Strangways Developments Pty Ltd Environmental Audit Review Report

SECTION 2498 HUNDRED OF STRANGWAYS, HUMPTY DOO, NORTHERN TERRITORY

- Final
- August 2004

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Sinclair Knight Merz
ABN 37 001 024 095
590 Orrong Road, Armadale 3143
PO Box 2500
Malvern VIC 3144 Australia
Tel: +61 3 9248 3100
Fax: +61 3 9248 3364
Web: www.skmconsulting.com

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Summary

The site at Section 2498 Hundred of Strangways, Humpty Doo, Northern Territory was used between 1981 and 1997 for the storage of sulphur by Energy Resources of Australia Pty Ltd. After closure of this operation, the sulphur and sulphur-containing soils were removed and the site subjected to an environmental assessment and audit (EWL Sciences 2001, and Tonkin Consulting 2001).

The audit outcome was a Statement of Environmental Audit which stated that the future site use was restricted by the presence of residual sulphur-affected (acidic) soil and contaminated shallow (phreatic) groundwater. The Statement required further treatment and monitoring of contaminated soils and monitoring of contaminated groundwater until environmental quality objectives were met, to the satisfaction of an environmental auditor. The site was sold to developer Strangways Developments Pty Ltd, who engaged consultants EWL Sciences to undertake the monitoring and remediation program and Mr Richard Graham of Sinclair Knight Merz to be the auditor. The proposed future site use is rural residential.

The auditor endorsed the soil quality objective specified in the 2001 Statement of Environmental Audit, that soil pH shall be 5.0 $\pm$ 0.5, consistent with the background soil pH in the area. Further soil pH monitoring and treatment of localised acidic patches of surface soil with lime was undertaken to the auditor's requirements.

The auditor reviewed and amended the groundwater beneficial uses and quality objectives, and determined that the relevant beneficial use for shallow groundwater was protection of surface water ecosystem health after discharge of groundwater to the wetland and stream on the site. This use would be protected if the groundwater down-gradient of the former source (the sulphur stockpile) at the zone of discharge to the wetland and stream flowing through the site met freshwater ecosystem protection guidelines based on the ANZECC/ARMCANZ (2000) trigger values for 95% species protection. Further monitoring of the groundwater at a number of bores in the area between the source and discharge zone was undertaken between January and June 2003.

The soil and groundwater monitoring and remediation program undertaken in 2002-2003 has been documented in EWL Sciences (July 2003 and August 2003). The present auditor is satisfied that this program has complied with the scope of the auditor review required by the previous Statement of Environmental Audit (Tonkin Consulting 2001) and the requirements of the present auditor.

The findings of this current audit are summarised as follows:

a) Treatment of acidic sulfur-affected surface soils in the former sulfur stockpile area and borrow pit No. 1 has been effective in meeting the objective for soil pH of 5.0 $\pm$ 5 (or background for the area). Further soil treatment by lime application is not required.

b) Sulfur pellets remain visible in the affected areas, and in the opinion of the auditor these present an unacceptable aesthetic constraint on future residential site use. The auditor recommends that a minimum of 300mm clean topsoil be placed over these areas during development and prior to use for residential purposes.

c) Further monitoring of the deep (beneficial use) aquifer at the former sulfur stockpile area has confirmed that the site use has not resulted in pollution of the deep aquifer at the site.

d) Further monitoring of the shallow phreatic groundwater at the former sulfur stockpile area (source zone) and in the flow and discharge zones between the source zone and the stream/wetland has confirmed that:

   - Groundwater pH has increased and concentrations of contaminants, in particular the metals/metalloids aluminium, copper, nickel, lead and zinc, have reduced substantially with time over the period 1997-2003.
   - Contaminant concentrations in the source and flow zones remain elevated and pH remains low (acidic), and the shallow groundwater in these areas is likely to be unsuitable for any extractive beneficial use. However, that the phreatic groundwater is an unreliable resource and not currently used (or likely to be used in future) for extractive uses.
   - Contaminant concentrations in the stream-side discharge zone generally comply with, or (for copper, lead and zinc) remain slightly above, the adopted water quality guidelines for the protection of aquatic ecosystems (ANZECC/ ARMCANZ 2000). After consideration of a range of relevant factors mitigating the potential risk, the auditor concludes that the groundwater quality does not present a significant or unacceptable risk of harm to the ecological health of the wetland and stream.

The auditor is of the opinion that the remaining issues of sulfur-affected soil and contaminated shallow groundwater, as discussed in this audit report, present constraints on the audit outcome but can be addressed through management requirements for the future development and use of the site. The proposed site development may proceed subject to these constraints. Specifically, no groundwater bores are to be installed in a defined area where shallow groundwater is contaminated or potentially contaminated from the former sulfur storage use. On the advice of the NT Department of Infrastructure, Planning and Environment, this restriction is to apply to groundwater bores installed to any depth (ie to the deep beneficial use aquifer as well as the shallow groundwater).

Accordingly, the auditor has issued a Statement of Environmental Audit (attached to this audit report) which specifies these constraints and requirements. The Statement of Environmental Audit will have the effect of superseding the earlier May 2001 Statement.

1. Introduction

1.1 Background

The site which is the subject of this audit review report is an area of 62.01ha, being Section 2498 Hundred of Strangways, Humpty Doo, about 30km south-east of Darwin, Northern Territory.

A small (about 1ha) portion of the site was used between about 1981 and late 1997 by Energy Resources of Australia Ltd (ERA) to store sulfur prior to its transport and use at the ERA Ranger Mine.

After use of the site for sulfur stockpiling ceased in November 1997, the sulfur was removed and a program of site rehabilitation and environmental assessment was undertaken by consultants EWL Sciences for ERA, and reported in EWL Sciences reports (in particular May 2001).

The investigations found that near-surface soils at the sulfur stockpile area and a nearby borrow pit area were contaminated with sulfur and had low (acidic) pH, while the shallow groundwater at and near the sulfur stockpile area had low pH and was contaminated with heavy metals.

The site was subject to a formal environmental audit by Mr Adrian Hall of Tonkin Consulting (May 2001). The audit outcome was the issue of a conditional Statement of Environmental Audit which required that further soil and groundwater monitoring and soil remediation be undertaken to achieve compliance with specified environmental quality objectives. Compliance was to be determined by an environmental auditor.

Ownership of the site was transferred to Strangways Developments Pty Ltd in 2001. Subject to compliance with environmental and planning requirements, Strangways Developments proposes to develop the site for rural residential use.

In May 2002, Strangways Developments engaged Mr Richard Graham of Sinclair Knight Merz, consulting engineers, to undertake the ongoing auditor role, and specifically to review the results of the further monitoring and remediation program and confirm (if and when appropriate) that the environmental objectives were met and the environmental conditions of the site are suitable for the proposed use.

This audit report presents the findings of the auditor's review of the further monitoring and remediation program, and supports the auditor's decision to issue a further Statement of Environmental Audit.

1.2 Audit Context

The Northern Territory manages land contamination in accordance with the Waste Management and Pollution Control Act 1998 (WMPC Act). This Act does not contain specific provisions for contaminated land identification, assessment, auditing or management, although the Department of Infrastructure, Planning and Environment can use instruments such as Pollution Abatement Notices under the Act to require responsible parties to implement contaminated land assessment, clean-up or management measures.

The NT Government currently manages contaminated land in accordance with the National Environment Protection (Assessment of Site Contamination) Measure (NEPC 1999), and requires the use of environmental auditors accredited by the Victorian Environment Protection Authority.

The NT Government proposes to prepare an Environment Protection (Site Contamination) Objective (EPO) in accordance with Section 19 of the WMPC Act to formalise the process and controls over contaminated land.

In the case of the site at Section 2498 Hundred of Strangways, the former owner ERA commissioned an environmental assessment, remediation and audit process which was consistent with the NT Government requirements. The Statement of Environmental Audit issued by Mr Hall of Tonkin Consulting (May 2001) required the on-going involvement of an accredited auditor to review the findings of a soil and groundwater monitoring program and determine whether and when the environmental quality objectives are met.

The summary of the audit report and Statement of Environmental Audit issued by Mr Hall is attached in Appendix B of the present audit review report. The summary of the principal environmental assessment report (EWL Sciences, 2001) is also attached in Appendix B. The full documentation of the assessment/remediation program (EWL Services, May 2001) and audit (Tonkin Consulting, May 2001) should be consulted for more detailed information.

1.3 Objectives and Scope of Audit Review

The audit review undertaken by Sinclair Knight Merz had the following objectives and scope:

- To advise on, monitor and review the findings of the further soil remediation and validation program to determine when the condition of the soils in the affected areas complied with soil quality objectives appropriate for proposed future land uses;
- To advise on, monitor and review the findings of the further groundwater monitoring program to determine when the condition of the shallow (phreatic) groundwater in the affected areas complies with groundwater quality objectives and the contaminated groundwater plume no longer poses unacceptable human health or environmental risks;

- To determine any ongoing controls necessary for the site to be considered suitable for the proposed land use (or other land uses under the zoning);
- To prepare a report on the environmental audit review (this report) and, if appropriate, issue a further Certificate or Statement of Environmental Audit for the site. Note that the issue of a new Statement of Environmental Audit is considered necessary and appropriate, as the previous audit Statement does not state conditions under which some of the site (specifically the former sulfur stockpile site and borrow pit No 1) would be suitable for the proposed rural residential land use.
- Provide a copy of the audit review report to the NT Department of Infrastructure, Planning and Environment (DIPE), to enable the Department to make planning decisions on the suitability of the site for future use; and
- Through this process, to provide assurances to the site owner, planning authority, prospective site owners and occupants and the nearby community that the development and use of the site may proceed without unacceptable risks to human health or environmental quality.

The scope of the audit review included a site inspection by the auditor in July 2002, in the company of a representative of EWL Sciences, and discussions with EWL Sciences, the site owner (Strangways Developments) and representatives of the NT DIPE. The auditor reviewed all relevant documents during the audit process. A list of documents relied upon is provided in Appendix A of this audit review report.

1.4 Limitations

This environmental audit review report and the accompanying Statement of Environmental Audit relate to the site defined by Certificate of Title Volume 179, Folio 055, as Section 2498 Hundred of Strangways, and have been prepared in accordance with the appropriate legislation, policies and requirements of the Northern Territory Government.

The audit report and Statement have been prepared for Strangways Developments Pty Ltd for the purposes described in the audit report, including informing prospective purchasers and occupants of land at the site. It is acknowledged that the audit report and Statement may also be used by the Northern Territory Department of Infrastructure, Planning and Environment in reaching their conclusions about environmental conditions at the site. The scope of work performed in connection with the audit may not be appropriate to satisfy the needs of any other person. Any other person's use of, or reliance on, the audit report and Statement, or the findings, conclusions, recommendations or any other material presented in them, is at that person's sole risk.

The conclusions of this environmental audit report and the issue of the Statement of Environmental Audit are based on a review of information which was available to the auditor at the time of the audit and relating to the environmental quality conditions of the audit site. Sinclair Knight Merz

and the environmental auditor are satisfied that the information and data available were adequate for this purpose.

Sinclair Knight Merz and the environmental auditor have taken due care to consider all reasonably available information in undertaking this audit and have taken this information to represent a fair and reasonable characterisation of the environmental status of the site, but recognise that any site assessment program is necessarily limited in scope and true site conditions may differ from those inferred from the available data.

Whilst all reasonable care has been taken, to the extent practical under normal auditing procedures, to assure the reliability of the information, the environmental auditor and Sinclair Knight Merz cannot warrant that this is the case. If the information is subsequently determined to be false, inaccurate, misleading or incomplete, it is possible that the environmental auditor's conclusions as expressed in the audit report may change. Sinclair Knight Merz and the environmental auditor disclaim any responsibility for inconsistencies between the findings of this audit report (and the issue of a Statement of Environmental Audit) and information or data which may become available after the date of completion of this audit.

Sinclair Knight Merz or the auditor did not conduct validation testing by sampling and analysis of site soils or groundwater, but relied on the data produced from the stages of site assessment undertaken by consultants EWL Sciences Pty Ltd. The auditor is satisfied that the data were reliable for the purpose for which they have been used, and the independent testing was not justified in this case.

This environmental audit applies to the condition of the site at the time the site assessment was undertaken. The environmental auditor and Sinclair Knight Merz cannot be responsible for future activities that may result in changes to the site conditions. In the event that site conditions have since changed or are likely to change in the future, the environmental auditor recommends that the property owner engage an environmental consultant to confirm that the site conditions remain suitable for its proposed use.

It is not possible in an environmental audit report to present all data that could be of interest to all readers of this report. Readers are therefore referred to the referenced documentation for further information and data.

2. Review of Site Characteristics and History

This section of the audit report presents a brief review of site characteristics and history of use.

2.1 Site Description and History

The site subject to this audit review is located at Section 2498 Hundred of Strangways, Humpty Doo, Northern Territory, as shown on Figure 1.1 of Tonkin Consulting (2001). A copy of this figure is attached in Appendix B of this present audit report. The site has an area of 62.01 ha, as defined by Certificate of Title Volume 179 Folio 055. A copy of the Title and other planning documents are attached in Appendix C of this audit report.

The land is currently zoned Zone RL1 (Rural Living 1) under the Litchfield Area Plan 2004, which permits subdivision into allotments of minimum area 2 ha. It is understood that the developer will seek a rezoning to allow a reduction in lot size, such as Zone RR (Rural Residential) which allows subdivision to a minimum lot size of 1 ha. In that case it is proposed that the subdivided lots will be supplied with mains water but will rely on septic tanks for sewage disposal. The NT Department of Infrastructure, Planning and Environment has advised that for lot sizes less that 2ha, groundwater extraction bores will not be permitted on the grounds that adequate separation of at least 100m between contamination sources (septic tanks) and groundwater bores cannot be provided.

The site was used to stockpile sulfur (in the form of elemental sulfur pellets) by ERA between about 1981 and 1997. The sulfur stockpile was located on an area of about 1ha as shown on Figure 1.2 and 1.3 of Tonkin Consulting (2001), attached in Appendix B of this audit report. Other site features included:

- Three borrow pits (as shown on the attached figures), used for soil or gravel extraction
- A security fence and access track
- Caretaker accommodation
- A watercourse (and stream-side wetland) flowing through the site from east to west.

Over this period of use of the site for sulfur stockpiling, a number of fires occurred in the stockpile, in 1989, 1990 and 1996. The sulfur stockpile was decommissioned in November 1997, by removal of the sulfur and a 50mm layer of soil contaminated with sulfur residue. These materials were disposed off site.

2.2 Geology and Hydrogeology

The geology and hydrogeology of the site and region is described in detail in EWL Sciences site assessment reports, specifically Section 3 of EWL Sciences (May 2001), and is summarised briefly below:

The site geology and soil types are:

- A red-brown gravelly clay loam surface layer with increasing clay content beyond 1m depth, overlying
- A 1m layer of cemented laterite or ferricrete, overlying
- 0.5-1.0m of white clay (pallid zone), overlying
- Weathered shale (Whites Formation and Acacia Gap Quartzite) at about 4-5m depth

The regional hydrogeology is characterised by the presence of confined aquifers in key geological units, as well as phreatic (shallow, unconfined) aquifers in the overlying surficial units.

EWL Sciences (2001) and the previous auditor (Tonkin Consulting, 2001) developed a hydrogeological and hydrological model of the site, which included:

- Shallow, unconfined phreatic groundwater – the phreatic groundwater is recharged by rainwater infiltration and the watertable depth is highly dependent on the wet/dry season, with depth to groundwater variable from at or near surface after the wet season to 8-10m below ground surface after the dry season.

  The phreatic groundwater is not a reliable resource and is not used for extractive purposes in the area. However, on the site the phreatic groundwater discharges to the surface stream and wetland during periods of elevated watertable (during and after the wet season).

- Deep, confined aquifer – the depth to the deep aquifer varies from about 40-80m below ground level (bgl), and the standing water level in bores installed into this aquifer is about 10-20m bgl. This aquifer is a reliable resource and used in the area for potable, domestic and irrigation purposes.

This hydrogeological and hydrological model is illustrated in Figure 3 of EWL Sciences (August 2003), a copy of which is attached in Appendix B.

2.3 Surface Waters

An ephemeral stream bordered by a wetland flows from east to west through the site (refer Figure 1.3 of Tonkin Consulting, 2001), which in turn flows to Bees Creek about 1km west of the site. The shallow phreatic groundwater discharges via horizontal flow to this stream/wetland during and following the wet season.

3. Review of Previous Assessment, Remediation and Audit Program

3.1 Overview

Following closure and remediation of the sulfur stockpile operations on the site, ERA engaged consultants EWL Sciences to assess the environmental conditions of the site, identify further remediation needs and provide information to support the audit by Mr Adrian Hall of Tonkin Consulting.

The site assessment was undertaken and reported in stages, and included both soil and groundwater quality investigation.

The findings of the assessment are documented in detail in EWL Sciences (2001) and preceding EWL reports, and reviewed by the previous auditor (Tonkin Consulting, 2001). The summaries of EWL Sciences (May 2001) and Tonkin Consulting (2001) are attached in Appendix B of this audit report, and the key findings of the assessment and audit program are summarised below.

3.2 Soil Contamination and Remediation

The soil contamination investigation and remediation actions proceeded in a staged manner. The sulfur residues and heavily sulfur contaminated soils were removed in 1997-1998 after site decommissioning, and remaining soils in the former stockpile area were found to contain elevated sulfur concentrations and low (acidic) pH. The low pH was derived from oxidation of the elemental sulfur and generation of acidic (sulfuric acid) conditions.

Lime was applied to the stockpile area soils on three occasions in 1998-2000 to neutralise the acidic soil conditions, and validation sampling and analysis indicated that this remediation had some beneficial effect. Soil pH was measured at 25 sites in the former stockpile area and three sites in borrow pit No 1 in 1998, 1999 and 2000 (after successive applications of lime) and showed that the average soil pH increased from 5.0 to 5.6 in that time (EWL Sciences, 2001, Section 4.5.3, Table 1.3 and Figure 7).

The auditor (Tonkin Consulting, 2001) adopted a pH guideline (remedial goal) of pH 5.0 ± 0.5, consistent with the background soil pH in the area. He noted that the soil pH data after remediation in September 2000 showed that 12 of the 28 sampling locations reported pH < 5.0.

Test pits showed that residual elemental sulfur pellets were not present beyond a depth of about 20cm from the surface, and it was recommended that no further soil removal was justified.

Revegetation of the former sulfur stockpile and borrow pit No 1 areas achieved a healthy vegetation cover.

Soil testing reported elevated sulfur concentrations in the former stockpile area (average 2800mg/kg, range 300-16900mg/kg and 95% UCL mean 4090mg/kg) and to a much lesser extent in the area inside the security fence around the stockpile (average 378mg/kg, range 55-800mg/kg and 95% UCL mean 810mg/kg) compared to the balance of the site (average 183mg/kg, range 45-2390mg/kg, 95% UCL mean 350mg/kg). The interim urban ecological investigation level (EIL) recommended by the NEPM (NEPC 1999) of 600mg/kg was exceeded in soils in the former stockpile area and in localised areas elsewhere.

The consultants (EWL Sciences, 2001, Section 5) assessed the potential health and ecological risks associated with the soil contamination, specifically the elevated sulfur concentrations and low (acidic) pH. The qualitative risk assessment considered the issues of low soil pH, high sulfur concentrations and heavy metal concentrations and recommended management measures to mitigate the risks. The recommendations were endorsed by the auditor and incorporated into the Statement of Environmental Audit (Tonkin Consulting, 2001). In summary:

a) The low soil pH was considered to present an unacceptable risk of mobilisation of heavy metals from the site soils. Further monitoring and lime application was recommended to achieve and confirm compliance with the adopted target of pH 5.0 ± 0.5.
b) Elevated sulfur concentrations were considered to present potential risks of three types:
    - Aesthetically-objectionable visible sulfur pellets – considered to be minor and further removal impractical;
    - Aesthetically-objectionable surface precipitation of epsomite/gypsum salts (from application of lime to sulfur-affected soils) – the white patches resulting were considered to be minor and localised but able to be remediated readily if required;
    - Potential corrosion of concrete structures in sulfur-affected soil – concrete to be used for foundations or pipes was recommended to be high alumina or super-sulfated concrete, based on ADAS soil sulfur suitability ratings.
c) Heavy metal (specifically arsenic) concentrations in soils - elevated concentrations of arsenic in soils above the EIL of 20mg/kg were considered to be naturally occurring and the potential for leaching of arsenic and other metals from the soils is to be addressed by lime application to raise pH to background levels.

3.3 Groundwater Contamination

In consultation with the previous auditor, EWL Sciences undertook an investigation of groundwater quality by means of monitoring bores in the shallow phreatic groundwater and the deeper, confined “beneficial use” aquifer. The groundwater bore locations are shown on Figure 6 of EWL Sciences (2001) and Figure 1.2 of Tonkin Consulting, 2001 (included in Appendix B of this present audit report). The monitoring bore network included:

- Shallow bores 22440 and 22441 installed by ERA in 1983, respectively at the north-west corner of the sulfur stockpile and near the stream down-gradient of the stockpile, and to depths of 4.5 to 5m at the base of the lateritised zone;
- Nested pairs of shallow aquifer bores, installed in early 1998 and screened respectively above the cemented laterite layer (to depth 1.5 to 2.5m bgl) and at the base of the lateritised zones (to depth 5.5m), at bore locations HD11/12 inside the sulfur stockpile and HD21/22, HD31/32, HD51/52 and HD61/62 in the groundwater flow and discharge zones between the stockpile area and the stream/wetland to the north/north-west of the stockpile area;
- Background bores HDA, HDB and HD4 in the shallow phreatic aquifer, outside of the area potentially impacted by the sulfur storage or other site activities;
- Deep bore HDD installed to a depth of 60m in the beneficial use aquifer, at the north-western corner of the former sulfur stockpile, to assess whether the contamination from the shallow aquifer has penetrated to the deeper aquifer;
- Four surface water sampling locations HDS1-4 on the stream flowing through the site.

It is understood that groundwater quality at or near the former borrow pit No. 1 was not investigated on the basis that the impacts of short-term sulfur storage or placement at this location were relatively minor compared to the SSA (Ian Hollingsworth, EWL Sciences, pers. comm.).

The groundwater bores and stream were sampled on a number of occasions in the period 1997-2000. The findings are described and discussed in EWL Sciences (2001) and Tonkin Consulting (2001) and briefly summarised below.

Contaminants of concern in the shallow phreatic groundwater were pH and metals/metalloids, in particular aluminium, copper, lead and zinc, and to a lesser extent beryllium, chromium and iron. Low (acidic) pH and elevated metals concentrations were recorded in all the bores at and down-gradient of the former sulfur stockpile.

This effect was attributed to leaching of acid from oxidation of the sulfur through the soil profile displacing ion-exchangeable cations and dissolving metals naturally present in the soils through a process of accelerated weathering (EWL Sciences, 2001). Background phreatic bores did not show elevated metals concentrations or low pH.

The groundwater data (summarised in Table 21 of EWL Sciences, 2001 included in Appendix B) show that the lowest pH 3.5-3.8 and highest metal concentrations were reported for bore 22440 immediately downgradient of the former sulfur stockpile, and pH increased and metals concentrations decreased with distance way from this source.

Concentrations of metals in all shallow bores exceeded groundwater investigation levels (GIL) for freshwater aquatic ecosystem protection (NEPM 1999, based on ANZECC 1992 ecosystem

protection guidelines) for one or more of aluminium, copper, lead and zinc. The shallow groundwater also contained elevated concentrations of sulfate.

Elevated metal/metalloid concentrations above GILs also were reported in most of the stream samples, including samples from upstream of the flow zone from the sulfur stockpile, indicating that stream concentrations were naturally elevated.

From the phreatic groundwater monitoring data, EWL Sciences (2001) concluded that that concentrations of the contaminants of concern had reduced considerably over the period of monitoring 1997-2000 (refer to Figures 10-14 for bore 22440), due to the soil remediation by lime application, leaching of contaminants over successive wet seasons and plume migration/attenuation processes.

Section 5.4 of EWL Sciences (2001) assessed the risks of environmental harm from the contamination of the phreatic groundwater, and concluded that:

- The contaminated groundwater plume is likely to be less extensive and concentrations within it lower than in past years, ie the plume is contracting rather than expanding.
- Concentrations in the phreatic groundwater near the stream (bores HD61/62) are at or close to background.
- Any impact on the stream water quality is likely to have been realised in the past, and the potential for future water quality impacts are very low and risks to ecological receptors (stream ecosystems) is also very low.
- A further 2-3 wet seasons beyond 2000-2001 are likely to be required for pH of the phreatic groundwater at the source area (bore 22440) to return to background levels.
- As the phreatic groundwater is not used for extractive purposes (drinking water, domestic or stock water supply, irrigation, etc) the potential risks arising from contamination are confined to impact on surface water ecosystems after discharge of shallow groundwater to the stream or wetlands, or percolation of contaminated shallow groundwater to the deep beneficial use aquifer.
- The deep groundwater in the beneficial use aquifer (HDD) was not contaminated with metals/ metalloids or sulfate and was at neutral pH (6.5-7.1). These results indicated that the contamination in the surface soils and shallow phreatic groundwater does not extend to the deeper aquifer, confirming that hydraulic connection between the two aquifers is likely to negligible.
- Active remediation of the contaminated phreatic groundwater was not recommended, but on-going monitoring was recommended in order to confirm the decreasing trends in metals concentrations (and increasing trend in pH) at the bores between the source zone and the

stream. Selected shallow bores 22440, HD12 and HD22 as well as background bore HDA and the deep beneficial use bore HDD were recommended for on-going monitoring.

3.4 Audit Outcome

The previous environmental auditor, Adrian Hall (Tonkin Consulting, 2001) endorsed the risk assessment undertaken by EWL Sciences for soil and groundwater contamination, and the Management Plan prepared for the site (EWL Sciences, 2001, Section 6). The key features of the Management Plan are summarised in Table 25 of EWL Sciences (2001), a copy of which is included in Appendix B of this present audit report, and were incorporated into the Statement of Environmental Audit issued by Mr Hall (copy in Appendix B of this present report).

In summary, the key components of the Statement of Environmental Audit and the future site Management Plan are as follows:

a) The site, other than the former sulfur stockpile and borrow pit No. 1, is suitable for the proposed rural residential land use (or other permitted uses), provided that:
   - Shallow groundwater is not used for any purpose other than environmental monitoring; and
   - Shallow groundwater is to be monitored annually in accordance with the management plan (Table 25, EWL Sciences, 2001), until the environmental auditor "is satisfied that all nominated Groundwater Investigation Levels (GILs) are met and that the contaminated groundwater plume no longer poses unacceptable human health or environmental risks".

b) The former sulfur stockpile and borrow pit No. 1 are suitable for non-residential land uses ("flora and fauna sanctuary and retail agricultural stall"), provided that:
   - Areas of low soil pH are to be treated with lime and monitored annually "until the auditor is satisfied that all pH values meet the nominated target (that is pH 5.0 ± 0.5) and that contaminated soils no longer pose unacceptable human health or environmental risks";
   - In-ground concrete structures to be designed and constructed taking account of ADAS (1974) soil sulfur suitability ratings; and
   - The sulfur stockpile area and borrow pit No 1 are to be delineated by a survey plan prepared by a licensed surveyor, for the approval of the auditor.

After issue of the environmental audit report and Statement of Environmental Audit (Tonkin Consulting, 2001), ownership of the site and responsibility for implementation of the audit and management plan recommendations transferred to Strangways Developments.

Strangways Developments engaged EWL Sciences to continue to conduct the soil and groundwater monitoring program, and Mr Richard Graham of Sinclair Knight Merz Pty Ltd as the environmental auditor to oversee and review compliance with the audit recommendations and Statement conditions.

The following sections of this audit report describe the program of further monitoring, remediation and validation program for soils (Section 4) and monitoring of groundwater (Section 5) which were undertaken since May 2001, and present the auditor's review of the outcome of these programs and compliance with the Statement conditions.

4. Soil Monitoring and Remediation

4.1 Overview

EWL Sciences conducted further soil remediation (by lime addition) and soil quality monitoring at the affected areas of the site, and the findings are reported in EWL Sciences (August 2003). The localised areas of acidic surface soil were also remediated and validated as reported in EWL Sciences (July 2003).

The environmental auditor provided comment on the soil monitoring program and findings, and recommendations for the scope of remediation required.

The soil monitoring, remediation and validation program is summarised below. The EWL Sciences reports (July and August 2003) should be referred to for more detailed information.

4.2 Site Survey

The affected areas were delineated by survey markers and surveyed by licensed surveyors, Ausurv Pty Ltd, as required by the Statement of Environmental Audit in June 2001, and the survey plan (reference Dwg No. 1031-1, was included as Figure 1 of EWL Sciences, August 2003). A signed copy of this survey plan was subsequently obtained by the present auditor, and is attached in Appendix C of this audit report. The former sulfur stockpile area is shown as "Area B" and the borrow pit No. 1 as "Area C". The auditor considers that the requirement of the Statement of Environmental Audit of May 2001 requiring survey of these areas has been met.

4.3 Soil Monitoring

In accordance with the management plan requirements for annual soil monitoring at the end of the wet season, a soil sampling and analysis event for surface soils at the former sulfur stockpile area and borrow pit No. 1 was undertaken in May 2002. Soil sample analysis was undertaken at Northern Territory Environmental Laboratories (NTEL). The results generally complied with the agreed target of pH greater than 5.0 ± 0.5, with a small number of low pH or anomalous results. Subsequently, duplicate sample analysis and reanalysis at a second laboratory (AGAL) was undertaken to resolve these issues. The auditor has compiled all soil pH data for the former sulfur stockpile and borrow pit No. 1 areas in Table 1 in this audit report. Review of all the available data has confirmed that the pH of the soil at all locations complies with the target, based on the following considerations:

Table 1 - Summary of Soil pH Data in Former Sulfur Stockpile and Borrow Pit No.1 Areas

Sample Location	Sampling Dates						Average per location
	22/05/98	30/03/99	25/09/00	14/05/02	14/5/02 (1)	14/5/02 (2)	
C1			6.2	3.9	5.9	4.0	5.00
C2			4.0	5.3			4.65
C3			5.0	7.4			6.20
V11	3.9	5.9	4.3	7.2	7.2	6.9	5.90
V12	5.3	4.5	6.8	8.5			6.28
V13	3.6	3.8	4.8	8.3			5.13
V14	4.3	4.1	3.9	6.7			4.75
V15	5.7	4.1	4.7	6.5			5.25
V21	6.5	6.7	5.0	8.8	8.4	8.5	7.32
V22	4.6	7.9	6.1	8.4			6.75
V23	4.0	8.1	4.1	5.9			5.53
V24	3.8	4.6	7.9	4.6			5.23
V25	5.3	6.1	6.0	5.8			5.80
V31	8.2	8.4	8.3	7.4			8.08
V32	7.7	8.3	8.0	5.7			7.43
V33	4.0	7.8	8.7	7.6			7.03
V34	6.4	6.5	4.2	6.5			5.90
V35	5.3	7.5	6.6	6.3			6.43
V41	8.1	6.7	4.9	6.5	7.6	7.0	6.80
V42	5.8	5.8	6.9	7.9			6.60
V43	3.6	4.6	7.1	4.5			4.95
V44	2.9	3.4	5.0	4.8			4.03
V45	5.3	5.6	5.6	6.9			5.85
V51	4.1	6.6	4.0	8.7			5.85
V52	5.2	5.1	4.3	5.2			4.95
V53	3.9	5.0	4.6	5.0			4.63
V54	3.8	4.7	4.7	6.4			4.90
V55	5.4	6.0	5.0	7.1			5.88
Arithmetic Mean	5.1	5.9	5.6	6.6	7.3	6.6	5.8
Median	5.2	5.9	5.0	6.5	7.4	7.0	5.9
Standard Deviation	1.4	1.5	1.4	1.4	1.0	1.9	1.0
Standard Error							
Minimum	2.9	3.4	3.9	3.9	5.9	4.0	4.0
Maximum	8.2	8.4	8.7	8.8	8.4	8.5	8.08
1st Quartile	3.9	4.6	4.5	5.6	6.9	6.2	4.99
3rd Quartile	5.7	6.7	6.7	7.5	7.8	7.4	6.47
n	25.0	25.0	28.0	28.0	4.0	4.0	28.0

All analysis undertaken at NTEL, except (1) duplicate samples from 14/5/02 analysed at AGAL and (2) reanalysis of same samples at AGAL

Sample locations C1, C2 and C3 in Borrow Pit No.1
Sample locations V11 - V55 in former Sulfur Stockpile Area

- Although the measured soil pH at any one location varies between monitoring events over the period 1998-2002 (as is expected given the inherently heterogeneous nature of the material being sampled and the uneven effectiveness of the pH modification from lime application), the trend at most sampling locations has been for increasing pH as a result of the periodic application of lime over the former sulfur stockpile and borrow pit No. 1 areas.
- The site average pH over the affected areas has increased from 5.1 in 1998 to 6.6 in 2002.
- All individual soil pH results in 2002 were above 4.5, except location C1 in the borrow pit area where the soil pH was 3.9 in 2002. Duplicate analysis results for this sample at AGAL were pH 5.9 and (on reanalysis in duplicate) 4.0 and 4.1. The pH of a sample from this location in September 2000 was 6.2. These results indicate that the soil pH is quite variable in this location but the average pH of 5.0 over all samples in 2000-2002 complies with the target pH.
- All locations where soil pH was below the target in 2000 (7 locations with soil pH in the range 3.9 to 4.3) were found to have pH which complied with the target in 2002 (pH results were in the range 5.2 to 8.7).

4.4 Further Soil Remediation and Validation

As noted during the auditor's site inspection in June 2002, small localised areas of weathered acidic soil remain where the previous lime mixing has been ineffective. The resulting visual impact of the encrustation or deposition of epsomite or gypsum formed from the lime application process is, in the auditor's opinion, unacceptable on a sensitive (residential) use site.

EWL recommended further lime addition to the affected soil in five patches. The auditor advised that, in his opinion, the addition of lime to the soil surface will be ineffective (as this method used previously has resulted in the unacceptable appearance) and that mixing is required. The auditor recommended that these areas should be treated by either:

- Excavation of the aesthetically unacceptable soil material and disposal to a suitable off-site landfill, or
- Excavation and treatment by further lime addition (if necessary to achieve final soil pH which complies with the target) and mechanical mixing to achieve more effective contact between lime and acidic soils, and resultant neutralisation, followed by visual assessment, pH testing to confirm compliance with the target, and replacement of the treated soil on the site.

From discussions the auditor understood that the second option was preferred, and that the appropriate time for the soil treatment was considered to be in the dry season.

EWL Sciences' *Validation Report* (July 2003) describes the further remediation of the patches of acidic soil in the former sulfur stockpile area, which was undertaken in early July 2003. A copy of

the summary of this report is attached in Appendix B of this audit report. The remediation was conducted in accordance with the auditor's recommendations and comprised excavation of 10-15m^3 of affected soil mixing with lime at a rate of 40kg lime per tonne of soil. Subsequent validation testing confirms that the pH of the lime-treated soil is satisfactory (although now higher at 7-8 pH units than the naturally acidic background levels).

Sulfur granules remain scattered at low density across the surface in the former sulfur stockpile area and the borrow pit no. 1. The auditor is satisfied that these granules do not pose a health or environmental risk for future use of the site, but their presence is likely to be unacceptable on or near the surface of a residential site. The auditor recommended the placement of a minimum 300mm layer of clean topsoil over the affected areas prior to or at the time of development of the site for residential use. This is the minimum depth commonly accepted in order to minimise the risk of disturbance and exposure of underlying soil during normal residential gardening activities. This recommendation has been adopted in the recommendations of EWL Sciences (July 2003).

4.5 Conclusions and Statement of Audit

The Statement of Environmental Audit issued in May 2001 required that the "program of annual monitoring of soil pH, and applying agricultural lime as necessary…...should be continued until the auditor is satisfied that all pH values meet the nominated target, and that the contaminated soils no longer pose unacceptable human health or environmental risks."

The auditor was satisfied that the program of further monitoring of soil pH levels and the validation of additional lime-treated soil has been undertaken in accordance with good practice and the auditor's requirements. The soil pH data show considerable variability as expected given the inherent heterogeneity of the pH of both acidic, sulphur-affected soils and pH modified, treated soils. However, the monitoring and validation program used appropriate procedures (analytical procedures, experienced laboratories and quality control/quality assurance, including duplicate analysis and reanalysis when requested by the auditor), and the data are considered to be reliable for the purposes for which they are used.

Subject to the satisfactory compliance with the recommendation for placement of a clean soil layer over soils in the former sulphur stockpile and borrow pit No 1 areas containing sulfur residues, the auditor is of the opinion that the objectives of the soil remediation program have been satisfactorily met. Soil quality monitoring may be discontinued.

The sulfur affected areas will, along with the balance of the site, be suitable for the proposed rural residential land use, or other uses permitted under the Litchfield Area Plan.

The auditor has issued a new Statement of Environmental Audit to this effect (refer Section 6 of this audit report). This has the effect of superseding the previous audit Statement (Tonkin

Consulting, May 2001) which restricted land uses on the former sulfur stockpile and borrow pit No. 1 to non-residential uses.

The survey plan attached as Attachment 1 of the new Statement of Environmental Audit shows the areas where a clean soil layer is to be placed prior to residential use, namely Area B (the former sulfur stockpile area) and Area C (borrow pit no. 1).

5. Groundwater Monitoring and Risk Assessment

5.1 Review of Monitoring Program and Objectives

The present auditor reviewed the available groundwater information and the monitoring program required by the previous auditor in the context of the relevant groundwater beneficial use(s) requiring protection.

This review led to the revision of the monitoring program and the groundwater quality objectives which, if achieved, would constitute the "end point" for the monitoring program and the auditor review process.

The auditor advised Strangways Developments and EWL Sciences of the findings of this review in January 2003. This advice is summarised below.

The auditor noted that the required annual groundwater monitoring program was not conducted in December 2001 – January 2002.

The auditor reviewed the relevant groundwater beneficial uses and the groundwater quality guidelines adopted in the assessment report (EWL Sciences, May 2001) and the environmental audit report (Tonkin Consulting, May 2001), and generally endorsed the approach taken in these reports. However, the auditor recommended that the water quality guidelines for the protection of relevant beneficial uses, in particular aquatic ecosystems, should use the ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, rather than the ANZECC 1992 guidelines (which the 2000 guidelines effectively supersede). In practice, the guidelines for relevant contaminants of concern are similar in both these documents.

The auditor also noted that the detection limits reported by the laboratories in past groundwater monitoring events have for some contaminants varied between events and in some cases been significantly above the groundwater guidelines, which makes it difficult to conclude from reported non-detections that actual concentrations are below the guidelines. The auditor asked that for future monitoring events EWL ensure that laboratories conduct analyses and report to the lowest reasonably achievable limits of detection.

The auditor noted that the relevant beneficial use for the shallow phreatic groundwater is that of protection of ecosystems, in particular aquatic ecosystems in the wetland and ephemeral stream flowing through the site north of the former sulfur stockpile area (SSA). The exposure pathway is understood to be:

- Acidic soil conditions on the SSA (and acidic water which previously ponded on and flowed from the SSA) mobilising heavy metals from soils
- Leaching of the metals to the shallow watertable in the wet season and contaminated groundwater flow to the north-west, to discharge to the stream and stream-side wetland
- Potentially toxic effects on aquatic ecosystems and in-stream or riparian vegetation, including benthic (sediment-dwelling) organisms which are potentially exposed to "undiluted" groundwater discharging at the interface with the stream or wetland sediments

The Statement of Environmental Audit issued by Adrian Hall in May 2001 required a groundwater monitoring program "annually……until the auditor is satisfied that all nominated Groundwater Investigation Levels (GILs) are met, and that the contaminated groundwater plume no longer poses unacceptable human health or environmental risks."

Although the previous auditor's intentions were not entirely clear, the present auditor advised that it is reasonable to consider that this end-point will be reached when the groundwater monitoring program demonstrates with confidence that the groundwater discharging to the stream is not contaminated at concentrations above the relevant guidelines for freshwater aquatic ecosystem protection. Specifically, the auditor recommended using the trigger values for the 95% species level of protection in freshwater (ANZECC/ARMCANZ 2000). The guidelines recommend for protection of slightly to moderately disturbed ecosystems "if local biological effects data unavailable, apply 95% protection levels ….. as default, low-risk trigger valves".

Groundwater quality in bores placed down hydraulic-gradient from the contaminant source (SSA) and close to but up hydraulic-gradient from the receptor (the stream) should be assessed to determine whether the objective is met. The attenuation and dilution processes operating in the distance of groundwater travel between the source and receptor will mean that it is unrealistically conservative to require that groundwater quality at or near the source (eg bore 22440) meet the guideline levels.

In order to achieve the audit process end-point as efficiently as possible, the auditor recommended that the monitoring program as specified by the previous audit (Tonkin Consulting 2001) and detailed in EWL Sciences (2001) Section 6, Table 25 be varied as follows for the monitoring event proposed for January 2003:

- Increase the number of bores to be sampled to include bores 22440, HD11/12, HD21/22, HD51/52, HD61/62, HDA and HDD. Both bores in the pairs of shallow bores (eg HD11 and HD12) should be sampled for analysis where the bores contain adequate water.
- Add nickel and zinc to the list of analytes.

The auditor expected that results of the January 2003 groundwater monitoring program (combined with the trends evident from the previous monitoring up to December 2000, and the modelling and

risk assessment reported in EWL Sciences 2001) would enable a sound assessment of the risks (if any) remaining to the aquatic ecology at the site.

Although the shallow phreatic groundwater is not a viable water supply resource for extractive purposes, such as potable (drinking) water supply, primary contact recreation (via filling of swimming pools or spas), irrigation or stock water supply, the auditor notes that the suitability of the shallow groundwater for these uses must be considered for the purposes of a statutory environmental audit (in accordance with Victorian EPA guidelines for audits, recognised by the NT Government). This issue is discussed in Section 5.2.4.

5.2 Results of Groundwater Monitoring, 2003

5.2.1 Overview

The scope and findings of the 2003 round of groundwater monitoring are presented in EWL Sciences (August 2003) and summarised below, with auditor's comments.

Selected groundwater monitoring bores (background shallow bore HDA, shallow phreatic groundwater bores 22440, HD11/HD12, HD21/HD22, HD51/HD52 and HD61/HD62) and deep beneficial use aquifer bore HDD) were sampled on 22 January 2003, and analysed for the range of indicators as agreed. After the results were reviewed by EWL Sciences and the environmental auditor, bores HDD and HD61/HD62 were resampled on 4 March 2003 for additional analysis to resolve anomalies or provide more reliable data to support conclusions on the contamination status of the groundwater. The agreed scope of investigation was undertaken, with minor exceptions which do not substantially undermine the conclusions from the monitoring program.

All groundwater monitoring data for the 2003 program is summarised in Table 5 of EWL Sciences (August 2003), a copy of which is attached in Appendix B of this audit report.

The auditor has further summarised all shallow groundwater data for the period 2000-2003 and relevant water quality guidelines for potential beneficial uses, in Table 2 of this audit report. This summary demonstrates that the contaminants of concern for shallow groundwater in the discharge zone (bores HD61/62) are pH, aluminium, copper, lead and zinc, with respect to the relevant beneficial use of protection of aquatic ecosystems.

5.2.2 Possible Contamination of Bore HDD

The sampling and analysis of deep groundwater bore HDD in January 2003 found elevated concentrations of some metals, in particular copper, nickel and zinc. EWL resampled bore HDD in March 2003, with analysis for a more complete range of anions/cations and metals/metalloids, in order to fully assess the possible source and significance of the contamination found in the deep bore HDD in January 2003. The case presented in Section 3.1 of EWL (August 2003) to support

Table 2 – Summary of Phreatic Groundwater Quality Data[1] and Guidelines

Contaminant	Average Concentration and (Range) for Background Bore HDA	Average Concentration and (Range) for Source Zone Bore 22440	Average Concentration and (Range) for Flow Zone Bores HD21/22, HD31/32 and HD51/52	Average Concentration and (Range) for Discharge Zone Bores HD61/62	Average Concentration for Discharge Zone Bores HD61/62 for Jan-June 2003	Groundwater Quality Objectives (mg/L)				
						Protection of Aquatic Ecosystems (Freshwater) [2]	Drinking Water Supply [3] Health (Aesthetic)	Primary Contact Recreation[6]	Irrigation of Parks and Gardens[7]	Stock Water Supply[8]
pH	6.6 (5.7-7.1)	3.4-3.5 (3.5)	4.9 (3.7-5.8)	5.8 (5.1-6.5)	5.8	6.5 – 9	- (6.5-8.5)	6.5 – 8.5	NA	NA
TDS	146 (12-280)	288 (205-370)	260 (70-480)	69 (43-108)	72	1000	500/1000 [5]	1000	3,500	13,000
Aluminium (Al)	0.024 (<0.002-0.056)	8.6 (5.4-12)	0.089 (<0.002-0.41)	0.084 (0.004-0.33)	0.10/<0.005[9]	0.005 [4]	- (0.2)	0.2	5 (20)	5
total Chromium (Cr)	0.0012 (<0.001-0.0013)	0.0017 (0.001-0.021)	All <0.001	<0.001	NT	0.01	NA	0.05	0.1 (1)	1
Copper (Cu)	0.0023 (<0.001-0.005)	0.039 (0.027-0.055)	0.010 (0.002-0.039)	0.009 (<0.001-0.039)	0.0035	0.0014	1.5 (1.0)	1	0.2 (5)	0.4 – 5[8]
Lead (Pb)	All <0.001	0.049 (0.037-0.062)	0.013 (<0.0001-0.038)	0.004 (<0.0001- 0.013)	0.0047	0.0034	0.01	0.05	2 (5)	0.1
Manganese (Mn)	0.002	0.26 (0.0014-0.52)	0.47 (0.014-2.7)	0.008	NT	1.9	0.5 (0.1)	0.1	0.2 (10)	NA
Iron (Fe)	0.03	0.117 (0.043-0.19)	0.067 (<0.005-0.46)	0.008	NT	1.0	- (0.3)	0.3	0.2 (10)	NA
Nickel (Ni)	All <0.001	0.057 (0.055-0.058)	0.019 (0.015-0.023)	0.0046 (0.0016-0.0068)	0.0046	0.011	0.02 (-)	0.1	0.2 (2)	1
Zinc (Zn)	0.013 (<0.001-0.027)	0.09 (0.069-0.11)	0.047 (0.011-0.11)	0.024 (0.009-0.059)	0.017	0.008	- (3.0)	5	2 (5)	20
Sulfate	0.81	180 (150-210)	185 (2.5-360)	0.56	NT	NA	500 (250)	400	NA	1000

Notes

(1) all data in mg/L except pH. Data for period 2000 to 2003 used in data summary. For non-detect sample results, limit of detection assumed in calculating averages. Where single number given, one result only available.

(2) ANZECC (2000) Trigger Values (TV) for freshwaters for 95% species level of protection (considered appropriate for protection of slightly to moderately disturbed ecosystems). Where TVs not available, ANZECC (1992) freshwater guidelines used for aluminium and chromium

(3) from NHMRC (1996) Australian Drinking Water Guidelines. Guidelines are respectively for human health protection and (in brackets) aesthetics

(4) aluminium guideline for pH < 6.5. Guideline is 20x less stringent if pH >6.5

(5 TDS <500 mg/L desirable, <1000 mg/L acceptable

(6) ANZECC (2000) Table 5.2.3 guidelines for recreational purposes

(7 ANZECC (2000) Table 4.2.10 long-term irrigation trigger value (up to 100 yrs) and (in brackets) short-term irrigation TV (up to 20 yrs) respectively

(8) ANZECC (2000) Table 4.3.2 low risk trigger values for livestock drinking water. TV for Cu varies between 0.4 (sheep), 1 (cattle) and 5 (pigs, poultry) Guideline for sulfate is from ANZECC (1992)

(9) two average results for Al are for standard 0.45 micron and finer 0.2 micron filtered samples respectively

NT = not tested NA = not available

the conclusion that water quality in the deep bore HDD has not been affected by leakage of shallow contaminated water is plausible and accepted by the auditor.

The scope of further monitoring was also to have included monitoring of another nearby water supply bore, to assist in identifying possible contamination of bore HDD. Subsequently this was not required, by agreement with the auditor, on the basis that that EWL had compiled data for bores in the regional beneficial use aquifer which were adequate for comparison with the HDD results. These data demonstrated that the metals concentrations in HDD were not characteristic of the regional water quality. EWL Sciences (August 2003) (Section 3.2) refers to regional data from Radke *et al* (1998) and local data from EWL Sciences (2001) which indicate that the deep groundwater at the site (bore HDD) has significantly higher nickel and zinc concentrations than other water supply bores in the area. This data indicates that HDD may be contaminated from an on-site source, or that local geochemistry is uncharacteristic of that elsewhere in the area or region.

On the available data, the water quality in HDD complies with current Australian drinking water quality guidelines, although the nickel concentration in January 2003 marginally exceeded the guideline (refer Table 5 of EWL report, August 2003). The HDD zinc concentrations in 2000-2003 are considerably higher than those in the shallow aquifer, indicating that the deep groundwater zinc concentrations are not derived from leakage from the shallow groundwater. This conclusion is supported by the low concentrations of other metals/metalloids (such as aluminium) in HDD compared to high concentrations in shallow groundwater (bore 22440).

5.2.3 Contamination of Phreatic Groundwater

The monitoring of the shallow phreatic groundwater bores in the source zone (bore 22440), flow zone (bores HD21/22 and HD51/52) and discharge zone (bores HD61/62) in January 2003 confirmed that the shallow groundwater was contaminated with metals/metalloids aluminium (Al), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni) and zinc (Zn), sulfate and low (acidic) pH at the source zone (the former sulfur stockpile area), with generally decreasing contaminant concentrations and increasing pH as the groundwater migrates through the flow zone towards the wetland and stream discharge zone.

EWL Sciences (August 2003) discusses the data and time series trends for each zone, and considers compliance (or otherwise) with the revised objective of the site groundwater monitoring program to achieve compliance with water quality objectives for the protection of freshwater aquatic ecosystems in groundwater as it discharges to the surface water body, but not necessarily in the source or flow field zones.

Relevant data for the discussion below are presented in Table 21 of EWL Sciences (2001), Figures 8-20 and Table 5 of EWL Sciences (August 2003) and the present auditor's data summary Table 2.

Source Zone bores 22440, HD11/HD12

The data since commencement of monitoring in 1997 showed that the contaminant concentrations in shallow groundwater quality in the source zone reduced rapidly and dramatically following the removal of the sulfur stockpile and contaminated soil in 1997-1998. Over the period since 1998, contaminant concentrations and pH have been variable, with little or no clear trend towards lower concentrations or increased pH. The contaminant concentrations remain significantly above background levels in 2003. Although a gradual improvement is expected over time, it appears that there remains significant potential for solubilisation of metals/metalloids in the shallow groundwater from the source zone.

Flow Field Zone bores HD21/HD22 and HD51/HD52

The data for these bores also show a significant reduction in contaminant concentrations after source removal in 1997-1998, but no clear trend since that time. The 2003 data show similar contaminant concentrations to the previous 2000 data. Concentrations of Al, Cu, Pb and Ni in the flow field zone remain significantly above background, although pH and Zn are more similar to background concentrations.

Contaminant concentrations in the flow field zone are reduced from those in the source zone, confirming that attenuation processes are having a measurable effect over that flow distance.

Discharge Zone bores HD61/HD62

The contaminant concentrations in the bores in the discharge zone (near-stream location) are the best indicators of groundwater quality which will be discharged to the wetland/stream and exposed to benthic and in-stream aquatic organisms and ecosystems. These data should therefore be compared to the relevant water quality guidelines to identify compliance (or non compliance) with objectives for groundwater quality. In accordance with the auditor's recommendations, EWL adopted the ANZECC/ARMCANZ (2000) freshwater trigger values (TV) for 95% species protection as the appropriate water quality objectives.

Following auditor's review of the data from the January and March 2003 monitoring events, a third sample was taken from HD62 (HD61 was dry) in June 2003, specifically to clarify the effect of fine particulate concentrations on metal/metalloid concentrations.

The groundwater data for the discharge zone bores are presented and discussed in EWL Sciences (August 2003), Section 3.4. The results for contaminants Cu, Pb and Zn were variable, both between the sampling events in January, March and June 2003 and between the 2003 data and previous 1998-2000 data. The contaminant concentrations in the shallow bore HD61 were higher than in the deeper HD62 in January 2003, but the relative concentrations were reversed in March 2003 (refer Table 5 of EWL August 2003). Concentrations of Cn and Zn in June 2003 (both 0.45

μm and 0.2 μm filtered samples) were similar to those in March 2002, while the Pb concentrations reduced to non-detect (both filtered samples) in June 2003.

One possible explanation for the observed temporal trend is that the high metal concentrations in the shallow groundwater (HD61) reflect solubilisation in the early wet season through rainfall infiltration, followed by leaching to greater depth and increased concentrations observed at a later time in the deeper groundwater (HD62). EWL (August 2003, Section 3.1) refer to a possible "first flush" effect from percolating acidic rainfall to explain the variations between contaminant concentrations in the two bores. The effect would be expected to cause (as was observed) elevated metal concentrations early in the wet season in the shallowest bore (HD61 compared to HD62).

EWL (Section 2.2) also note that blank (equipment rinsate water) samples indicated a possible contamination source (other than the groundwater itself) for elevated Cu and Zn concentrations. However, in the auditor's opinion, this would not appear to adequately account for the elevated Cu, Pb or Zn concentrations reported for the two bores on the two occasions, other than possibly Cu and Zn in HD61 in January 2003.

EWL Sciences (August 2003), Section 3.4, argues that groundwater will be discharging to the wetland and stream when water levels in the bore HD61 are high, in particular above the land surface as was the case in March 2003. On that sampling occasion the concentrations of Cu, Pb and Zn were the lowest measured and complied with the ecosystem protection guidelines (refer Table 5 of EWL August 2003). However, from the auditor's understanding of the hydrological conditions and groundwater quality variability, it should be acknowledged that groundwater will discharge at times when metals concentrations are higher than the adopted water quality guidelines (as indicated by the accumulated data for bores HD61 and HD62), such as when both water levels and contaminant concentrations are high in HD61 earlier in the wet season..

If the average concentrations over the two (or three) sampling events in 2003 and two bores (HD61 and HD62) are taken to be the best available indication of discharge zone shallow phreatic groundwater quality, the concentrations of Cu, Pb and Zn are each about 2x the water quality objectives for ecosystem protection:

- average Cu concentration 3.5 μg/L compared to guideline of 1.4 μg/L
- average Pb concentration 4.7 μg/L compared to guideline of 3.4 μg/L
- average Zn concentration of 17 μg/L compared to guideline of 8 μg/L

The HD61/HD62 groundwater pH is slightly acidic and outside the guideline range (average 5.8 compared to the guideline of 6.5-9, but the pH is similar to background groundwater and stream pH

levels. The groundwater concentrations of other contaminants of potential concern including Cr, Fe, Mn and Ni, comply with the ecosystem protection objectives.

These data are shown in the data summary in Table 2 of this audit report. Considering the inherent conservatism of the objectives, the exceedences of guidelines for the metals Cu, Pb and Zn do not appear to represent a substantial risk to wetland/stream ecosystem health.

Following review of the January and March 2003 data, the auditor recommended another round of groundwater sampling at HD61/HD62 (if water remains in the shallow aquifer) to confirm dissolved contaminant concentrations. Analysis was undertaken for pH, Al, Cu, Pb and Zn. Any turbid samples were to be filtered in the field before acid preservation (or not preserved and filtered in the laboratory) to avoid a contribution to the analysis result from fine particulates, which were believed to be contributing to the elevated aluminium (and perhaps other metals) concentrations in earlier samples.

The deeper of the shallow discharge zone bores (HD62) was resampled in June 2003 (the water level had dropped post-wet season so that HD61 was dry) and samples were filtered using both standard (0.45 μm) and finer (0.2 μm) filters to remove particulates.

The results confirm that the variable and usually elevated concentrations of aluminium in these bores in preceding monitoring events was attributable to fine particulates, which were removed by filtration with a finer 0.2 μm filter. It is reasonable that only dissolved contaminant concentrations should be considered in assessing the risks of groundwater discharge to the surface water environment. On this basis the aluminium concentrations dissolved in the phreatic groundwater do not exceed background or stream concentrations (in the absence of reliable Australian guidelines), and the auditor is of the opinion that aluminium concentrations in groundwater do not present a risk to stream ecosystems.

The auditor notes that Table 5 of the EWL (August 2003) report does not include a water quality objective (investigation level) for Al, using instead the background concentration of 25 μg/L.

The auditor notes that ANZECC/ARMCANZ (2000) does not propose a high-reliability or moderate-reliability TV for Al where pH is below 6.5 (as it is here). However, these guidelines propose a low-reliability TV of 0.8 μg/L, while the older ANZECC (1992) guidelines and NEPM (1999) groundwater investigation levels (based on the 1992 guidelines) include a guideline of 5 μg/L for Al in freshwaters where pH<6.5. The corresponding guidelines for pH>6.5 are moderate-reliability TV of 55 μg/L and GIL of 100 μg/L. The guideline documents discuss the toxicity of Al to aquatic species, and note that the maximum toxicity occurs at pH in the range 5-5.2.

The auditor concludes that an appropriate objective for Al in this case is relatively low, of the order of 5 µg/L. However, this is over-ridden by the naturally high stream (and groundwater) Al concentrations. Data for the stream at this site (eg upstream sample location HDS3, February-May 2000) show Al concentrations of about 25-30 µg/L. Presumably the stream ecosystem is adapted to these Al concentrations. Also, the background shallow groundwater Al concentrations have been reported as variable and sometimes high (eg bore HDA 56 µg/L in May 2000).

The average Al concentration at the two bores HD61/HD62 over the three 2003 sampling events in samples using standard filtration of 0.45 µm is 100 µg/L, which is about 4x the stream concentration. This suggests that the groundwater may pose a risk of adverse impact on the stream ecosystem. However, the results from the most recent monitoring event (June 2003) using 0.45 µm filter are 2x stream concentrations, and with the finer filter (0.2 µm), Al was not detectable. These results indicate that Al in shallow groundwater does not pose a significant risk to stream ecosystem health.

5.2.4 Risks To Extractive Groundwater Uses

While it is understood (as discussed in Section 2.2) that the shallow phreatic groundwater is not (nor is likely to be) used for extractive purposes, in accordance with Victorian EPA guidelines for statutory environmental audits (which are recognised by the NT Government), all potential beneficial uses of groundwater need to be considered. Therefore, comment is provided below on the suitability (or otherwise) of the shallow groundwater for extractive uses. The auditor's data summary in Table 2 of this report includes groundwater objectives for extractive beneficial uses.

The background groundwater quality in the area is slightly acidic, but otherwise is suitable for any beneficial use. In the area affected by the contamination from the former sulphur stockpile, the shallow groundwater:

- is likely to be unsuitable for potable (drinking water) supply due to acidity and elevated concentrations of some or all of Al, Fe, Pb, Mn and Ni in the source and flow zones,
- on the most recent (Jan-June 2003) data, groundwater in the discharge zone (characterised by bores HD61/62) is suitable for potable water supply (and other extractive uses) except for slightly acidic pH of 5.8. However, this acidity is not considered to be a significant constraint as background monitoring bores confirm that groundwater in the area is naturally slightly acidic,
- is likely to be unsuitable for primary contact recreation (swimming or bathing) due to acidity and elevated concentrations of Al, Pb and Mn in the source zone, and

- may be unsuitable for long-term irrigation use due to elevated concentrations of Al, Mn and Fe in the source and flow zones.

It is likely that the shallow groundwater table rises to within the plant root zone in the wet season. It is unlikely that adverse effects on the health of plants would result during this time, as contaminant concentrations only slightly exceed the long-term irrigation trigger values, and these TVs are very conservative (short-term TVs are 20x the long-term TVs, and are not exceeded).

Note that aluminium is included above on the basis of concentrations in samples filtered with the standard 0.45 μm filter. These Al concentrations have been shown to be associated with fine particulates, which may in practice be removed by bore construction or in treatment prior to use.

5.3 Conclusions and Statement of Audit

From a detailed review of the available data and reports, the auditor concludes that the groundwater monitoring program has demonstrated that groundwater quality down-gradient of the former sulfur stockpile in the near-stream discharge zone does not significantly exceed the relevant guideline concentrations for protection of aquatic ecosystems, and so is unlikely to pose a significant risk to wetland or stream ecosystems. The auditor acknowledges that the discharge zone groundwater data for Cu, Pb and Zn do not strictly comply with adopted ecosystem guidelines (ANZECC/ARMCANZ 2000 freshwater trigger values for 95% level species protection). However, these guidelines are not intended to be remediation goals (NEPC 1999), but rather exceedence of these guidelines is intended to trigger further consideration of ecological risks. The auditor has therefore considered the risks, in light of a range of other factors, including:

- The inherent conservatism of the trigger values
- The relatively low degree of exceedence of the guidelines (by a factor of about 2x)
- The expected continued decrease in groundwater contaminant concentrations with time
- The considerable dilution and dispersion likely as groundwater discharges into the wetland and stream environment
- The relatively small zone of wetland and stream potentially affected
- Background concentrations of the contaminants of concern in groundwater and surface waters and the likely adaption of ecosystems to slightly elevated contaminant concentrations.

The auditor is of the opinion that strict adherence to the adopted water quality guidelines is unnecessary and unrealistic. On all the available evidence, the auditor concludes that the groundwater quality in the discharge zone does not present a significant risk to ecosystem health in the wetland and stream on the site or downstream.

The shallow groundwater is not a viable water resource for extractive uses in the area, due to poor bore yield and the seasonal nature of this aquifer. However, under the current policies and guidelines for auditors which apply in Victoria (and adopted in NT), an auditor is obliged to impose a restriction on the use of groundwater for extractive uses where groundwater quality is unsuitable for one or more of those uses. This restriction appears as condition (a) in the Statement of Environmental Audit incorporated in Section 6 of this audit report.

The NT DIPE (Peter Jolly, pers. comm.) has advised that restrictions on groundwater bore installation and extractive use in the affected area should apply to the deep (beneficial use) aquifer as well as the shallow groundwater, on the basis that vertical leakage of contaminated shallow groundwater may contaminate the deeper aquifer. This leakage may occur naturally, and be enhanced by deep bore installation and use.

The area where restrictions on groundwater bore installation and use are to apply has been defined by considering the groundwater monitoring data for the shallow groundwater bores in the affected area, and estimating the area in which groundwater quality is unsuitable or potentially unsuitable for one or more extractive uses. As discussed above, the groundwater quality guidelines for the uses of potable water and primary contact recreation (swimming) are exceeded in the bores in the source (sulfur stockpile) and flow zones (to the north-west of the source zone) for one or more of the contaminants (pH and metals). Comment was also received from DIPE in making this estimate of the affected area.

The auditor is of the opinion that a reasonable estimate of the area affected by contaminated shallow groundwater can be made based on existing information, without further bore installation and monitoring.

The appropriate area for imposition of groundwater use restriction is that shown shaded on the copy of the survey plan attached as Attachment 2 to the Statement of Environmental Audit (in Section 6 of this audit report). The area includes the former sulfur stockpile area (Area B on the plan) and is extended 100m to the north and 150m to the west of Area B. The coordinates of this area are shown on the site plan. Note, however, that Attachment 2 is not a signed survey plan as the auditor has included the (unsurveyed) additional coordinates of the groundwater restriction area.

Subject to these restrictions being imposed, the auditor is satisfied that no further groundwater investigation or remediation is necessary. The annual groundwater monitoring program may be discontinued.

The auditor has issued a new Statement of Environmental Audit which incorporates the conclusions of this audit and constraints on the extractive uses of any groundwater in the area of the site where shallow groundwater has been contaminated by the former sulfur storage use of the site (as described above). The new Statement does not include a requirement for further monitoring of the groundwater.

The new Statement will have the effect of superseding the previous Statement issued by Mr Adrian Hall of Tonkin Consulting in May 2001.

6. Audit Conclusions and Statement of Environmental Audit

6.1 Conclusions and Recommendations

This audit has complied with the scope of the auditor review required by the Statement of Environmental Audit issued by Mr Adrian Hall of Tonkin Consulting in May 2001. The findings of this current audit are summarised as follows:

a) Treatment of acidic sulfur-affected surface soils in the former sulfur stockpile area and borrow pit No. 1 has been effective in meeting the objective for soil pH set by the previous auditor, that is pH 5.0 $\pm$ 5 (or background for the area). Further soil treatment by lime application is not required.

b) Sulfur pellets remain visible in the affected areas, and in the opinion of the auditor these present an unacceptable aesthetic constraint on future residential site use. The auditor recommends that a minimum of 300mm clean topsoil be placed over these areas during development and prior to use for residential purposes.

c) Further monitoring of the deep (beneficial use) aquifer at the former sulfur stockpile area has confirmed that the site use has not resulted in pollution of the deep aquifer at the site.

d) Further monitoring of the shallow phreatic groundwater at the former sulfur stockpile area and in the flow and discharge zones between that source area and the stream/wetland to the north/ north-west has confirmed that:

- Groundwater pH has increased and concentrations of contaminants, in particular the metals/metalloids aluminium, copper, nickel, lead and zinc, have reduced substantially with time over the period 1997-2003.
- Contaminant (metals) concentrations in the source and flow zones remain elevated and pH remains low (acidic), and the shallow groundwater in these areas is likely to be unsuitable for extractive beneficial uses, in particular drinking water or filling of swimming pools or spas.
- Contaminant concentrations in the stream-side discharge zone generally comply with, or (for copper, lead and zinc) remain slightly above, the adopted water quality guidelines for the protection of aquatic ecosystems (from ANZECC/ ARMCANZ 2000). After consideration of a range of relevant factors mitigating the potential risk, the auditor concludes that the groundwater quality does not present a significant or unacceptable risk of harm to the ecological health of the wetland and stream.

6.2 Statement of Environmental Audit

The auditor is of the opinion that the remaining issues of sulfur-affected soil and contaminated shallow groundwater, as discussed in this audit report, present constraints on the audit outcome but

can be addressed through management requirements for the future development and use of the site. The proposed site development may proceed subject to these constraints. Specifically, no groundwater bores are to be installed in a defined area (shown as the groundwater use restricted area on Attachment 2 of the Statement of Environmental Audit) where shallow groundwater is contaminated from the former sulfur storage use. On the advice of the NT Department of Infrastructure, Planning and Environment, this restriction is to apply to groundwater bores installed to any depth (ie to the deep beneficial use aquifer as well as the shallow groundwater).

Accordingly, the auditor has issued a Statement of Environmental Audit which specifies these constraints and requirements. The Statement is attached on the following pages.

The auditor understands that the NT DIPE will attach a Caution Notice to the title or titles of land within the areas with soil or groundwater restrictions, which will enable future landowners to access information about the soil and groundwater conditions and restrictions on groundwater use.

Statement of Environmental Audit
Section 2498 Hundred of Strangways, Humpty Doo, NT

I, Richard Alan Graham of Sinclair Knight Merz, a person appointed by the Environment Protection Authority of Victoria under the Environment Protection Act 1970 ("the Act") as an environmental auditor for the purposes of the Act, having:

1. been requested by Mr Kevin Henry of Strangways Developments Pty Ltd to undertake an audit review and (if appropriate) issue a Certificate or Statement of Environmental Audit in relation to the site located at Section 2498 Hundred of Strangways, Humpty Doo, Northern Territory ("the site") owned and occupied by Strangways Developments Pty Ltd.

2. had regard to, amongst other things:

   (i) guidelines issued by the Victorian EPA and endorsed by the Northern Territory Department of Infrastructure, Planning and Environment;
   (ii) the beneficial uses that may be made of the site; and
   (iii) relevant environment protection policies and environmental quality guidelines.

   in making a total assessment of the nature and extent of any harm or detriment caused to, or the risk of any possible harm or detriment which may be caused to, any beneficial use made of the site by any industrial processes or activity, waste or substance (including any chemical substance); and

3. completed an environmental audit report in general accordance with Section 53X of the above Act, a copy of which has been sent to the Northern Territory Department of Infrastructure, Planning and Environment.

HEREBY STATE that I am of the opinion that:

The site is suitable for the land uses permitted (or given the consent of the relevant planning authority) for Zone RR (Rural Residential), Zone RL1 (Rural Living 1) or other applicable zone under the Litchfield Area Plan 2004, subject to the conditions attached below

(a) no groundwater bores, other than for the purposes of environmental monitoring, are to be installed and no extractive use made of groundwater (from any aquifer) in the area where groundwater is affected or potentially affected by contamination derived from the former sulphur stockpile use of the site (being the area shown as the groundwater use restricted area on Attachment 2 to this Statement of Environmental Audit); and

(b) areas where sulfur residues remain in surface soils, namely Area B (being the former sulfur stockpile area) and Area C (being the former borrow pit No. 1), as shown on the signed survey plan at Attachment 1 to this Statement of Environmental Audit, are suitable for the beneficial uses associated with the above land uses, subject to the additional conditions below:

SKM

(i) a minimum of 300mm clean topsoil shall be placed over Area B and Area C during development and prior to use for residential purposes to effectively remove the aesthetic effect of visible sulfur pellets remaining in surface soils in these areas; and

(ii) the ADAS (1974) soil sulfur suitability ratings (or other approved rating method) for concrete pipes and footings should be used to assess any construction involving in-ground placement of concrete, and (based on this assessment) the use of high alumina or super-sulfated concrete and cement should be specified for all below groundwater concrete structures such as pipes and footings.

The condition of the site is detrimental or potentially detrimental to (one or more) beneficial uses of the site. Accordingly I have not issued the equivalent of an unconditional Certificate of Environmental Audit for the site, reasons for which are presented in the environmental audit report and are summarised as follows:

(i) the shallow groundwater is contaminated in the vicinity of the former sulfur stockpile with low pH and elevated concentrations of some heavy metals; and

(ii) the near surface soils in the former sulfur stockpile area and borrow pit No. 1 contain visible pellets of sulfur, which are potentially aesthetically unacceptable if visible on the soil surface of a residential site.

This Statement of Environmental Audit forms part of the Environmental Audit Report entitled *Environmental Audit Review Report, Section 2498 Hundred of Strangways, Humpty Doo, Northern Territory*, for Strangways Developments Pty Ltd. SKM Reference DI04788, August 2004.

3 AUGUST 2004

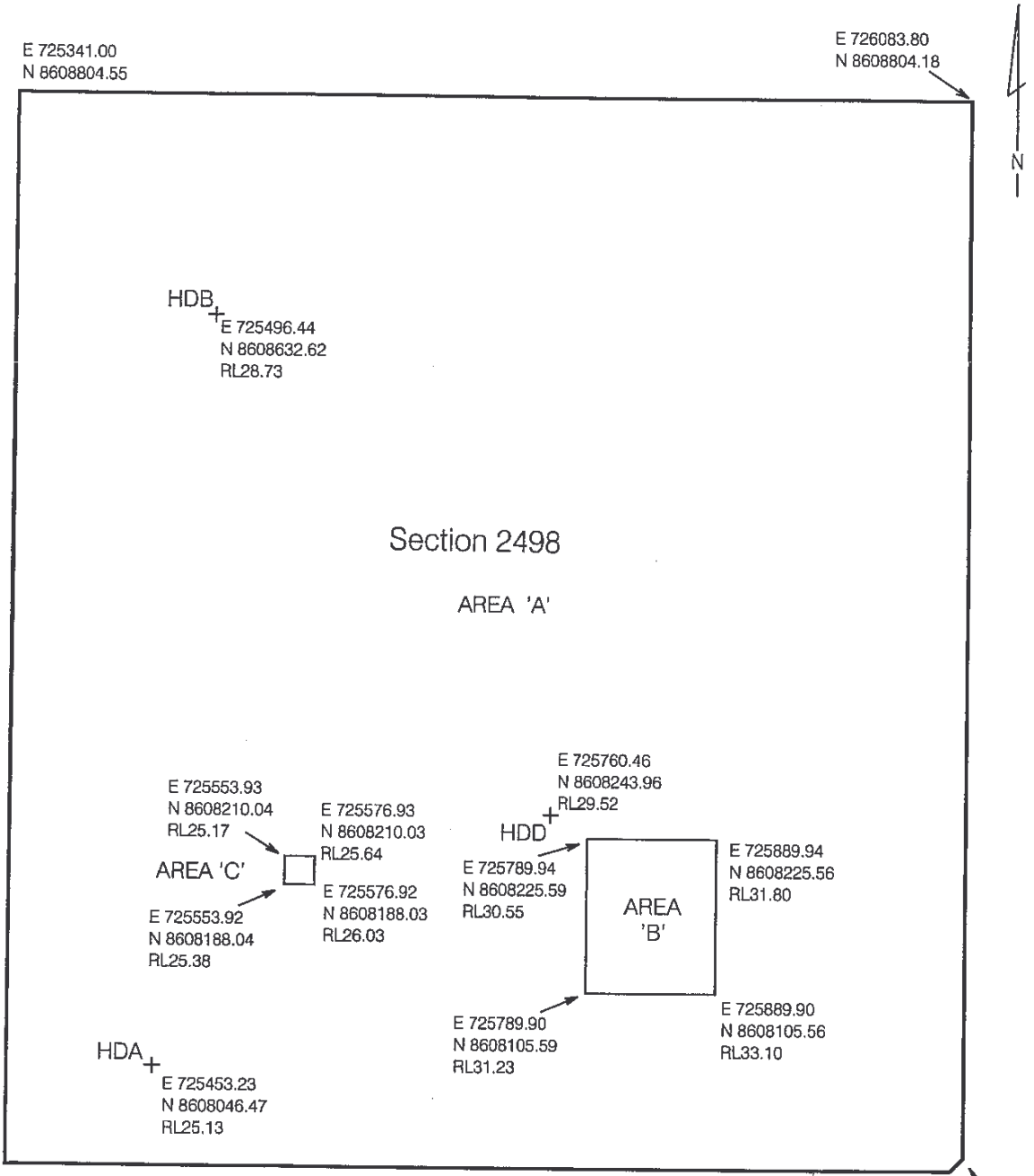
.....

Date Signed

.....

Richard A Graham
Environmental Auditor
(appointed pursuant to the Victorian Environment Protection Act 1970)

Attachment 1
to Statement of Environmental Audit
for Section 2498 Hundred of Strangways,
Humpty Doo, NT
SKM Reference DI4788, August 2004



To the best of my knowledge the co-ordinates & AHD levels shown are those that actually represent the GDA'94 & AHD levels for those points shown. Datum was derived from information received from the then Northern Territory Department of Lands Planning

2/5/04.

signed
Michael Milford
Licensed Surveyor

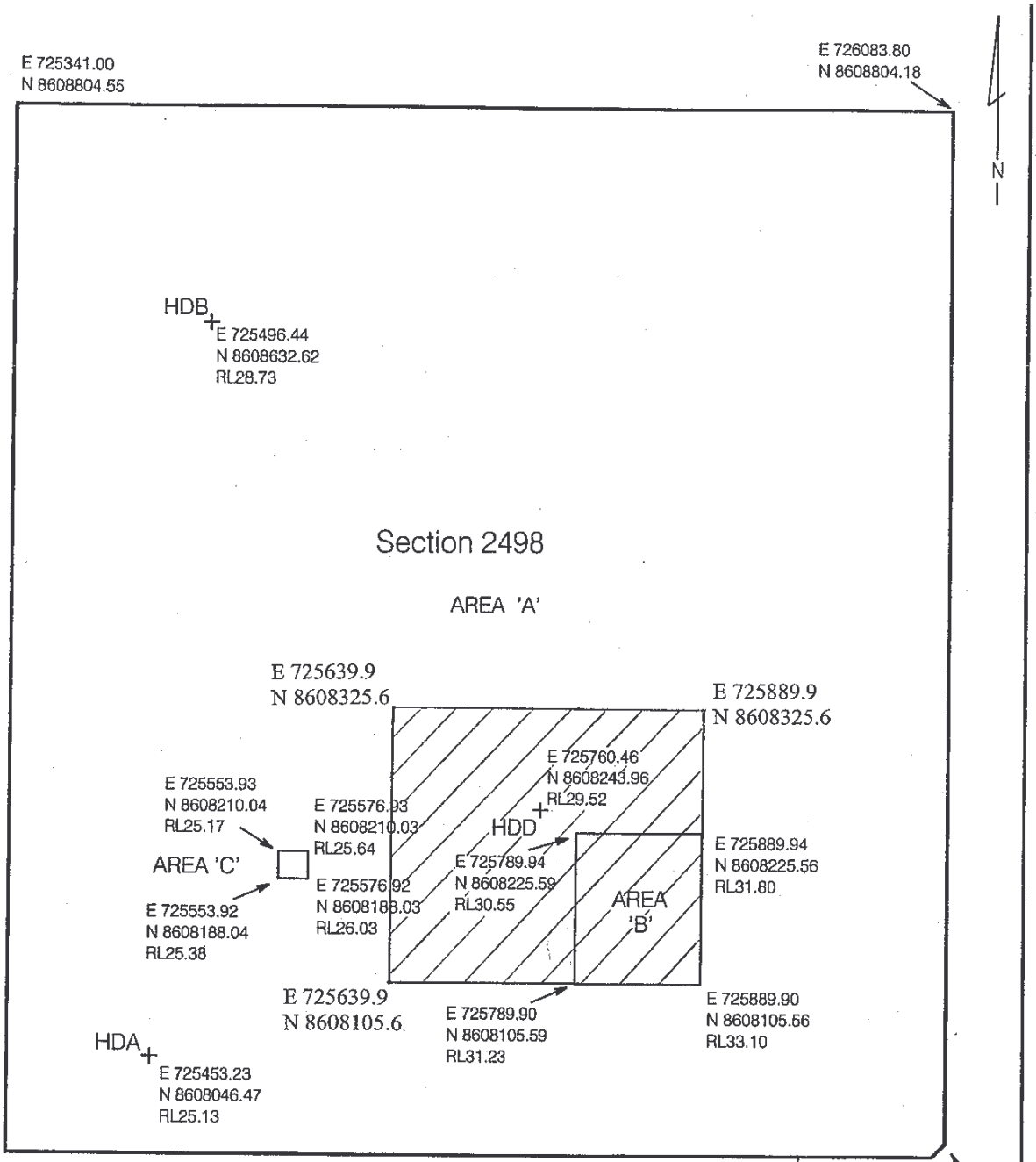
date

0 50 100 150 200 250
metres

NOTE: Co-ordinates are GDA '94 and AHD.

AUSURV PTY. LTD. CONSULTING SURVEYORS Ph: (08) 8981 6444 Fax: (08) 8941 2111 Email: ausurv@octa4.net.au	Surveyed L.J.T. Drawn C.S.D.S. Checked CAD File 01-5020_EML.DGN	Detail Survey Section 2498 Strangways, Litchfield Shire	Scale 1 : 5000 Date 7 JUN 01 File No. ASV01-1031 Drawing No. 1031-1	Sheet 1 of 1 Amdt. - Plot Size A4

Attachment 2
to Statement of Environmental Audit
for Section 2498 Hundred of Strangways,
Humpty Doo, NT
SKM Reference DI4788, August 2004



KEY:

Areas B and C – sulfur residue affected areas

Groundwater use restricted area

0 50 100 150 200 250
metres

NOTE: Co-ordinates are GDA '94 and AHD.

AUSURV PTY. LTD. CONSULTING SURVEYORS Ph: (08) 8981 6444 Fax: (08) 8941 2111 Email: ausurv@octa4.net.au	Surveyed L.J.T. Drawn C.S.D.S. Checked CAD File 01-5020 EML.DGN	Detail Survey Section 2498 Strangways, Litchfield Shire	Scale 1 : 5000 Date 7 JUN 01 File No. ASV01-1031 Drawing No. 1031-1	Sheet 1 of 1 Amdt. - Plot Size A4

Appendix A List of Documents Reviewed

- Australian and New Zealand Environment and Conservation Council (1992). Australian Water Quality Guidelines for Fresh and Marine Waters, November 1992.
- ANZECC/ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, October 2000.
- Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council (1992). Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.
- Environment Protection Authority of Victoria (2002). Environmental Auditor (Contaminated Land) Guidelines for Issue of Certificates and Statements of Environmental Audit. EPA Publication759b. Original version May 2001, reissued June 2001, and effective from 1 July 2001. Amended June 2002.
- EWL Sciences (2001). Completion of Audit Report Requirements for Section 2498 Strangways, Humpty Doo. Report of Job No 347 to ERA Ranger Mine, May 2001.
- EWL Sciences (July 2003). Validation Report. Report of Job No. 556 to Sinclair Knight Merz, July 2003.
- EWL Sciences (August 2003). Annual Soil and Groundwater Monitoring at Section 2498 Strangways. Report of Job No 444 to Strangways Developments Pty Ltd.
- National Environmental Health Forum (1999). Health-based Soil Investigation Levels. National Environmental Health Forum Monographs Soil Series No. 1, Third Edition (forms Schedule B(7a) to NEPC 1999).
- National Environment Protection Council (1999). National Environment Protection (Assessment of Site Contamination) Measure 1999. NEPC Service Corporation, December 1999.
- National Health and Medical Research Council/Agricultural and Resource Management Council of Australia and New Zealand (1996). Australian Drinking Water Guidelines.
- Standards Australia (1997). Australian Standard AS4482.1-1997: Guide to the Sampling and Investigation of Potentially Contaminated Soil. Part 1: Non-volatile and Semi-volatile Compounds. September 1997.
- Swartjes, F.A (1999). Risk-Based Assessment of Soil and Groundwater Quality in the Netherlands: Standards and Remediation Urgency. Risk Analysis, Vol 19, No 6, 1999.

- Tonkin Consulting (2001). Section 2498 Hundred of Strangways, Humpty Doo NT: Environmental Audit Report (3 volumes). Report Ref. No. 990869RA1, for Energy Resources of Australia Ltd. May 2001.
- US Environmental Protection Agency Region 9 (2001). Preliminary Remediation Goals (PRGs) Update. Access from www.epa.gov/region09/waste/sfund/prg/
- Victorian Government (1997). State Environment Protection Policy for Groundwaters of Victoria. Victorian Government Gazette, 17 December 1997.
- Victorian Government (2002). State Environment Protection Policy (Prevention and Management of Contamination of Land). Vic. Govt Gazette No. S95, 4 June 2002.
- VROM (2000). Netherlands Ministerial Circular on Target and Intervention Values for soil remediation. Reference DBO/1999226863.

Appendix B Extracts from Assessment and Audit Reports, 2001-2003

EWL Sciences Pty Ltd
Darwin Office 482 Stuart Highway, Winnellie NT 0820
PO Box 39443, Winnellie NT 0821
Tel: (08) 8922 5200 Fax (08) 8922 5260

EWL Sciences
earth · water · life

ACN 000 955 171 Registered Research Agency No 31639

COMPLETION OF AUDIT REPORT REQUIREMENTS FOR SECTION 2498, STRANGWAYS HUMPTY DOO

for

ERA Ranger Mine

by

EWL Sciences Pty Ltd

Authors: I Hollingsworth, A Puhalovich & A Zimmermann

May 2001

EXECUTIVE SUMMARY

This is the fifth and final report out of a series of reports documenting the remediation of the former sulfur stockpile facility at Section 2498 Hundred of Strangways, Humpty Doo near Darwin. About 1 ha of the 62.1 ha property was utilised by ERA Ranger Mine for stockpiling sulfur from 1982 until 1997.

Preliminary investigations between November 1997 and February 1998 indicated high sulfur concentrations and elevated levels of some heavy metals in the soils of the former stockpile area and in an old borrow pit nearby and in the shallow groundwater beneath and downgradient of the former stockpile area. This was followed by more detailed site investigations and assessments, the removal of contaminated surface soils and rehabilitation of the site, and a validation and monitoring program.

This report addresses additional remediation and investigative works required by the auditor, a health and ecological risk assessment (based on National Environmental Protection Council guidelines) and a land management plan for the site. The main outcomes are:

Soils

- The bitumen hardstand and the concrete slab of the former caretakers quarters were removed in September 1999 and May 2000 respectively. Levels of organochlorine (OC) pesticides, polychlorinated biphenyls (PCB's), organophosphate (OP) pesticides and hydrocarbons in the soils underneath these areas were below the HIL guideline values.
- No evidence of the formation of secondary sulfides was provided by measurements of dissolved oxygen concentrations at 10 monitoring bores and soil profile investigations (incl. total sulfur, acid neutralising capacity, net acid producing potential) near the bore with the highest concentrations of sulfate (22440).
- Small amounts (<2% by area) of visible elemental sulfur were observed to a maximum depth of 20 cm in some shallow soil profiles and in localised patches on the surface. Removal of the residual sulfur would require substantial earthworks. The expense of such remediation works would not justify the benefits, since (a) elemental sulfur is of low toxicity and non-carcinogenic (Australian Health, 1999) and (b) the abundance of the remaining elemental sulfur (although visible at very close range) was assessed to be low.
- Surface soil monitoring from 1998 to 2000 demonstrated that the soil pH was within the range (± 0.5) of the site specific background pH of 5.0 at the majority of the measured plots and that the re-established vegetation was in good condition. Since a limited number of soil samples demonstrated pH values significantly (> 0.5) below the site specific pH of 5.0, it is recommended to continue the soil monitoring program and, if the results are not satisfactory, to apply further lime to areas with low pH, until the soil pH is controlled. In general, soil pH should be monitored at the end of the wet season to assess the long term success of the remediation and the requirements for further liming.
- Sulfur and sulfate concentrations exceeded the EIL guideline levels for built structures in some areas of the former stockpile area and borrow pit #1, which may pose a risk of corrosion to buried concrete structures. Therefore, it is recommended to use the ADAS soil sulfur suitability ratings (ADAS 1974) (or other appropriate rating method) for all in-ground structures and materials.

Groundwater

- A deep bore (HDD, 60m) was installed near the most contaminated bore 22440 to investigate for potential impacts of sulfur storage on the deep beneficial use aquifer.
- Two additional background bores (HDA, HDB) were installed in the shallow phreatic aquifer.
- Water analysis results (including Victorian EPA screening analysis) indicated a low level groundwater contamination of some heavy metals, which was restricted to the shallow aquifer under and immediately downgradient of the former sulfur stockpile area. The deep beneficial use aquifer did not appear to be affected by the low level contamination of the shallow aquifer. The water quality results were below GIL drinking guideline values. The water quality results of the background bores indicated naturally elevated levels of metals in the groundwater of the local shallow phreatic aquifer.
- Water quality monitoring of the most contaminated bore 22440 indicated a decreasing trend in contaminant levels of the shallow aquifer since the start of the remediation works in 1997. As demonstrated in a leaching study of soil cores, the improvements in water quality are a likely consequence of the passive remediation process (liming). The application of lime has raised the pH, and consequently stopped the dissolution of natural heavy metals in the soil.

Local Hydrogeology and Contaminant Transport

- Borelog data and other information from the area indicated that the local hydrogeology comprises a deep confined aquifer in fractured shales, an upper shallow phreatic aquifer within 2m of the land surface and shales of very low permeability separating the 2 aquifers.
- The shallow aquifer is recharged mainly by rainwater with an infiltration rate of approximately 600mm per year and dries out at the end of the dry season. Discharge occurs via evapotranspiration or into the nearby creek line. Recharge to the deeper aquifer appears to be limited to localised areas of fractured rock outcrop up-slope of the former sulfur stockpile area.
- Modelling of the fate and transport of the shallow groundwater contaminants indicated that the risk of a detrimental impact on nearby stream water or the deep beneficial uses aquifer, which is the main local domestic water supply, is very low. This was partly owing to the high dilution of recharge from the phreatic groundwater plume to the deep aquifer or to the creek (dilution factor estimates of 10 and 8 respectively). Active remediation of the residual contamination of the phreatic groundwater is therefore not recommended. However, ongoing monitoring is recommended to confirm the observed declining trends in heavy metal concentrations.

Future Monitoring and Land Management

Based on the current status of the site, the following monitoring program is recommended:

- Soil pH in former stockpile area and borrow pit #1 should be monitored annually at the end of the wet season (April/May).
- The phreatic groundwater should be monitored at the 3 most contaminated bores (22440, HD12, HD12) and at 1 background bore (HDA) annually at the beginning of the wet season (Dec/Jan, depending on rainfall). Bore water should be tested for pH and EC

in the field and for Al, As, Cu, Pb, pH and EC by a NATA accredited laboratory. The beneficial use aquifer (HDD) should also be included in the monitoring program as a precaution.

Based on the precautionary principle it is recommended that "Temporary Conditions" are placed on the land use for the former stockpile area and borrow pit #1, which could be attached to the "Statement of Environmental Audit". The temporary conditions should exclude the use of the phreatic groundwater and the temporary land use should not restrict ongoing monitoring and possible remediation works. Under the RL1 zoning regulations (DLPE 2000), the most suitable land use would be the development of the area into a temporary "flora and fauna sanctuary". Alternatively, semi-commercial land uses, such as "Retail Agricultural Stall", as permitted and defined under the RL1 zoning regulations (DLPE 2000), would also be suitable as temporary land use options.

The contaminant status of the site should be reviewed annually. Depending on the outcomes of this review, the "Temporary Conditions" could be lifted or the monitoring program continued and possibly adjusted. Once the appropriate environmental guideline targets have been met, the Statement of Environmental Audit should be reviewed and the former stockpile and borrow pit #1 areas released for rural residential living and the land uses defined under the Litchfield Area Plan 1992 RL1 zone objectives (DLPE 2000).

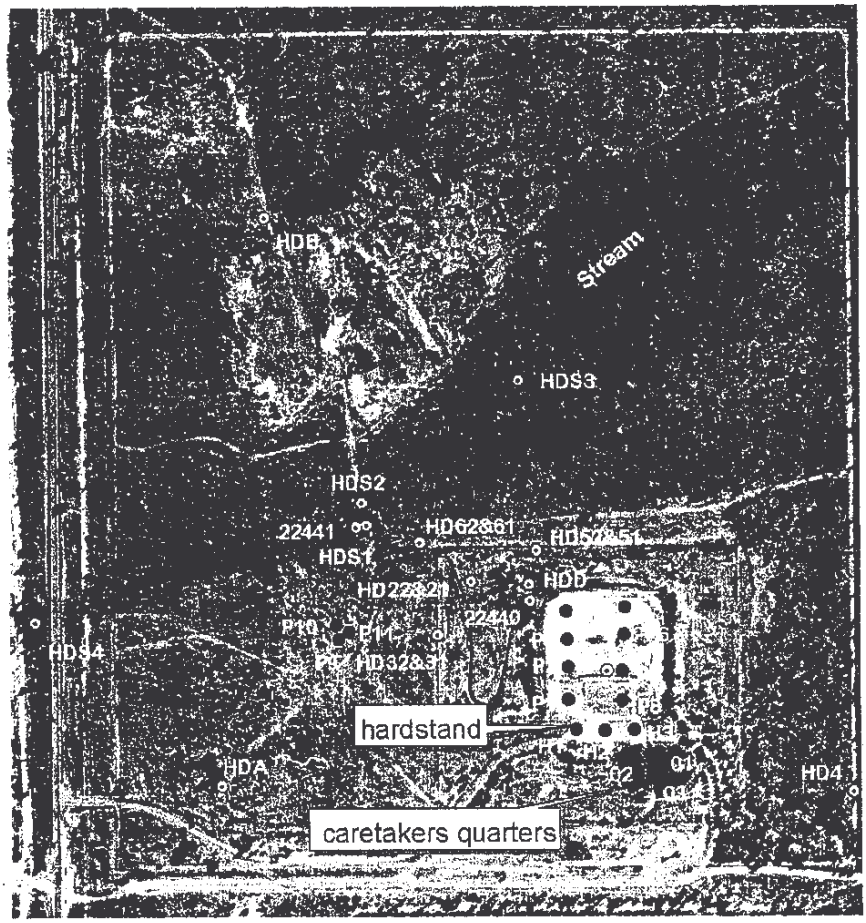


Figure 6 Groundwater, stream water and soil sampling stations monitored at Section 2498 Strangways since January 2000.

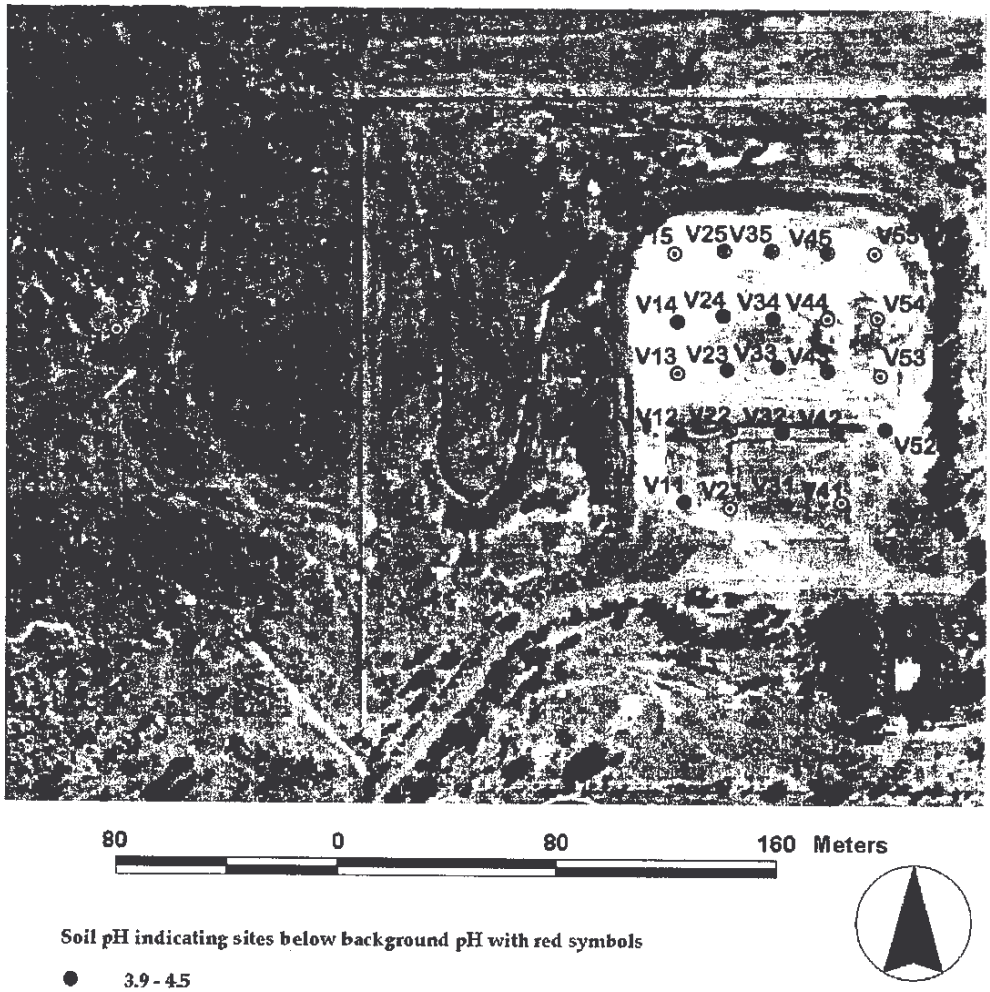


Figure 7 Soil pH monitoring sites. Sites with surface pH less than background are shown in red.

Table 21 Water chemistry results (mg.L^{-1}), highlighting water quality parameters that exceed the GIL values.

DATE	SITE	REPORT ID	Al	Cr	Cu	Fe	Pb	Mg	Mn	Zn	HCO3	Cl	TDS	SO_4	pH	EC (mS/cm)	DO (mg/L)	comment
15/02/00	22440	RN146197	12	0.002	0.037	0.043	0.056	13	0.0014	0.11	0	3.3	370	210	3.5	0.058	-	phreatic groundwater
15/02/00	22440/1	RN146197	11	0.002	0.035	0.9	0.065	19	1.5	0.098	0	3.4	410	230	3.5	0.65	-	phreatic groundwater
15/02/00	22440/2	RN146197	1	<0.001	0.005	0.13	0.13	74	1.7	0.17	0	3.9	570	390	3.8	0.89	-	phreatic groundwater
15/02/00	HD11	RN146197	0.1	<0.001	0.006	<0.005	0.006	0.78	0.004	0.019	0	3	46	9.8	4.4	0.07	-	phreatic groundwater
15/02/00	HD12	RN146197	0.038	<0.001	0.001	<0.005	0.0028	0.36	0.003	0.017	0	3.6	20	2.5	4.8	0.03	-	phreatic groundwater
15/02/00	HD21	RN146197	0.069	<0.001	0.002	<0.005	0.018	27	0.25	0.011	3.7	2.9	370	230	4.8	0.057	-	phreatic groundwater
15/02/00	HD22	RN146197	<0.002	<0.001	0.0023	<0.005	0.008	24	0.091	0.039	11	4.4	320	2.5	5.4	0.5	-	phreatic groundwater
15/02/00	HD4	RN146197	0.002	<0.001	<0.001	4.9	<0.0001	0.18	0.029	0.031	7.4	4.6	19	0.82	5.2	0.03	-	Phreatic background
15/02/00	HD51	RN146197	0.41	<0.001	0.005	0.46	0.0032	18	2.7	0.056	0	2.4	280	150	3.7	0.044	-	phreatic groundwater
15/02/00	HD52	RN146197	0.013	<0.001	0.006	0.012	0.0054	37	0.24	0.094	0	3.7	380	250	4.8	0.06	-	phreatic groundwater
15/02/00	HDS1	RN146197	0.14	<0.001	<0.001	0.036	0.001	1.1	0.1	0.037	11	2.6	29	10	5	0.04	-	Stream at stockpile inlet
15/02/00	HDS3	RN146197	0.026	<0.001	<0.001	0.046	0.0001	0.19	0.003	0.042	7.4	2.5	9.2	0	5.6	0.01	-	Stream background
15/02/00	HDS4	RN146197	0.035	<0.001	<0.001	<0.005	0.0002	0.55	0.02	0.011	4.4	3.3	14	3.1	5.6	0.02	-	Stream at property boundary
23/05/00	22440	RN164073	5.4	0.001	0.035	0.19	0.04	11	0.52	0.069	0	3.6	290	150	3.39	0.278	4.26	phreatic groundwater
23/05/00	22440/1	RN164073	3.5	<0.001	0.025	0.82	0.038	16	0.64	0.076	0	3.4	330	160	3.41	0.423	3.71	phreatic groundwater
23/05/00	HD11	RN164073	0.093	<0.001	0.015	0.047	0.005	0.97	0.006	0.027	0	3.8	35	8.3	4.27	0.046	4.04	phreatic groundwater
23/05/00	HD12	RN164073	0.038	<0.001	0.014	0.007	0.003	0.48	0.003	0.024	3.1	4.3	22	3.2	4.65	0.028	3.18	phreatic groundwater
23/05/00	HD21	RN164073	0.05	<0.001	0.007	0.034	0.015	32	0.2	0.028	2	3.7	480	360	4.76	0.628	2.81	phreatic groundwater
23/05/00	HD22	RN164073	0.002	<0.001	0.003	<0.005	0.004	22	0.051	0.047	13	4.5	330	220	5.25	0.435	1.77	phreatic groundwater
23/05/00	HD32	RN164073	0.002	<0.001	0.025	<0.005	<0.0001	5.2	0.014	0.019	37	6.9	70	8.3	5.77	0.087	3.31	Stream in main channel
23/05/00	HD4	RN164073	0.005	<0.001	<0.001	11.0	<0.0001	0.29	0.025	0.031	0	5.5	23	0.75	4.5	0.036	-	Phreatic background
23/05/00	HD52	RN164073	0.013	<0.001	0.039	0.01	0.004	32	0.2	0.11	3.8	3.8	370	260	5.01	0.495	7.05	phreatic groundwater
23/05/00	HD62	RN164073	0.004	<0.001	0.039	0.008	<0.0001	3.7	0.008	0.059	35	5.2	54	0.56	5.79	0.304	3.29	phreatic groundwater
23/05/00	HDA	RN164073	0.056	<0.001	0.005	0.03	<0.0001	9.2	0.002	0.012	248	2.7	280	0.81	6.93	0.359	5.39	Phreatic background
23/05/00	HDB	RN164073	0.017	<0.001	0.006	0.014	<0.0001	0.6	0.004	0.016	5.6	2.4	14	0.2	4.69	0.018	6.6	Phreatic background
23/05/00	HDS2	RN164073	0.027	<0.001	<0.001	0.11	<0.0001	0.44	0.008	0.007	8	2.9	13	0.32	6.17	0.007	6.4	Stream in main channel
23/05/00	HDS3	RN164073	0.029	<0.001	<0.001	0.17	<0.0001	0.45	0.009	0.004	6.3	2.7	13	3.2	5.63	0.015	5.86	Stream background
23/05/00	HDS4	RN164073	0.032	<0.001	<0.001	0.14	<0.0001	0.72	0.03	0.006	8.3	2.9	20	4.6	5.46	0.057	1.2	Phreatic background
13/12/00	22440	RN200020 *	9.600	0.0021	0.055		0.062			0.088				-	3.4	0.470	0.24	Phreatic groundwater
13/12/00	HDA	RN200020 *	<0.002	0.0013	0.001		<0.0001			<0.001				-	7.1	0.155	1.59	Phreatic background
GIL Aquatic Ecosystems/Fresh Water			<0.005 (pH <6.5) <0.1 (pH >6.5)	0.01	0.002-0.005	1	0.001-0.005			0.005-0.05						1.5	6	
30/10/00	HDD	RN191269	0.015	0.002	<0.001	0.230	<0.0001			0.110	85	7.8	150	34	7.1	0.24		Confined groundwater aquifer
13/12/00	HDD	RN200020 *	<0.002	<0.001	<0.001		<0.0001			0.012				-	6.5	0.195	0.24	Confined groundwater aquifer
GIL Drinking Water/Health/Aesthetic			0.2		2.0	0.3	0.01		0.5	3.0		250		400				

Table 25 Overview of the land and water management plan for the former stockpile area and borrow pit #1..

ISSUE	RESPONSE	PLAN
Localised low Soil pH	Annual monitoring at the end of the wet season until all pH values meet the target.	**Sample Location:** 1. Former sulfur stockpile area, 25 sites approximately 20 m apart in a grid pattern. 2. Borrow Pit 1, 3 sites approximately 20 m apart. **Sample Depth:** 0-10 cm horizon **Frequency:** annually **Time:** end of wet season (April/May depending on rainfall), **Analyse:** Soil $pH_{(1:5)}$[1] **Action:** Apply agricultural lime at a rate of 5 t/ha where pH is less than 4.5. **Target:** pH 5.0 (± 0.5) **Review:** annually
High soil sulfur and sulfate residues	Construction conditions	Use ADAS soil sulfur suitability ratings (ADAS 1974) for concrete pipes and footings (or other appropriate rating method) in the former sulfur stockpile area.
Phreatic groundwater (Aquifer A) contamination	Annual monitoring at the beginning of the wet season until all GIL are met.	**Sample Location:** • 1 phreatic groundwater background bore (HDA) • 3 phreatic groundwater contaminated bores (22440, HD12, HD22) • 1 beneficial use aquifer bore (HDD) **Frequency:** annually **Time:** beginning of the wet season (Jan/Dec depending on rainfall) **Analyse:** Heavy metals (Al, As, Cu, Pb), pH & EC by a certified laboratory, field pH & EC **Target:** recommended GIL Aquatic Ecosystems/Fresh Water guidelines **Review:** annually

[1] Rayment & Higginson (1991)

Energy Resources of Australia Limited

Section 2498 Hundred of Strangways
Humpty Doo NT
Environmental Audit Report

Volume 1 of 3

Principal Contact
Adrian Hall

May 2001

ADELAIDE
TONKIN CONSULTING
5 COOKE TERRACE
WAYVILLE SA 5034
T +61 8 8273 3100
F +61 8 8273 3110
E adelaide@tonkin.com.au

MOUNT GAMBIER
JONES TONKIN
1 KRUMMEL STREET
MOUNT GAMBIER SA 5290
PO BOX 1192
MOUNT GAMBIER SA 5291
T +61 8 8723 5002
F +61 8 8723 5004
E mtgambier@tonkin.com.au

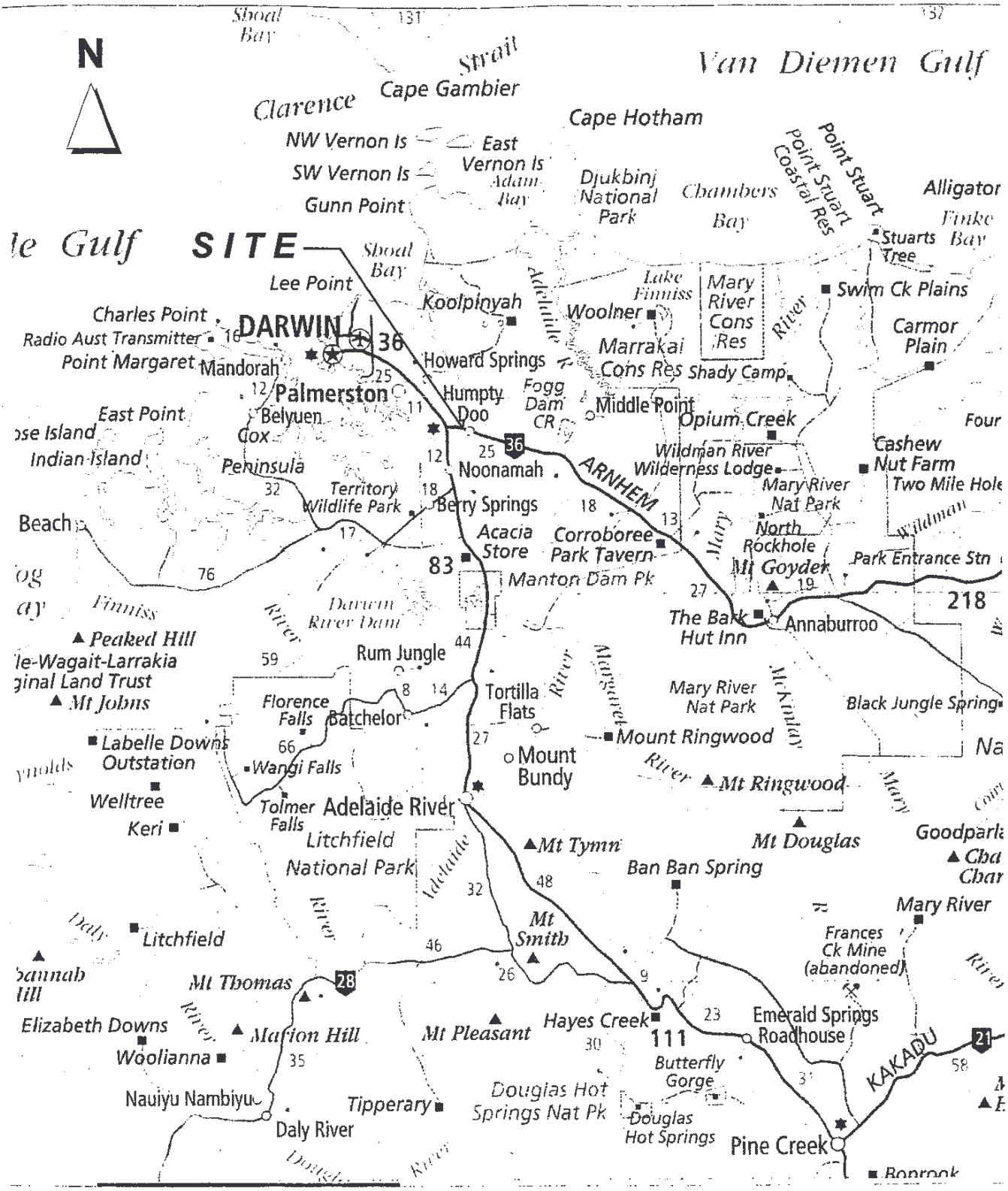
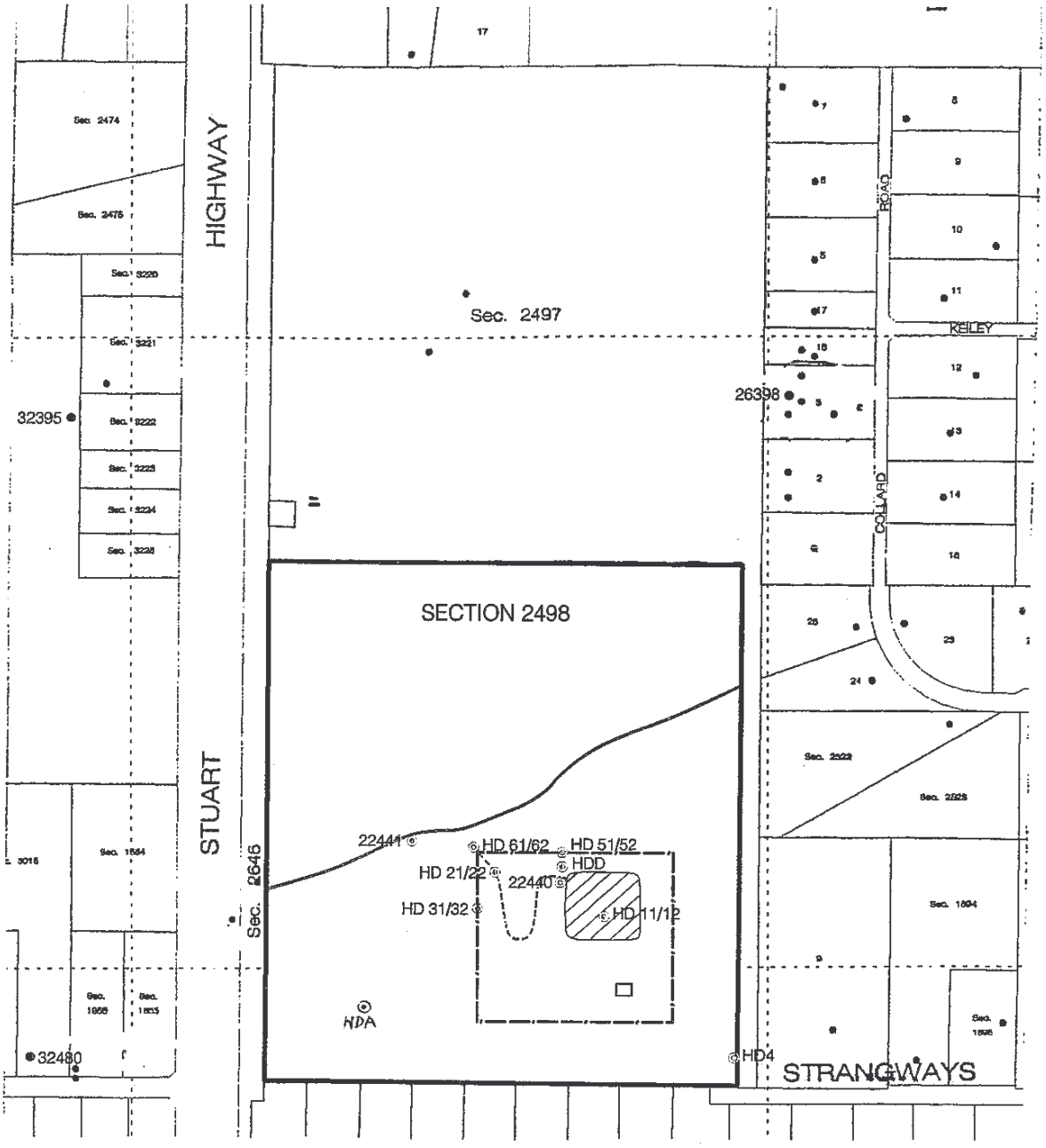


Figure 1.1
Site Location

Tonkin ENGINEERING SCIENCE
ADELAIDE
TONKIN CONSULTING
5 COOKE TERRACE
WAYVILLE SA 5034
T +61 8 8273 3100
F +61 8 8273 3110
E adelaide@tonkin.com.au

Data: Australia Road Atlas (2000)
Date: 15/01/2001
Drawing: fig11.wor
Drawn: T.F.
Job No: 99.0869

ERA Ranger Mine
Section 2498, Strangways Rd
Humpty Doo, NT
Site Audit Report



LEGEND

- Security Fence
- Caretaker Accomodation
- Sulfur Stockpile Area
- Registered Bore (off site)
- Monitoring Well (on site)
- Stream
- Drainage Channel
- Extent of Audit

100 50 0 100 200 300 Metres

BAR SCALE - 1:10,000 (Approx.)

Figure 1.2

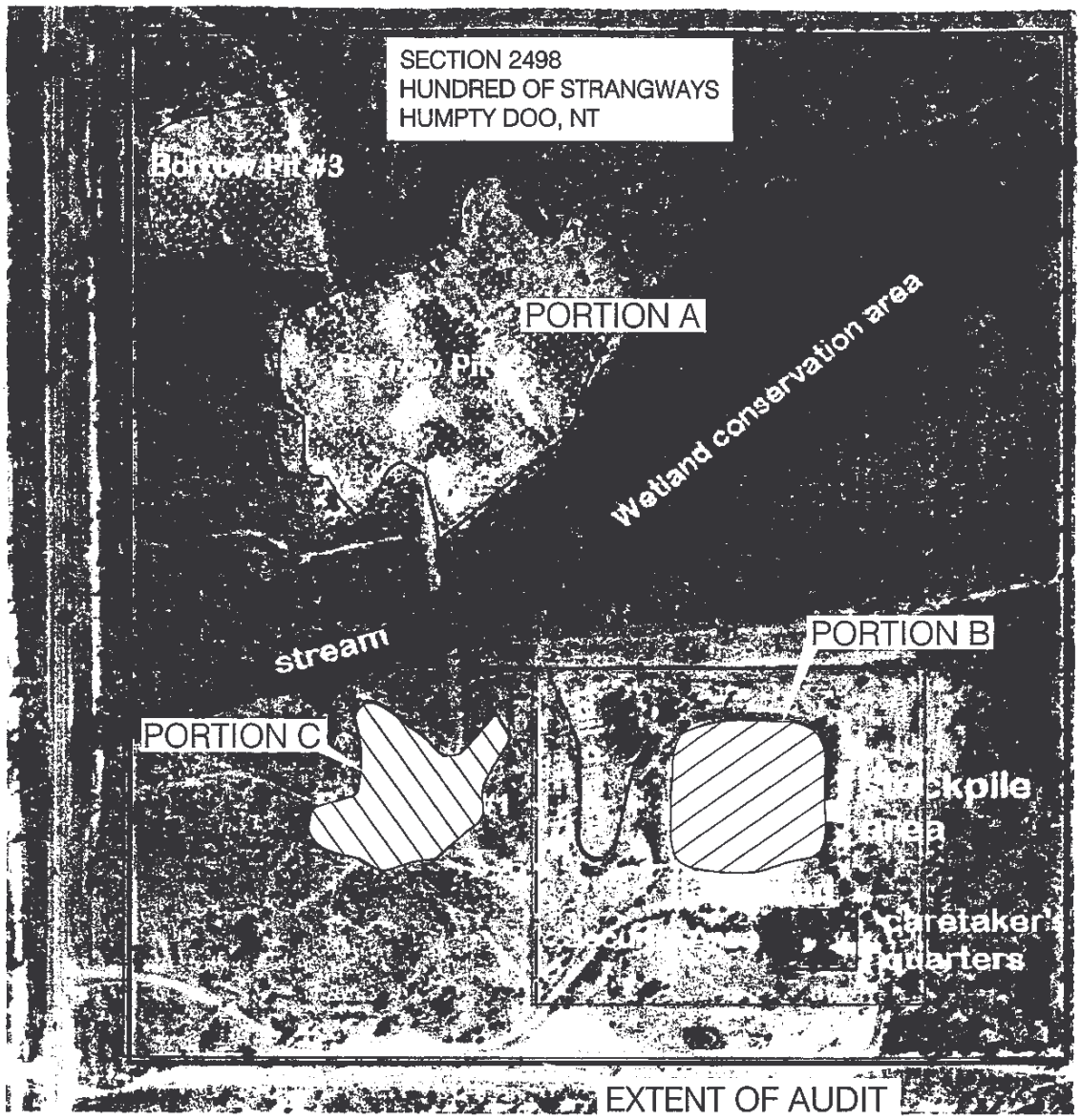
Site Plan Showing Extent of Audit and Groundwater Monitoring Well Locations

Lands Planning Environment, Northern Territory Government (27/03/2000) for: EWL (2000a) Figure 1

ADELAIDE
TONKIN CONSULTING
5 COOKE TERRACE
WAYVILLE SA 5034
T +61 8 8273 3100
F +61 8 8273 3110
E adelaide@tonkin.com.au

Revision:	
Date:	30/05/2001
Drawing:	Figure12.dwg
Drawn:	T.F.
Job No:	99.0869
Scale:	As Shown

ERA Ranger Mine
Section 2498, Hundred of Strangways
Humpty Doo, NT
Environmental Audit Report



NOTE: PORTION A IS THE WHOLE OF THE SITE
EXCLUDING PORTIONS B AND C.

100 50 0 100 200 300 Metres

BAR SCALE - 1:5,000 (Approx.)

EWL (2001) Figure 2

Figure 1.3

Site Plan Showing Portions A, B & C

ADELAIDE
TONKIN CONSULTING
5 COOKE TERRACE
WAYVILLE SA 5034
T +61 8 8273 3100
F +61 8 8273 3110
E adelaide@tonkin.com.au

Revision:
Date: 30/05/20001
Drawing: Figure13.dwg
Drawn: T.F.
Job No: 99.0869
Scale: As Shown

ERA Ranger Mine
Section 2498, Hundred of Strangways
Humpty Doo, NT
Environmental Audit Report

EXECUTIVE SUMMARY

This Environmental Audit Report has been prepared for the proposed residential development of the site located at Section 2498, Hundred of Strangways, Humpty Doo, Northern Territory (see Location Plan, Figure 1.1). This report follows the completion of preliminary site investigations, detailed site investigations, remediation and validation prepared by EWL Sciences for Energy Resources of Australia Limited.

The report has been prepared in accordance with the Victorian Environment Protection Authority (EPA) *Guidelines for Environmental auditors Contaminated Land, Issue of Certificates of Environmental Audit,* WH 91/14, May 1992, and other relevant guidelines issued by the Victorian EPA and endorsed by the Department of Lands, Planning and Environment (DLP&E), Northern Territory.

Summary information is set out as follows:

Name of auditor
Mr Adrian Hall of Tonkin Consulting

Date of appointment as an Accredited Environmental Auditor under the Environment Protection Authority Act, 1970, Victoria
7 January 1997

Name of person making a request for a Environmental Audit Report
Mr Andrew Jackson (Manager Energy Resources of Australia Limited)

Name of primary consultant undertaking site investigations
EWL Sciences Pty Ltd

Date of appointment as auditor for this site
13 December 1999

Date of notification of Department of Lands, Planning and Environment (DLP&E)
4 January 2000

Address of the site being audited
35 Strangways Road, Humpty Doo, Northern Territory

Lands Title Information
Volume 179, Folio 055, Section 2498 Hundred of Strangways.

Land Use Zoning
Rural Living 1

Name of current site owner and occupier
Ranger Uranium Mines Pty Ltd

Documentation reviewed

1. EWL Sciences (2000a), *ERA Sulfur Stockpile Rehabilitation, Preliminary Site Investigations,* for Energy Resources of Australia Limited, April 2000.

2. EWL Sciences (2000b), *ERA Humpty Doo Sulfur Stockpile, Stage 2 Report, Detailed Site Investigation,* for Energy Resources of Australia Limited, April 2000.
3. EWL Sciences (2000c), *Remediation Action Plan, Humpty Doo Sulfur Stockpile, Stage 3 Report,* for Energy Resources of Australia Limited, April 2000.
4. EWL Sciences (2000d), *Validation Report for External auditor of Remediation at the Humpty Doo Sulfur Stockpile Site,* for Energy Resources of Australia Limited, April 2000.
5. EWL Sciences (2001), *Completion of Audit Report Requirements for Section 2498, Strangways Humpty Doo,* for Energy Resources of Australia Limited, May 2001.

Audit Conclusions

The conclusions of this Environmental Audit are set out as follows:

1. The studies conducted by EWL Sciences were assessed by the auditor as being adequate to determine the contamination status of the site.

2. The overall sampling frequency (i.e. the test location spacing and the selection of samples) is considered by the auditor to be acceptable. The analytical parameters are considered by the auditor to be sufficient to adequately characterise the level of soil contamination on the site.

3. The overall methodology and QA/QC procedures employed by EWL Sciences are considered by the auditor to be acceptable for the purposes of this Audit.

4. The near surface soils in the Former Sulfur Stockpile Area and Borrow Pit No 1 are contaminated, with unacceptably low pH, and unacceptably high concentrations of sulfur.

5. Elsewhere on the site there are no unacceptable human health or ecological risks associated with the soils.

6. The shallow phreatic groundwater (Aquifer A) is polluted in the vicinity of well 22440, with unacceptably low pH, and unacceptably high concentrations of some heavy metals.

7. The deep beneficial use aquifer (Aquifer B) has not been impacted by contamination from near surface soils or shallow phreatic groundwater.

8. The potential for off site effects of contaminant migration from the site, e.g. as a result of leaching of contaminants to the groundwater table, or stormwater runoff, is negligible.

On the basis of the above conclusions, the auditor considers that

1. Portion A of the site (being the whole site excluding the Former Sulfur Stockpile Area, Portion B, and Borrow Pit No 1, Portion C, as indicated on Figure 1.3) is suitable for the following beneficial uses:

    - *rural residential living*
    - *all uses permitted under the Litchfield Area Plan, 1992, for Zone RL1 (Rural Living 1);*

    subject to the following conditions:

(i) there should be no use of phreatic groundwater from Aquifer A of the site, as defined in section 3.6 of the EWL Sciences (2001) report, other than for the purposes of environmental monitoring;

(ii) there should be a programme of annual groundwater monitoring of the phreatic groundwater, as outlined in Section 6, and in particular Table 25, of the EWL Sciences (2001) report; a review of the programme should be undertaken by the auditor annually, and the programme should be continued until the auditor is satisfied that all nominated Groundwater Investigation Levels (GILs) are met, and that the contaminated groundwater plume no longer poses unacceptable human health or environmental risks.

2. Portion B of the site (being the Former Sulfur Stockpile Area, as indicated on Figure 1.3) and Portion C of the site (being the Borrow Pit No 1, as indicated on Figure 1.3) are suitable for the following beneficial uses:

- *flora and fauna sanctuary*
- *retail agricultural stall*

as permitted under the Litchfield Area Plan, 1992, for Zone RL1 (Rural Living 1);

subject to the following additional conditions:

(i) there should be a programme of annual monitoring of soil pH, and applying agricultural lime as necessary, as outlined in Section 6, and in particular Table 25, of the EWL Sciences (2001) report; a review of the programme should be undertaken by the auditor annually, and the programme should be continued until the auditor is satisfied that all pH values meet the nominated target, and that the contaminated soils no longer pose unacceptable human health or environmental risks;

(ii) the ADAS (1974) soil sulfur suitability ratings (or other approved rating method) for concrete pipes and footings should be used to assess any construction involving in-ground placement of concrete; the use of high alumina or super-sulfated concrete and cement should be specified for all below ground concrete structures such as pipes and footings.

It is also a condition of this statement that Portions B and C should be clearly delineated using survey markers set out by a licensed surveyor, and that within 3 months of the date of this statement a survey plan prepared by a licensed surveyor, and clearly showing the locations and extent of Portions B and C, should be submitted to the auditor for approval.

Signed: A.M.D. Hall

AMD Hall, MIE Aust
Chartered Professional Engineer
Associate Director
Environmental auditor (Contaminated Land)

TONKIN CONSULTING
Date: 31 May 2001

STATEMENT OF ENVIRONMENTAL AUDIT

I, Adrian Michael Dickinson Hall of Tonkin Consulting, a person appointed by the Environment Protection Authority of Victoria under the Environment Protection Act 1970 ("the Act") as an environmental auditor for the purposes of the Act, having:-

1. been requested by Energy Resources of Australia Limited to issue a Statement of Environmental Audit in relation to the site located at Section 2498 Hundred of Strangways, Humpty Doo ("the site") owned occupied by Ranger Uranium Mines Pty Ltd;

2. had regard to, amongst other things,-

   (i) guidelines issued by the Victorian EPA and endorsed by the Department of Lands, Planning and Environment, Northern Territory;
   (ii) the beneficial uses that may be made of the above site; and
   (iii) relevant environment protection policies and related waste management policies;

   in making a total assessment of the nature and extent of any harm or detriment caused to, or the risk of any possible harm or detriment which may be caused to, any beneficial use made of the site by any industrial processes or activity, waste or substance (including any chemical substance);

   and

3. completed an Environmental Audit Report in general accordance with Section 57 of the above Act, a copy of which has been sent to the Department of Lands, Planning and Environment, Northern Territory.

HEREBY STATE that I am of the opinion that:

1. Portion A of the site (being the whole site excluding the Former Sulfur Stockpile Area, Portion B, and Borrow Pit No 1, Portion C, as indicated on Figure 1.3) is suitable for the following beneficial uses subject to the conditions attached thereto:-

   - *rural residential living*
   - *all uses permitted under the Litchfield Area Plan, 1992, for Zone RL1 (Rural Living 1);*

   Subject to:

   (i) there should be no use of phreatic groundwater from Aquifer A of the site, as defined in section 3.6 of the EWL Sciences (2001) report, other than for the purposes of environmental monitoring;

   (ii) there should be a programme of annual groundwater monitoring of the phreatic groundwater, as outlined in Section 6, and in particular Table 25, of the EWL Sciences (2001) report; a review of the programme should be undertaken by the auditor annually, and the programme should be continued until the auditor is satisfied that all nominated Groundwater Investigation Levels (GILs) are met, and that the contaminated groundwater plume no longer poses unacceptable human health or environmental risks.

2. Portion B of the site (being the Former Sulfur Stockpile Area, as indicated on Figure 1.3) and Portion C of the site (being the Borrow Pit No 1, as indicated on Figure 1.3) are suitable for the following beneficial uses subject to the additional conditions attached thereto:-

   - *flora and fauna sanctuary*
   - *retail agricultural stall*

   as permitted under the Litchfield Area Plan, 1992, for Zone RL1 (Rural Living 1);

   Subject to:

   (i) there should be a programme of annual monitoring of soil pH, and applying agricultural lime as necessary, as outlined in Section 6, and in particular Table 25, of the EWL Sciences (2001) report; a review of the programme should be undertaken by the auditor annually, and the programme should be continued until the auditor is satisfied that all pH values meet the nominated target, and that the contaminated soils no longer pose unacceptable human health or environmental risks;

   (ii) the ADAS (1974) soil sulfur suitability ratings (or other approved rating method) for concrete pipes and footings should be used to assess any construction involving in-ground placement of concrete; the use of high alumina or super-sulfated concrete and cement should be specified for all below ground concrete structures such as pipes and footings.

   It is also a condition of this statement that Portions B and C should be clearly delineated using survey markers set out by a licensed surveyor, and that within 3 months of the date of this statement a survey plan prepared by a licensed surveyor, and clearly showing the locations and extent of Portions B and C, should be submitted to the auditor for approval.

3. I have not issued the equivalent of an unconditional Certificate of Environmental Audit for the site, reasons for which are presented in the Environmental Audit Report and are summarised as follows:

   (i) The phreatic groundwater (Aquifer A) is polluted in the vicinity of well 22440, with unacceptably low pH, and unacceptably high concentrations of some heavy metals;

   (ii) The near surface soils in the Former Sulfur Stockpile Area and Borrow Pit No 1 are contaminated, with unacceptably low pH, and unacceptably high concentrations of sulfur.

This Statement of Environmental Audit should be read in conjunction with, and forms part of, the Environmental Audit Report entitled

Tonkin Consulting (2001), *Section 2498 Strangways, Humpty Doo NT, Environmental Audit Report,* for Energy Resources of Australia Limited, Reference No 990869RA1, May 2001.

Further details regarding the condition of the site may be found in the Environmental Audit Report.

DATED: 31 May 2001

Signed: A. M. D. Hall

Adrian Michael Dickinson Hall
ENVIRONMENTAL AUDITOR (CONTAMINATED LAND)

EWL Sciences Pty Ltd
Darwin Office 482 Stuart Highway, Winnellie NT 0820
PO Box 39443, Winnellie NT 0821

EWL Sciences
earth · water · life

ABN 12 000 955 171 Registered Research Agency No 31639

Validation Report

for

Sinclair Knight Mertz

by

EWL Sciences Pty Ltd

Author: Ian Hollingsworth & Che Gibson

Date July 2003

Project Manager: _____
Ian Hollingsworth

Reviewer: _____
Che Gibson

General Manager: _____
Dr A R Milnes

Distribution: *Client* *3 Hardcopies*
EWL Sciences *Authors, Library, General Manager*

EXECUTIVE SUMMARY

Project Focus

This report deals specifically with ongoing soil remediation work to meet external audit requirements at the former ERA sulfur stockpile site at Section 2498 Strangways. Strangways Developments Pty Ltd owns and plans to develop the site for residential use. A statement of Environmental Audit from an environmental auditor for contaminated land (Adrian Hall, Tonkin & Associates) was issued prior to the transfer of ownership from ERA to Strangways Developments. This statement prevented development of Areas B and C (identified in Figure 1) until soil pH in Areas B and C returned to background levels of 5.0±0.5 units and groundwater conditions were met in the vicinity of the former sulfur stockpile area. Agricultural lime had been subsequently applied at a rate of 10 t/ha (in addition to the 50 t/ha already applied since the site was decommissioned in 1997) to Areas B and C and monitored soil pH at a grid of sites spaced approximately 25 m apart, according to directions in the statement of environmental audit.

Subsequent to their purchase of the property, Strangways Developments appointed Rick Graham (SKM Consulting) as the environmental auditor to oversee the monitoring program and to determine whether the audit conditions were being met. The monitoring showed that Areas B and C met soil quality conditions. However, continuing aesthetic impacts were associated with persistent low level contamination of the land surface with elemental sulfur and small (2 m diameter) areas of localised acid soil weathering in Area B which were not identified in the grid of soil monitoring sites.

The monitoring report recommended that,

- lime be added at a rate of 40 kg per tonne to approximately ten cubic meters of laterite material in the former sulfur stockpile area (Area B) associated with five hotspots, 2 m diameter slick patches containing epsomite crystals.

Therefore the focussing question of this report was:

"Has the additional lime application to soil successfully remediated the small areas of acid soil that were identified in the monitoring programme."

Methodology

Localised hotspots of acid soil in Area B were visually identified from surface efflorescences, sulfur contamination and an oily appearance typical of the acid weathering process. These areas were marked with paint and steel pickets. Subsequently, a bulldozer was used to excavate marked areas until residual sulfur contamination was removed. Two stockpiles were formed Seven hundred kilograms of agricultural lime was mixed into the stockpiled material. Composite samples were made up from three samples from each stockpile and the soil pH was measured in the field using a standard procedure, prior to and after the lime application and mixing. Final soil pH was measured to determine whether the liming process had been successful.

Major Findings

Excavation down to 0.3 m in the designated hotspots removed all of the particulate sulfur found *in-situ*. Stockpiling the soil and mixing in 600 kg of agricultural lime raised the soil pH from an initial value of 3.5 to 4.0 to a final value of 7.0 to 8.0. The finding that localised soil pH is now above the background of 5.0±0.5 units will not have any detrimental environmental impact.

Outcomes

Soil acidity is no longer considered to be a constraint to the beneficial use of the site

Future Actions

A minimum of 300 mm of topsoil needs to be spread over Area B and Area C when it is developed for residential use so as to reliably remove the aesthetic impact of minor, visible sulfur residues on the surface.

EWL Sciences Pty Ltd
Darwin Office 482 Stuart Highway, Winnellie NT 0820
PO Box 39443, Winnellie NT 0821

EWL Sciences
earth · water · life

ABN 12 000 955 171 Registered Research Agency No 31639

Annual Soil and Groundwater Monitoring at Section 2498 Strangways

for

Strangways Development Pty Ltd
by

EWL Sciences Pty Ltd

Authors:
I D Hollingsworth & C Gibson
August 2003

Project Manager: _____
Ian Hollingsworth

Reviewer: _____
Dr D Klessa

General Manager: _____
Dr A R Milnes

Distribution: *Client* *3 Hardcopies + CD Rom*
EWL Sciences *Authors, Library, General Manager*

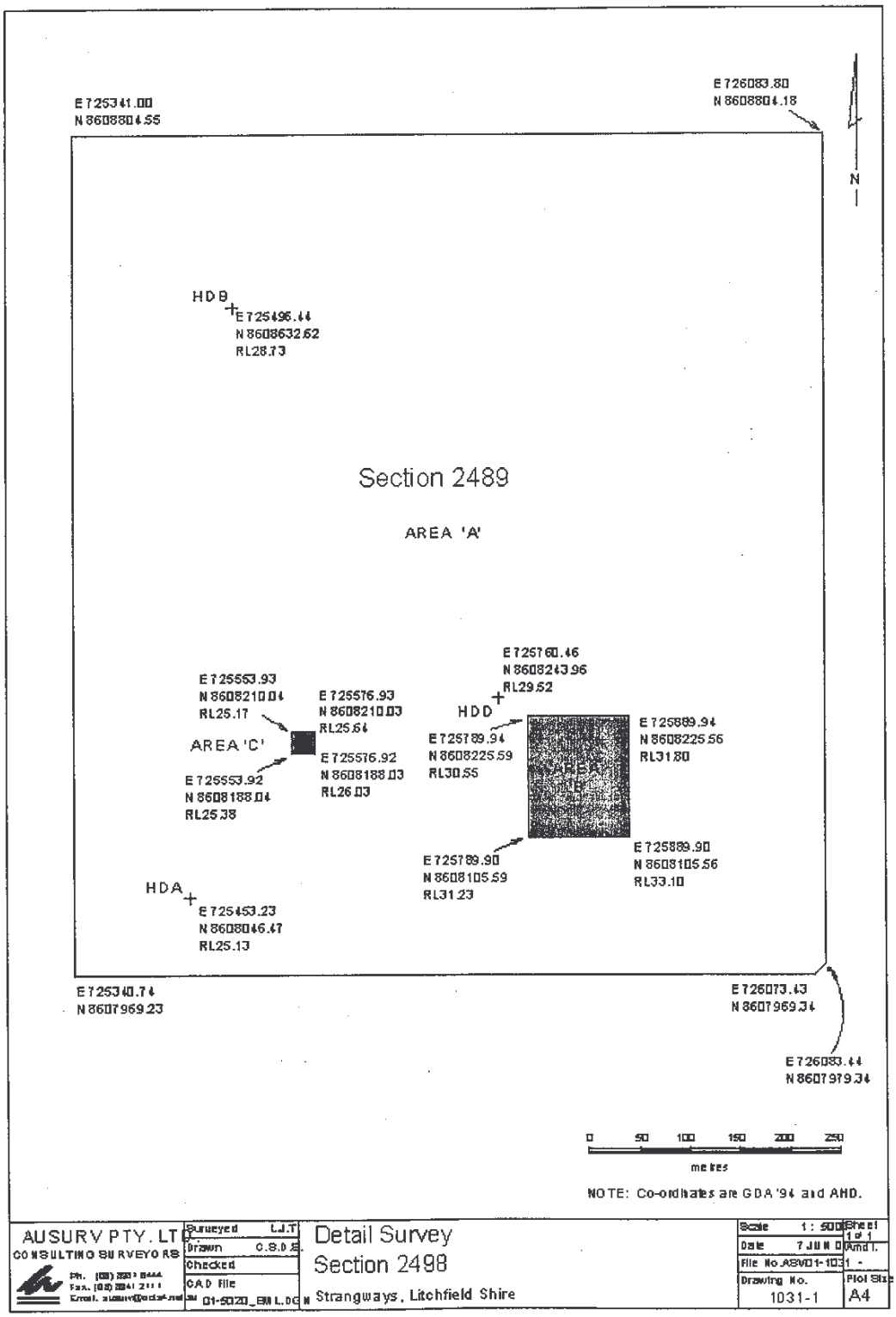


Figure 1 Areas B and C that have identified land use constraints

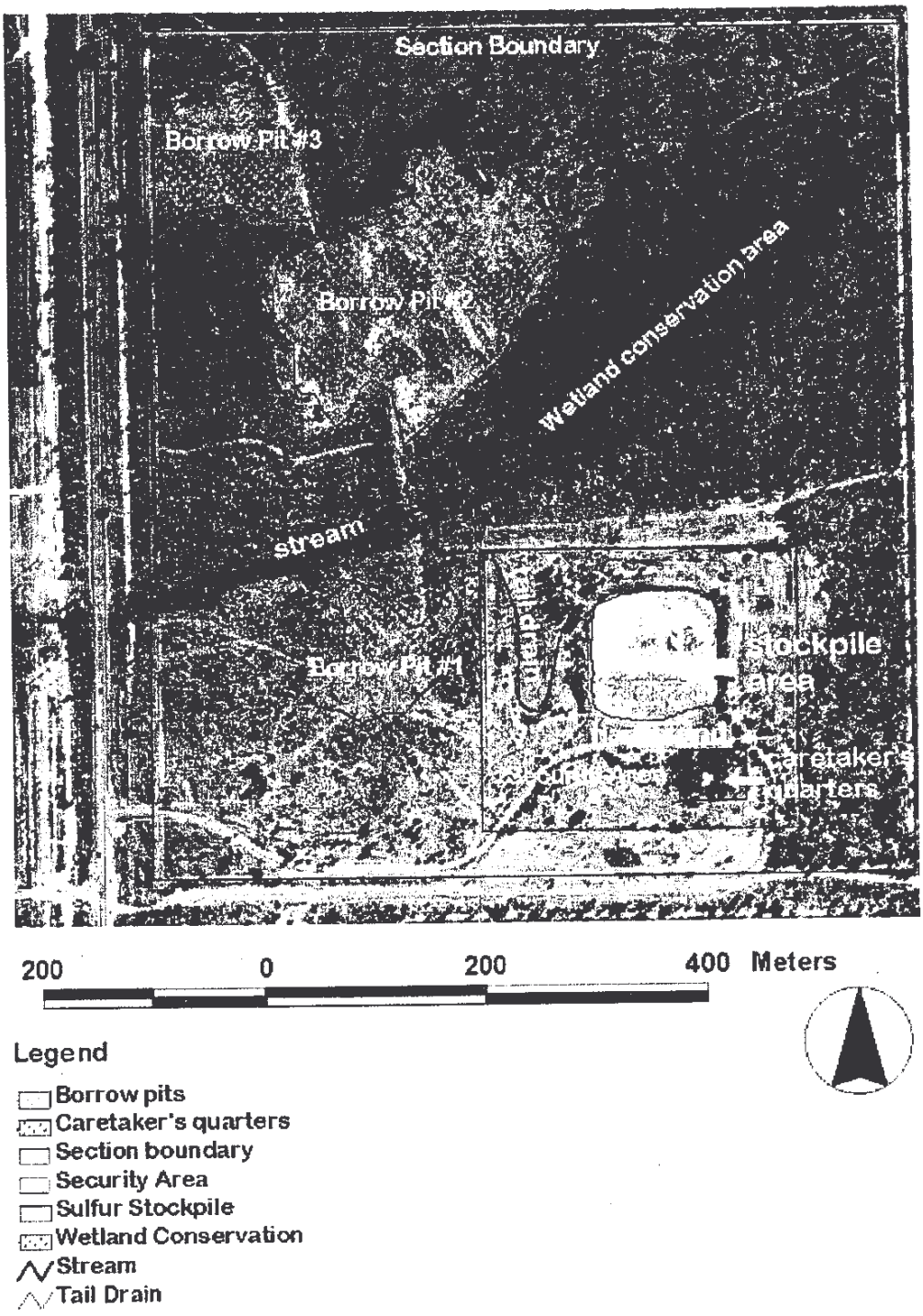


Figure 2 Site plan showing surface drainage, boundary and surface facilities prior to remediation work.

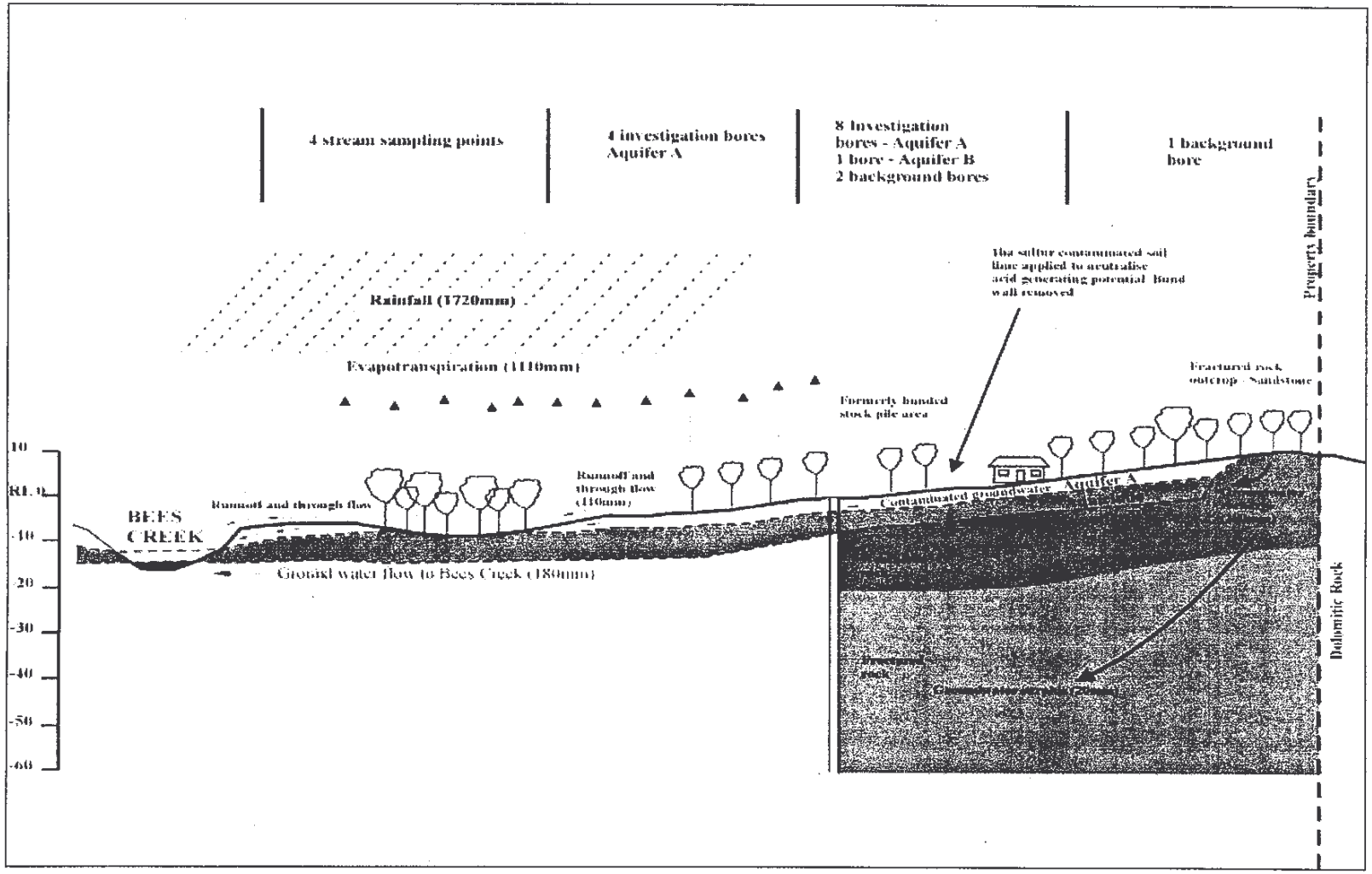


Figure 3 Conceptual model indicating recharge rates and groundwater flow.

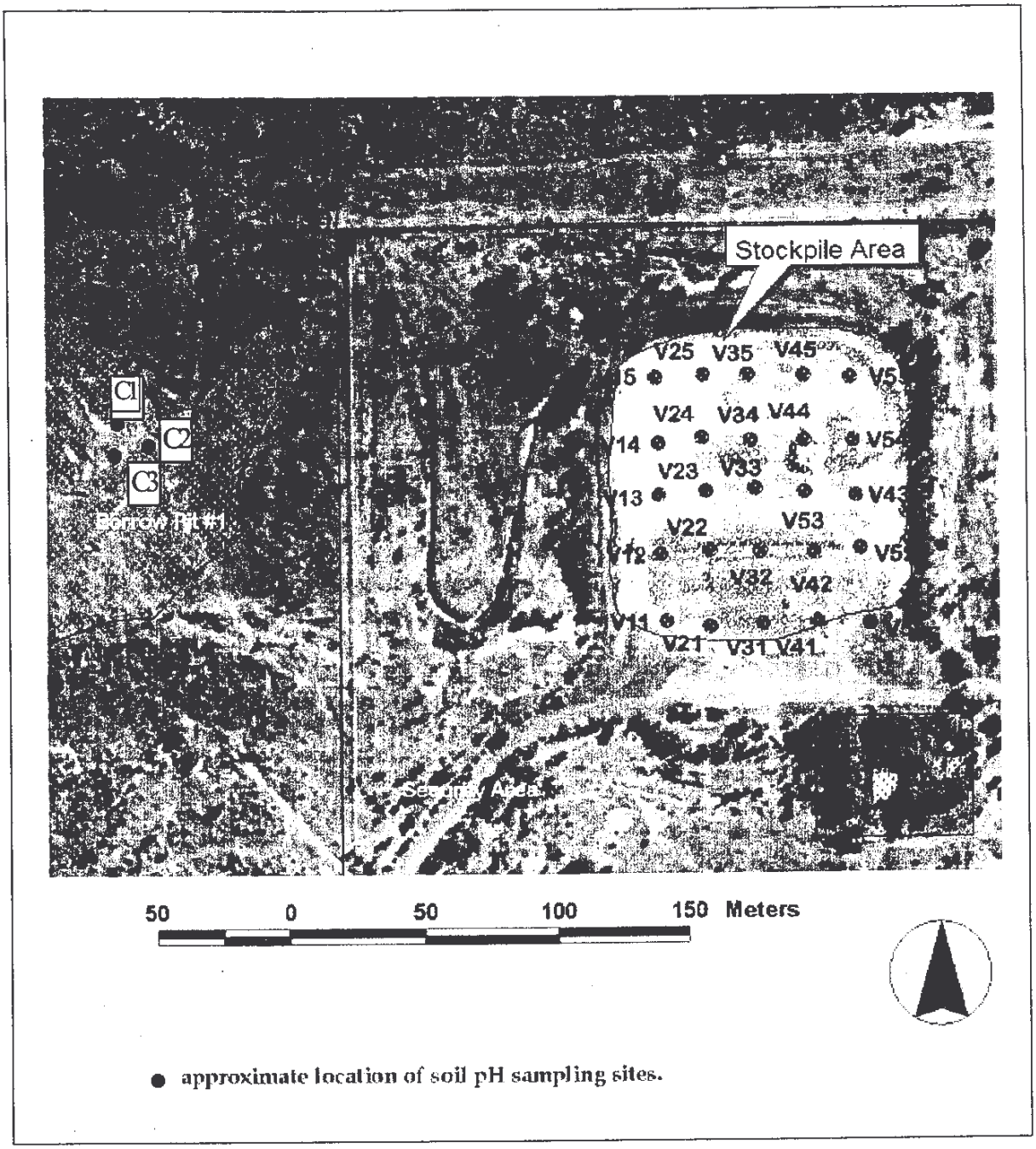


Figure 5 Soil sampling site locations

Table 5 Laboratory results for groundwater sampled on the 22nd January and the 4th March 2003

Bore	Date Sampled	Description	Analytical Results (µ/L)							
			EC (µS/cm)	pH	Al	As	Cu	Pb	Ni	Zn
Background										
HDA	22/1/2003	Background	20	5.7	15	<1	<1	<1	<1	27
Zone 1 – former sulfur stockpile area										
HDD*	22/1/2003	Beneficial use bore	84	5.9	<5	<1	1.9	<1	22	210
	4/3/2003		93	6.3	6	<1	1	<1	10	130
22440	22/1/2003	Stockpile area bore	340	3.5	7500	<1	27	37	58	92
22440	22/1/2003	Duplicate	330	3.5	7600	<1	29	38	49	79
HD11	22/1/2003	Inside stockpile, shallow phreatic	48	4.1	150	<1	8.3	8.5	7.1	66
HD12	22/1/2003	Inside stockpile, deeper phreatic	26	4.7	75	<1	4.8	5.1	3.4	17
Zone 2 – flow field between the former stockpile and the wetland										
HD21	22/1/2003	Below stockpile, shallow phreatic	220	3.9	240	<1	12	38	23	36
HD22	22/1/2003	Below stockpile, deeper phreatic	390	5.3	<5	<1	2.1	3.3	15	45
HD51	22/1/2003	Below stockpile, shallow phreatic	130	5.2	98	<1	4.9	28	15	25
HD52	22/1/2003	Below stockpile, deeper phreatic	140	5.2	160	<1	13	23	22	52
Zone 3 – Discharge zone into wetland										
HD61	22/1/2003	Creekside, shallow phreatic	180	5.1	45	<1	2.5	13	6.8	12
	4/3/2003		145	6	52	<1	<1	<1	6	9
HD62	22/1/2003	Creekside, deeper phreatic	71	5.6	13	<1	<1	1.4	1.6	10
	4/3/2003		85	5.8	330	<1	7	7	4	28
Examinining the effect of <0.45 µm diameter particulate material on measured concentrations										
	10/6/2003	< 0.45 µm		6.5	37		5	< 1		26
				6.5	130		6	< 1		26
				6.5	< 5		6	< 1		31
	Mean concentrations after standard field filtration (< 0.45 µm)				**57**		**6**	< 1		**28**
		< 0.20 µm			< 5		4	< 1		25
					< 5		5	< 1		24
					< 5		4	< 1		30
	Mean concentrations after laboratory filtration to < 0.20 µm				**< 5**		**4**	**< 1**		**26**
Investigation levels	ENVIRONMENTAL		-	-	25[1]	24	1.4	3.4	11	8
	DRINKING WATER						1000	10	20	3000

Factors by which the Investigation level is exceeded

10 x trigger level (highly exceeded)

5 x trigger level (moderately exceeded)

<5 x trigger level (slightly exceeded)

[1] Based on background observations reported in Hollingsworth, I., and Puhalovich, A. (2001). "Completion of Audit Report Requirements for Section 2498, Strangways Humpty Doo." EWLS, Winnellie.

Appendix C Title and Site Plans

Date registered
09.10.1987

Volume 179 Folio 055

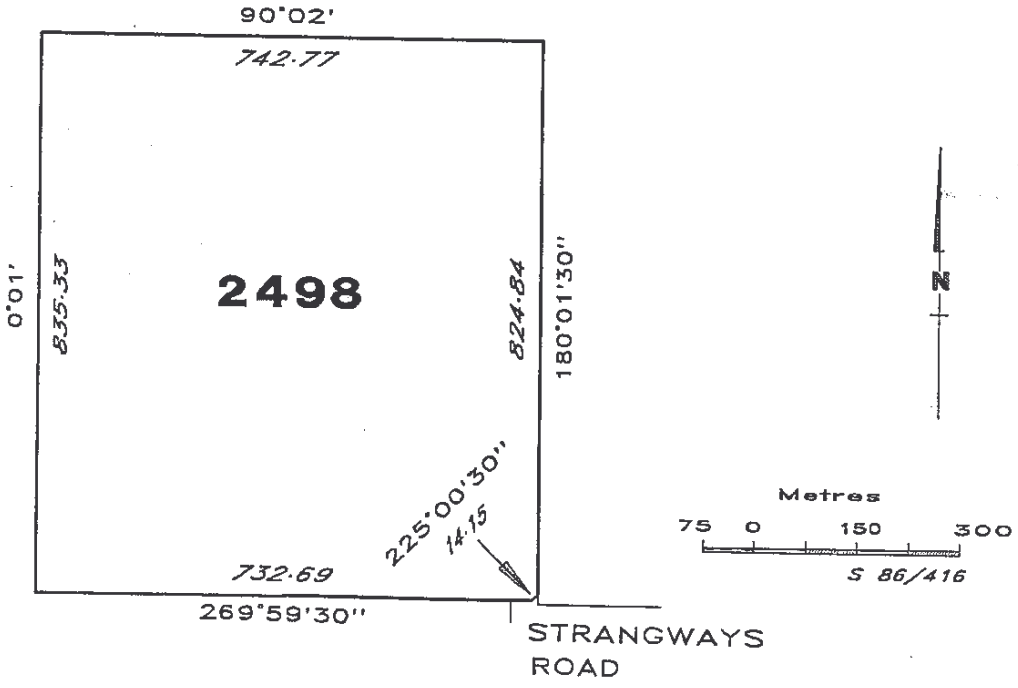
SEARCH CERTIFICATE

Section 2498 Hundred of Strangways from plan S 86/416
Area under title is 62 hectares 100 square metres

Owner:
Ranger Uranium Mines Pty Ltd
of Suite 2, Second Floor, 26 Mitchell Street, Darwin NT 0800

Registered Date	Dealing number	Description

End of Dealings



 Searched on 28/01/00 at 13:14:11 by BUDG

Record of Administrative Interests and Information 28/01/00 13:14:11
(See section 191E of the Real Property Act)

Title register is 179 055

CUSTODIAN - REGISTRAR GENERAL (08 8999 6520)
Previous title(s)
Easements
None found
Transfers
None found

CUSTODIAN - SURVEYOR GENERAL (08 8999 7934)
Property
Section 2498 Hundred of Strangways from plan S 86/416
Address
35 Strangways Rd, Humpty Doo
Survey plan
S 86/416
Map reference
Code 373 Scale 010000 Sheet 06.08
Code 373 Scale 010000 Sheet 06.09
Parcel status
Current
Parcel area
62 hectares 100 square metres
Parent Parcel
Section 361 Hundred of Strangways from plan A 000477
Survey Comments
None found for S 86/416
Proposed Easements
None found

CUSTODIAN - VALUER GENERAL (08 8946 0650)
Owners Last Known Address
RANGER URANIUM MINES PTY LTD, LOCKED BAG 1,JABIRU NT 0886
Unimproved capital value
$320,000 on 01/07/1997
$180,000 on 01/07/1994
$120,000 on 01/07/1991
$120,000 on 01/01/1989
$120,000 on 01/01/1986
Valuation improvements
12/04/1995 House
09/11/1987 Land

CUSTODIAN - PROPERTY PURCHASING (08 8999 7722)
Acquisitions
None found

CUSTODIAN - BUILDING ADVISORY SERVICE (08 8999 7474)
Building Applications
26/11/1990 Occupancy permit A CARETAKERS ACCOMODATION
Building class House
Area 128 square meters

CUSTODIAN - TOWN PLANNING (08 8999 7867)
Town Plan Zone
Litchfield Area Plan- Rural residential 1 (2ha) (LAPRL1)
Planning Policies

Printer RNNH, CICS system CXP7, From terminal T09E
User ID L2B , User name Lynette Bergmans

Record of Administrative Interests and Information 28/01/00 13:14:11
(See section 191E of the Real Property Act)

Title register is 179 055
None found
Planning Proposals
None found.
Land use surveys
12/04/1995 Primary (1111) Single dwelling house

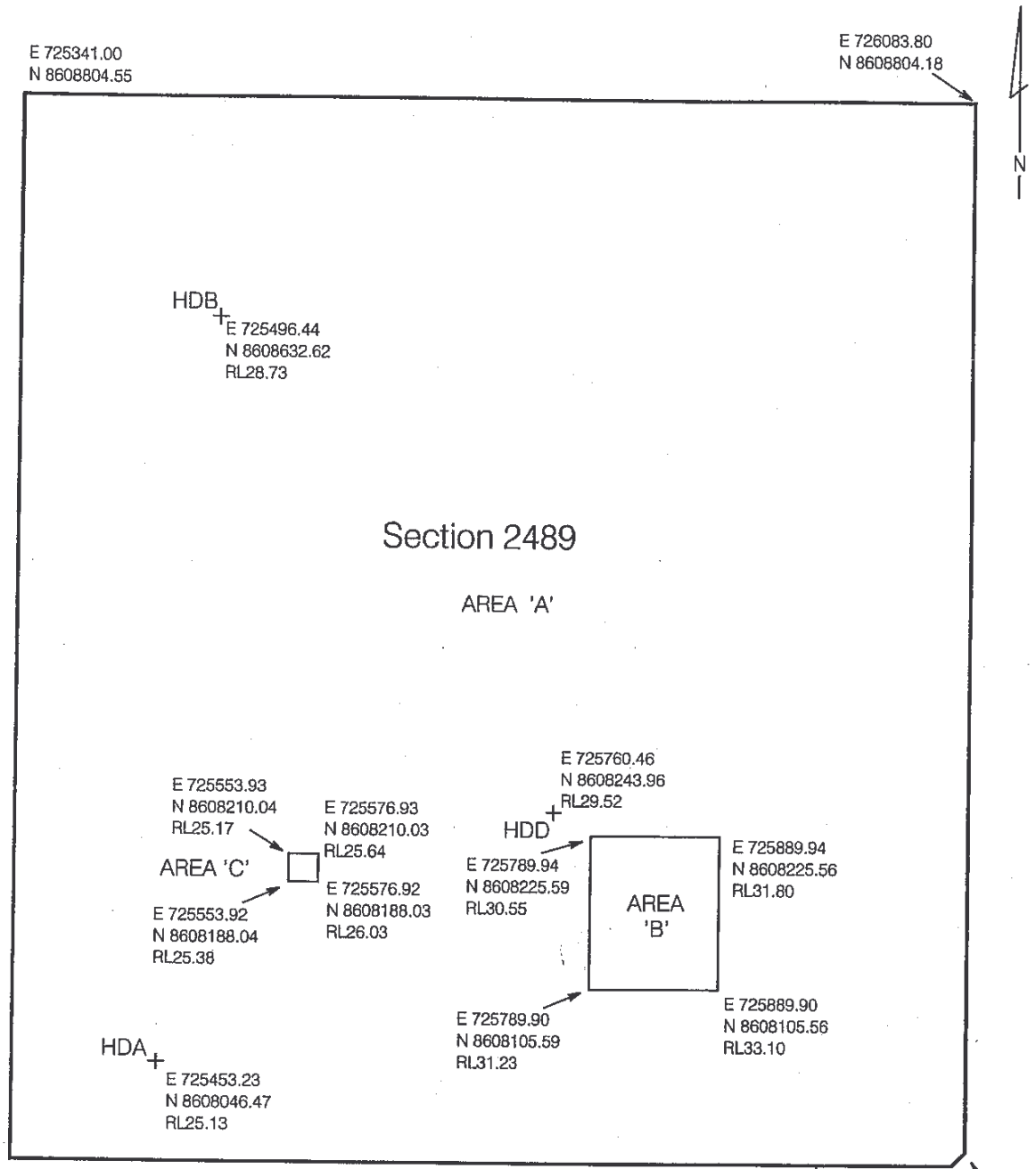
CUSTODIAN - POWER AND WATER AUTHORITY (08 8982 7777)
Meters on parcel.
Power and Water Authority - Water : 1
Power and Water Authority - Electricity: 1

CUSTODIAN - VARIOUS
Other interests
For account balances contact the Power and Water Authority and Litchfield Shire Council
No data found for Intersect

NOTE: The Record of Administrative Interests and Information is not part of the Register of Titles and is not guaranteed by the Northern Territory of Australia, and the N.T. Government accepts no liability for any omission, misstatement or inaccuracy contained in this statement

(Gregory John Shanahan)
Registrar-General

Printer RNNH, CICS system CXP7, From terminal T09E
User ID L2B , User name Lynette Bergmans



To the best of my knowledge the co-ordinates & AHD levels shown are those that actually represent the GDA'94 & AHD levels for those points shown. Datum was derived from information received from the then Northern Territory Department of Lands Planning

2/5/04.

signed date

Michael Milford
Licensed Surveyor

0 50 100 150 200 250
metres

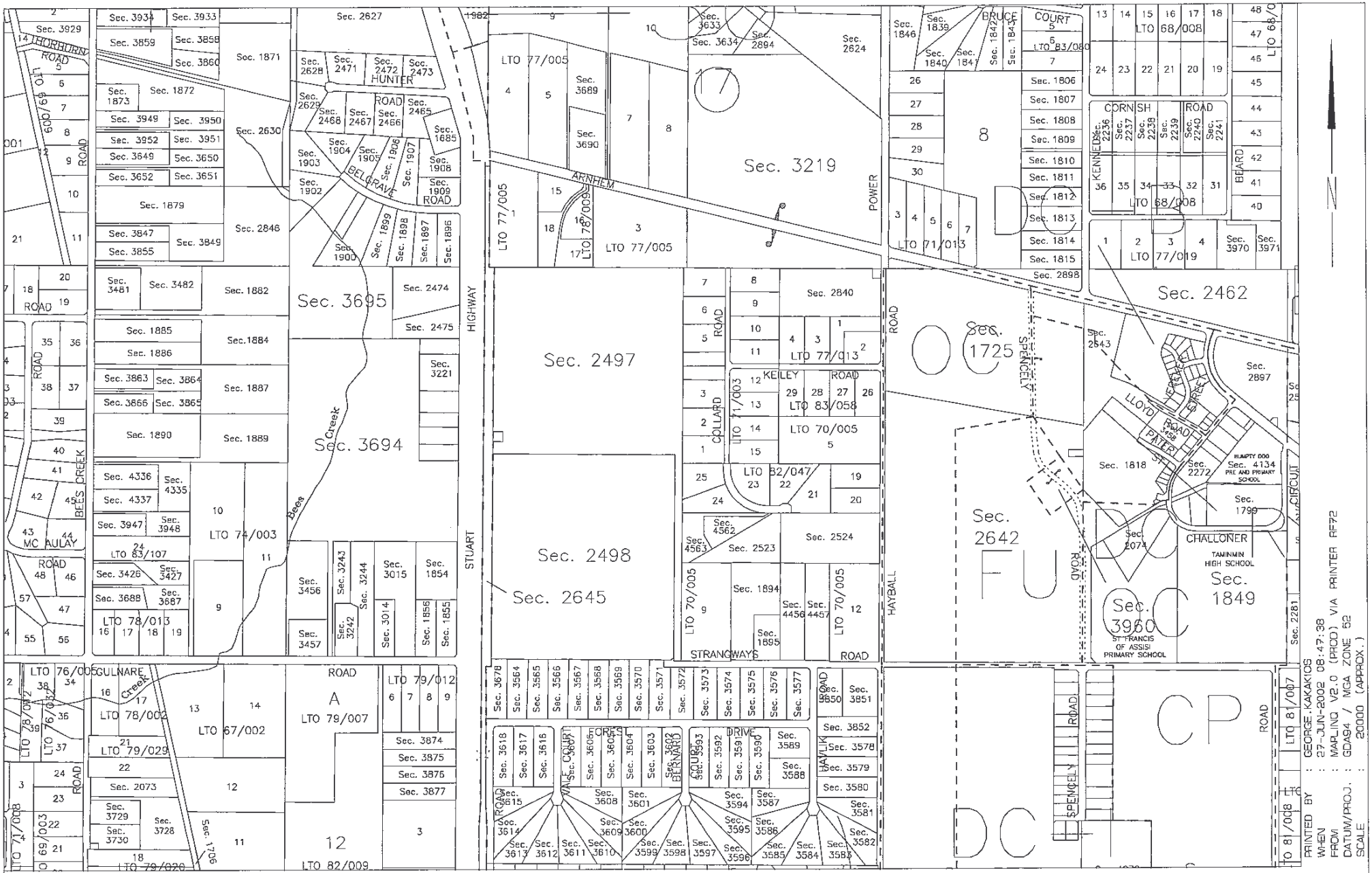
NOTE: Co-ordinates are GDA '94 and AHD.

AUSURV PTY. LTD.
CONSULTING SURVEYORS
Ph: (08) 8981 6444
Fax: (08) 8941 2111
Email: ausurv@octa4.net.au

Surveyed	L.J.T.
Drawn	C.S.D.S.
Checked	
CAD File	01-5020_EML.DGN

Detail Survey
Section 2498
Strangways, Litchfield Shire

Scale	1 : 5000
Date	7 JUN 01
File No.	ASV01-1031
Drawing No.	1031-1
Sheet	1 of 1
Amdt.	-
Plot Size	A4


Sec. 3934
Sec. 3933
Sec. 3929
Sec. 3859
Sec. 3858
Sec. 3860
Sec. 1871
Sec. 2627
Sec. 2628
Sec. 2471
Sec. 2472
Sec. 2473
HUNTER
ROAD
Sec. 1872
Sec. 1873
Sec. 2629
Sec. 2468
Sec. 2467
Sec. 2466
Sec. 2465
Sec. 1685
Sec. 3949
Sec. 3950
Sec. 2630
Sec. 1904
Sec. 1905
Sec. 1906
Sec. 1907
Sec. 1903
Sec. 1908
Sec. 3952
Sec. 3951
Sec. 3649
Sec. 3650
BELGRAVE
Sec. 1902
Sec. 1909
ROAD
Sec. 3652
Sec. 3651
Sec. 1879
Sec. 2846
Sec. 3847
Sec. 3849
Sec. 3855
Sec. 1900
Sec. 1899
Sec. 1898
Sec. 1897
Sec. 1896
Sec. 3481
Sec. 3482
Sec. 1882
Sec. 3695
Sec. 2474
Sec. 2475
Sec. 1885
Sec. 1886
Sec.1884
Sec. 3863
Sec. 3864
Sec. 1887
Sec. 3866
Sec. 3865
Sec. 1890
Sec. 1889
Sec. 3694
Sec. 3221
Sec. 4336
Sec. 4335
Sec. 4337
Sec. 3947
Sec. 3948
LTO 83/107
Sec. 3426
Sec. 3427
Sec. 3688
Sec. 3687
LTO 78/013
LTO 74/003
Sec. 3456
Sec. 3457
Sec. 3243
Sec. 3244
Sec. 3242
Sec. 3014
Sec. 3015
Sec. 1854
Sec. 1856
Sec. 1855
BEES CREEK
MC AULAY
ROAD
Bees Creek
HIGHWAY
STUART
LTO 77/005
Sec. 3689
Sec. 3690
Sec. 3219
Sec. 3633
Sec. 3634
Sec. 2894
Sec. 2624
ARNHEM
POWER
LTO 78/005
Sec. 2497
Sec. 2498
Sec. 2645
Sec. 2840
LTO 77/013
KELLEY
LTO 83/058
COLLARD
LTO 71/003
LTO 70/005
LTO 82/047
Sec. 4562
Sec. 4563
Sec. 2523
Sec. 2524
Sec. 1894
Sec. 1895
Sec. 4456
Sec. 4457
STRANGWAYS
HAYBALL
Sec. 1846
Sec. 1839
Sec. 1840
Sec. 1841
Sec. 1842
Sec. 1843
BRUCE
COURT
LTO 83/080
Sec. 1806
Sec. 1807
Sec. 1808
Sec. 1809
Sec. 1810
Sec. 1811
Sec. 1812
Sec. 1813
Sec. 1814
Sec. 1815
Sec. 2898
LTO 71/013
LTO 68/008
CORNISH
KENNEDY
BEARD
Sec. 2236
Sec. 2237
Sec. 2238
Sec. 2239
Sec. 2240
Sec. 2241
LTO 77/019
Sec. 3970
Sec. 3971
Sec. 2462
Sec. 1725
Sec. 2643
SPENCELY
Sec. 2897
LLOYD
ROAD
PATER
Sec. 1818
Sec. 2272
Sec. 4134
PRE AND PRIMARY SCHOOL
Sec. 1799
Sec. 2074
CHALLONER
CIRCUIT
TAMINMIN HIGH SCHOOL
Sec. 1849
Sec. 2642
Sec. 3960
ST FRANCIS OF ASSISI PRIMARY SCHOOL
Sec. 2281
LTO 81/007
LTO 81/008
LTO 76/005
GULNARE
Creek
LTO 78/002
LTO 67/002
LTO 79/029
Sec. 2073
Sec. 3729
Sec. 3730
Sec. 3728
Sec. 1706
LTO 79/026
LTO 74/008
LTO 69/003
ROAD
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LTO 79/007
12
LTO 82/009
LTO 79/012
Sec. 3874
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Sec. 3595
Sec. 3596
Sec. 3597
Sec. 3598
Sec. 3599
Sec. 3600
Sec. 3601
Sec. 3608
Sec. 3609
Sec. 3610
Sec. 3611
Sec. 3612
Sec. 3613
Sec. 3614
Sec. 3615
VALE COURT
CORNISH
BERNARD
COURT
DRIVE
HAYLUK
OC
FU
CP
DC
SPENCELY
ROAD
CIRCUIT
N
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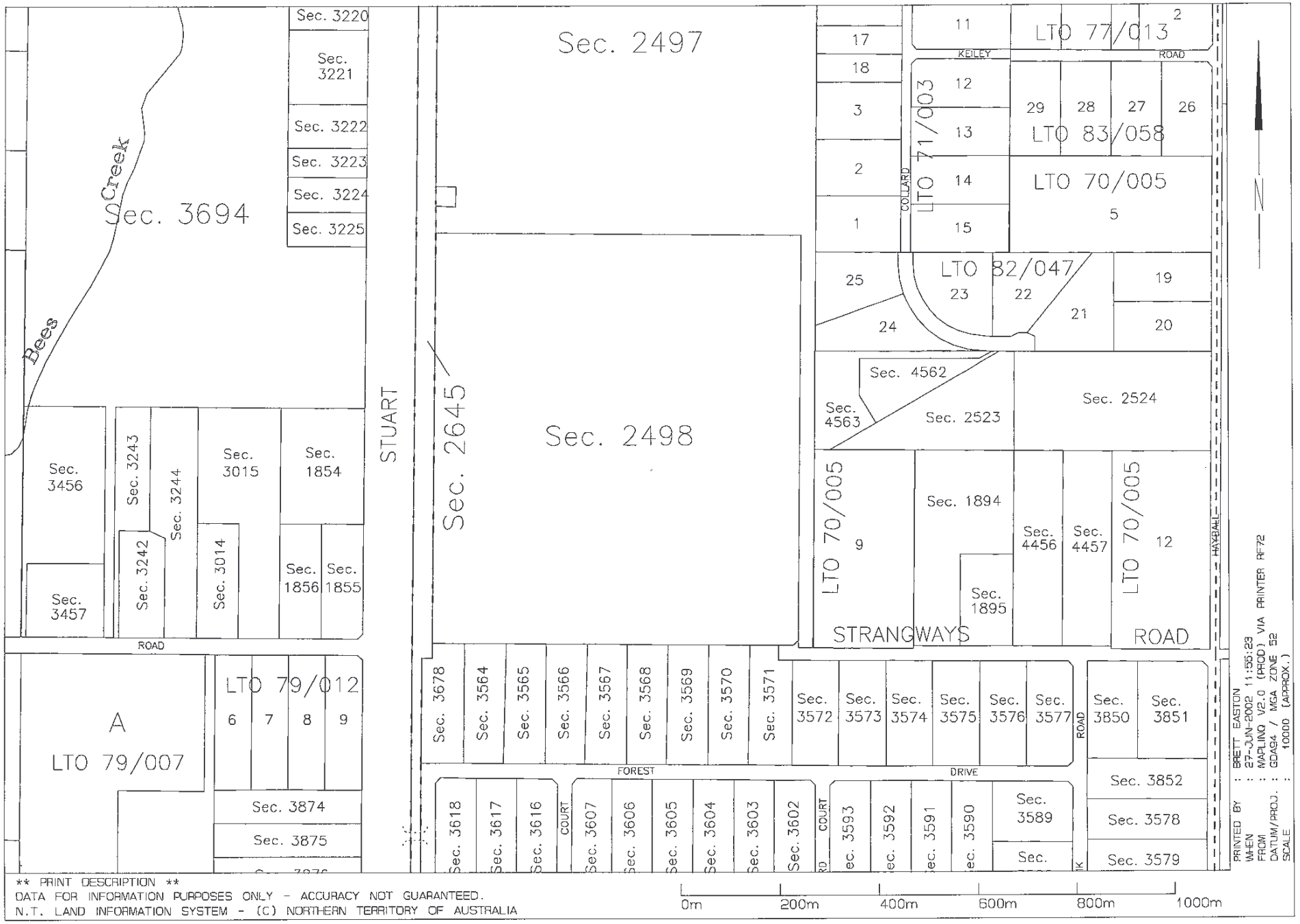

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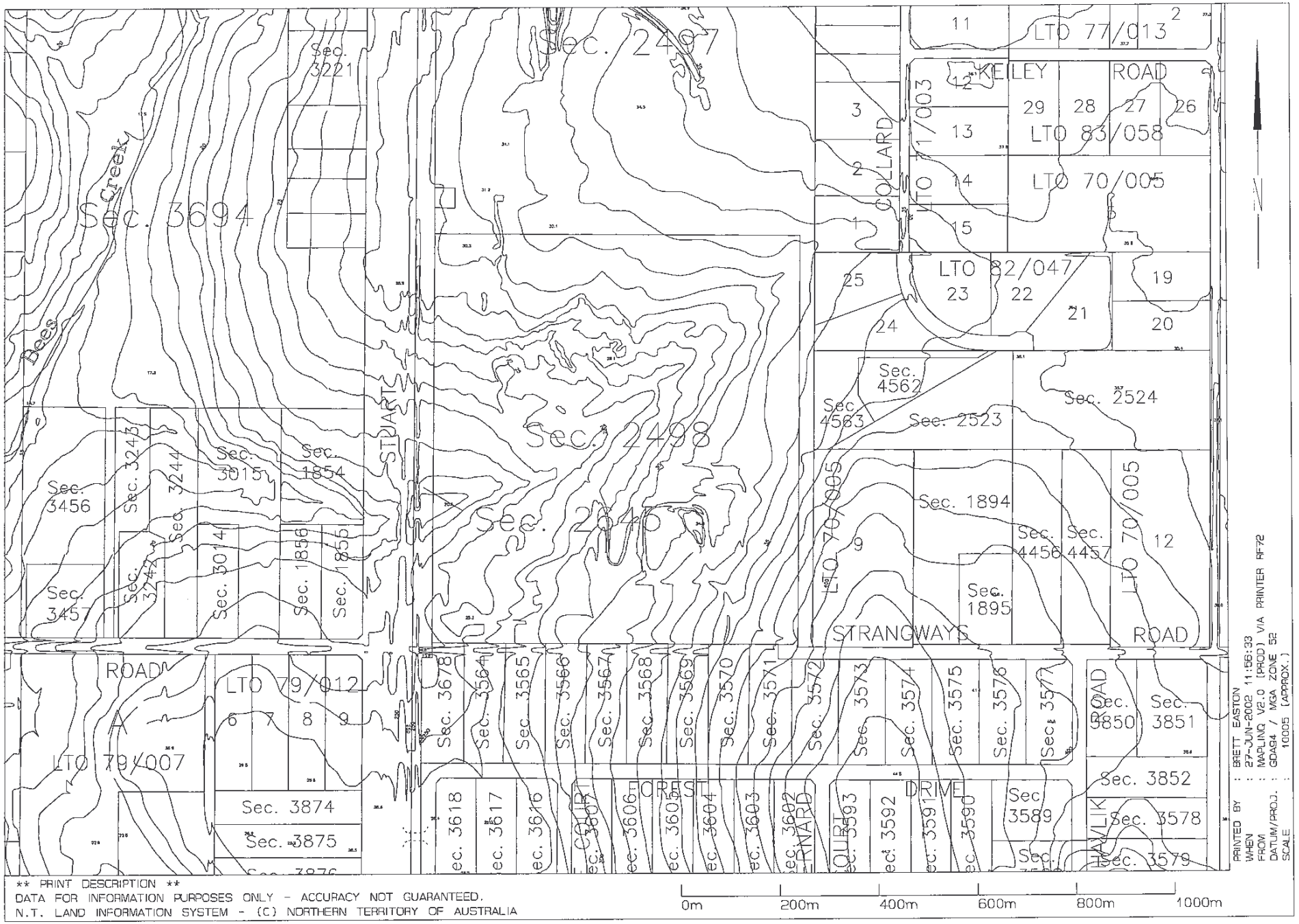

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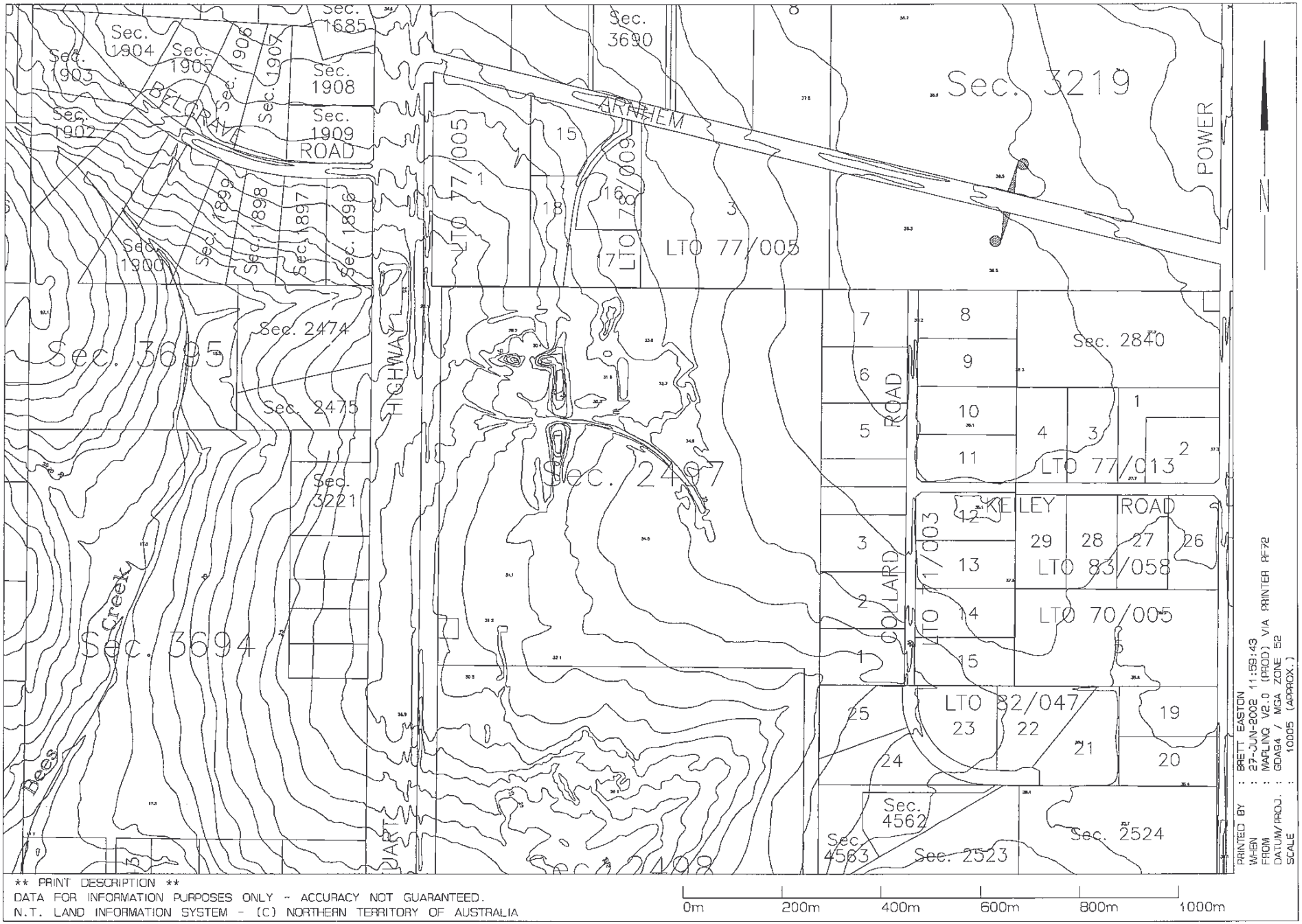

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