introduced is that all affected contaminated areas on the sub-divisions downstream of the mine tailings, must be securely fenced so that access to the contaminated soils for livestock is prevented.

Access to the mining lease areas by local residents should also be restricted, preferably by fencing, but as a minimum including warning signs at frequent intervals and particularly around dams. Fencing to prevent access to the tailings areas on the mine lease by grazing animals would also be highly recommended. Secure fencing of the dams should also be considered essential to both restrict the potential for locals to catch fish and for children to play in the contaminated water and to prevent animals from drinking from these dams. This fencing would also need to be inspected regularly to ensure that it is not being by-passed.

The public information program must also make people aware of the potential hazards associated with mine tailings sands that may have been removed from the site for home building purposes. Efforts must be made to locate and inform local residents who may have sourced sand from the tailings heaps for landscaping, etc. If these were used for garden areas for growing of vegetables or in areas particularly accessed by children, for example sand pits, they could be exposed to levels of arsenic well in excess of the threshold values for health risks indicated in this assessment. It is recommended that some attempt be made to recover these materials or at the minimum test it to assess whether it needs to be removed.

Further soil and water testing programs are considered extremely important to confirm the boundaries of the affected areas in both lateral and vertical extent. It is possible that where surface test results did not indicate the presence of arsenic or mercury, these contaminants could be present at depth in older sediments and may be brought back to the surface during future developments. The information on water quality in the area and in the Moorabool catchment is extremely limited and based on very few data points. As a minimum, a comprehensive water quality testing program, to be carried out in both low flow and high flow conditions in the dams and along Paddock Creek is necessary to establish reliable water quality data for the survey. This should be accompanied by a wider research of contaminant concentrations in the fish and crustaceans that are being caught for food from the dams in the areas, together with research into actual levels of consumption to establish whether this comprises a potential significant source of intake that has to be managed.

The cost of permanent remediation solutions such as the removal of contaminated soils is likely to be extremely high in relation to possible benefits and is not likely to be necessary in all cases. Long term measures that seek to clean up the site should therefore be assessed in terms of their practicality in relation to the size of the properties and the extent of tailings or contaminated soils affected and against the potential cost of alternatives such as excision of the affected areas. All of the sub-divisions downstream of the mining lease are around 8 hectares in extent and therefore it is unlikely to be practical for them to be farmed if a substantial proportion of the available area is either fenced off, excised or under remediation. For example, the occupants of Lot 5 depend on their careful management of all of their resources to make ends meet, and this is now considerably curtailed by the temporary management measures implemented to date.

A management option in this case may be the removal of affected areas from the worst affected sub-divisions and the consolidation of the remaining land into fewer larger blocks with some residents removed.

Any management measure must also be practical and take into account the geology, topography and condition of the surrounding land. The mining lease is covered to several metres depth in mine tailings that are known to be contaminated with arsenic to levels that potentially comprise an unacceptable human health risk if people are exposed to it for sufficient lengths of time. It is therefore not practical to either excavate and remove, or to cover with a capping the affected soils on the affected sub-divisions downstream from the mine lease, whilst the run-off and seepage from the tailings dams and mine lease area itself has not been controlled. If the seepage and run-off from the mine lease continues, it could over time re-contaminate any remediated areas downstream.

To be beneficial, management of any contaminated areas on the sub-divisions, or excised from land titles, would also have to be staged to minimise overall expenditure. The cost of excavation or capping, or any other permanent solution is likely to be considerable and must be balanced against the cost of removal of residents and/or permanent isolation of the affected areas. However, as a minimum part of this process, it is recommended that the dams that are located within tailings affected areas be decommissioned and filled in to prevent further use by livestock or by residents.

Diversion of surface run-off around the mine lease at Mount Egerton would reduce the volume of water that would otherwise flush out arsenic and mercury and other metals from the tailings dams, and would allow the remaining leachate to be managed. There could also be some consideration of who is responsible for controlling and elimination of any pollution emanating from the mine lease.

An argument could be made for requiring Tech-Sol Resources to improve its own management of the lease. Tech-Sol Resources should therefore be asked to consider the recycling of water from the tailings dams through their process. Any surplus would need to be run through a water treatment plant to precipitate the metals before disposal of the effluent. These measures would assist protection of downstream ecosystems and ultimately the quality of water in Bostock Dam.

A monitoring program of water quality in the dams, in the lower reaches of Paddock Creek and at the entry point into Bostock Dam (which is a source of water supply for Geelong), should be undertaken to establish contaminant levels downstream from the site. Although contaminant levels in the water of Bostock Dam appear not to be excessive from the data available to date, it is recommended that Fish in Bostock Dam also be tested for arsenic and mercury to eliminate them as a potential source of contaminants to the local population. If contamination is reaching Bostock Dam despite the dilution effects that could be inferred if the situation is similar to that in the Barwon Catchment, management measures to intercept the affected seepage or surface waters in Paddock Creek may be advisable in the long term to preserve this resource.

8.4 PRIORITISATION OF MANAGEMENT MEASURES

In order to establish some idea of the priority in which the above management measures could be considered, each of the above measures has been given a set of ratings based on the relative cost; potential effectiveness; anticipated community acceptance in terms of what the community as a whole is likely to deem appropriate; and judgement on their desirability in order to effectively limit exposure to the sources of contamination. The highest ratings are given to the likely lowest cost options, and to the more effective or more desirable/acceptable results.

In order to arrive at an order of priority, the individual ratings for each potential management measure were then multiplied to arrive at an overall rating, the highest numbers representing the measures likely to be most cost effective. The results of this process are indicated in Table 18.

This does not necessarily mean that the highest rating options would automatically be the ones completed. Some options are mutually exclusive or would need to be carried out together to be effective. Some judgement is therefore needed to assess the right combination of measures that would result in effective management of the contamination whilst maintaining a degree of trust with the affected community.

On the above basis, it would appear that community consultation should be high on the list of priorities for further action by the EPA. Followed generally by further studies of the extent of the contamination in the affected media and biota.

Simple and cheap measures to improve physical protection of residents such as fencing and warning signs would be the next option to consider once the problem areas are fully known. The more expensive options to either improve the properties by covering or removal of affected soils, filling in of the dams, or the interception or improvement of the quality of the surface run-off or underground leachate would be the next for consideration but would have to be co-ordinated to be effective as indicated above.

Removal of the residents would appear to be relatively low on the list of priorities unless if it was selective. Finally, the 'do nothing' option is not seen to be feasible, both from effectiveness and from a community acceptance point of view.

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See Appendices D and E for further references on bio-availability and toxicity of arsenic and mercury in humans and animals.

10. LIMITATIONS OF REPORT

The Risk Assessment undertaken for this report is based on and limited by the information supplied by the EPA and others with regard to soil conditions and the soil and water contamination understood to be present on the site. Conclusions made must be considered in light of the limited extent of the study and of the information provided.

We have prepared this report for the EPA, H&CS, DAE&M and DCNR in accordance with generally accepted consulting practice. No other warranty, expressed or implied, is made as to the professional advice indicated in this report. This report has not been prepared for the use by parties other than the client, and it's consulting advisers. It may not contain sufficient information for the purposes of other parties or for other uses.

It is recommended that any plans and specifications prepared by others and relating to the content of this report, or any amendments to those plans and specifications, be reviewed by Dames & Moore to verify that the intent of our recommendations is properly reflected in the design or specifications.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions and contaminant concentrations can change in a limited time. This should be borne in mind if the report is used after a protracted delay. There are always some variations in subsurface conditions across a site which cannot be fully defined by investigation. Hence it is unlikely that the measurements and values obtained from sampling and testing which have been provided for this assessment, and on which this risk assessment is based, will represent the extremes of conditions which exist within the site.

This report does not, and does not purport to, give legal advice on the actual or potential environmental liabilities of any individual or organisation, or draw conclusions as to whether any particular circumstances constitute a breach of relevant legislation. This advice can only be given by qualified legal practitioners.

for DAMES & MOORE

Ken Mival
Environmental Auditor
(Contaminated Land)