

Public Submission
on the
Proposed Development
of the
Beverley Uranium Deposit
by Heathgate Resources Pty Ltd
(aka General Atomics)

by

Gavin Mudd

PhD Student - Part Time Lecturer

School of the Built Environment
Victoria University of Technology
c/o P.O. Box 81
Watsonia, VIC 3087

Ph (03) 9688 4106 - Fax (03) 9458 5055
Email - GavinMudd@vut.edu.au

The following is the full version of my public submission. I faxed through a summary on Friday August 21ST.

This was approved by John Bastin (8303 0748).

DISCLAIMER

All views expressed in this report represent those of the primary author. In no way are they meant to convey the views of any other organisation, institution or company that may have contributed to the completion of this report.

Every attempt has been made to quote technical sources correctly and completely, but no liability can be assumed for actions arising out of the use of this report.

THE USE OF MUDD, 1998a

The copy of my detailed report on In Situ Leach Uranium Mining is submitted as an addendum to my submission. It is provided on the basis as a supporting document to my submission. It is only provided on this basis only, and the author will vigorously defend his copyright if the report is reproduced for any other purpose than the requirements of an EIS submission. It is expected to receive a detailed response from both the proponent in their Final or Supplement to the EIS, and the government in their Assessment Report of both the Draft and Final EIS's.

Under no circumstances is the report to be provided outside the EIS process to any other persons, companies, organisations or entities without first obtaining the written permission of the author.

To : Manager - Environmental Impact Assessment Branch
Planning SA, 136 North Tce, Adelaide SA 5000

**Public Submission on the Proposed Development of the Beverley Uranium Mine
by Heathgate Resources Pty Ltd (aka General Atomics)**

As a professional Hydrogeologist/Environmental Engineer (see attached CV, Appendix One), close to completing my PhD on the interaction of tailings and groundwater, I feel it is important to have on the public record a strong critique of both the In Situ Leach (ISL) mining technique and the *Proposed* Beverley Uranium ISL Mine.

If one cares to study the international experience of ISL, based on technical data from the operation of ISL mines across the USA, Eastern Europe and the former Soviet Block countries and not blandly accepting industry rhetoric and corporate propaganda, it is easily and convincingly demonstrated that the current proposal by Heathgate Resources Pty Ltd, acting solely on behalf of their parent company General Atomics (GA) of the USA, does not match any resemblance of credible environmental management, ethics nor technical credibility.

I have recently completed such an extensive review, and submit this report as an Addendum to my EIS submission (Mudd, 1998a).

The Liberal Policy Platform on election re-iterated that any new uranium mine approval would need to meet environmental, safeguard and indigenous criteria, and be world's best practice. Heathgate are proposing world's worst standards and must not be approved as it currently stands.

It is recommended that :

- the current Field Leach Trial be closed and the groundwater be restored;
- all information and circumstances concerning the spill in March and apparent collusion between the company and the government in failing to notify the public, and especially the Native Title claimant groups, be the subject of an inquiry;
- the spill and Field Leach Trial be studied by an reputable organisation independent of both government and industry and paid for by the company;
- the spill inquiry should be separate to the Environmental Impact Assessment (EIA) process, and the EIA process should be halted until such time as a satisfactory public outcome has been achieved;
- any approvals for Beverley include mandatory restoration and cleanup of groundwater to the original quality of the aquifer at that zone;
- a minimum of one year's background quality data be obtained from all aquifers in the vicinity of the Beverley site before the process of ISL begins;
- all radiation sources be quantified and the data released, especially radon, thorium and radium;
- all liquid wastes be evaporated and the resultant sludge be managed in an on-site radioactive waste repository;
- the use of alkaline leaching chemistry be unequivocally enforced;
- detailed monitoring program be released in the ensuing EIS Supplement;
- all details concerning possible sales contracts finalised to date be released, to disclose any conflict of interest.

To achieve this, a NEW Draft EIS must be required.

Section 1 - Introduction

1.2.1 - The Nuclear Fuel Cycle

The element uranium is unique in its behaviour, making it suitable for nuclear purposes but it is this very behaviour which makes it a fundamental danger to the environment and health of human beings. Despite documented health concerns at numerous nuclear facilities worldwide, albeit uranium mines, reprocessing facilities, nuclear power stations or former nuclear weapons sites, the EIS does not address any of these aspects. It is stated that, "under the formal guidelines, it specifically does *not* address" (page 1-3) :

- policy issues about the appropriateness of uranium mining;
- broader issues relating to the use of exported uranium in the nuclear fuel cycle.

This stifles the proposal to concern over pipe sizes or how often monitoring environmental damage should be undertaken. Neither the proponent nor the federal and state governments are prepared to address these fundamental issues related to the nuclear fuel cycle in public, and simply bow to industry heavyweights like General Atomics for a short term profit and pass the burden of intractable radioactive waste onto future generations.

1.5 - The EIS Process

The spirit of the Environment Protection (Impact of Proposals) Act (EPIoP) 1974 is that an EIS be undertaken by an independent consultant to the proponent, to ensure no bias and reliability in the information presented. The Beverley EIS was in fact prepared by the proponent themselves, with a number of sub-consultants undertaking specific tasks.

Out of the studies undertaken for the EIS, a total of ten out of the twenty-two were undertaken by the proponent.

Despite the supposed legality of this under the EPIoP Act, it leaves significant ethical questions about the reliability and independence of the data and information presented in the EIS.

If Heathgate were to publish within a recognised academic journal, it is believed that the EIS would not meet the requisite standards of intellectual integrity and technical independence and rigour.

The general public could therefore not be expected to believe the EIS is a scientifically and ethically sound document. There are many instances pointed throughout the EIS where this will be demonstrated in this submission.

The fact that a uranium mine is currently operating at the Beverley site is further proof that both the proponents and government are attempting to avoid any level of public scrutiny and merely ensure development of the project proceeds at the pace the proponent determines, irrespective.

Section 2 - Background

2.1.3 - The ISL Technique

It is asserted that Heathgate, upon acquiring the Beverley deposit, "initiated new investigations into mining the deposit, taking advantage of advances in *in situ* leach technology and extended USA operating experience", and going on to state that "*in situ* leach mining for uranium has moved from a relatively new technique to one widely used and accepted in the USA and elsewhere" (page 2-2). This is an important example of lack of rigour - many of these myths can be easily discounted if one bothers to examine the easily available international literature (refer to Mudd, 1998a) :

- ***the USA has very little experience with ACID ISL***
 - both the regulators and the nuclear industry have consistently avoided this because of the intractable problems caused by the use of acid solutions, such as the mobilisation of numerous and toxic levels of heavy metals;
 - all commercial scale ISL mines in the USA in Texas and Wyoming have used alkaline solutions, ***NOT ACID***;
 - the few trials of acid (about 6 pilot sites) did not represent any economic advantage over alkaline solutions and did not have "successful" restoration (see later section on Nine Mile Lake or 4.7 of Mudd, 1998a);

- no ISL mine in the western world has ever used acids.

- ***what advances in ISL does the EIS refer to ?***
 - do they mean the probable integrity of production bores (although many are still documented to leak even in "more modern times" - eg, USNRC, 1997) ? the development of gaseous oxygen injection systems ? the use of Reverse Osmosis to improve the ability to restore groundwater after ISL mining is complete ?

Why are they so vague ?

- ***many countries around the world are shutting down their ISL mines***
 - despite the EIS stating that the ISL technique is widely used and accepted "elsewhere", this is not the case;
 - the Czech Republic, Bulgaria and Germany are shutting down and attempting to clean up their former Uranium ISL mines - these used acid solutions;
 - restoration at many of these sites is proving difficult, primarily because of the use of sulphuric acid leaching chemistry, and efforts are expected to last several decades in order to protect the quality of the groundwater, as these supply water to many residents and nearby towns (refer to Section 5; Mudd, 1998a).

2.2.3 - Development to Date

Heathgate have already established a series of bores across the Beverley deposit. The documents pertaining to the approvals for these still remain unavailable to the public, and hence much of the information and assumptions presented in the EIS cannot be verified. Only part of this information is presented within the EIS or Supporting Documents. Heathgate must release the following documents :

- Heathgate Resources Pty Ltd (1996) - Beverley Uranium Project : Declaration of Environmental Factors (DEF) in Support of a Proposal to Undertake a Drilling Program at Beverley, South Australia. Geoprojects Pty Ltd, October, 1996, Adelaide.
- Heathgate Resources Pty Ltd (1997a) - Beverley Uranium Project : Declaration of Environmental Factors (DEF) in Support of a Proposal to Undertake a Water Well Drilling and Hydrogeological Testing Program at Beverley, South Australia. Geoprojects Pty Ltd / Fatchen Environmental Pty Ltd, March 1997, Adelaide.

2.2.4 - the Field Leach Trial Philosophy

The original attempt to develop the Honeymoon deposit south-east of Lake Frome incorporated the Field Leach Trial (FLT) within it's EIS process, and the FLT was only given approval after the EIS process was complete.

A similar process is followed in the USA, where there has to be a full evaluation of a trial or Pilot-Scale study of ISL at a particular deposit, including restoration, before the regulators will accept and review proposals for a full scale facility (refer Sections 4.2, 4.4 & 4.6; Mudd, 1998a).

Why Heathgate have been able to bypass both such requirements and receive special treatment is unclear. They are unequivocally mining uranium and should be expected to meet the same standards as industry peers. The fact that the federal Environment Minister has exempted the FLT from the EIS is further proof that governments are ideologically driven to approve and facilitate the nuclear industry without rigorous public debate or consultation (Hill, 1997).

The EIS correctly points out that laboratory column leaching experiments on retrieved core sample are not always accurate in forecasting field leach solution efficiency, however, it fails to mention the following :

- no alkaline solutions have ever been tested in the field at Beverley, and therefore it is unknown whether they are a viable leaching reagent for the Beverley deposit. Field leach trials at Nine Mile Lake (Wyoming, USA), where the deposit was low in carbonate and therefore thought to be ideal for acid, both acid and alkaline solutions were used - neither showed overall cost advantages - but alkaline leaching showed significant environmental advantages due to lower heavy metal mobilisation (refer to Section 4.9; Mudd, 1998a; references listed separately in this submission);
- **the use of acid is NOT CONVENTIONAL !!!!!**

- in the USA, a field leach trial with demonstrated successful restoration of groundwater quality after the trial is required by regulators before permitting any commercial proposal -

Heathgate are not undertaking restoration of the FLT sites

More information will be presented on these aspects in later sections of this submission.

As with the DEF for the FLT, no specific operational, technical or environmental parameters are highlighted or discussed in the EIS that operation of the FLT was intended to elucidate and refine for the EIS. Presumably they would refer to :

- aquifer permeability and flow behaviour;
- possible clay and gangue mineral interactions with chemistry and flow;
- progressive concentration of numerous radionuclides and heavy metals in the leaching solutions and possible interference with the processing plant;
- uranium depletion curves and kinetic rates of dissolution;
- radionuclide concentrations and radiation exposure levels;
- formation of mineral precipitates from the concentrated leach solution brines (such as gypsum or jarosite); etc.

The results and methodology of the early "field test" referred to on page 2-8 must be released.

- It was presumably a single bore push-pull test or perhaps something else ?
- Did it use alkaline or acid solutions ? (such alkaline and acidic Push-pull tests were undertaken at Honeymoon in 1977 and 1979 respectively; refer to Section 6.2; Mudd, 1998a) ?

Other comments on the use of acid ISL :

- ***the uranium extraction techniques at other uranium mining and milling operations are irrelevant*** - especially Olympic Dam, since it is completely different mineralogy and process design;
- claims that alkaline extract less uranium are false - the column tests presented on page 5-6 show that, given more time, alkaline solutions can extract nearly the same proportion of uranium, although, typical of the EIS, the exact alkaline and acidic reagents used are not given;
- ***the level of heavy metals in the ore is essentially irrelevant - it is the equilibrium concentration of the numerous toxic metals within an extremely acidic and oxidising environment, as most heavy metals are highly soluble under such aggressive chemical conditions*** (a fact borne out by the concentrations of the FLT solutions - refer to relevant section of this submission);
- low carbonate levels were also observed at Nine Mile Lake in the USA, although this was not found to be any advantage since the use of acid solutions made restoration much more difficult - the use of alkaline solutions was considered as efficient and economic as acid.

2.5.1 - Commonwealth Approvals Process

As one can expect, Heathgate are attempting to manipulate the approvals process by announcing "Heads of Agreements" for sales contracts at the same time as releasing their EIS (UIC, 1998A).

How can a company begin negotiating the sale of uranium they have not even produced yet, do not even have an approved EIS to produce uranium from their "proposed" mine, without Commonwealth approvals for permission to open negotiations for sales contracts or approvals for an export permit on the basis of a sales contract ?

Since the "agreement" is with a "US Utility", it is presumably only with a General Atomics (GA) affiliated utility, either owned outright by GA or part-interest and thus has no substantive commercial or political meaning.

Some would say that the Beverley Project is merely an attempt to produce cheap uranium by avoiding the strict environmental standards that apply to ISL mines in the USA (although even these standards have not prevented massive and extensive contamination at sites such as Irigary in Wyoming or Burns in Texas).

This is presumably intended to prolong the economic quagmire that many US nuclear utilities find themselves in - many nuclear power stations are closing ahead of schedule since they are too expensive in the marketplace (eg - On January 15, Commonwealth Edison Company announced the permanent shutdown of the Zion 1 and 2 nuclear power plants, effective immediately; WISE, 1998).

The economic returns to Australia will be minimal, but we will potentially be left with a toxic legacy in the groundwater and surface soils of the Lake Frome region for thousands of years. To sacrifice our environmental and indigenous heritage to prop up an ailing overseas industry, especially the nuclear power industry, is horrendous and governments should be demanding at least the same level of environmental and commercial standards as ISL mines in the USA.

2.5.2 - State Approvals Process

In Victoria, there is now strict regulations in place for the protection of groundwater through the newly released State Environment Protection Policy (SEPP) Groundwaters of Victoria (EPA, 1997). Under this statutory policy, the technique of ISL Uranium Mining would arguably be illegal. At the very least the proponent would be required to restore groundwater following ISL to pre-mining quality at that point in the aquifer, and not just the maximum quality regionally or whatever figure the proponent might choose to suit their profit margin. The information presented in the EIS on State legislation provides a concerning framework for regulating ISL proposals or mines.

Firstly, all uranium mining and milling activities are exempt from the Environment Protection Act (page 2-13), and only come under the jurisdiction of the Radiation Control and Protection Act. As such, statutory environmental bodies like the Environment Protection Authority whom the public expect to be involved, have no say in the impacts on groundwater, possible surface impacts or other aspects of uranium mines.

This is not the situation in the USA - as well as coming under the jurisdiction of the US-Nuclear Regulatory Commission; in Wyoming all ISL mines have to comply with the Department of Environmental Quality (DEQ); in Texas, ISL mines have to comply with the Texas Water Commission (TWC) and the Texas Bureau of Radiation Control or TBRC). Thus government environmental departments have a statutory role in regulating the operation of ISL mines.

Section 3 - Need for the Proposal

This pitifully small section optimises the scant regard the proponent has for public intellect. All the arguments and data presented for the optimistic view of uranium sales and nuclear power are merely the proponents own propaganda (eg - Graham, 1998). Nuclear power does not have a viable future and never will - communities the world over have been resisting the development of nuclear power, and will continue to do so.

Even the Liberal Party have an Anti-Nuclear Power Policy.

A quote from their policy (Liberal Environment Policy, 1996) :

"The Shadow Minister for Resources and Energy announced early in 1994 that the Coalition had ruled out the establishment of nuclear enrichment and nuclear energy plants in Australia."

It should be pointed out that many uranium deposits, once promulgated as prospective mines, are now on hold by their companies due to their view of market conditions as unfavourable. Examples include :

- Kintyre, Western Australia - Rio Tinto have officially declared the project on hold due to market conditions (UIC, 1998b);
- Angela, Northern Territory - another potential ISL mine owned by the inaptly named Uranium Australia NL, no immediate plans due to "economic reasons" according to Chair Guido Staltari (ABC WebNews, 1998);
- Crownpoint, New Mexico, USA - aggressive development plans by Uranium Resources Inc., apparently on hold due to market conditions (Robinson, pers. comm.).

A review by the US Department of Energy (USDoE, 1997a - refer Appendix 2) demonstrated that in the USA, the most optimistic case for nuclear power is relatively stable until 2010, from where there will be a gradual decline in nuclear capacity. The worst case scenario was a rapid decline from 99 GW in 1996 to about 21 GW in 2015.

Given that Commonwealth Edison has closed it's Zion 1 & 2 reactors ahead of schedule, and the fact that nuclear power is now the most expensive power option in the USA, the outlook for the world's largest nuclear power country is not promising at all. The EIS does admit that the outlook for western nuclear capacity is "stabilised" - but it fails to acknowledge it's own industry projections of sharp declines.

The EIS asserts that the future for nuclear power is in East Asia, particularly South Korea and Taiwan. However, with the severe economic downturn across Asia, the overly ambitious and politically-led campaigns to establish broad-based nuclear power programmes have had to be revised and postponed (eg - Indonesia).

General Atomics have been active in trying to sell nuclear technologies and reactors to countries in Asia and Eastern Europe that have nuclear weapons ambitions (Moody, 1992 - refer Appendix 3).

The recent nuclear tests by India and Pakistan, and the drawn-out tensions between these two countries, have destroyed the myth that the expansion of nuclear power can be without the risk of nuclear weapons proliferation - a fact recognised over 20 years ago in the Fox Inquiry. India's nuclear reactor from which they derived their weapons material was from an "Atoms for Peace" program.

Nuclear power is ***NOT*** the answer to the intransigent Greenhouse Problem either. To replace fossil fuels with deadly high-level radioactive waste is a Faustian bargain that no community is prepared to accept (such as in Gorleben in Germany, where in 1997 about 80,000 citizens from the local community prevented the disposal of high-level waste at a proposed facility).

Australia has the best research and technology on solar and other alternative and more environmentally friendly energy solutions, with the manufacturing facilities and the best environmental conditions to develop a major export industry. Such an industry in the long term, given the right research and development and encouragement from government that the mining industry currently receives, replace reliance on coal and other raw materials. Such industries have the potential to create more jobs in total compared to the mining industry and jobs that are more sustainable and less susceptible to global commodities markets.

A new internal government study recently leaked in the United Kingdom estimates that renewable energy could supply half of the UK's electricity by 2025 at a lower cost than new nuclear or coal-fired power stations (Uranium Institute, 1998).

The EIS is therefore misrepresenting the facts.

There is no economic or political imperative to extract the uranium from the Beverley deposit - only General Atomic's desperate attempt to bolster the floundering viability of an industry doomed to extinction sometime early in the 21st century.

Section 4 - Proposed Development

4.1.2 - Outline of In Situ Leach Methods

As can be expected, Heathgate fail to properly outline the In Situ Leach method :

- No mention of groundwater restoration is made.

At all known ISL mines worldwide reviewed in Mudd (1998), the restoration of groundwater was considered critical in determining the overall environmental impact of a particular project. In the USA, the restoration of groundwater quality represents an average of 40% of total decommissioning costs, with some sites the capital costs of groundwater restoration alone reaching US\$16 million (refer Section, 4.11; Mudd, 1998a).

4.1.3 - Suitability of Beverley for the In Situ Leach Method

Although it is presented that the Beverley uranium deposit is suitable for the ISL mining technique, by reviewing international literature (see Section 3; Mudd, 1998a), it can be shown that there are considered to be some **SIX fatal flaws** in determining the suitability of a deposit to a commercial ISL mine. The two flaws relevant to the Beverley deposit are :

- a highly faulted formation;
- presence of organics and humates.

There is some portion of the EIS spent considering the Poontana Fault, and it is claimed, that it is impermeable and therefore no operational or environmental issue. This is critically disputed and will be dealt with in more detail later in this submission.

However, the fact that the presence of faults is considered internationally as a potentially fatal flaw in the suitability of a deposit for ISL mining and environmental control of solutions should sound alarm bells to both the proponent (who, given the worldwide experience of some Heathgate employees or contractors, would have to be aware of the literature referenced in Mudd, 1998a) and the state and federal governments.

The issue of organic content within the Beverley mineralised aquifer is not dealt with adequately, and this will be discussed later in this submission.

4.1.4 - Field Leach Trial

As to be expected, Heathgate have completely misrepresented and obfuscated the Field Leach Trial (FLT), despite making an enormous push to establish the FLT to allow them to investigate commercial, operational and environmental parameters for the project as input to for presentation within their EIS.

Heathgate were invited to comment on this author's critique of the DEF (Mudd, 1998c), however, Heathgate did not acknowledge receipt of the critique, nor respond to it. This is not community consultation nor professional.

There is an alarming lack of information presented on page 4-5

- the exact site of the trial wellfield and processing plant - the North or Central Beverley deposit (the 1997 DEF's installed two patterns) ?
- any operational, environmental or other problems encountered during the FLT (there were persistent rumours from locals of significant problems) ?
- time it began, solution flow rates, disposal of waste solutions, current status (at the time of writing the EIS) - operating or on a care and maintenance, the quantity of uranium produced (plans for this uranium) ?

In order to determine that the FLT is only operating on the North Beverley FLT wellfield array, one has to turn back to page 2-8, where the only other information such as date of commencement is given as January 2, 1998.

Why be so awkward in presenting the results of the FLT ? If Heathgate are as proud of their FLT as they claim to be, they should have nothing to hide and should be prepared to release the data clearly and concisely in an act of good faith and open and transparent community consultation. As presented, one has to suspect their motives.

The fact that the Central Beverley wellfield pattern is yet to be leached, is important.

- The Central Beverley Wellfield must be leached trialing Alkaline Solutions

Thus Heathgate will be able to demonstrate the efficacy of acid versus alkaline using actual field data, and not merely assumptions that suit their ideological and corporate agenda.

The results from this trial and the northern trial must then be released publicly in a separate document prior to the preparation and release of the EIS Supplement.

The phrase "that using alkaline leaching chemistry would necessarily be inferior to using acid leaching chemistry" is IRRELEVANT (emphasis added).

The use of alkaline leach solutions has been demonstrated by nearly 25 years of alkaline ISL mines in the USA, and other trials and ISL mines across the world. Such a phrase is insulting in the extreme to industry colleagues in the USA and should be publicly retracted by the proponent.

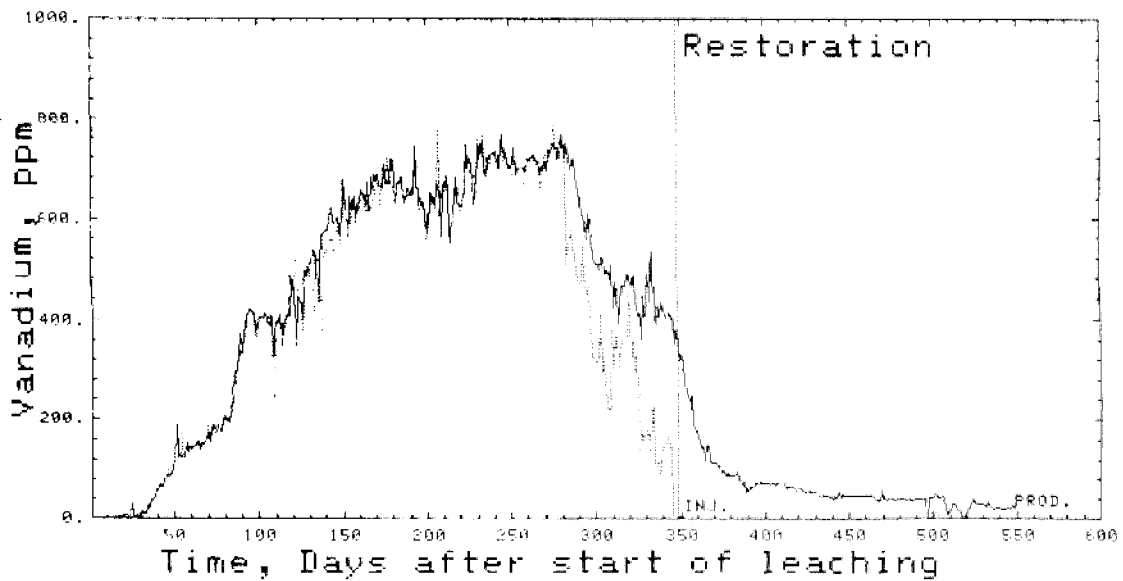
The reference to the uranium extraction processes at Ranger and Olympic Dam should be deleted and treated as irrelevant for the choice of sulphuric acid ISL.

Table 4.1 (page 4-6) - Field Leach Trial Chemistry

This should be thrown out as irrelevant garbage and Heathgate forced to re-submit the entire section on the FLT.

- **the regulators in the USA require by law statistically derived background groundwater quality data determining from a minimum of one year's environmental monitoring, including variability** (refer to Sections 4.4 & 4.6; Mudd, 1998a);
 - given that approval for the FLT was only in mid-November 1997 and the FLT began on January 2, 1998, **the FLT fails to meet USA regulatory standards**;
 - the presentation of some elements is **UNSCIENTIFIC** :
 - the use of significant digits is fundamentally wrong (eg - chlorine is "1988.26" - no chemical analysis is this accurate nor precise - should be given as 1,990);
 - this gives a false impression of accuracy;
 - there is no indication of variability, such as standard deviation, maximum or minimum (**legally required in the USA**);
 - the number of samples the averages are based on are NOT presented - such as three or fifty ?;
 - no carbon species are included, especially in background groundwater quality (such as bicarbonate or carbonic acid at a pH of 2);
 - no redox potential is included - this would be critical for Heathgate to know operationally as well as environmentally and they must have field data - the DEF said they will monitor Eh;
 - no trends are presented - anyone who cares to examine international literature or with an ounce of understanding of chemistry, would know that the ISL process will involve trends in many parameters - such as increasing concentration as the leach solution is recycled through the process plant and wellfield - ***none are presented*** (by reference to Table 4.2, page 4-9, the average uranium concentration expected during commercial operation is only 150 mg/l, over 25% lower than the FLT concentration of 210 mg/l, demonstrating changing concentrations over time);
 - on page 4-37, it is stated that "**...after a period of time they (process solutions) become saturated with trace ions...**" - chloride, molybdenum and vanadium are known to interfere with the metallurgical extraction process, for example.
 - the Nine Mile Lake FLT of acid ISL showed marked concentration of many toxic metals over time due to recycling of the leach solutions;
 - no mention is made of the different toxicity of the chemical form of many species, such as Chromium VI (valence state 6+), which is much more acutely toxic than Chromium III (valence state 3+) - the highly oxidised state of extracted leach solutions would arguably contain chromium in the more soluble and toxic 6+ state, for example (Fetter, 1993);
 - the units of Molybdenum (Mo in µg/l) appear to be incorrect;
- no RADON or THORIUM is presented !!!!!**

Figure 1 - Nine Mile Lake - Vanadium Concentration Trends
 (Nigbor et al., 1982 - note, it is believed the use of ppm is incorrect, should be ppb)



- the charge balance for the Extraction Solution is about -6.3% and for the Waste Solution about -7.3%. Given the saline nature of the solutions, such errors are tolerable (5% or lower is preferred), although the data presented in Table 4-1 cannot demonstrate whether there is any anion or cation bias in the analysis.
- many elements are increased in concentration by up to nearly 1,000 times :

Table 1 - Factor of Concentration Change in Extraction and Injection Solutions

	Ext.	Inj.		Ext.	Inj.		Ext.	Inj.		Ext.	Inj.
Al	168	167	Cr	29	1.5	Mo	0.68	0.51	SO ₄	2.6	2.7
As	25	20	Cu	1.0	4.0	Na	1.2	1.2	Si	2.6	2.6
B	0.66	0.60	F	3.6	3.4	Ni	510	498	U	514	36
Ca	1.48	1.47	Fe	35	35	NO ₃	6.9	2.6	V	780	760
Cd	210	204	K	1.4	1.4	Pb	3.8	2.5	Zn	0.86	0.59
Cl	0.99	0.95	Mg	1.5	1.5	Ra ²²⁶	12.6	10.7			
Co	38	37	Mn	2.9	2.7	Se					

An analysis of the leach solution geochemistry to examine the potential for mineral precipitates forming will be presented later in this submission, along with an analysis of the question of water quality and restoration.

At Nine Mile Lake, the **thorium concentration increased dramatically by a factor of nearly 600,000** (refer Section 4.7; Mudd, 1998a). Thorium-sulphate is quite soluble under low pH and oxidised conditions (Langmuir, 1997; Fetter, 1993). Curiously, no radium or thorium analyses were presented following restoration of the Nine Mile Lake FLT of sulphuric acid.

The release of radon gas is recognised as one of the major radiation concerns for ISL mines in the USA and around the world (Mudd, 1998a).

The exclusion of radon and thorium from the FLT chemical analyses is a significant breach of due process, and some would say, might be argued as professionally negligent.

4.1.5 - Proposed Staged Development

Table 4-3 does not include any monitoring bores !!!!

4.2.2 - Wellfield Facilities

The wellfield schematic presented in Figure 4.8 does not represent good monitoring and could very easily not detect an excursion :

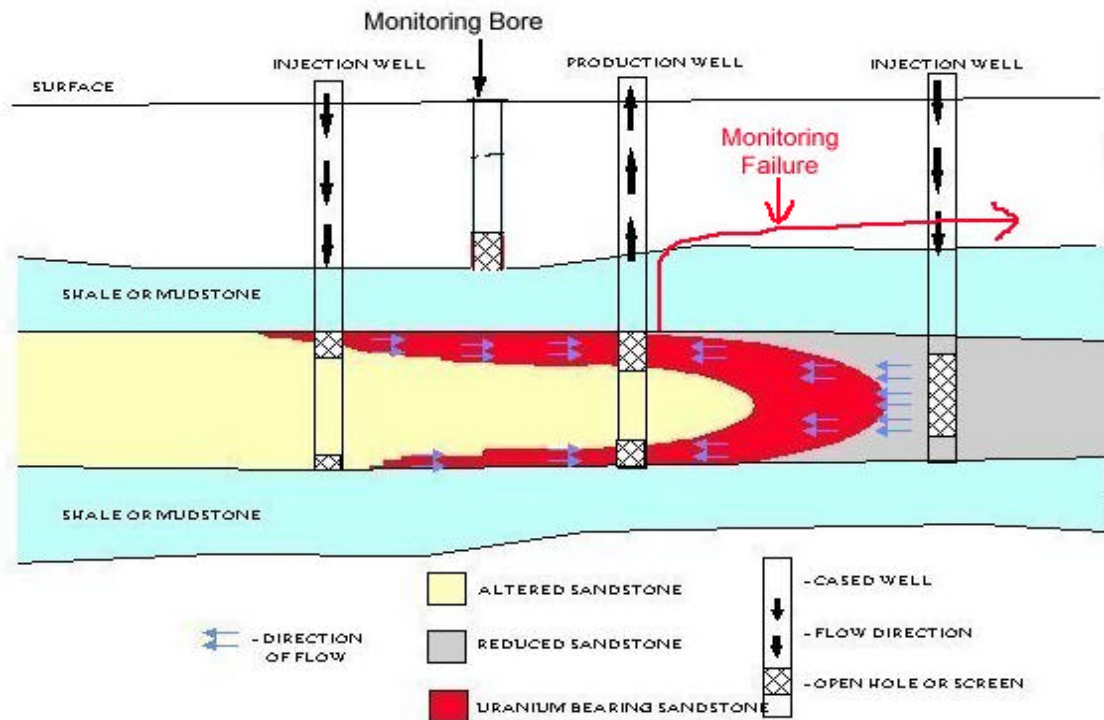
- due to the known anisotropic behaviour of palaeochannel aquifers, the ore zone monitoring wells may not be spaced close enough to detect an excursion, especially if such an excursion were to occur in a subchannel of the wider palaeochannel (refer Figure 16; Mudd, 1998a);
- the monitoring of the Willawortina aquifer above the ore zone does not include bores between the edge of the wellfield and the outer rim of ore zone monitoring wells - thus if there is a slow leak in a production bore, it may develop undetected;
- if Heathgate extract more groundwater from the Great Artesian Basin (GAB) than currently proposed, it may stress the fault to the point where present flow conditions are altered - *the fact that faults all around the region are recognised as mechanisms for discharge of GAB water through springs or into other regional aquifers, should highlight that the Poontana Fault that forms the western edge of the Beverley palaeochannel system can never be simply ignored.*

Above figure based on a cross-section through Figure 4-8 of the EIS.

Monitoring arrangements and requirements will be further discussed later in this submission.

SURFACE PIPES WON'T CRACK WITH WEATHERING, EXPANSION AND CRACKING ?

Figure 2 - Willawortina Monitoring Failure



(Figure 2 indicative only)

4.2.3 - Camps, Airstrips and Local Roads

Based on Figure 4-7, the location of a major mine access road that cuts across the north-eastern extent of the North ore zone is **UNACCEPTABLE**.

All access roads must avoid active or potential mining zones, except those directly associated with mine and wellfield infrastructure. It is also more prudent to avoid the major mine road crossing the Jenny Creek 100-year floodplain so close to the mine site.

It is recommended that the road presented on the south-west of the retention lease boundary be the main access road.

4.2.4 - Power

It is ironic that Heathgate, a subsidiary of nuclear multinational General Atomics, are incorporating the use of solar power and more energy efficient systems when they are protagonists for nuclear power ! !

This is carte blanche admission that alternative energy technologies are economically and environmentally viable ! ! Perhaps they aren't so "alternative" after all !!!

4.2.5 - Water Supply

The location of the proposed new water bore into the Great Artesian Basin would appear to be right through the Poontana Fault. This must not be allowed as it could provide a conduit for flow should an excursion scenario identified above occur. The most appropriate place for the location of the new GAB bore would be outside the current Retention Lease area and to the south-west of the current and proposed camp site.

Do they expect any boundary effects from the west ? Will the Poontana Fault interfere in any way with expected flows ?

4.5.1 - Wellfield Planning, Construction and Operations

What proprietary groundwater modelling software are Heathgate proposing to use ? The public domain finite-difference groundwater model MODFLOW with a proprietary graphical interface (eg - Visual MODFLOW) ? Or perhaps a finite-element groundwater model (eg - AQUIFEM-N) ?

The capabilities of different computer models are quite varied, and some need modification in order to account for the specific behaviour of faults, for example. The ability of each model to accurately model the boundary effects of the palaeochannel are also important.

Heathgate must release ALL details concerning groundwater models to allow independent technical assessment.

The frequency of ore delineation drilling must be detailed.

The technique used to "adequately plug and abandon" such bores must also be released.

Any examination of international literature reveals that exploration bores not adequately plugged provide the most common cause of excursions (eg - USEPA, 1995; Mudd, 1998a).

The use of a "groundwater sweep" or pre-conditioning of new wellfield ore zones is not necessarily appropriate - if it is to achieve lower levels of calcium and chloride for uranium extraction within the process plant, concentrations of calcium and chloride are actually increased or stable in FLT production and waste solutions, respectively. Thus a "groundwater sweep" could maintain current concentrations or possibly increase them!! Alternatively, Heathgate may have not explained the proposal clearly.

Another complicating factor is that the progressive mining of the three Beverley deposits North to South gradually increases the salinity of the groundwater being mined - it is expected this would exacerbate the levels of calcium and chloride in production and waste solutions.

The possible use of GAB water from the new bore for groundwater pre-conditioning must be quantified.

The proponent must also make assurances that they will not use excessive quantities of water from the GAB - ie, above what they presently propose.

It is typical of proponents in EIS's to leave out important data such as this - so they can include it in the EIS Supplement and argue that they have listened to public concern, when the technical data should have been included in the first place to be a rigorous EIS (many such comments were made concerning the Olympic Dam Expansion Project EIS - eg, MPI, 1997; RAC, 1997; FoEA, 1997).

4.5.2 - Well Construction

The use of PVC is preferred over stainless steel, as this is likely to minimise (though not prevent) potential corrosion and well integrity problems. The use of steel in Texas led to many excursions (Section 4.8; Mudd, 1998a).

Due to the intense nature of drilling in ISL mines, there will be a significant quantity of radioactively mineralised sediments brought to the surface. It is not believed that the simple covering up of drilling mud pits will be sufficient to ensure adequate radiation protection measures.

The previous discharges of radioactive solutions to surface soils at Beverley (1973, 1981, 1997 and 1998) prove that the radionuclides, especially radium, will remain among the uppermost layers of soil, and therefore available within the food chain for bioconcentration. This will be discussed further later in this submission.

All drill cuttings from the mineralised zone must be transported to a centralised radioactive waste containment facility on site, engineered to minimise the ingress of infiltration and any degassing of radon.

Well integrity testing must incorporate a high enough pressure to account for the depth of the deposit, that is - 110 metres. If a "hypothetical" situation were to occur where either the well screen became clogged (due to mineral precipitation, sediment buildup or another mechanism) and the fluid pressure were to increase rapidly before detection, the bore and screen is capable of withstanding the intense hydraulic pressures created.

The viability of ISL mines in deeper uranium deposits has always been questionable - the state of New Mexico is known to have several such uranium deposits. Development has been precluded to date because of the difficulties associated with deep bores and the higher hydraulic pressures involved, although attempts are currently underway to develop the controversial Crownpoint ISL project in the same aquifer used by many Navajo communities.

Thus, incorporating a factor of safety of about 10%, a minimum well integrity test should be conducted at about 1,250 kPa, still well below the calculated fracture level of 1,705 kPa.

The Willawortina Formation is not labelled as either clay or sand in Figure 4-13.

4.5.3 - Solution Pipelines

All pipelines must be buried below the surface and contained within a bunded cover system.

Where solution pipelines cross flood prone creek areas, they must be buried below the natural surface and contained within a bunded cover system including a leak detection system. This should ensure that damage from any flood event is minimised, although it is noted that only a 100 ARI flood is used as the base case. This is not considered satisfactory, as there have been greater floods in the region, floods which caused infamous problems and interference with seepage monitoring at the Olympic Dam Tailings Retention System (refer to Section 3.4; Mudd, 1998a).

All wells must be individually monitored - pattern manifold monitoring is unacceptable as it possibly averages out errors in flows from individual bores across the whole 5-spot pattern.

More on Flood issues will be presented later in this submission.

4.6.1 - Gypsum Control

The EIS does recognise that gypsum is an important mineral that may precipitate during operation of the leaching process. However, it does make one fundamental mistake (which could be seen as bordering on professional incompetence) :

The calculation of the gypsum solubility product is based on background quality, not leaching phase quality, where calcium levels are 50% higher and sulphate levels twice as high.

Such an oversight can hardly be considered accidental, especially given the supposed expertise and experience of some Heathgate employees and contractors.

Also, the Saturation Index (SI) is the most appropriate way to present calculations of mineral precipitation, not the Solubility Product. A negative SI shows that the water is undersaturated with respect to that particular mineral, and a positive value shows it is over-saturated and thus is likely to precipitate that mineral.

By using the geochemical model PHREEQC (Parkhurst, 1996), it can be demonstrated that by varying the concentrations of calcium and sulphate from background to levels derived from the FLT, the problems of gypsum precipitation will be significant and possibly worse than predicted in the EIS.

Table 2 - Gypsum Calculations (mg/l)

Deposit	Background			Saturation Index	Leaching Phase			Saturation Index	
	pH	Ca	SO ₄		pH	Ca	SO ₄	Ca-SO ₄	FLT
North	7	380	1,600	- 0.14	2.25	547	3,910	0.10	-0.05
Central	7	610	2,100	0.08	-	-	-	-	-
South	6.8	850	2,500	0.22	-	-	-	-	-
			Waste Solutions		2.07	546	4,135	0.09	-0.05

Although it is acknowledged that the presence of higher concentrations of sodium and chloride within the solutions may increase gypsum solubility (the SI in the right-most column is an attempt to account for this effect), enough data is not presented in the EIS on the overall expected chemistry for all ore zones and as such the more technically accurate analysis cannot be made.

The data output from the above limited analysis can be found in Appendix 4.

The fact that calcium and sulphate concentrations have been allowed to exceed the solubility limit for gypsum during the Field Leach Trial at North Beverley, where the concentrations are the lowest of the three ore zones, does not signal a degree of confidence in the ability of Heathgate to achieve their stated aims on page 4-29 to control gypsum formation.

Based on the above Saturation Index calculation for the FLT, it would be reasonable to expect that gypsum precipitation problems were encountered in the FLT to date. The higher pH of the waste solutions might be an indicator of this (Heathgate did argue in their response to comments on the FLT DEF that precipitation problems could be controlled by pH).

It is imperative that Heathgate release ALL the FLT data to demonstrate the efficacy of their environmental management, and thereby demonstrate their suitability as a potential licensee for the Beverley Project.

4.6.2 - Flow Control

The aquifer sediments across the three ore zones at Beverley are not all likely to possess high permeability. In fact, the nature of palaeochannel or braided river type geological environments is their wide variability, even across small areas (refer Figure 2, Section 1.1; Mudd, 1998a). This is evidenced by the original drilling of trial wellfield patterns at Honeymoon, where the fourth pattern intersected silts with no or minimal uranium mineralisation and was subsequently not completed (SCRA, 1997 & 1998).

No mention is made of possible gypsum or mineral formation within the interstitial space of the aquifer and consequent reductions in flow rates and injectivity, and possible flow control problems arising from such a scenario.

No mention is made of spatially variable and time-dependent aquifer characteristics, such as permeability, storage coefficients, possible consolidation or subsidence effects, etc. The anisotropic properties across the channel aquifer system are not likely to merely align along the same axis, especially given the new interpretation of three main palaeochannels. This makes prediction of exact flows and behaviour quite problematic, on both operational and environmental grounds.

A subsidence analysis is required by regulators in Wyoming before any new ISL permit is given.

No mention is made of possible clay interactions with leach solution chemistry and flow. There is well documented evidence in the USA that leach solutions affect clays through ion exchange and swelling, thereby reducing permeability. Although this was commonly from the use of sodium-based lixivants, such problems have been noted at both Beverley and Honeymoon before (Mudd, 1998a).

No mention is made of possible screen plugging due to silt entrapment - Heathgate have consistently obfuscated this aspect, and some might say could be seen as outright lying (see Mudd, 1998b).

- For the DEF for the FLT, comments from the (then) Department of Housing and Urban Development (DHUD) questioned the possibility of fine sand and silts in re-circulated leach solutions and buildup within the retention pond. Heathgate's emphatic reply was (Heathgate, 1998c; page 10) :

"Entrainment will be minimal to nil."

- However, in the latest version of their Beverley Project Profile (Heathgate, 1998b; presumably released in February 1998) and the current EIS it is clearly stated that with reference to the retention pond :

"The solid wastes include the relatively small amount of sand that is produced with the pumped water." (Heathgate, 1998b; page 10).

"Other solid wastes generated from operations will be sand and silt derived from the ore zone and entrained with the pregnant leachate." (EIS - Heathgate, 1998a; page 4-34).

"...or sands carried with the development water...would also be radioactive." (EIS - Heathgate, 1998a; page 4-37).

How can Heathgate be trusted if they consistently obfuscate the truth ?

Any hydrogeologist would agree and know from first hand experience that entrainment or discharge of fine sands and silts from a sedimentary aquifer will occur, despite a bore's gravel pack.

Thus there are many significant issues that remain unresolved with regards to solution flow control through the ore zones, and Heathgate have demonstrated they cannot be trusted.

4.7.1 - Radioactive Solid Wastes

The calculation of radium buildup is **WRONG**.

By using the figures presented :

$$\text{Radium Buildup} = 0.005 \times 250 \times 60 \times 60 \times 24 \times 365 \times 10,000 = \mathbf{394 \text{ GBq}}$$

(bleed) (flow) (seconds to years) (radioactivity)

The buildup of radium uses a bleed rate of 0.5%, whereas earlier in Section 4.6.5 a bleed rate of up to 5% is suggested. According the calculation of radium buildup in 4.7.1, the total radium level could therefore be as high as 3,942 GBq, and not the "360" GBq as suggested.

All low-level radioactive wastes must be stored and managed on the proposed Beverley site.

It is inappropriate and too risky for transport of radioactive wastes over the long distances from the Beverley site to wherever the federal government thinks it's going to build a national low-level radioactive waste dump.

The Radioactive Waste Containment facility must be triple lined with HDPE-clay-HDPE, and a leak detection system, and the waste must remain in as dry a state as possible.

The current proposed site for the waste facility (Figure 4-7) is adjacent to the main southern solution trunk pipe and the southern ore zone.

It must be located away from all mining zones and away from any possibility of a 1,000 year flood covering or encroaching on the site. Thus **IF** a major spill or surface leak were to occur (and precedents do exist in the USA - at the Burns ISL site in Texas, one such spill, originally reported by the company as only 380,00 litres, involved over 3,200,000 litres; see Section 4.8; Mudd, 1998, page 66).

It must also be separate and distant from the Non-radioactive Solids Waste Containment Facility.

The facility must be engineered, constructed and operated to prevent ingress of infiltration and minimise the degassing of radon. Upon closure of the mine site and containment facility radon emanation rates from the surface of the site must be within the same standard deviation as current pre-mining background levels.

Heathgate must pay for monitoring of the site for at least 1,000 years to ensure pastoral interests in the region are protected and uncompromised.

4.7.2 - Non-Radioactive Solid Wastes

The sanitary landfill must meet the same standards and specifications as municipal facilities are expected to meet in major metropolitan cities such as Adelaide.

The facility must be lined, with either a double-HDPE and leak detection system or a clay-HDPE combined system.

The facility must be located away from the Radioactive Waste Containment Facility and from all mining zones, from any possibility of a 1,000 year flood covering or encroaching on the site. Thus ***IF*** a major spill or surface leak were to occur (and precedents do exist in the USA - at the Burns ISL site in Texas, one such spill, *originally reported by the company as only 380,00 litres*, involved over **3,200,000 litres**; refer Mudd, 1998, page 66).

4.8 - Liquid Waste Handling

The claims concerning concentrations in waste solutions are **MISREPRESENTED**.

A comparison of the concentrations in different parts of the EIS is warranted.

Table 3 - Waste Solutions Comparison

EIS page	4-35	4-35	Table 4-1 (page 4-6)	
	Bleed	Process	Extraction	Injection
Volumes	0.65 to 6.5 Ml/wk	0.1 Ml/wk	na	na
Uranium	up to 5 mg/l	10 to 50 g/l	211 mg/l	15 mg/l
Free Acid	5 mg/l (0.5%)	up to 100 g/l	866 mg/l	1,277 mg/l
Radium	<u>?????</u>	up to 10,000 Bq/l	9,881 Bq/l	8,414 Bq/l
Selenium	<u>Trace ?????</u>	<u>?????</u>	250 µg/l	260 µg/l
Molybdenum	<u>Trace ?????</u>	<u>?????</u>	1.56 µg/l	1.17 µg/l
Other Metals	<u>?????</u>	<u>"Minor"</u>	various - up to 800x higher	various - up to 800x higher

Assuming the above figures are somehow consistent, then the disposal of waste process solutions alone will entail the loss of between 1 and 5 tonnes of uranium per week (100,000 litres times 10 to 50 g/l uranium concentration), or 50 to 250 tonnes per year. In other words, Heathgate plan to waste as much as 5% to 25% of the uranium recovered from the ore zone. What a waste of effort !!!!

I challenge Heathgate to substantiate why they are happy to waste so much product so readily and turn it into toxic liquid waste, mobile within the environment ?

At many ISL sites undergoing decommissioning, the lower values of uranium in the waste injection stream form the basis for economic restoration of groundwater and simultaneous production of uranium (eg - USDoE, 1995a, 1995b, 1996, 1997b & 1998).

The above table proves that the data set compiled in Section 4.8 of the EIS is ***misleading*** and cannot be considered credible.

Why don't Heathgate present ACTUAL DISPOSAL SOLUTION DATA from the FLT ?

Do they have something to hide ?

Assuming the above data is correct somehow, then taking 650,000 litres per week at 5 mg/l of uranium and simply mixing it with 100,000 litres per week at say the lower value of 10,000 mg/l uranium in waste processing solutions, and assuming no reactions occur (simple mixing),

***the resultant concentration is 1,333 mg/l uranium
in the disposal solution***

Again, as with the DEF for the FLT, the figures are nonsensical as presented and point to continued environmental problems or possible hiding of the truth.

What if the Stage 2 plant is running at 100% efficiency ? Or perhaps over at 120% (precedents do exist - such as Nine Mile Lake and other sites in the USA; Mudd, 1998a) ?

Given the high evaporation rates from the arid to semi-arid climate of the Beverley site :

**HEATHGATE MUST EVAPORATE
ALL LIQUID WASTES**

This is the main option used in the USA, with deep-well disposal being a last resort, and limited to aquifers with a Total Dissolved Solids (salinity) level of greater than 10,000 mg/l (see Sections 4.4 and 4.6, Mudd, 1998a). The current FLT Disposal array and the EIS-proposed site is within an area closer to 4,000 mg/l, so again Heathgate's proposals do not meet USA regulatory standards nor world's best practice.

As mentioned on page 4-35, there is a very real likelihood for disposal fluids to migrate into active mining zones. Especially given that :

- waste solutions are injected under a certain degree of pressure;
- the induced piezometric gradient within the disposal area is likely to cause waste solutions to migrate away from the disposal well array.

The disposal of solutions with high levels of excess sulphuric acid and oxidants will create a situation where the uranium and many metals will remain soluble and therefore mobile, due to the low pH and high redox potential.

Heathgate cannot avoid this fact :

They cannot argue that the aquifer is amenable to the use of acid ISL due to low levels of acid consumers, and then argue that the aquifer will then mystically be able to attenuate any waste solution because of the presence of acid consumers.

Given that Heathgate have made provision for two more holding ponds, it is imperative they are held accountable and EVAPORATE waste solutions.

Figure 4-15 does NOT include monitoring of the Willawortina aquifer!!!!

The B2 unit is not labelled or coloured as either clay or sand. This must be explicitly clear.

Are the bold black numbers with horizontal arrows between the different bores distances or something else ? The drawing is at a very poor scale nonetheless and confusing.

What about monitoring east or west of disposal wells ?

What about monitoring downstream (south) of disposal bore H54R (to the right in Fig. 4-15) ?

Given that there is a slight overall gradient within the Beverley palaeochannel in this direction, and the interpreted geology suggests the channel eventually migrates towards Lake Frome, this is a serious failure of proposed environmental monitoring.

On what frequency will flows into disposal wells be monitored ?

Monitoring of disposal wells must be continuous.

This should include (at a minimum) - flow, pH and electrical conductivity. With the rapid advance in recent years of field and downhole bore equipment, such techniques are economically feasible and Heathgate should not be forced to simply increase it's profit margin at the expense of ethical and necessary environmental monitoring methodologies.

Is each disposal well 0.5 l/s each or is it 0.5 l/s for both wells simultaneously ?

However, despite the above perhaps pedantic comments, the fundamental philosophy behind disposal wells is fundamentally flawed and totally environmentally unacceptable.

The pumping underground of such liquid wastes will increase the average concentration of many environmentally sensitive and toxic heavy metals and radionuclides by up to 1,000 times or possibly more. Not only will the injected solutions be considerably higher, but the geochemical controls that existed before acid-ISL will have been removed entirely, and no attenuation mechanisms will be able to lower the average concentrations of all metals.

It is not believed that clays alone will completely attenuate all acidity, heavy metals and radionuclides and thereby influence their concentration to miraculously to return to "background". Even if clays were to attenuate many of the elements, this would mostly be through adsorption - and such elements would therefore be readily available for *desorption*, and thereby mobile again within the groundwater.

The groundwater flow and quality will be completely altered by the ISL process, and Heathgate will not be leaving it within the same use category, but much, much worse if they are allowed to use disposal bores.

For example, the level of cadmium within native groundwater is 0.2 µg/l, and the average lixiviant concentration is 41 µg/l. The drinking water guideline for cadmium is 5 µg/l (refer Section 1.2; Mudd, 1998a). The same can be shown for aluminium, arsenic, selenium and vanadium.

Although the level of radionuclides is prohibitive for stock or any other water use without treatment - Heathgate are treating Great Artesian Basin water before use !!!!

The operation of unrestricted ISL at Beverley will mobilise the uranium to considerably higher levels, thereby making it even more prohibitive for treatment, a cost that Heathgate has avoided and simply passed on to future residents, pastoralists and the wider environment of the western Lake Frome Basin.

HEATHGATE MUST EVAPORATE **ALL LIQUID WASTES**

4.9.1 - Water Usage

The quote on page 4-36 "...Beverley aquifer is *essentially* a closed system with no recharge or discharge" (emphasis added) must be deleted as irrelevant and retracted by the proponent.

If the Beverley aquifer was a closed system, then how did the groundwater flow into the mineralised zone ? How did the uranium therefore mystically undergo transport and deposition from Mt Painter to Beverley ?

Another reference in point on page 4-36 of the EIS is the quote "to discourage the ingress of groundwater from parts of the palaeochannel *outside* the mining zones".

In earlier literature by Heathgate, it was clearly shown that they **HAVE NO IDEA** of the extent of the palaeochannel beyond about 500 metres north and south of the mineralised zone (Heathgate, 1997d; refer Figure 30, page 108, Mudd, 1998a).

Since there has been no further drilling in the past 25 odd years outside the actual mineralised zone, no claim can be made about delineating the palaeochannel beyond such a distance.

Therefore, how can Heathgate argue the aquifer is "essentially a closed system" when they have no idea about the extent of the aquifer they intend to mine and use as their toxic waste disposal system ?

Time and time again Heathgate and its consultants make subtle references to the fact that the Beverley aquifer is ***NOT ISOLATED***, and yet they still maintain that it is entirely separate from regional groundwater systems. The use of terms such as "*semi-isolated*" in the DEF (Heathgate, 1998b, page 3-1) and "*essentially*" closed in the EIS make a mockery of any claim that the Beverley aquifer is isolated.

Any hydrogeologist should agree that it is a fundamental law of nature that water will flow underground from one place to another. Darcy's Law. Unchangeable. Even the GAB takes up to 2 million years to flow from eastern Queensland to central South Australia. Not one colleague believes that such a palaeochannel aquifer like the Beverley system is even partly isolated, let alone completely on the area of mineralisation found.

It is simply ludicrous and professionally outrageous that Heathgate are able to make such unfounded assumptions and yet any attempt to hold them accountable and justify their assertions appears to meet with derision towards such views and collusion between the proponent and government.

Further discussions about this fundamental operational and environmental point will be made in the critique of Section 6.

The statement that "*the overall balance of water in the ore zone aquifer be maintained, to limit the possibilities for excursions*" (emphasis added; page 4-36) is misleading. Although the balance of water extraction and injection may be averaged over the whole area being mined, there is a continual cycle of water being moved, and in small areas such as the disposal array, there is a gradual accumulation of water while a gradual decline in mined areas. This is proven by the quote on page 4-37 "*not all water produced can be returned to the aquifer*".

Why a figure of 27 ML/year for the Minesite Camp and 80% efficiency for the Reverse Osmosis plant ? On what basis ?

Evaporative losses need to be quantified in detail and the source of any makeup water stated explicitly - Great Artesian Basin or Namba or ?

What effect will the salinity level have on evaporation rates ? Will it slow down evaporation ?

Figure 4-16 is misleading as it appears that the wellfield production system is separate and distant from the disposal system.

Will the depth of water in holding and development ponds affect evaporation rates, especially in the hot, dry summer ?

Will the evaporation in the plant holding pond(s) lead to evaporative concentration of solutions ?

The figures of 6,709.3 ML/year extraction and 6,706 ML/year injection on page 4-39 are inconsistent with Figure 4-16 and the table below.

The use of Evaporation ponds for waste solution disposal will ensure a negative water balance within the Namba or Beverley aquifer, and thereby help to minimise any excess pressure buildup and possible excursions.

4.10 - Surface Water Management and Sediment Control

It is not acceptable for any sediments to leave the Beverley mine site. There are numerous admissions within the EIS that such sediments will contain radionuclides, and such releases into the wider environment must be prevented at all costs. For example (page 4-37) :

Since the water contains radionuclides, some of the resulting dust would also be radioactive.

- see Section in this submission on solid wastes and sediment entrainment in circulating solutions.

Seeing as the broader western Lake Frome region is used for pastoralism, it is imperative that radionuclides not be allowed to bioaccumulate within sheep and the wider environment due to what would appear to be low levels of radionuclides in sediment runoff.

Any pipes crossing the Jenny Creek floodplain must be completely buried, bundled and incorporate a leak detection system, as already recommended. They must **PREVENT ALL IMPEDANCE** of surface floods, as any resistance is likely to lead to excessive pressure buildup and a higher risk of pipe breakages.

The releases that occurred at the Beverley site during hydrogeologic pump testing in 1973 under Western Nuclear-OTP investigations and especially with the further series of pump tests in 1981 by the South Australian Uranium Corporation (SAUC) demonstrate that release of radionuclides to surface sediments and their subsequent erosion can be highly significant. These and other releases and their implications will be discussed in much more later in this submission.

4.11 - Handling of Spills and Accidental Releases

As suggested on page 4-39, Heathgate's proposed handling of spills will concentrate on "**spillage control**" and **NOT PREVENTION**.

It is not believed that, given the assurances over pages 4-39 to 4-40, that "**any spills will be small**". Given that there was a surface spill within three months of the FLT, one has to be outright suspicious of any claims that Heathgate make.

In the USA, **ALL** spills require notification to regulators within 24 hours, followed by a written report within 7 days (see Sections 4.4 and 4.6; Mudd, 1998a).

ALL SPILLS OR ACCIDENTS OF ANY KIND MUST BE REPORTED TO THE GOVERNMENT AND PUBLIC IMMEDIATELY WITHIN 24 HOURS

**A WRITTEN REPORT MUST BE
PUBLICLY RELEASED WITHIN 7
DAYS OF THE INCIDENT**

**ALL SPILLS MUST BE CLEANED
UP WITHIN 90 days**

All bunds must be constructed of a relatively impermeable material, such as HDPE or a thick layer of clay. A leak detection system must also be incorporated.

"Leaks might occur anywhere in the system" - *what an admission* !!!!!

However, the following sentence contains a worrying point :

How long is "reasonably quickly" ?

What if electrical controls fail ?

How frequent will manual inspections be made ?

It is not accepted that only the release of pregnant lixiviant will constitute a spill that requires remediation. This lack of commitment to the environment and health of workers is deeply concerning, which is also evident in the attempted cover-up or avoidance of the March 1998 spill episode.

It is blatantly obvious when you see a sentence such as "any yellowcake spill would be immediately recovered" (page 4-40) that Heathgate are only interested in one thing - their bottom line. For a company to obviously state they will only clean up a spill if it's economically attractive is putrid in the extreme.

**ANY SPILL OF RADIONUCLIDES,
HEAVY METALS OR OTHER
PROCESS CHEMICALS IS A
SIGNIFICANT HAZARD**

It is **IMPERATIVE THAT THE PROCESS PLANTS BE COMPLETELY SEALED** and all spills and drainage directed quickly into the plant evaporation pond.

At some sites in the USA, such as Irigary in Wyoming and Burns in Texas, there was no effective seal in the process plants, and yellowcake and other chemicals leaked beneath the plant and created a horrendous legacy of contamination. The recent trip to the USA for representatives of the Adnyamathanha (that was funded by Heathgate) included a visit to Irigary, to supposedly say this is the "worst" example of a poorly run ISL mine. I beg to differ - Heathgate's current proposals match the poor environmental proposals found at Irigary, Burns, and many other highly contaminated ISL minesites around the world.

It should be pointed out that the current FLT was not sealed in such a manner during a site visit in December 1997 (visit <http://home.vicnet.net.au/~seaus/proposed/bevfltjpgs.html>). Cracks were visible in the HDPE lining underneath process plant equipment - should a spill occur, this would lead to soil contamination beneath the site.

It is clear that Heathgate are only concerned with absolute bare minimum compliance with the letter of the law as it suits their profit margin, not with it's spirit or even increasing public expectations of corporate environmental performance.

The fact that they will refuse to clean up every spill (and based on overseas experience, it is more than likely there will be more spills and releases at the surface and underground at Beverley, and in all probability much more severe than the recent March 1998 spill) proves they have no commitment to any claim of responsible environmental management.

The proposals for Spill Management, as presented in the EIS, only focus on events after the fact and adopt a "wait-and-see" approach, which is completely unacceptable and entails significant commercial risk. This approach is entirely inconsistent with the Precautionary Principle.

4.12 - Gaseous Emissions and Dust Generation

It is pathetic that **NO RADON sources are quantified.**

The operation of ISL mines overseas has demonstrated that radon is a major health concern for both workers and the broader region in which the ISL mine operates.

The nature of groundwater pumping - airlifting - is likely to enhance radon release.

What about the process plant as a source of radon ?

What about holding ponds as a source of radon ?

Why have these not been quantified ?

The use of the term "**unmeasurable**" is completely unacceptable. The release of radon due to ISL operations will lead to radioactive materials being dispersed over a wide area, especially to the south-southwest in the direction of prevailing winds. Radon decays into highly radioactive solids (Polonium, Bismuth, Lead) that will fall out or lodge in lung tissue if inhaled.

With an average wind velocity of 4 to 6 m/s (about 14 to 22 km/hr) presented in the EIS, the release of radon could easily reach the southern parts of South Australia, where the exposure to radon and its by-products will be invisible to all citizens.

More comments on this issue will be made on Section 10 later.

Given that Heathgate made a concerted push to establish the FLT to help refine radiation exposures, it might be seen by some as professionally negligent to omit all radiation releases in the form of radon from the EIS.

Assuming that Heathgate are forced to restore groundwater, the total length of time a bare wellfield may be exposed for dust generation may easily exceed 24 months, especially given the extended length of time needed for groundwater restoration at the Nine Mile Lake pilot trial site in Wyoming, USA - a total of one year's leaching and one year's restoration.

Given the arid to semi-arid nature of the region, hydromulching will place an unnecessary strain on the productive biomass capacity, since plants will likely not be able to regenerate at rates akin to those needed for covering affected wellfield areas.

The use of limited watering could lead to bioaccumulation of radionuclides and heavy metals within the plants and grasses encouraged to grow.

The arid nature of the climate will also make rehabilitation difficult - evidenced by the difficulty of regrowth near the current FLT site.

(visit <http://home.vicnet.net.au/~seaus/proposed/bevfltjpgs.html>)

The radioactive and non-radioactive waste containment sites are also likely sources of dusts - these remain unrecognised.

What measures are going to be used to prevent and minimise dust generation at these sites ?

Are the various holding ponds likely to generate evaporative salts that could pose a dust problem ?

4.13.1 - Workforce Requirements and Sources

Despite Heathgate trying to promote the "fly-in/fly-out" work proposal for Beverley, other such mine operators are finding it difficult to find and maintain a workforce for their operations, especially at fly-in/out mines in Queensland. This was reported by the ABC on July 3, 1998 (see Appendix Five).

The nature of ISL mining will require a core of highly skilled and academically trained engineers and scientists, as well as a range of tradespeople. The gravity of the new technology being proposed for Beverley should sound a stark warning not only for the proponent, but for governments as well.

The constant rotation of staff does not bode well for optimal management and operation of new technology minesites.

The number of night shift workers appears to be too low to ensure adequate operation of the entire site and prompt response if a spill or accident were to occur.

Such a proposal is inadequate for the inherent risks with an ISL mine - especially given that a low number of shift workers was complicit in the massive overnight spill at Burns, Texas.

4.14 - Movement Control

The lack of any movement from the site will be a further impediment to attracting workers for the proposed mine, especially given its proximity to the Gammon Ranges National Park, the Arkaroola Sanctuary and the Lake Frome GAB Springs.

4.15 - Community Liaison

It would appear that Heathgate's mandate for community consultation is to merely ***inform or tell*** people of what they intend to undertake, and not develop the project in co-operation with the concerns and wishes of all stakeholders of the region, such as the Adnyamathanha people, pastoralists, tourist operators and environmental representatives.

Such an attitude does not bode well for future relations concerning the project.

Section 5 - Alternatives

5.1 - Application of Ecologically Sustainable Development (ESD) Principles

This is perhaps the worst case of obfuscating the truth in the EIS yet.

To place uranium mining within the ESD context is **ABSOLUTE CRAP**, to avoid mixing words.

The nuclear industry produces the most toxic waste legacy for future generations known to humanity, and we are still grappling with how to manage the previous generation's high level nuclear waste. The nuclear industry presents fundamental threats to the broad exposure of workers at every stage of the nuclear fuel cycle and the release of radionuclides to the wider environment and public at large, yet the nuclear industry refuses to address these issues (proven again by the fact this EIS avoids such questions, begging questions of collusion with government on this matter).

If Heathgate were so confident about the nuclear fuel cycle being able to meet the criteria of ESD, then why don't they attempt to prove it and incorporate their supposed scientific proof in their public documents such as this EIS ?

It is because the nuclear industry is fundamentally the worst example against ESD and they know they cannot justify it.

This is not "safeguarding the welfare of future generations" at all and **Heathgate must retract the entire Section 5.1.**

5.2.1 - Impact on World Uranium Markets

Heathgate admit that to not proceed with development of Beverley will have no significant impact on world uranium markets - although it might impact on General Atomics own markets !!!

The only reason Beverley is "cost-effective" is because they are allowed to propose sulphuric acid leaching, and walk away from ethical responsibilities to restore groundwater.

5.2.2 - Loss of Employment Benefits

The number of jobs are **INSIGNIFICANT**, especially compared with industry giant Olympic Dam.

5.2.3 - Loss of Benefits to Aboriginal Interests

For Heathgate to be promoting the mining and destruction of Aboriginal heritage as part of ***reconciliation*** might be viewed by some as criminal. Heathgate have admitted that they recognise the uranium and stories of "poison ground" as an important part of Adnyamathanha heritage, yet they intend to destroy that.

For Aboriginal communities to have to agree to such circumstances in order to fund their communities is a sad reflection on both state and federal governments, and some might say is ***environmental racism***. The royalty payments are not the same as those paid in the Northern Territory, and could be seen as much, much smaller. And so Heathgate can not be seen as a good faith negotiator with regards to these agreements, especially since they threatened to take the final unsigned Native Title claimant group to court if they didn't sign by mid-July.

5.2.4 - Loss of Benefits to State and National Community

The purported benefits to state and federal governments are very small, and it is not believed that these will more than cover the costs incurred by government in providing services to date, such as (alleged) regulatory review and control.

Governments can better invest their time and taxpayer's money by promoting projects which are in line with ESD principles, such as renewable energy projects of solar or wind.

5.2.5 - Benefits of Not Proceeding

Some amazing admissions by Heathgate :

"groundwater regimes and characteristics will remain unaltered"

"there will be no further disruption to Aboriginal heritage"

"there will be no alteration to local biodiversity"

How many times do Heathgate need to contradict themselves before our supposed government regulators pull them up on such carte blanche admissions ?

5.3 - Alternative Mining Methods

5.3.1 - Open Cut Mining

The 1970's evaluation of using an open cut mine was only abandoned because of ***DEPRESSED URANIUM MARKETS, NOT "economic, production and environmental grounds"***.

On page 2-2, it is stated that "external influences caused the project to be wound down and mothballed in June 1974" (exactly the same quote is also found on page 3-1 of the DEF; Heathgate, 1998b).

"External influences" can only mean market conditions, and the EIS is therefore misrepresenting the truth.

Again, further admissions of significant and wide reaching environmental and radionuclide impacts from an open cut !!!!

However, in terms of ESD, the current ISL proposal by Heathgate does include significant environmental impacts, and should be stopped until world's best standards are adopted.

5.3.2 - Underground Mining

Again, intractable environmental problems are identified, especially the increased radiation exposures resulting from an underground operation. However, one statement is concerning and begs further clarification.

"The integrity of the separation between the ore-bearing aquifer and overlying aquifers is still likely to be breached" - is this in reference to In Situ mining or Underground ? It is unclear.

Such a "breaching of aquifer integrity" is still likely under In Situ Leach mining anyway.

The issue of subsidence is recognised as important, and could lead to changes in surface drainage.

However, given the uncemented and the nature of the aquifer sands and sediments in the broad Lake From region, what guarantee can Heathgate make regarding subsidence for ISL operations ? Especially since an overall cone of depression needs to be maintained during mining, can they categorically rule out subsidence problems at Beverley ?

What about subsidence arising from extraction from the Great Artesian Basin ?

Remembering that in Wyoming a subsidence analysis is required for permit approvals (see Section 4.4; Mudd, 1998a).

5.4 - Alternative In Situ Leach Approaches

First and foremost, Heathgate fail to recognise the restoration of groundwater as one part of an Alternative ISL approach.

5.4.1 - Acid Leach Versus Alkaline Leach

This section is extremely distorted and must be completely re-written and published.

Although acid leaching is widely known to have faster rates of dissolution and leaching, it is possible for high total recovery using alkaline solutions under field conditions. By reference to Mudd (1998a), it can be shown that at some sites internationally, a high recovery of uranium is possible with alkaline solutions. At Crow Butte in Nebraska, estimated uranium recoveries are said to be about 85% - yet Heathgate are basing their entire proposal on a minimum of 65% uranium recovery rate.

What recovery rate has the FLT determined to date ?

Heathgate cannot claim on page 2-8 that *"individual deposits have individual characteristics that are not all assessable in laboratory bench tests"*, and then claim on page 5-5 when it suits them that *"this is simply demonstrated by column leach laboratory studies on Beverley ores"*.

These two statements are entirely inconsistent and directly contradict one another.

The use of laboratory tests, according to international literature (which, again, both Heathgate and government regulators should be aware of) can only indicate the amenability of a particular ore deposit to specific leach solution compositions and highlight some possible operational or environmental problems that may arise (such as clay swelling or mineral precipitation).

Any correlation to field behaviour without actual data is fallacious and must not be believed.

Yet again Heathgate's EIS misrepresents the facts.

The column studies presented in Figure 5-1 lack a ridiculous amount of scientific detail that would allow one to judge the veracity of Heathgate's above statements :

- when were these tests done ? by who ?
- what size columns were used ?
- what samples are they ? North, Central or South Beverley ?
- how were they preserved from the field to the lab ? time lag ?
- to what degree was the sample disturbed during drilling and transport ?
how did this affect permeability and leach solution contact with the ore ?
- what acids were used ? quantities ? (presumably only sulphuric acid ?)
- what alkalis were used ? quantities ? (given that in the USA ISL mines have moved away from ammonia or sodium-bicarbonate based leach solutions and generally use just oxygen and carbon dioxide - it is hoped one of the two alkali tests included a carbon dioxide and oxygen leach solution)
- why four acid tests and only two alkali tests ? Such testing skews results, especially since there are more suitable alkaline reagents than acid reagents.
- what was the strength of the respective leach solutions ? (solution strength is also known to affect leach solution efficiency; Mudd, 1998a)
- what flow rates were used in the tests ? was it the same for all columns ?
- was restoration undertaken for each column ? (this was undertaken for Nine Mile Lake before field leach trials, and was the primary reason they thought sulphuric acid might be a viable leachant, except the lab tests failed to predict field behaviour accurately - refer Section 4.7; Mudd, 1998a)
- what levels of heavy metals were measured during all column tests ?

Failing to provide the above scientific information prevents comment on claims by Heathgate concerning the use of acid versus alkaline leach solutions. If Heathgate were to attempt to publish in a reputable scientific journal, the above information would be compulsory for peer technical review.

Why prohibit the general public from such data in the most fundamental document a whole mining project is entirely dependent upon ?

Despite the claim that total uranium recovery would be higher for acid leach solutions, Figure 5-1 actually shows that alkaline leach solutions can achieve greater than 80% to 95% total uranium recovery.

The fact that a later statement in the next paragraph states "the same wellfield might take 2 years to achieve the same depletion using an alkaline leach" (emphasis added) proves that Heathgate admit alkaline solutions are viable for the Beverley deposit, but it knows that if it doesn't need to undertake restoration, then acids are much better for their profit margin.

Heathgate have stated publicly before at community meetings with the Adnyamathanha that (Davenport meeting, Port Augusta, February 28, 1998; notes by Dr Matthews) :

Heathgate are prepared to use alkaline solutions.

- Suitability of Beverley Deposit for Acid Leach

On page 5-6, it is recognised that alkaline solutions will mobilise lower overall levels of heavy metals. Thus it is clear that Heathgate are aware that alkaline-ISL will lead to a lower overall pollution load - **they must be forced to use alkaline solutions.**

Any geochemist should understand that it is not simply the bulk concentration with aquifer sediments of heavy metals that will determine solubility. The fact that the concentration of some heavy metals are low is irrelevant - it is the mineral geochemical or form the metals are in, whether they are adsorbed to clay surfaces for example, and the geochemical state of the groundwater.

By promoting a highly acidic and oxidising geochemical state, the conditions are ripe for very high and environmentally sensitive levels of many toxic heavy metals. The data presented in Table 4-1 is proof of this - many metals are increased at least an order of magnitude, with some nearly 1,000 times higher (eg - vanadium).

It is not agreed that "the level of metal mobilisation is not sufficient to affect the process". Although the level of heavy metals may not directly interfere with the metallurgical extraction process, it has a devastating effect

The level of many metals, as already highlighted in this submission, before ISL was well below drinking water quality, yet after injection of acids and oxidising agents are much worse.

The quality of the water has thus been very significantly and adversely affected. Before ISL, the main concerns were radionuclides, whereas now the problem extends further to include several heavy metals.

The low levels of carbonate-bicarbonate within the Beverley mineralised zone demonstrate that the process of ISL will create ripe conditions for continued radionuclide and heavy metal migration after mining. That is, there are low levels of acid consumers, and so the groundwater will remain acidic and oxidised and several radionuclides and heavy metals will remain soluble and therefore highly mobile.

Again, Heathgate would be aware that Nine Mile Lake, which also had low calcium and carbonate levels, proved that such geochemical features are irrelevant if the restoration of groundwater is required.

The presence of low iron concentrations, although beneficial in a geochemical and leaching sense, may not prove effective in an operational sense. The redox behaviour of iron in groundwater is widely considered to be controlled primarily by bacteria, such as *Thiobacillus* species in Acid Mine Drainage problems. Another issue is that the rates of these bacterially-controlled redox reactions are generally slow and may not be compatible with the relatively rapid leaching phases being proposed.

The presence of bacteria in the overall leaching process and dynamic geochemistry occurring during ISL can, however, have negative physical and operational impacts. The promotion of bacterial growth comes at the cost of slow plugging of the aquifer pore space with biomass, which reduces permeability and therefore injectivity efficiency and the ability to control solution movement. This has been documented at ISL mines in the USA, Bulgaria and the Czech Republic (refer pages 30, 74 and 75, and Sections 3.3, 5.1 and 5.2 respectively; Mudd, 1998a).

Perhaps the only reason that potential jarosite problems are highlighted with the use of ferric iron oxidising agents in acid ISL (which do not appear to be effective on Beverley ore based on Figure 5-1, despite claims low iron helps leaching) is that this is the infamous problem with the Honeymoon trial of ISL in the early 1980's (see Section 6.2; Mudd, 1998a).

There is still potential for unwanted mineral precipitation with sulphuric acid and oxygen leach solution chemistry - especially gypsum.

Why don't Heathgate mention gypsum precipitation ?

Especially since they made such a point about avoiding gypsum problems earlier in the EIS on page 4-29.

The fact that the FLT has shown that once operational pH has been established, very little acid is required to be added to maintain low pH, proves that

RESTORATION IS PARAMOUNT

How many times does it need to be stated that because of the exact geochemical nature of the ISL process, especially using acids, the environmental or natural controls on radionuclide and heavy metal migration have been removed ?

If there is no competition nor consumption of acids to date, then how will the groundwater naturally return to pre-mining levels ?

Heathgate must be forced to actively restore groundwater quality to pre-mining levels and establish the same reducing environment that existed prior to ISL mining.

On what basis do Heathgate claim that the use of a bicarbonate leach would require up to 3,000 mg/l bicarbonate (HCO₃) ?

Table 4 - Alkaline Leach Geochemical Analysis : Calcite (CaCO₃) Precipitation

Ore Zone	Concentration			Saturation	Concentration			Saturation
	pH	Ca	HCO ₃	Index	pH	Ca	HCO ₃	Index
North	6.5	380	3,000	0.81	7.2	380	3,000	1.50
Central	6.5	610	3,000	0.99	7.2	610	3,000	1.68
South	6.5	850	3,000	1.10	7.2	850	3,000	1.79

The above analysis (PHREEQC output found in Appendix 4) clearly demonstrates that, despite the appalling lack of geochemical data provided to justify assertions, a quick analysis using a public domain groundwater geochemistry model, like PHREEQC, can decisively prove that their assertions are **WRONG**.

The same PHREEQC analysis also shows that the groundwater is undersaturated with respect to carbon dioxide, suggesting CO₂ as a viable alkaline leaching agent.

The main options to be drawn from the above analysis could be :

- a calcium reduction step would be needed before ISL proceeds;
- a lower concentration of bicarbonate has to be used;
- the use of carbon dioxide is a viable leaching agent.

Given that many large ISL mines are now operating in the USA (eg - Crow Butte, Nebraska and Highland, Wyoming) using gaseous carbon dioxide and oxygen prove that the use of alkaline leach solution chemistry is economically viable, and provides significant reductions in pollution load from radionuclides and heavy metals.

- End Use of Mined Aquifer

For the first time, Heathgate acknowledge that one of the principle choices in alkaline or acid leaching chemistry is "any post-mining groundwater restoration requirements".

The point that the Beverley ore zone groundwater is in excess of drinking or stock water standards is **largely irrelevant** - even the good quality water they make such a fuss of extracting from the Great Artesian Basin requires treatment before they use it.

The average radionuclides content presented in Table 4-1 is :

Uranium (mg/l)	0.41	Factor - 20.5
Radium (Bq/l)	787	Factor - 1,574

Again, their calculations appear incorrect.

However, the figures apparently used on page 5-7 are based on Table 6-18 - these values, presented inconsistently in Bq/l and not mg/l or µg/l, are highly variable and no statistically significant data are presented, no standard deviation, and no median and mean. This will be further discussed later in this submission.

Although the Beverley aquifer contains certain levels of radionuclides, **surrounding aquifers do not.**

Based on the hydrogeologic information prepared to date by Heathgate (Heathgate, 1997a, 1997b & 1998a) and a review of international literature concerning the potential for contamination of surrounding aquifers from ISL mining (Mudd, 1998a), it can be concluded that there is a very high probability that surrounding groundwater quality will be contaminated and thus their quality will be severely impacted.

The argument concerning stock water is again false - the Northern and Central ore zones have salinity levels which would be good for stock use, and although the Southern ore zone would not be preferred, it is a good emergency supply of water.

Heathgate only take the maximum salinity and use this to justify the aquifer as no use - *they selectively ignore their own (questionable) monitoring data.*

The upper channel sand aquifer at Honeymoon has a salinity of 10,000 mg/l (SCRA, 1997 & 1998), and Southern Cross Resources (and the previous Joint Venturers) are allowed to make a big commotion about the top of the three aquifers at Honeymoon being used as a source for potable and stock water, although the potable water is treated and the stock water presumably not.

Why are Heathgate being allowed to follow different standards to their industry colleagues ?

The requirement for disposal wells in the USA is **misrepresented.**

Although there are no restoration requirements on aquifers used for disposal of liquid wastes, it must be demonstrated that such waste disposal will not exceed the current groundwater quality category for that aquifer. *An aquifer is not automatically designated as a potential waste disposal unit purely based on it's salinity or other parameters.*

Many ISL mines in the USA use **EVAPORATION** as their main liquid waste disposal regime, not liquid waste disposal via injection bores.

As it is correctly pointed out on page 5-7, the Texas regulatory requirement for a disposal well is a **MINIMUM TDS of 10,000 mg/l.**

BEVERLEY HAS TDS FROM 3,300 to 13,200 mg/l.

Thus it would be illegal in Texas to use the Beverley aquifer as a waste disposal unit.

Again, Heathgate selectively present their own data and fail to present it accurately.

Not all deposits in the USA have had low calcium or carbonate content, and Nine Mile Lake is one such example of this.

**Refer pages 55 to 59, Section 4.7, Mudd, 1998a,
for a complete account of Nine Mile Lake.**

The Nine Mile Lake sulphuric acid ISL project was an experimental ISL trial or pilot scale study that was never commercialised.

Restoration of the acid trial at Nine Mile Lake was **NOT** regarded as successful. The regulators in Wyoming have referred to restoration at early ISL trials as satisfactory, not successful or ideal (Chancellor, 1997).

The average TDS before ISL, as given in Nigbor et al., 1981 & 1982, is $4,300 \pm 550$ mg/l. It is unclear where Heathgate have obtained their figure from.

**The uranium, radium and heavy metal content of
Nine Mile Lake was similar to that around North
and Central Beverley.**

Refer pages 56 & 58, Section 4.7; Mudd, 1998.

However, there was no radium or thorium analyses presented after restoration. And some elements still remained quite high after restoration (page 58; Mudd, 1998a) :

Table 5 - Selected Nine Mile Lake Restoration

Element	Conc. (mg/l)	Factor
Zinc	2.0	100
Vanadium	14 ^a	28
pH	6.0	7.0
Selenium	0.013	6.5
Uranium	1.3	5.7

^a - it is believed the correct units for vanadium should be µg/l.

The following points are crucial in understanding Nine Mile Lake (NML) :

- based on column leaching studies of NML ore, it was believed significant savings could be made through the use of acid lixivants;
- column studies also predicted about 13 pore volumes of groundwater would be needed for restoration;
- restoration took nearly a year, the same length of time as acid leaching;
- **however, restoration took nearly 20 pore volumes, and pH was the last parameter to return to near baseline.**

Despite the active and quite aggressive restoration sequence undertaken at NML, the groundwater still maintained a slightly acidic and oxidising geochemical environment. The problems with this are proven by the fact that uranium concentration is still 1.3 mg/l after restoration, since the geochemical conditions are suited for such uranium mobilisation.

Due to the difficulties in restoration, acid leaching was not considered any more economic than alkaline leaching, yet alkaline leaching offered fewer environmental problems.

The data set for the alkaline ISL trial conducted at Nine Mile Lake was not able to be sourced for Mudd (1998a) nor this submission, although one 5-spot pattern was being completed for this purpose at the time of writing Nigbor et al., 1981 & 1982.

I am happy to provide copies of Nine Mile Lake references (at cost) if requested.

How many times does it need to be pointed out that Heathgate are misrepresenting many facts in their EIS ?

5.4.2 - Ion Exchange Versus Solvent Extraction

Why is Ion Exchange preferred when the salinity at South Beverley is greater than the 8,000 mg/l used to justify such a choice ?

Why are Heathgate simply using a different salinity figure in the previous section and yet use a lower figure here ?

Assuming Heathgate do switch to Solvent Extraction at some later stage in the mine, **IF** the mine proceeds to commercial development, what will be the likely complexing of uranium and organic solvents in disposal solutions ?

The reason solvent extraction works is because of the complexes formed between uranium and organic solvents. If these solutions were to be disposed of back into the Beverley aquifer, the solubility of uranium is likely to remain high and therefore it is likely to remain highly mobile within the aquifer.

A good overview of failed radioactive waste disposal sites where organic agents interfered with expected attenuation mechanisms in groundwater is found on page 29, Section 3.2, Mudd, 1998.

The question of "clean precipitates" is also important. Do they expect much impurities in the final product ?

A problem with the use of acid leach solutions is that the ability to produce a pure yellowcake product is much harder. Advice from a former employee of an ISL, now working in the USEPA, suggested that at trial of acid ISL at a site in New Mexico they switched from acids to alkaline because the yellowcake product was too impure (Rinaldo, pers. comm.).

Section 6 - Existing Physical and Biological Environment

Figure 6-1 - Regional Geology

The use of the same red dot for uranium occurrences and homesteads is confusing and a poor choice of colours.

The year of MESA publication is incomplete.

Figure 6-3 - Regional Geologic Section A-A'

There are very few height units displayed - the "20 m" on the left column appears to be incorrect and is presumably 200 m.

Figure 6-5 - Beverley Deposit Stratigraphic Cross-Sections

The choice of colours is confusing - what soil types are found within the Willawortina ?

Are we expected to believe they are clays or sands or a nice even mixture ?

6.2.1 - Namba Formation

- Alpha Mudstone

As presented in Figure 6-5, it would appear possible for connection of channel sands across the Poontana Fault zone, especially towards the southern zone.

As such, the Beverley Clay (B2) layer that supposedly confines and isolates the Beverley aquifer is not necessarily complete. This could have dire consequences if solutions are not maintained within the mining zone.

- Beverley Sands

Given the fluvial nature of deposition, the properties of the aquifer will be highly heterogeneous and thus hard to predict.

What studies are Heathgate referring to regarding the "unrecognised eastern boundary at least 2.5 km distant" ?

Has this been identified in pumping tests, merely a desk study or recent further drilling ? If it was pumping tests, how could the influence of pump tests be felt so far from the ore zones ?

The re-interpretation of the palaeochannel structure is curious, to say the least.

Heathgate are admitting that the Beverley aquifer is not bound to the east by clays!!!

This is in complete contradiction to the previous 1982 EIS for proposed development of Beverley by the South Australian Uranium Corporation (SAUC, 1982).

On page 75 of SAUC, 1982, it is stated :

"The change in lithology to the east (Fig. 9) is very important as the lateral change into clay provides an impermeable barrier to groundwater on that side of the ore body."

Given that Heathgate now interpret easterly to south-easterly channel directions, perhaps they can highlight the main recharge mechanisms or sources for the respective channels ?

- Lower Beverley Unit

Heathgate state on page 6-9 that the Lower Beverley Sand units are *"present in the north and south extending for at least 2 km beyond the mineralised areas"*.

Thus again an admission by Heathgate that the Beverley mineralised aquifer is not isolated at all, and more than likely is hydraulically connected to other saturated stratigraphic units.

The Cross-section A in Figure 6-5 shows that it might be possible for periodic flushing of Willawortina groundwater to enter the Beverley channel. This is in fact highlighted as one possible explanation as to why North Beverley is of a lower salinity than the remainder of the palaeochannel on page 6-66.

How can such an aquifer therefore be considered isolated ?

The complex nature of braided river depositional environments is recognised on page 6-10 - *"the overall complex cyclic cut-and-fill pattern (channel-in-channel)"*.

This channel-in-channel behaviour will lead to high variability and recalcitrant difficulties in identifying possible excursions along sub-channels.

6.2.2 - Willawortina Formation

It is recognised on page 6-11 that *"considerable variations in lithology can be anticipated at the scale of the Beverley deposit"*.

Again, this variability will lead to difficulties in establishing quality monitoring bores in the first place, and in ensuring any possibility (but good probability) of an excursion into a Willawortina saturated unit.

6.2.3 - Structure and Faulting

Has the growth of the Poontana Fault zone during sedimentation created any zones of sands within the fault ? Such features are noted elsewhere in Australia, such as the Latrobe Valley.

Is there any possibility of re-activating the Poontana Fault by mining activities ? Especially due to extraction of large quantities of water from the Great Artesian Basin (for that area) ?

6.2.4 - Mineralisation

The recognition of secondary mobilisation of uranium mineralisation in the past at Beverley proves that the general lack or low concentrations of strong reducing agents will create the ideal geochemical environment for significant mobilisation of radionuclides and heavy metals after acid ISL if no restoration is attempted.

Can Heathgate articulate where they believe radionuclide daughter elements, such as radium or thorium, have migrated to ?

A further quote on page 6-12 further proves that Heathgate explicitly understand the Beverley aquifer is **NOT** isolated :

"While a satisfactory transport mechanism is not readily demonstrable at the present time, a palaeo-hydrogeological connection is implied."

If there were alternate or interim sources for the uranium within the Namba Formation, this implies acknowledgement that the Beverley aquifer is indeed hydraulically connected and **NOT** isolated.

Is there any uranium mineralisation west of the Poontana Fault ?

Why is there no representative cross-section showing the pattern of uranium mineralisation ?

6.2.5 - Geochemical Environment

If the main clays are kaolinite and montmorillonite (highly reactive), does the high sodium in FLT solutions concentration induce any clay swelling and permeability loss ?

The source zones of the nine samples are not identified.

No variation in trace elements is given, and many heavy metals are missing - eg cadmium, chromium, lead, barium, etc.

6.4 - Seismicity

Although the EIS goes to great lengths to argue the unlikely event of an earthquake, it is only on the basis of probabilities they are gambling on.

It appears that the figure of "1.0" on page 6-15 (paragraph 8) is incorrect, and should be "0.09 to **0.1**".

What happens in 200 years or even 1,000 years if there is a Mercalli Level VII or higher earthquake ? How will Heathgate maintain the isolated nature of the palaeochannel and thereby minimise contamination of surrounding groundwater systems ?

6.7.1 - Rainfall

Why have Heathgate not included any Greenhouse Effect scenario ?

It is illogical and unacceptable for a company to exaggerate it's own industry's future due to concerns on the Greenhouse Effect, and yet completely ignore it when they undertake their own assessments.

Over the last century Australia's climate has been experiencing wetter years, with more erratic and violent rainfall events - many of the recent floods are proof of this pattern. This work has been undertaken by CSIRO.

Beverley is an area with unseasonal climate behaviour, and if a flash flood were to occur, it is not unscientific nor unreasonable to expect a major flood event of high intensity. Such potentialities are recognised, albeit indirectly, in the EIS :

"There appears to have been a real increase in rainfall since about 1948"

(page 6-29);

"There is no meteorological reason why similar major rainfall events could not occur at the Beverley site." (page 6-30).

The implications of a severe flash flood at Beverley are thus extremely important, and a high flow flood could wreak havoc if the site was unprotected for such potentialities.

6.7.3 - Evaporation

There is no actual site data!!!!

It is presumed that the Bureau of Meteorology (1996) used either an average of the nearest pan data (eg - Yunta and Moomba, crude approach and not justifiable for a full scale mine proposal) or based evaporation rates on consideration of wind speed, temperature and relative humidity. The presented estimates of evaporation are thus largely irrelevant and speculative and actual evaporation rates could be expected to be outside the range presented.

This has important implications for the project water balance, and especially since Heathgate should be forced to evaporate their liquid wastes.

Any such calculations cannot be trusted without site-based data.

Why Heathgate would be prepared to risk commercial capital on such limited data is unclear, especially given the infamous mistakes made with both Ranger and Olympic Dam concerning water budget estimates (too much on-site water and not enough, respectively).

6.8 - Surface Hydrology

Again, there is limited regional and site specific data.

The acronym "**ARI**" is unlisted and not expanded at any point. It is presumably "**Average Recurrence Interval**".

6.8.1 - Streamflow Information

The regional map showing the location of all gauging stations should be included in the EIS, and not a supporting document.

Figure 2.1, (BC Tonkin & Associates, 1997 - EIS Supporting Document), shows that all streamflow gauges are a significant distance from Beverley. As such, the catchment characteristics may be different and the calibrated models used to generate flood predictions may not be relevant.

6.8.2 - Rainfall Runoff Modelling

An ARI of 100 years is not acceptable given the risks of ruptured trunk lines and distribution pipes that cross Jenny Creek or Four Mile Creek during a flood event.

The map containing the location of Peak Flow - RORB Modelling should be included in the EIS, not the supporting document. By examination of Figure 3.2, (BC Tonkin & Associates, 1997), it can be seen that :

- only 3 of the Jenny Creek estimate points are within the Beverley Retention Lease area;
- no location is marked for Outwash Creek nor Four Mile Creek.

Thus the exact nature of flood flows across Beverley remain uncertain.

6.8.2 - Floodplain Mapping

Although it is argued that the extent of flood inundation will be similar under higher flood events, it ignores the fact that higher flood events will entail faster and more powerful flows, which have increased potential to damage trunk lines and pipes and other Beverley infrastructure.

It is not believed that floodplain modelling could predict flood height to within 1.0 metre.

6.8.4 - Interpretation of Flood Risk

Table 6-16 demonstrates that it is a 1 in 67 chance to 1 in 40 chance of a 1,000 year flood occurring at Beverley.

Given the gravity of potential problems during a major flood, it should be mandatory to use the 1,000 ARI for flood risk.

6.9.1 - Outline of Regional Hydrogeology

It is not agreed that "*the hydrogeology of the region is reasonably well understood*" (page 6-42). If it was, then Heathgate would be able to both qualify and quantify many of the hydrogeologic relationships between different aquifers and reasons for differences in salinity, for example.

"Reasonable" is not good enough for the risks involved in uranium mining, especially solution mining.

6.9.6 - Beverley Palaeochannels

Further evidence yet again that the Beverley Palaeochannels CANNOT BE ISOLATED :

"Thick and continuous sands are restricted to the B3B unit along the axes of the three channels, reaching maximum thickness to the south in the Central and South channels and in the Tewelina Channel 3 to 4 km north east of the current FLT site" (page 6-44).

The statements on the bottom half of page 6-44 concerning the extension of B3a sand units contradicts earlier information and diagrams presented in the EIS :

- Figure 6-5 explicitly shows the B3a sand extending well beyond the Beverley leases without clay or silts to confine it;
- the location of current FLT pumping arrays are located within the centre of the channel sequence, and thus hydrogeological boundary effects should not be readily evident unless Heathgate have been pumping at higher rates than that suggested in their DEF !!!

Is there any possibility that, as the eastern side of the Poontana Fault zone was downthrust during active fault development, there was any sands incorporated within the fault fill ?

Such an occurrence would not guarantee that the Poontana Fault remains relatively impermeable.

The first water supply borefield for the Olympic Dam was located within a sub-basin (inaptly named the Borefield sub-basin) that was thought to be hydraulically separated from the major mound springs of the area. However, since there was continual expansion of this borefield the stress across the fault zone appears to have become too great and flow was induced, affecting the mound springs (refer page 36, Section 3.6; Mudd, 1998a).

Although the arguments presented on page 6-45 are valid for the present situation, this is a natural equilibrium position established over many thousands of years. The proposed development of Beverley may significantly alter this equilibrium, and induce changes in flow directions.

Figure 6-21 is completely inconsistent with Figure 6-5.
THEY CONTRADICT EACH OTHER MARKEDLY

Does the anisotropy in permeability vary across the three channel zones ? Vertically ?

Again, the problems of bores showing hydraulic leakage proves the inherent problems of flow control and analysis in sedimentary palaeochannel aquifers. There will always be a significant amount of operational and environmental uncertainty.

If there is bore leakage losses during the operational phase of leaching, how will Heathgate ensure that they are monitoring all such sands lenses to detect these losses and excursions ? Although if they are not required to restore groundwater quality post-mining, then such intractable contamination is largely irrelevant for Heathgate, and only an issue for residents, the wider environment of the Lake Frome region for thousands of years and the damage to Australia's natural heritage.

It is not believed that ALL old exploration and abandoned bores **WON'T LEAK**.

Experience overseas, such as Eastern Europe, Wyoming and Texas for example, demonstrate that old exploration and abandoned bores can provide a conduit for escape of leaching solutions (eg - USEPA, 1995; Sections 4.7 & 4.8; Mudd, 1998a).

The fact that there has been about 1,200 bores drilled previously at Beverley, plus plans for over 1,000 more, will arguably provide a certainty that both old and new bores will leak at some point in time.

Although the August and September 1997 pumping tests showed no immediate connection, problems with this testing include :

- only the Northern and Central zones were tested;
- the tests were only near one exploration bore each and cannot be extrapolated across the entire Beverley deposit and 1,200 old bores;
- the tests were not conducted long enough to establish significant stress across an old bore - operational mines are continuous, and therefore the pump tests should have been conducted for a minimum of one month.

The use of infill drilling ahead of actual production bore installation is also likely to enhance the potential for excursions.

The number of data points the piezometric surface of the B3 Sand is based upon is **ENTIRELY INADEQUATE**.

The difference in head levels presented in Figure 6-22 is within error tolerances for field measurement, and thus given the scarcity of data, cannot be considered as reliable.

There does appear to be a slight overall gradient from north to south, consistent with long-term migration or flow towards Lake Frome (this was argued within the DEF for the FLT). Based on Figure 6-22, the hydraulic gradient is about 0.0001, giving a range of Darcy velocities from 0.004 m/year to 0.9 m/year - quite slow, but not stagnant by any estimation (GAB velocities are of the order of 2 m/year).

The slow recovery in bores does not necessarily indicate an isolated aquifer - it could simply mean that flow from an adjacent but hydraulically connected aquifer occurs at different rates and may not replenish the palaeochannel rapidly. The use of the word "almost" twice in the paragraph below Table 6-17 on page 6-48 again shows the uncertainty involved in determining both the qualitative and quantitative aspects of the hydrogeology of the Beverley area.

The reference to "*semi-regional scale salinity zoning.....due to historic interaction between water in the channel and brines developed in the vicinity of the evaporative sink of Lake Frome*" (page 6-49) again shows explicit acknowledgement that the Beverley palaeochannel **IS NOT ISOLATED !!!!**

Table 6-18 - Site Groundwater Radionuclides and Dissolved Solids

The units for uranium (Bq/l) are inconsistent with the rest of the EIS and should be presented in mg/l or both units for ease of comparison, especially to water quality standards (which are all in mg/l).

It is possible the units are incorrect in the first place, and are maybe mg/l instead.

Is the concentration of 16,000 for H46 correct ? This seems extremely high for "background".

Much of the data in this table is questionable, a fact acknowledged in the DEF for the FLT. It is merely a regurgitation of the old SAUC, 1982, information and

no new data is presented.

Problems with some of the monitoring data includes (page 6-65) :

- no hydraulic connection with an aquifer;
- no well development prior to sampling;
- no laboratory certificate.

Where is major ion data ?

Na ? Ca ? Cl ? SO4 ? etc.

Heavy Metal data ? Pb Cd Ni V ? etc.

How can the general public compare the overall quality of Beverley aquifer water with various standards if the requisite data is **WITHHELD** ?

Especially since a more complete data set is available in SAUC, 1982, which is where it appears much of Table 6-18 is derived from.

There is a severe deficiency of certified radon analyses in the EIS.

It is recommended that a complete suite of fresh groundwater samples be obtained from all bores, and the following analyses undertaken on every sample :

- Parameters : pH (Field & Lab.), EC, Eh (Field), Dissolved Oxygen (Field)
- Major Ions : Na, K, Ca, Mg, Fe, Al, Cl, SO₄, F, SiO₂, Total N, Total Alkalinity.
- Heavy Metals : As, B, Ba, Cd, Cr, Co, Cu, Hg, Mn, Mo, Ni, Pb, V, Zn
- Radionuclides : U (µg/l), Ra²²⁶, Rn²²², Th²³⁰, Gross Alpha (α).

6.9.7 - Confining Beds for Mineralised Zones

The fact that the salinity of North Beverley is lower than that of South Beverley should demonstrate that such flushing of water upwards across the Alpha Mudstone may be possible, and this is recognised on page 6-66 "or throughflow from basement".

Again, the extensive nature of previous drilling activities (when an open cut was planned before world uranium markets mothballed development) **WILL GIVE A HIGH PROBABILITY THAT SOME OLD EXPLORATION BORES WILL LEAK.**

If clay and silt lenses are of "limited areal extent" (page 6-49), they cannot be expected to provide a high degree of confinement during solution mining, especially considering the highly heterogeneous nature of channel-in-channel fingering.

The figures for the width of the sand (page 6-50 to 6-51) are in direct contrast to Figure 6-5, where it would appear that the sands extend for more than 1 km.

Do the hydraulic data collected to date demonstrate appreciable boundary effects that lead to enhanced drawdowns ? If so, will these create negative feedback problems for adequate control of hydraulic pressures for full-scale mining ?

6.9.8 - Willawortina Formation

Many of the bores shown in Figure 6-2 do not appear to correlate with 6-23.

In the area on the southern edge of the Beverley Exploration Lease area, the Willawortina head appears to be 35 m yet no data point exists in this region.

Taking an "average" head across such a large region such as that in Figure 6-23 is foolhardy and nothing short of ridiculous, especially given that the intention of the figure is to illustrate the regional variation and groundwater flow direction towards the SOUTH-EAST to Lake Frome, not south-west as suggested on page 6-51.

Besides, the data is **OVER 30 YEARS OLD !!!!**

No company or government should base any decision on data so old, especially given the dynamic use of groundwater and possible changes over such long periods of time.

It is recommended that a completely new piezometric surface be established by field measurement of the heads in all Willawortina bores.

It is quite odd that Heathgate have used this data, given that they are very well aware of the bad mistakes with the use of the **same data in SAUC, 1982.**

Based on Figure 6-23, the head difference of 15 m and a distance of 30 km, the hydraulic gradient is 0.0005, giving a Darcy velocity range of 0.02 m/yr to 0.33 m/yr (or residence times of 1,500,000 to 91,000 years).

Given the thin nature of the water-bearing sands of the lower Willawortina Formation, do what degree do they interconnect ? The fingering and pressure regime discussed on page 6-54 could lead to the situation where an excursion remains impossible to detect.

What about overproduction by higher injection rates ? This *will cause enhanced potential for upward leakage.*

Table 6-19 - Stock Wells and Springs

Appalling lack of water quality data !!!!!

A complete analysis such as that listed on page 46 of this submission is required, at a bare minimum. *Such a comprehensive list would be required in the USA.*

This data is simply a regurgitation of older, questionable SAUC, 1982, data *with no new Heathgate acquired data at all.*

Figure 6-24 - Willawortina Formation Local Water Levels

Why wasn't this data included within 6-23 ?

Basing a whole trial mine on the presence of two monitoring bores is flawed, and an unacceptable level of monitoring.

***It is UNSCIENTIFIC to draw contours
based on two points !!!!!***

Especially if they are indeed different sand lenses !!!!!

6.9.9 - Regional and District Groundwater Quality

When were the samples taken ? 1996 or 1997 or 1998 ? what month ?

***A COMPLETE GROUNDWATER QUALITY
ANALYSIS IS REQUIRED, INCLUDING METALS***

Three of the four GAB bores are not present within Figure 6-28.

The units for uranium are incorrect - "Bq/l" : should be either *mg/l* or *µg/l* or *Bq/l*.

Why weren't the extra 3 GAB bores analysed for radionuclides ? pH & K in all samples ?

Figures 6-28 & 6-29 - Baseline Study Area

To what water source are these figures referring ?

Are they shallow Willawortina aquifers ? Surface water samples ? Date of samples ?

This information must be within the main text of any EIS.

6.9.10 - Groundwater Quality in the Baseline Study Area

Although it is claimed on page 6-61 there is wide variation in uranium content within the shallow aquifers (shown on Figure 6-31), all but one are below the recommended stock level of 200 mg/l (see Table 4, page 7; Mudd, 1998a).

How do concentrations increase to the **WEST** ?

In Figure 6-31, the outlier of 310 µg/l is **EAST**.

The continual presence of simple mistakes does not bode well for confidence in the EIS.

This demonstrates the generally low levels of uranium currently in Willawortina aquifers, and the fact that this aquifer must be protected, especially given the potentially long residence times involved.

The levels of radionuclides in the shallow aquifers is generally quite low, and therefore should be protected.

Figures 6-31 to 6-33 - Date of samples ?

If the radium content of Camp Bore is known to be 406 times lower based on current sampling, why include the old value of 178.7 Bq/l ?

It is in Heathgate's interests to exaggerate the radionuclide and salinity content of all waters to create the impression of "toxic" water and thereby avoid ethical and professional responsibilities for restoration of their proposed mine.

6.9.11 - Groundwater Quality in Beverley Site Aquifers

Why is groundwater quality data so disorganised ? Willawortina quality data is presented several pages before Section 6.9.11 - very unprofessional, let alone awkward.

What about groundwater quality around South Beverley ?

The variability must be statistically quantified, not guessed or estimated.

The fact that the Willawortina contains better quality water than the Namba or mineralised aquifer should be enough reason for Heathgate to be forced to restore the groundwater quality after mining is finished.

The water quality of the Namba aquifer is exaggerated - at Honeymoon the upper aquifer water at a salinity of 10,000 mg/l is used for both camp water as well as stock water.

The EIS lies about Beverley water quality with regards to cows and calves :

- Maximum TDS for lactating cows & calves is up to 6,000 mg/l;
- Maximum TDS for dry cows is up to 10,000 mg/l;
- **North Beverley ranges from 2,700 to about 6,150 mg/l;**
- **Only ONE SAMPLE FROM NORTH BEVERLEY IS >6,000 mg/l;**
- **Central Beverley ranges from 6,000 to 9,000 mg/l.**

Given the above, why is it stated (page 6-65) that "*Figure 6.34.....clearly shows the three groups with the North Group having salinities of less than 6,000 mg/l....*". The next paragraph goes on to state (page 6-65) "*....are at or close to the upper limit for dry cattle.....*" :

What contradictions !!!!

The acknowledgement of the overall differences in salinity from North to South Beverley as possibly due to either historic interaction of channel groundwaters with brines from Lake Frome or throughflow downwards from the Willawortina or upwards from basement again explicitly recognises that the Beverley palaeochannel is ***NOT ISOLATED*** !!!

It is not believed that density differences due to salinity can explain the difference across North to South Beverley.

Why is Figure 6-35 located several pages after both water quality and piezometric data presented ?

Table 6-22 - Radionuclides in Surface Waters

The units of mg/l for uranium have to be ***INCORRECT***.

It is assumed mg/l are correct.

Otherwise they should be mining the surface waters for uranium !!!!

6.9.12 - Radionuclides in Potential Water Supplies

The author cannot determine how the averages of 50, 70 and 10 times higher in uranium, radium and radon have been calculated.

What are the thorium levels ?

6.9.13 - Groundwater Flow, Interchange and Discharge

Was the Masters of Diaconu (1997) independent or funded in part or whole by Heathgate ?

Figure 6-36 shows diagrammatically what there are consistent references to throughout the EIS - that the Beverley aquifer is indeed hydraulically connected to regional groundwater systems.

The work of Diaconu is only based on conceptual computer modelling and not actual extensive field data. Although it would appear to be plausible on a regional scale, it is not believed it can predict individual aquifer behaviour on a small scale due to the high heterogeneity of the sand lenses involved.

The clay aquitard will take longer than 3 days to respond precisely because it is an aquitard !!!

One test of a relatively short duration does not rule out the possibility that old exploration bores will leak.

Although it is agreed that the current aquifer water is relatively stagnant (though still flowing at up to 1 m/yr), this does not necessarily indicate a "bounded hydraulic system" :

it only suggests the lack of recharge.

Given the arid to semi-arid nature of the climate, this is not surprising in the least.

There is very low rainfall, and as such, it could be reasonably expected that recharge to the deeper aquifers is less than a few percent.

The alteration of the natural hydraulic regime during ISL mining could induce flow vertically as well as horizontally, a fact pointed out several times in this submission already.

Why are only North and Central Beverley used as examples to cite supposed isolation ?

What is the pressure regime at South Beverley ?

Did the water mixing calculations (presumably using PHREEQC - this should be stated in the EIS) include Beverley or Namba formation water ? Lake Frome brines ? equilibration and reaction with minerals in aquifer sediments ?

The bounding of the mineralised parts of the channel to the north and south, or across the main axis of the palaeochannel, are not consistent with the formation of the palaeochannel. Bars or low permeability zones are aligned along the direction of flow, and not perpendicular to flow as the zones to the north and south as suggested on page 6-71.

6.9.14 - Conceptual Model of the Beverley Aquifer System

Many of the concepts presented here have been questioned throughout this submission :

- the Poontana Fault remaining impermeable - *questionable*;
- the B1 clay preventing excursions through unsealed old bores - *questionable*;
- the possible historic exchange of waters between different aquifers;
- the flow and hydrochemical data presented within the EIS is based on the "spurious" old data that is "now considered to be incorrect".

If other faults in the broad Lake Frome region are known to be permeable, such as the Mt Jacob fault for example (Figure 6-36, page 6-69), how can they guarantee the impermeability of the Poontana Fault since it was created in the same sediments as the other faults under presumably similar tectonic stresses ?

Even on Figure 6-36 possible flow along the Poontana Fault is shown !!!

The behaviour of faults is not necessarily the same over long periods of time, especially when there is active pumping and alteration of "natural" hydraulic regimes.

The statement on page 6-73 "with a very small component of horizontal flow from outside the boundaries of the pumped aquifers" is in direct contrast to that on page 6-71 stating "there is no lateral flow".

How long will it take for the natural hydraulic regime to mystically re-assert itself ?

6.11 - Noise

The word "form" is presumably incorrect - those dang spell checkers !!!

Figure 6-53 & 6-54 - Aerial Photograph of Portion of Retention Leas, 1972 & 1996

The Retention Lease should be outlined - it is unclear where the lease starts and ends.

Section 7 - Cultural Environment

7.1 - Aboriginal Involvement in Site Investigations and Management

Who are the representatives of the Adnyamathanha and Kuyani Heathgate are dealing with ?

Do they have the full support and confidence of their communities ?

Are payments made to date to these individuals ? Or are they in a trust account for broad community benefit like they should be ?

7.2 - Significance to Aboriginal People

Why won't Heathgate acknowledge that Adnyamathanha elders and customary stories about the Beverley area as "poison ground" ?

The Paralana Hot Springs are also considered as bad water, and a "no go zone".

Heathgate have recognised publicly before that the uranium is part of Aboriginal heritage because of this fact, at the Belcanoona meeting, December 1998.

Section 8 - Socio-Economic Environment

8.1.1 - Local Population

Will the general social problems identified become worse with the mine workforce ?

8.1.2 - District Population

The 1991 census is not included in the Reference list.

8.2.7 - Resource Industries

The prior work undertaken at Mt Painter was uneconomic and no mine eventuated. It was originally targeted to supply the UK and USA weapons programs of the 1950's and 1960's. Radium Hill was mined, although still uneconomic, it did supply the UK with uranium for their weapons, which were later tested at Maralinga. Radium Hill is now considered mined out, and no "economic" deposit remains. Thus the uranium produced historically from the region has contributed directly to nuclear proliferation.

Heathgate should get their facts right.

Section 9 - Environmental Impacts and Amelioration

9.1.1 - Initial Construction and Stage 2 Impacts

This section underestimates impacts associated from construction, especially due to bare ground and dust and the extensive borrow sources required for all aspects of site construction.

Given the concerns of some government regulators with the DEF concerning the source of borrow material (see Mudd, 1998b), it is stunning Heathgate have deliberately avoided quantifying this aspect. Unregulated or unmanaged borrow pits can leave visual scars on the landscape that can last decades. They can potentially interfere with floods also.

All borrow material must be quantified and qualified.

9.1.2 - Continuing Development of Wellfields

What are the physical impacts Heathgate expect from installation and operation of new wellfields ? What standards will be applied to rehabilitation ?

There must be some bores that are not sealed after mining - this includes both production bores and monitoring bores. This will enable continued monitoring of the ore zone and surrounding aquifers after mining ceases and any residual movement of toxic solutions to be ascertained.

9.1.3 - Long Term Outcomes of In Situ Leach

Again, this section is pitiful and shows Heathgate's complete disregard for the environmental impacts of the ISL mining process.

Given the nature of many retention and evaporation ponds and the processing plant, the natural landform will not be maintained in its present shape and appearance.

The confining layer has a high probability of becoming breached during ISL mining.

With the extensive nature of wells drilled through the Beverley clay and Willawortina Formation, the site will behave like a pin-cushion.

**IT WILL BE IMPOSSIBLE FOR HEATHGATE
TO SEAL EVERY BORE PERFECTLY
DURING OPERATION AND AFTER MINING
CEASES.**

This is demonstrated from ISL mines worldwide (Mudd, 1998a).

What will the residual pH of the aquifer be ? What has the FLT suggested ?

How long will it take for acidity to return to baseline or pre-mining levels ? What will be the levels of all radionuclides and heavy metals at this pH ?

Again, the lack of acid consumers within the Beverley sands proves that low pH levels can be maintained for significantly long periods of time.

9.2.1 - Mining in Namba Formation

It is not believed that all areas of the ore zones proposed to be mined will have a similar permeability to the Field Leach Trial patterns. By reference to Table 6-17, it can easily be seen that the permeability varies markedly over two orders of magnitude or more, and that the FLT patterns are at the upper limit of the permeability range. Besides, they are in a palaeochannel or braided river depositional environment which are infamous for exhibiting wide variability and permeability problems - Heathgate employees and sub-contractors would be VERY WELL AWARE of this.

The fact that the original bores installed by AGC in 1981 to 1982 had problems like this proves the above facts. Again, this was also found during the initial installation of the fourth 5-spot pattern at Honeymoon.

The end result is that Heathgate will need to use pressure in some areas, and this will not only hamper operational performance, but also lead to increased risks of excursions both horizontally and vertically.

What method was used to calculate the fracture pressure ?

The method used to calculate total aquifer volume affected during mining is **INCORRECT**.

Firstly, there will be a greater than 3 m thick section of the aquifer affected during mining, due to mixing within the aquifer during fluid migration between injection and extraction wells.

Why is a porosity of 0.25 used when on page 6-14 it is suggested as 0.30 to 0.44 ?

This could affect the total volumes involved, being up to 33,660 m³.

What if porosity changes during mining due to clay swelling, mineral precipitation or consolidation of sediments ? How will this be determined and flow rates adjusted ?

What do Heathgate consider the "economic" cut-off grade for uranium ?

At many uranium mine and milling sites undergoing decommissioning in the USA, including older ISL sites, a value of 5 mg/l is used for economic recovery simultaneous with restoration of groundwater. Many such sites contribute a small percentage of uranium production every year in the USA.

When the bleed stream is mixed with native groundwater, what will be the resultant pH ? Given the low levels of acid consumers within aquifer sediments, it is not believed that it will significantly affect or raise the pH of the mining solutions.

What volumes of native groundwater and bleed or tails water will be pumped through new and mined out areas ?

Although the overall water balance MAY be maintained, the pressures will be different across mined out and new areas due to either injection or extraction respectively.

All the calculations on page 9-5 should be presented within a table for ease of comparison and include a mine life of 15, 20 and 25 years.

The calculation of aquifer volume affected by the bleed stream is **INCORRECT** and **MISLEADING**.

By simply using a thickness of 3 m and a porosity of 0.25, it is explicitly assumed that the aquifer is devoid of water initially, and that injected water "*fills*" this empty pore space. This is **COMPLETELY FALSE**. The aquifer is saturated and the injected water is under pressure, and will mix and disperse through the aquifer at its allowable permeability. Any idea of a "square" or "circle" of affected aquifer volume is simply false and a poor technical calculation.

The recirculated water within the mining zone is through the whole mineralised area, and not simply the volume of pumped water. The total volume of aquifer affected over the life of the mine will therefore be those mineralised zones developed by Heathgate, mounting to the figure of 1,700,000 m³ presented and NOT the 19,125 m³ as poorly argued.

The mixing of groundwaters from outside the active mining zones will also increase the total volume of groundwater affected by ISL mining.

The total estimate of disposal area aquifer volumes *proves that earlier comments throughout this submission arguing that the neutral water balance is false since water will be extracted at the mining areas and injected at disposal sites.*

The evaporative losses at wellfield development ponds, where about 52% of the water is lost to evaporation, proves **ONCE AND FOR ALL EVAPORATION IS VIABLE DISPOSAL SOLUTION OPTION.**

Why aren't disposal volumes for a mine life of 25 years presented ?

Given the errors involved in the calculations and many variables involved in the movement of groundwater, no confidence can be placed on Heathgate's estimates and this **IS SIGNIFICANT**.

Why is only 6 months used to discuss head increases when mining could well last for 25 years ? Such logic is oxymoronic and a direct contradiction.

The rise of head at the disposal wells could be significantly underestimated :

- what about super-position of the increased head of disposal bores ? will this enhance the head between bores at monitoring bores ?
- given that the current two disposal wells are spaced close together, will there be any chemical interference from the interaction of solutions ?
- what is the predicted head for 15, 20 and 25 years of active disposal ?
- given that the head in both the Beverley and Willawortina aquifers are similar to begin with (refer to Figure 6-37), the disposal of water will lead to a much greater hydraulic gradient between the two aquifers - **THIS WILL ENHANCE THE POTENTIAL FOR EXCURSIONS INTO THE WILLAWORTINA !!!!!**

Why is a thickness of 30 m used at the disposal sites to calculate volumes affected when 3 m and 8 m are used elsewhere ? This is inconsistent. Especially given the two disposal bores have screened intervals of 4 m and 7 m both across the bottom of the palaeochannel.

The argument of radionuclide levels within the Beverley aquifer before mining is false - the act of ISL mining WITHOUT RESTORATION will vastly increase the levels of heavy metals and radionuclides in solution and thereby adversely affect it's potential future use.

To mention the migration of fluids between the disposal array and mining areas due to a difference in head and then argue that "*there is no hydraulic gradient in the Namba Formation to provide a driving force*" (page 9-7) is contradictory and inconsistent.

Given the much higher pressure at the disposal area, and the nature of ISL mining, there is an excellent probability that affected groundwater will migrate into surrounding groundwater systems and create intractable adverse environmental impacts.

Although the overall water budget may be close to "*neutral*", there will be areas across the palaeochannel that increase in water due to injection and others decrease due to extraction.

9.2.3 - Aquifer Conditioning Following Mining and Liquid Waste Disposal

Why 10% residual mining solutions and 90% native groundwater ? on what basis ?

When I undertake mixing calculations as suggested on page 9-7, I receive a pH of about 3.2, not 3.7 (refer Appendix 4) !!!

If there are low levels of acid consumers within the Beverley aquifer, how will they equilibrate the pH to about 4.5 ? on what basis and mineralogy is this expected to occur ?

It is not believed that at the disposal area the pH will be changed from 2.6 to 4.5 merely by equilibration with aquifer sediments. It is extremely hard for natural processes to alter the pH this much without aggressive mixing of chemicals otherwise unnatural to that system. For example, the principal reason there are large pH changes in acid mine drainage problems, is the introduction of water and oxygen into the rock mass and the conditions being made suitable for oxidation processes to proceed.

Will Heathgate actively alter pH to 4.5 after ISL mining ceases in all areas ?

Why not a higher pH value between 7 or 8, as the native groundwater is ?

9.2.4 - Willawortina (Overlying) Aquifer Effects

The many potential contamination sources of the Willawortina are recognised correctly, however, they are typically ignored or dismissed as improbable.

There is likely to be surface spills that may contaminate a Willawortina aquifer, a leak from an old exploration or abandoned bore, or a rupture in the surface distribution network.

The most recent pumping tests were not conducted long enough to ensure the bore was stressed in a similar fashion to continuous operation during mining.

A location map must be presented showing the planned sites of ALL monitoring bores, which should include Willawortina monitoring bores outside the mining zone and situated to detect a possible excursion along a "channel-in-channel".

What "*best available information*" do Heathgate refer to in discounting original comments on the 1982 SAUC Draft EIS ? Since there has been no further drilling since this time, are they simply assuming like at so many points in the EIS ?

The long term transfer of groundwater and contaminants between the Beverley and Willawortina aquifers as they both migrate towards Lake Frome is unknown, and can ultimately only be proven until after it occurs if Heathgate fail to fund further drilling to define the regional extent and detailed stratigraphy of both systems.

It is indeed plausible that they may mix as they approach Lake Frome. If the waters accumulate at this point, it should be possible to detect increased radionuclide content within evaporative salts.

9.2.5 - Great Artesian Basin (Underlying) Aquifer Effects

What happens if Heathgate have to dramatically increase their GAB water extraction ?

Such a scenario is not unlikely the progressively higher salinity may prove to be problematic in the process plant, requiring much fresher solutions to be used for mining purposes.

If higher flow rates were to be needed, then potential drawdown and interference from Camp Bore is possible, as well as potential problems with the boundary of the GAB just to the west of Beverley. Problems across the Poontana Fault zone may also be initiated.

9.3 - Environmental Controls as Part of Normal Operation

THERE IS NO MENTION OF MONITORING THE WILLAWORTINA AQUIFER !!!!!

At what frequency will Willawortina monitoring bores be sampled ?

What parameters will be monitored ?

At least weekly samples of pH and conductivity must be taken at all bores, and monthly samples be taken for *complete* cation, anion, heavy metal and radionuclide analysis.

Who will undertake the monthly analytical testing ? **It must be done by an independent chemical laboratory, and not by the proponent, to maintain integrity.**

9.3.1 - Ore Zone Aquifer Monitoring

At what frequency will monitoring of flows and water balances be carried out ?

Monitoring of bore pressure and flow must be continuous (easy with currently available technology off the shelf). Water balances must be carried out at least daily, and monitoring hardware and data be directly linked to computer to enable quick and easy determination of any change.

On what basis are the distances of 250 m and 100 m chosen ? Will this allow detection of excursions moving north-south along a sub- channel ? (refer Figure 16, page 31; Mudd, 1998a). The anisotropic nature of palaeochannel depositional environments will lead to inherent difficulties in predicting and capturing such behaviour.

Monitoring of all ore zone wells must be at least weekly if done manually, or preferably the use of continuous downhole probes should be used.

Monthly samples be taken for complete cation, anion, heavy metal and radionuclide analysis.

Who will undertake the monthly analytical testing ? **It must be done by an independent chemical laboratory, and not by the proponent, to maintain integrity.**

9.3.3 - Emergency Procedures

Although ISL mines in the USA have used alterations in bleed quantities to recover excursions, this does not necessarily fix the problem that caused the leak in the first place - the leaking bore casing may still exist; and residual contaminants may still remain in the affected aquifer zone.

The carte blanche admission that there will be spills from surface pipes and Heathgate's cavalier attitude to potential environmental contamination is deeply concerning, to be undeservedly polite.

ALL SPILLS MUST BE PROMPTLY CLEANED UP :

- all residual solutions recovered and placed in the evaporation ponds;***
- all contaminated soil cleaned up and placed in the radioactive waste repository.***

For EVERY SPILL, AN INDEPENDENT ORGANISATION MUST ASSESS :

- the circumstances of the spill;*
- the nature of the spill - quantities involved, acidity, heavy metal and radionuclide content, radiation exposure levels, etc.;*
- the effectiveness of remedial activities undertaken;*
- public liability associated with environmental releases;*
- measures implemented to minimise the recurrence of such a spill.*

9.3.4 - Holding Pond Leak Protection and Monitoring

There needs to be a clay or low permeability layer beneath the gravel leak detection layer. This will prevent rapid drainage of leaked solutions, should such an event occur.

At what frequency will the leak detection system be monitored ? It should be at least daily, or preferably continuous through probes and data loggers, as proposed for bores and all aspects of the process plant.

Given the significant depth to groundwater in the Willawortina, what other extraneous waters are Heathgate expecting around their holding ponds ?

If a different chemical signature solution is found beneath the pond, and the pond is not taken out of service, how will Heathgate continue to monitor the ponds effectively ? The presence of water would appear to prevent such a possibility.

The presence of any water beneath a holding pond must lead to that pond being taken out of service and the source identified, and remedial options implemented.

9.4.1 - Radon Release to Atmosphere During Airlifting of Groundwater

Why isn't the levels of radon (1,000 Bq/l) included in Table 4-1 ?

What is the maximum and minimum radon activity found to date ? standard deviation of sample population ? number of samples determined to date ?

Why aren't the radon analyses for different sources monitored during the FLT presented ?

The release of radon will lead to an increase in the overall radioactive load for the wider environment. The decay of radon leads to the formation of intensely radioactive forms of polonium, bismuth and lead - if an animal or human were to inhale the radon gas, they could potentially be exposed to this whole radioactive decay sequence within their lung, creating many opportunities for intense radiation in a small concentrated zone and increasing the chance of cancer or other adverse health effects.

Dispersion and Dilution are not accepted principles for environmental management.

9.4.2 - Other Radiation Emissions

This section completely ignores the issue of thorium - this is a long-lived alpha emitting radionuclide, that is highly mobile under acid-based ISL.

How much thorium will be in evaporation pond salts and other salts from the overall mine ?

The half-life of radium is about 1,600 years - quite a long half life to design for !!! This is ignored.

9.4.3 - Potential Radiological Impacts on Groundwater

Again, this section completely ignores the fundamental fact that, as currently predicted and proposed, Heathgate are intending to leave the Beverley aquifer with vastly increased levels of radionuclides, heavy metals and nearly 10,000 times higher in acidity (pH from 8.3 to 4.5). the conditions will be geochemically ripe to allow sustained high levels of radionuclides.

Thus the reference to "natural" should be deleted a irrelevant and retracted by Heathgate.

The radiological impacts on groundwater are thus severe and entirely unacceptable.

9.4.4 - Potential Radiological Impacts on Soils

MY GOD !!!!!

How can a company promulgate such ridiculous crap as science and benign environmental impact ?

Why is Heathgate so happy to dismiss the previous proponent's environmental disasters and yet avoid disclosing to the public and all traditional owners their own spill ?

The report on the previous direct contamination of surface soils and water systems by Sonter (1998a) is extremely concerning :

- the radium only penetrated up to 300 mm of soil, leaving it available to plants and grasses to absorb, and therefore for animals to eat the radium-contaminated vegetation, until the radium becomes concentrated through the food chain;
- the total radium released in 1973 and 1981 at Beverley is estimated to be 13 GBq (about 0.35 Ci or approximately 325 mg), less than 1% of which was retained in surface soils on site and the remainder reaching Jenny Creek and being dispersed throughout the environment (Sonter, 1998a);
- at Rum Jungle, where uranium tailings used to be directly discharged to the Finnis River, it has been estimated that a total of 450 curies (Ci) was released from the mine and mill - it has also been estimated that only 0.4 µCi (microcuries or four millionths of a curie) in the human body was sufficient to cause cancer (SEA-US Rum Jungle, 1998).

On such a basis, the 0.35 Ci of radium released at Beverley therefore contained around 875,000 human cancer doses.

The only appropriate phrase for this is **CRIMINAL NEGLIGENCE**, especially considering the 1981 pump test was actually performed by the Mines and Energy Department SA (MESA) under contract to SAUC.

Heathgate must release all of the data on their spill, and why they did not report it when EVERY SPILL REGARDLESS OF SIZE must be reported in the USA.

The fact that so much radium has been released to the environment is extremely worrying. It is IMPERATIVE THAT ALL SPILLS BE CLEANED UP TO PREVENT FURTHER RADIUM CONTAMINATION OF THE LAKE FROME BASIN.

Another worrying case of negligence is the remaining radium from the 1997 series of aquifer pump tests - this radium still remains in near surface soils. Thus the claim of no impacts from ponds is an outright lie, and there is likely to be leaks over the life of the mine.

Why won't Heathgate address the issue of bioconcentration of radionuclides in soils through the food chain ?

At former ISL sites across Eastern Europe and the former Soviet block, the radiological, heavy metal and acidic contamination of surface soils is one of the most critical environmental and health concerns since the sites are intended to be returned to their former agricultural use. The current level of radionuclides prohibits this at the moment due to the ready transfer of radionuclides through crops to animals and humans.

Figure 9-8 - Existing FLT Plant Equipment Viewed From Mine Access Track

The current FLT Plant does interrupt the serenity of the Lake Frome plains, and a full scale mine and plant would further disrupt such views.

9.16 - Impacts in Relation to Ecologically Sustainable Development

Heathgate must retract every dot point where it is stated that both uranium mining and In Situ Leach mining is seen as compliant with ESD Principles.

Every assertion made on pages 9-48 and 9-49 are criticised and either proven outright wrong or highly questionable in this submission.

To talk about one mine without placing the intractable nuclear waste arising from the Nuclear Fuel Cycle and the ever present and devastating threat of Nuclear Weapons is, some might say, foolhardy at best but in reality a lot worse.

SOLUTION URANIUM MINING
AND ESD DON'T MIX !!!!!

Section 10 - Radiation Exposures and Controls

10.3 - Occupational Radiation

Where is the radiation exposure levels ?

HARD SAMPLE DATA ?

Why are Heathgate allowed to promulgate the fiction that ISL mines entail low radiation exposures and then fail to provide the data to prove their assertions in their EIS ?

Again, this is negligence in the extreme, and for this reason alone the EIS MUST BE RE-SUBMITTED.

Why aren't individual radionuclides cited for different radiation sources ?

10.3.2 - Employee Dose Estimates

Although Heathgate dismiss the levels of radiation exposure as small (and by implication irrelevant), international research is suggesting that even at low exposures near 5 mSv there is chromosomal abnormalities and excess cancers arising from a direct result of exposure to low dose ionising radiation within a nuclear facility (Richardson, 1997; Kohnlein, 1998).

The use of respirators in yellowcake packaging will not prevent or minimise the inhalation of radon gas.

10.4.5 - Dispersion Modelling

The US EPA, 1995, reference is missing from the list.

The modelling as presented is irrelevant. It would appear that only one source term was used, despite the fact that the mine would have several distinct point sources, as well as diffuse sources of radon progeny associated with wellfields.

The first paragraph on page 10-12 is a typographical error.

Again, the "DISPERSE and DILUTE APPROACH" is environmentally unacceptable.

Section 12 - Overview of Environmental Safeguards, Monitoring and Management Plan

This entire section lacks specific detail on frequency, chemical analyses to be performed, and avenues for independent scrutiny of the EMMP.

There must be :

- Annual EMMP reports, released to any interested person or party;
- a Community Consultative Forum established, in a similar fashion to the forum at Ranger and Nabarlek, and the recent CCF at Olympic Dam;
- the CCF must have the power to recommend and implement changes to the EMMP, with government support to force the issue if necessary;
- the CCF must incorporate representatives from local residents, pastoralists, tourism, environment movement, indigenous peoples, workers of the site and both state and federal government representatives.

Section 13 - Decommissioning and Rehabilitation

13.1 - Objectives

Not one objective includes the restoration of groundwater !!!!

13.3 - Continuous Rehabilitation of Wellfields

There must be a large suite of wells that remain permanently open after the completion of ISL mining for ongoing groundwater monitoring. The bores remaining open must include the Willawortina, Beverley and Great Artesian Basin aquifers.

13.5 - Long Term Monitoring and Management

As highlighted above, not all wells should be sealed to ensure adequate opportunity to study the long term migration of mining and disposal solutions within the aquifers.

The Beverley aquifer wells must include wells inside and outside the mined ore zones, and must include one well every 250 m.

The Willawortina aquifer must be monitored north and south of the mined areas, and across the mined zones. All Willawortina bores must remain unsealed for long term monitoring.

All Great Artesian Basin bores must remain and be monitored for both pressure and water quality.

Sampling should be undertaken by an independent organisation, at the expense of Heathgate, and be conducted monthly for the first 10 years following the completion of solution mining, and thereby three monthly for the next 1,000 years, the same regulatory time frame uranium tailings dams from conventional mines are supposed to comply with.

The claim that the mined aquifer ***may have been mitigated*** within their proposed seven year decommissioning time frame are ***absolutely LUDICROUS***.

I repeat again, the general absence acid consumers within the Beverley host sands should sound LOUD alarm bells that it will take a mighty long time given the low flow rates for pH to rise to pre-mining levels. At Nine Mile Lake, where a pro-active and quite aggressive restoration sequence was undertaken that proved technically difficult, *it still took a year for pH to be within one unit of baseline levels*.

Given that Heathgate will have water treatment facilities on site as part of the overall mine process plant and infrastructure, any claim of excess cost is unfounded.

THEY MUST BE FORCED TO RESTORE GROUNDWATER

13.6 - Final Form and Use of Landscape

Given that pastoral use is the most probable end use after ISL mining, it is imperative that all surface spills and contaminated soils be removed and the site returned to pre-mining conditions.

Conclusions

It is believed that no matter how strong the case against the ISL technique or the current Beverley Proposal, it is likely that both federal and state governments will merely ignore these fundamental operational and environmental issues to suit their ideologically driven agenda without any examination of the need for uranium, the health and environmental risks arising from the entire nuclear fuel cycle, the rights of indigenous communities or Australia's international obligations in eliminating nuclear weapons.

As it currently stands, the BEVERLEY PROPOSAL is world's worst practice and

MUST BE DECISIVELY REJECTED

References

ABC WebNews, 1998, *Mining Companies Keep Labor Policy in Mind*, ABC July 13, 1998.

Chancellor R A, 1997, *Letter to Dr D B Matthews (CCSA)*, August 22, 1997, Wyoming Dept. of Environmental Quality, Land Quality Division.

EPA, 1997, *State Environment Protection Policy - Groundwaters of Victoria*, Environment Protection Authority (Victoria).

Fetter, C W, 1993, *Contaminant Hydrogeology*, Macmillan Publishing Company, 458 pages.

FoEA, 1997, *Public Submission on the Olympic Dam Expansion Project EIS*, Friends of the Earth Australia, July 18, 1997, 34 pages.

(<http://home.vicnet.net.au/~seaus/roxby/exp-foe-oz.html>)

Heathgate, 1997a, *Declaration of Environmental Factors (DEF) in Support of a Proposal to Undertake a Field Trial of Uranium Extraction by In Situ Leaching at Beverley, South Australia*; Prepared by Heathgate Resources Pty. Ltd., September 5, 1997.

Heathgate, 1997b, *Declaration of Environmental Factors in Support of a Proposal to Undertake a Water Well Drilling and Hydrogeological Testing Program at Beverley, South Australia*, Prepared by Geoprojects Pty Ltd / Fatchen Environmental Pty Ltd for Heathgate Resources Pty Ltd, March 7, 1997, (Unpublished).

Heathgate, 1998a, *Beverley Uranium Mine Environmental Impact Statement*, EIS Prepared by Heathgate Resources Pty Ltd, June 29, 1998.

Heathgate, 1998b, *Beverley Project Profile*, no date - presumed February 1998 (2ND version).

Heathgate, 1998c, *Letter from Heathgate Resources to Mines & Energy (SA) - response to DHUD Comments*, October 13, 1997, 7 pages.

Heathgate, 1998d, *Beverley Project Profile*, no date - presumed July 1997 (1ST version).

Hill, 1997, *Memo to Peter Body on Proposed ISL Trials at Beverley - Signed by Senator Robert Hill*, October 15, 1997.

Kohnlein, W, 1998, *Collection of Radiation Exposure Papers*, last updated April 1998.

(<http://www.foe.arc.net.au/kohnlein.html>)

Langmuir, D, 1997, *Aqueous Environmental Geochemistry*, Prentice Hall, USA, 600 pages.

Liberal Environment Policy, 1996, *Saving Our Natural Heritage*.

(<http://www.liberal.org.au/ARCHIVES/ENVI/envent.html>)

Moody, R, 1992, *The Gulliver File - Mines, People & Land : A Global Battleground*, published by Minewatch and WISE-Glen Aplin, 894 pages.

MPI, 1997, *Public Submission on the Olympic Dam Expansion Project EIS*, Mineral Policy Institute, July 1997, 14 pages.

(<http://www.hydra.org.au/mppi/docs/roxbyeis.html>)

Mudd, G M, 1998a, *An Environmental Critique of In Situ Leach Mining : The Case Against Solution Mining*, July 1998, 154 Research Report, Victoria University of Technology.

(<http://home.vicnet.net.au/~seaus/proposed/islsuks.html>)

Mudd, G M, 1998b, *The DEF Truth : Beverley's Freedom of Information Documents*, Review prepared for SEA-US Inc, last updated July 1998, 3 pages.

(<http://home.vicnet.net.au/~seaus/proposed/bevfoi.html>)

Mudd, G M, 1998c, *The Beverley Groundwater Sacrifice Zone : A Detailed Critique of the Declaration of Environmental Factors (DEF) for the Beverley Field Leaching Trial (FLT)*, Review prepared for SEA-US Inc, last updated February 1998, 13 pages.

(<http://home.vicnet.net.au/~seaus/proposed/bevfltdef.html>)

Parkhurst, D L, 1996, *PHREEQC - A Computer Program for Speciation, Reaction-Path, Advective-Transport, and Inverse Geochemical Calculations*, U.S. Geological Survey Water-Resources Investigations Report 95-4227.

(<http://water.usgs.gov/software/phreeqc.html>)

Richardson, D, 1997, *Low Dose Radiation Exposure*, Talk given at the Public Meeting on Worker's Health at ROXSTOP '97, September 25, 1997, 7 pages.

(<http://www.foe.org.au/roxstop97/tdave3.htm>)

Rinaldo, L E, 1998, *In Situ Leaching Advice*, Geologist, USEPA, April 6, 1998.

Robinson, P, pers. comm., 1998, Paul Robinson - Research Director, Southwest Research and Information Center, Albuquerque, New Mexico, USA.

RAC, 1997, *Public Submission on the Olympic Dam Expansion Project EIS*, Roxby Action Collective, July 1997, 12 pages.

(<http://home.vicnet.net.au/~seaus/roxby/exp-rac.html>)

SAUC, 1982, *Beverley Project Draft Environmental Impact Statement*, July 1982, 329 pages.

SCRA, 1997, *Honeymoon Uranium Project - Declaration of Environmental Factors*, Prepared by Southern Cross Resources Australia Pty Ltd, October 31, 1997, 67 pages.

SCRA, 1998, *Honeymoon Uranium Project - Declaration of Environmental Factors : Addendum*, Prepared by Southern Cross Resources Australia Pty Ltd, February 4, 1998, 15 pages.

SEA-US Rum Jungle, 1998, *Rum Jungle, NT- An Ongoing Environmental Calamity*, Background information prepared for SEA-US Inc, last updated January 26, 1998.

(<http://home.vicnet.net.au/~seaus/oldmines/rumjungle.html>)

Sonter, M, 1998a, *Report on Radioactive Anomaly at Beverley - EIS Supporting Document*; Mark Sonter Consulting, January 1998, 13 pages.

UIC, 1998a, UIC Weekly News Summary - July 3, 1998, Uranium Information Centre, Melbourne, VIC, 1 page.

UIC, 1998b, *Australia's Prospective Uranium Mines*, Nuclear Issues Paper, Uranium Information Centre, Melbourne, VIC, 8 pages.

Uranium Institute, 1998, *Uranium Institute News Briefing 98.33 (for the period 12 - 18 August 1998)*.

USDoe, 1995a, *Uranium Industry Annual 1994*, Energy Information Administration, DOE/EIA-0478(94), July 1995, 119 pages.

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

(<ftp://ftp.eia.doe.gov/pub/pdf/coal.nuclear/>)

USDoE, 1995b, Decommissioning of U.S. Uranium Production Facilities, Energy Information Administration, DOE/EIA-0592, February 1995, 119 pages.

(<ftp://ftp.eia.doe.gov/pub/pdf/coal.nuclear/0592.pdf>)

USDoE, 1996, *Uranium Industry Annual 1995*, Energy Information Administration, DOE/EIA-0478(95), May 1996, 65 pages.

(<ftp://ftp.eia.doe.gov/pub/pdf/coal.nuclear/>)

USDoE, 1998, *Uranium Industry Annual 1997*, Energy Information Administration, DOE/EIA-0478(97), April 1998, 69 pages.

(<http://www.eia.doe.gov/cneaf/nuclear/uia/> or <ftp://ftp.eia.doe.gov/pub/pdf/coal.nuclear/047897.pdf>)

USDoE, 1997a, *Nuclear Power Generation and Fuel Cycle Report 1997*, September 1997, DOE/EIA-0436(97), Energy Information Administration - Office of Coal, Nuclear, Electric and Alternate Fuels, US Department of Energy, Washington, DC 20585, 118 pages.

(<ftp://ftp.eia.doe.gov/pub/pdf/coal.nuclear/043697.pdf>)

USDoE, 1997b, *Uranium Industry Annual 1996*, Energy Information Administration, DOE/EIA-0478(96), April 1997, 78 pages.

(<ftp://ftp.eia.doe.gov/pub/pdf/coal.nuclear/047896.pdf>)

USEPA, 1995, *Technical Resource Document : Uranium - Extraction and Beneficiation of Ores and Minerals (Volume 5)*, U.S.EPA Office of Solid Waste, EPA/530-R-94-032, NTIS/PB94-200987, November 1994, 125 pages.

(<http://www.epa.gov/docs/OSWRCRA/other/mining/techdocs/uranium.wp>)

USNRC, 1997, *Information Notice 97-58 : Mechanical Integrity of In-Situ Leach Injection Wells and Piping*, July 31, 1997.

(visit <http://www.nrc.gov/>)

WISE, 1998, WISE (World Information Service on Energy) News Communiqué #485, January 23, 1998.

(<http://antenna.nl/~wise/485/cont.html>)

References - Nine Mile Lake (Wyoming, USA)

Nigbor, M T, W H Engelmann & D R Tweeton, 1982, *Case History of a Pilot-Scale Acidic In Situ Uranium Leaching Experiment*, United States Bureau of Mines, Report of Investigations 8652, 81 pages.

Nigbor, M T, W H Engelmann & D R Tweeton, 1981, *Case History of a Pilot-Scale Acidic Uranium In Situ Leaching Experiment*, In "*In Situ Mining Research*", Proceedings : Bureau of Mines Technology Transfer Seminar, Denver, Colorado, August 5, 1981, Information Circular 8852, 8 pages.

Appendix One :

About the Author

Brief Curriculum Vitae

Gavin M. Mudd

About the Author

Gavin Mudd has a B. Env. Eng. (Hons) *RMIT*, and is currently close to completing his PhD in Environmental Hydrogeology and Geomechanics at Victoria University of Technology (Footscray, VIC). Some major achievements are listed below.

Awards

- 1990** Dux, Year 12, Loyola College (Anderson Score - 374)
- 1991 - 1994** Best First, Second, Third and Fourth Year Student, RMIT Environmental Engineering
- 1994** Research Report for Env. Protection Authority on Environmental Management in Retail Petrol Facilities (fourth year Env. Eng. Investigation Project).
- 1994** Institution of Engineers Australia, Best Environmental Engineering Student
- 1995** Won an Aust. Postgraduate Award (Industry) PhD Scholarship at Victoria University of Technology (now nearing completion)

Work Experience

- 9 months consulting experience - contaminated site field work, environmental assessment, preparation of client reports, advanced groundwater modelling.
- PhD Research (March 1995 to present) - includes detailed analysis of groundwater geochemistry and flow patterns, solute transport modelling of reactive geochemistry, detailed field studies of coal ash leachability, computer modelling of leaching, unsaturated flow and evaporation processes, consulting on ash disposal sites.
- Semester One, 1998 - Lecturer in Earth Sciences/Geomechanics, VUT.

Papers to Date

Mudd, G M, J Kodikara & T McKinley, 1996, *Assessing the Environmental Impact of Coal Ash Disposal*, Paper presented at the Australian Institute of Energy 7TH Australian Coal Science Conference, Churchill, VIC, December 1996, 10 pages.

Mudd, G M & J Kodikara, 1997, *Modelling of Coal Ash Leaching*, International Association for Computer Methods and Advances in Geomechanics (IACMAG), Paper prepared for the 9TH International Conference, Wuhan, China, November 1997, 6 pages.

Mudd, G M, T R Weaver, J Kodikara & T McKinley, 1998, *Groundwater Chemistry of the Latrobe Valley Influenced by Coal Ash Disposal - 1 : Dissimilatory Sulphate Reduction and Acid Buffering*, Paper presented at the International Association of Hydrogeologists (IAH) Conference, "Groundwater : Sustainable Solutions", Melbourne, VIC, February 1998, 6 pages.

Mudd, G M, T R Weaver, J Kodikara & T McKinley, 1998, *Groundwater Chemistry of the Latrobe Valley Influenced by Coal Ash Disposal - 2 : Preliminary Kinetic Modelling*, Paper presented at the International Association of Hydrogeologists (IAH) Conference, "Groundwater : Sustainable Solutions", Melbourne, VIC, February 1998, 6 pages.

Mudd, G M, J Kodikara & T McKinley, 1998, *Coal Ash Leachability : Detailed Field Studies*, Paper prepared for the Australian Institute of Energy 8TH Australian Coal Science Conference, Sydney, NSW, December 1998, 6 pages.

Mudd, G M, 1998, *The Long Term Sustainability of Mound Springs in South Australia : Implications for Olympic Dam*, Paper accepted for Uranium Mining and Hydrogeology II, Freiberg, Germany, September, 1998.

- More conference and journal papers currently under preparation.

Appendix Two :

Extract from USDoE (1997)

Forecasts of USA and World Nuclear Capacity.

Nuclear power is an important source of electric energy and the amount of nuclear-generated electricity continued to grow as the performance of nuclear power plants improved. In 1996, nuclear power plants supplied 23 percent of the electricity production for countries with nuclear units, and 17 percent of the total electricity generated worldwide. However, the likelihood of nuclear power assuming a much larger role or even retaining its current share of electricity generation production is uncertain. The industry faces a complex set of issues including economic competitiveness, social acceptance, and the handling of nuclear waste, all of which contribute to the uncertain future of nuclear power. Nevertheless, for some countries the installed nuclear generating capacity is projected to continue to grow. Insufficient indigenous energy resources and concerns over energy independence make nuclear electric generation a viable option, especially for the countries of the Far East.

Current Status and Recent Developments

Watts Bar 1 May be the Last U.S. Reactor

During 1996, five nuclear reactors worldwide were connected to their respective electricity grid. In the United States, 110 reactors, having a total capacity of 100.7 GWe, were in operation (Figure OV1).¹ Watts Bar 1, connected to the grid in February 1996, could be the last commercial nuclear reactor constructed in the United States within the projected time frame. At year-end 1996, 442 commercial nuclear units with a total capacity of 351 net gigawatts-electric (GWe) were operating in 32 countries, generating 2,300 net terawatt-hours of electricity (Figure OV2).

Figure OV1. Historical U.S. Nuclear Capacity and Projected Capacity, 1980-2015

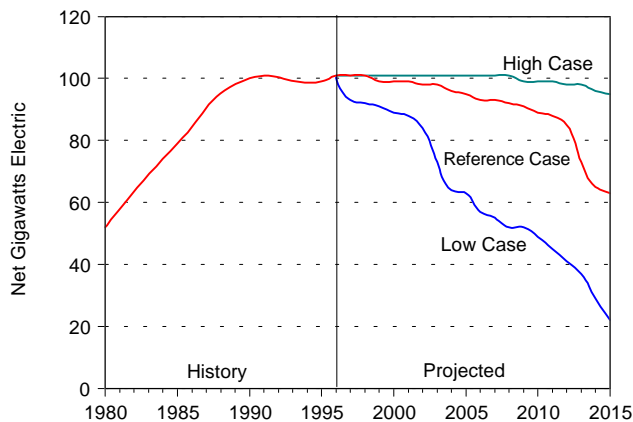
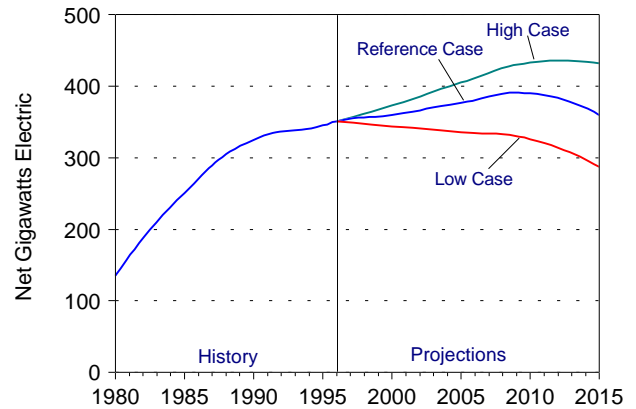


Figure OV2. World Nuclear Capacity, 1980-2015



Russia and South Korea Led in Units Under Construction

As of year-end 1996, 45 nuclear units were under construction. Russia and South Korea each had seven units under construction—the largest number for a single country. Additionally, there were 27 units in the planning stages, and 6 indefinitely deferred units that are not projected ever to be completed. Most of the planned units are located in China and Japan and are scheduled to begin operation between 2002 and 2010.

Record Nuclear Plant Performance Throughout the World

In 1996, record electricity production was reported in several countries, including Bulgaria, Finland, Germany, Hungary, India, Japan, South Korea, Ukraine, and the United States. In the United States, nuclear power accounted for 19.4 percent of the total generated electricity in 1996.² Germany’s nuclear electricity share was 30 percent with no new nuclear units having come online since 1989.

Reversal in Uranium Spot-Market Prices

The average uranium spot-market price for the unrestricted world market and the restricted U.S. market in 1996 were \$14.17 and \$15.57 per pound U₃O₈, respectively. Both prices had risen from 1995. However, prices began to decline in mid-1996 in response to utilities purchasing uranium in excess of immediate requirements. By May 1997, prices had fallen to \$10.50 per pound U₃O₈.

Appendix Three :

The Gulliver File on

General Atomics

Roger Moody (1992)

(References found in the original book)

Corporate Dossier on General Atomics from Moody (1992).

The "first company anywhere dedicated to building atomic reactors" (1), General Atomics (sic) was founded by Frederic de Hoffman, a former member of the Los Alamos team which constructed the Hiroshima and Nagasaki bombs (2). Later acquired by General Dynamics Corp, manufacturers of high-temperature gas-cooled (HTGR) reactors, nuclear fuels and nuclear steam systems, General Atomics was bought out by Gulf Oil in 1967 and renamed Gulf General Atomic Ltd (3). Somewhat later, half of Gulf's interests in the company was sold to Shell, but partially repurchased in 1979 (4). From 1980 until 1984, in the post-Three Mile Island era, General Atomic appears to have ended on the shelf, as it contended with complex litigation over Gulf's membership of the uranium cartel. During the previous decade it landed several contracts for reactors, for example with Delmarva Power and Light and Philadelphia Electric in the early '70s, and the Fort St Vrain HTGR station near Denver, Col, completed in 1972 (3) - though eight years later this station had still not reached full design power (5). The company also sold Indonesia its first reactor, a 250KW Triga Mark II which was operating at Bandung University in 1964. The reactor was upgraded to IMW in 1971 (6). Ironically, finance for the project derived from sale of Sumatran coal: one in the eye (or the bunker) for those who maintain nuclear power is always clean, while coal is always 'dirty' (7)!

In 1980, General Atomic offered to build a 25MW Triga in Indonesia - so far as is known, the offer was not taken up. If it were, this would have been the largest Triga built by the company anywhere (8).

During this period, General Atomic was also testing its Doublet III fusion reactor, with the support both of the US DoE and the electric utility industry in the States (5).

Gulf was the key US protagonist in the uranium cartel which effectively cornered the uranium market and quintupled uranium prices between 1972 and 1975. Since General Atomic was both a supplier of, and a contractor for, uranium during the '70s, it ended up (like Westinghouse) being sued by utilities and itself suing uranium mining companies which didn't deliver. (Unlike Westinghouse, however, there was never any doubt of Gulf's leading role in promoting the cartel.)

By late 1978, General Atomic was in the position of having to supply, to three utilities, uranium which it couldn't secure because its own supplier, the UNC, ceased deliveries while the cartel was being investigated by a Senate committee. The shortage - some 3,500,000 lbs of uranium oxide - was (fortunately for General Atomic) partly made up by supplies from the new Rabbit Lake mine, operated by Gulf's subsidiary Gulf Minerals Canada (9).

In mid-1984, General Atomic finally settled with UNC: it paid US\$130M in cash to the other company and assumed UNC's obligations to repay some 2.3 million pounds of uranium owed by UNC to a utility. At the same time, Socal/Chevron agreed to invest US\$100M in UNC through the purchase of unused stock (10).

As details of the cartel became public, General Atomic entered another dispute with a supplier - this time the Johnny "M" mine, jointly owned by Ranchers and HNG Oil. General Atomic originally agreed to purchase the output from the mine and filed suit against the other two companies when, in early 1976, they tried to revise or cancel their contracts because they couldn't deliver the full amount of ore. Ranchers and HNG countered with a claim that the contract had been unenforceable and should be therefore voided.

The litigation was partly settled the same year when Gulf States Utilities (the customer) accepted delivery of some uranium. Later the three companies agreed a profit-sharing arrangement which, it was estimated, would involve Rancher and HNG paying up to US\$60M to General Atomic from around 1981 onwards (11).

By early 1984, Gulf had settled its final suit with the utilities, setting up a US\$30M venture capital fund as part of a US\$70M settlement with the TVA (12). Three years earlier it also agreed to pay the Pennsylvania Power and Light Co US\$43.9M over seven years and supply it with 2.5M pounds U3Og until 1987 (13).

General Atomic's contribution to weapons programmes reared its ugly head in late 1989 in a (perhaps) surprising development, when the US Department of Energy (DoE) announced that it would be shipping 16.48 kg of 93% enriched (ie weapons grade) uranium to Romania, for use in a 14MW "research" reactor at Potesti one which had been supplied by General Atomic in the 1970s: the uranium had been manufactured by the company about ten years before (14).

Before his downfall, President Ceausescu of Romania had boasted that his country had the capacity to manufacture nuclear weapons (14). The 1989 deal was arranged by Edlow Inc, whose Vice-President Rod Fisk, when asked whether he was concerned how the material would be used, retorted: "That's a question you have to address to the US government" (14).

Appendix Four :

PHREEQC Analyses Output Data

Parkhurst, 1996

 Reading data base.

SOLUTION_MASTER_SPECIES
 SOLUTION_SPECIES
 PHASES
 EXCHANGE_MASTER_SPECIES
 EXCHANGE_SPECIES
 SURFACE_MASTER_SPECIES
 SURFACE_SPECIES
 END

 Reading input data for simulation 1.

TITLE Beverley EIS 1998 & Field Leach Trial Chemistry
 SOLUTION 1 Extraction Average

units	mg/l
pH	2.25
Ca	547.46
Mg	302.69
Na	1426.92
K	59.5
Fe	25.91
Al	36.87
Si	268.71 as SiO2
Cl	1974.7
S(6)	3910.46

SAVE solution 1

SOLUTION 2 Injection Average

units	mg/l
pH	2.07
Ca	546.11
Mg	303.08
Na	1423.08
K	59.38
Fe	26.1
Al	36.7
Si	266.04 as SiO2
Cl	1894.62
S(6)	4135.0

SAVE solution 2

SOLUTION 3 North Beverley Groundwater Quality

units	mg/l
pH	7.0
Ca	380.0
S(6)	1600.0

SAVE solution 3

SOLUTION 4 Central Beverley Groundwater Quality

units	mg/l
pH	7.0
Ca	610.0
S(6)	2100.0

SAVE solution 4

SOLUTION 5 South Beverley Groundwater Quality

units	mg/l
pH	6.8
Ca	850.0
S(6)	2500.0

SAVE solution 5

SOLUTION 6 North Beverley - ISL Phase

units	mg/l
pH	2.25
Ca	547.0
S(6)	3910.0

SAVE solution 6

SOLUTION 7 North Beverley - Waste Injection

units	mg/l
pH	2.07
Ca	546.0
S(6)	4135.0

SAVE solution 7

SOLUTION 8 North Beverley - Alkaline Leach Analysis

units	mg/l
pH	6.5
Ca	380.0
Alkalinity	3000.0 as HCO3

SAVE solution 8

SOLUTION 9 Central Beverley - Alkaline Leach Analysis

units	mg/l
pH	6.5
Ca	610.0
Alkalinity	3000.0 as HCO3

SAVE solution 9

SOLUTION 10 South Beverley - Alkaline Leach Analysis

units	mg/l
-------	------

```

pH          6.5
Ca          850.0
Alkalinity  3000.0 as HCO3
SAVE solution 10
SOLUTION 11 North Beverley - Alkaline Leach Analysis
units      mg/l
pH          7.2
Ca          380.0
Alkalinity  3000.0 as HCO3
SAVE solution 11
SOLUTION 12 Central Beverley - Alkaline Leach Analysis
units      mg/l
pH          7.2
Ca          610.0
Alkalinity  3000.0 as HCO3
SAVE solution 12
SOLUTION 13 South Beverley - Alkaline Leach Analysis
units      mg/l
pH          7.2
Ca          850.0
Alkalinity  3000.0 as HCO3
SAVE solution 13
SOLUTION 14 - FLT Background/Native Groundwater Quality
units      mg/l
pH          8.31
Ca          370.34
Mg          198.19
Na          1188.28
K           42.19
Fe          0.74
Al          0.22
Cl          1988.26
S(6)       1524.39
SAVE solution 14
END
-----
TITLE
-----
Beverley EIS 1998 & Field Leach Trial Chemistry
-----
Beginning of initial solution calculations.
-----
Initial solution 1.      Extraction Average
-----Solution composition-----
Elements      Molality      Moles
Al            1.378e-03    1.378e-03
Ca            1.378e-02    1.378e-02
Cl            5.618e-02    5.618e-02
Fe            4.680e-04    4.680e-04
K             1.535e-03    1.535e-03
Mg            1.256e-02    1.256e-02
Na            6.260e-02    6.260e-02
S(6)         4.106e-02    4.106e-02
Si            4.511e-03    4.511e-03
-----Description of solution-----
pH = 2.250
pe = 4.000
Activity of water = 0.997
Ionic strength = 1.476e-01
Mass of water (kg) = 1.000e+00
Total alkalinity (eq/kg) = -1.225e-02
Total carbon (mol/kg) = 0.000e+00
Total CO2 (mol/kg) = 0.000e+00
Temperature (deg C) = 25.000
Electrical balance (eq) = -4.169e-03
Iterations = 7
Total H = 1.110427e+02
Total O = 5.568849e+01
-----Distribution of species-----
Species      Molality      Activity      Log      Log      Log
              Molality      Activity      Molality  Activity  Gamma
H+           6.948e-03    5.623e-03    -2.158    -2.250    -0.092
OH-          2.428e-12    1.775e-12    -11.615   -11.751   -0.136
H2O          5.551e+01    9.968e-01    -0.001    -0.001    0.000
Al           1.378e-03
  ALSO4+     9.484e-04    7.208e-04    -3.023    -3.142    -0.119
  Al(SO4)2-  2.207e-04    1.677e-04    -3.656    -3.775    -0.119
  Al+3       2.079e-04    3.098e-05    -3.682    -4.509    -0.827
  AlHSO4+2   1.077e-06    3.594e-07    -5.968    -6.444    -0.477
  ALOH+2     1.635e-07    5.456e-08    -6.786    -7.263    -0.477
  Al(OH)2+   9.973e-11    7.579e-11    -10.001   -10.120   -0.119
  Al(OH)3    1.913e-15    1.980e-15    -14.718   -14.703    0.015
  Al(OH)4-   8.702e-19    6.614e-19    -18.060   -18.180   -0.119
Ca           1.378e-02
  Ca+2       9.212e-03    3.217e-03    -2.036    -2.493    -0.457

```

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

CaSO4	4.565e-03	4.723e-03	-2.341	-2.326	0.015
CaOH+	1.245e-13	9.464e-14	-12.905	-13.024	-0.119
Cl	5.618e-02				
Cl-	5.617e-02	4.127e-02	-1.250	-1.384	-0.134
FeCl+	8.351e-06	6.347e-06	-5.078	-5.197	-0.119
FeCl+2	3.974e-13	1.326e-13	-12.401	-12.877	-0.477
FeCl2+	3.216e-14	2.445e-14	-13.493	-13.612	-0.119
FeCl3	9.751e-17	1.009e-16	-16.011	-15.996	0.015
Fe(2)	4.680e-04				
Fe+2	3.116e-04	1.114e-04	-3.506	-3.953	-0.447
FeSO4	1.409e-04	1.458e-04	-3.851	-3.836	0.015
FeCl+	8.351e-06	6.347e-06	-5.078	-5.197	-0.119
FeHSO4+	7.089e-06	5.388e-06	-5.149	-5.269	-0.119
FeOH+	8.217e-12	6.245e-12	-11.085	-11.204	-0.119
Fe(3)	1.502e-11				
FeSO4+	1.129e-11	8.583e-12	-10.947	-11.066	-0.119
Fe(SO4)2-	1.818e-12	1.382e-12	-11.740	-11.860	-0.119
Fe+3	7.141e-13	1.064e-13	-12.146	-12.973	-0.827
FeCl+2	3.974e-13	1.326e-13	-12.401	-12.877	-0.477
FeHSO4+2	3.874e-13	1.292e-13	-12.412	-12.889	-0.477
FeOH+2	3.650e-13	1.218e-13	-12.438	-12.914	-0.477
FeCl2+	3.216e-14	2.445e-14	-13.493	-13.612	-0.119
Fe(OH)2+	9.405e-15	7.148e-15	-14.027	-14.146	-0.119
FeCl3	9.751e-17	1.009e-16	-16.011	-15.996	0.015
Fe(OH)3	1.578e-19	1.632e-19	-18.802	-18.787	0.015
Fe2(OH)2+4	3.220e-23	3.991e-25	-22.492	-24.399	-1.907
Fe(OH)4-	3.472e-26	2.639e-26	-25.459	-25.579	-0.119
Fe3(OH)4+5	5.683e-34	5.961e-37	-33.245	-36.225	-2.979
H(0)	4.328e-16				
H2	2.164e-16	2.239e-16	-15.665	-15.650	0.015
K	1.535e-03				
K+	1.461e-03	1.074e-03	-2.835	-2.969	-0.134
KSO4-	7.357e-05	5.591e-05	-4.133	-4.252	-0.119
KOH	6.378e-16	6.598e-16	-15.195	-15.181	0.015
Mg	1.256e-02				
Mg+2	7.781e-03	2.866e-03	-2.109	-2.543	-0.434
MgSO4	4.777e-03	4.942e-03	-2.321	-2.306	0.015
MgOH+	2.427e-12	1.844e-12	-11.615	-11.734	-0.119
Na	6.260e-02				
Na+	6.038e-02	4.587e-02	-1.219	-1.338	-0.119
NaSO4-	2.225e-03	1.691e-03	-2.653	-2.772	-0.119
NaOH	5.193e-14	5.372e-14	-13.285	-13.270	0.015
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-61.098	-61.083	0.015
S(6)	4.106e-02				
SO4-2	2.259e-02	7.357e-03	-1.646	-2.133	-0.487
HSO4-	5.292e-03	4.022e-03	-2.276	-2.396	-0.119
MgSO4	4.777e-03	4.942e-03	-2.321	-2.306	0.015
CaSO4	4.565e-03	4.723e-03	-2.341	-2.326	0.015
NaSO4-	2.225e-03	1.691e-03	-2.653	-2.772	-0.119
AlSO4+	9.484e-04	7.208e-04	-3.023	-3.142	-0.119
Al(SO4)2-	2.207e-04	1.677e-04	-3.656	-3.775	-0.119
FeSO4	1.409e-04	1.458e-04	-3.851	-3.836	0.015
KSO4-	7.357e-05	5.591e-05	-4.133	-4.252	-0.119
FeHSO4+	7.089e-06	5.388e-06	-5.149	-5.269	-0.119
AlHSO4+2	1.077e-06	3.594e-07	-5.968	-6.444	-0.477
FeSO4+	1.129e-11	8.583e-12	-10.947	-11.066	-0.119
Fe(SO4)2-	1.818e-12	1.382e-12	-11.740	-11.860	-0.119
FeHSO4+2	3.874e-13	1.292e-13	-12.412	-12.889	-0.477
Si	4.511e-03				
H4SiO4	4.511e-03	4.667e-03	-2.346	-2.331	0.015
H3SiO4-	1.610e-10	1.224e-10	-9.793	-9.912	-0.119
H2SiO4-2	4.436e-21	1.480e-21	-20.353	-20.830	-0.477

Saturation indices

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-8.56	2.24	10.80	Al(OH)3
Albite	-8.50	-3.83	4.66	NaAlSi3O8
Alunite	-5.87	-7.27	-1.40	KAl3(SO4)2(OH)6
Anhydrite	-0.27	-4.63	-4.36	CaSO4
Anorthite	-23.79	1.83	25.62	CaAl2Si2O8
Ca-Montmorillonite	-10.78	-3.00	7.78	Ca0.165Al2.33Si3.67O10(OH)2
Chalcedony	1.22	-2.33	-3.55	SiO2
Chlorite(14A)	-61.11	7.27	68.38	Mg5Al2Si3O10(OH)8
Chrysotile	-30.99	1.21	32.20	Mg3Si2O5(OH)4
Fe(OH)3(a)	-11.12	6.79	17.91	Fe(OH)3
Gibbsite	-5.87	2.24	8.11	Al(OH)3
Goethite	-5.23	6.79	12.02	FeOOH
Gypsum	-0.05	-4.63	-4.58	CaSO4:2H2O
H2(g)	-12.50	-12.50	0.00	H2
Hematite	-8.44	13.59	22.03	Fe2O3
Illite	-14.81	-2.94	11.86	K0.6Mg0.25Al2.3Si3.5O10(OH)2
Jarosite-K	-23.45	6.40	29.85	KFe3(SO4)2(OH)6
K-feldspar	-7.56	-5.47	2.09	KAlSi3O8
K-mica	-13.69	-0.99	12.70	KAl3Si3O10(OH)2
Kaolinite	-7.62	-0.18	7.43	Al2Si2O5(OH)4

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

Melanterite	-3.89	-6.10	-2.21	FeSO4:7H2O	
O2(g)	-58.12	25.00	83.12	O2	
Quartz	1.65	-2.33	-3.98	SiO2	
Sepiolite	-18.84	-3.08	15.76	Mg2Si3O7.5OH:3H2O	
Sepiolite(d)	-21.74	-3.08	18.66	Mg2Si3O7.5OH:3H2O	
SiO2(a)	0.38	-2.33	-2.71	SiO2	
Talc	-24.85	-3.45	21.40	Mg3Si4O10(OH)2	
Initial solution 2. Injection Average					
-----Solution composition-----					
Elements	Molality	Moles			
Al	1.372e-03	1.372e-03			
Ca	1.375e-02	1.375e-02			
Cl	5.391e-02	5.391e-02			
Fe	4.714e-04	4.714e-04			
K	1.532e-03	1.532e-03			
Mg	1.258e-02	1.258e-02			
Na	6.244e-02	6.244e-02			
S(6)	4.342e-02	4.342e-02			
Si	4.467e-03	4.467e-03			
-----Description of solution-----					
	pH	= 2.070			
	pe	= 4.000			
	Activity of water	= 0.997			
	Ionic strength	= 1.493e-01			
	Mass of water (kg)	= 1.000e+00			
	Total alkalinity (eq/kg)	= -1.847e-02			
	Total carbon (mol/kg)	= 0.000e+00			
	Total CO2 (mol/kg)	= 0.000e+00			
	Temperature (deg C)	= 25.000			
	Electrical balance (eq)	= -6.110e-04			
	Iterations	= 7			
	Total H	= 1.110488e+02			
	Total O	= 5.569777e+01			
-----Distribution of species-----					
Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	1.052e-02	8.511e-03	-1.978	-2.070	-0.092
OH-	1.606e-12	1.172e-12	-11.794	-11.931	-0.137
H2O	5.551e+01	9.967e-01	-0.001	-0.001	0.000
Al	1.372e-03				
AlSO4+	9.433e-04	7.164e-04	-3.025	-3.145	-0.120
Al(SO4)2-	2.171e-04	1.649e-04	-3.663	-3.783	-0.120
Al+3	2.100e-04	3.112e-05	-3.678	-4.507	-0.829
AlHSO4+2	1.625e-06	5.406e-07	-5.789	-6.267	-0.478
AlOH+2	1.088e-07	3.620e-08	-6.963	-7.441	-0.478
Al(OH)2+	4.376e-11	3.323e-11	-10.359	-10.478	-0.120
Al(OH)3	5.540e-16	5.734e-16	-15.256	-15.242	0.015
Al(OH)4-	1.666e-19	1.266e-19	-18.778	-18.898	-0.120
Ca	1.375e-02				
Ca+2	9.235e-03	3.214e-03	-2.035	-2.493	-0.458
CaSO4	4.510e-03	4.668e-03	-2.346	-2.331	0.015
CaOH+	8.226e-14	6.247e-14	-13.085	-13.204	-0.120
Cl	5.391e-02				
Cl-	5.390e-02	3.955e-02	-1.268	-1.403	-0.134
FeCl+	8.023e-06	6.093e-06	-5.096	-5.215	-0.120
FeCl+2	3.827e-13	1.273e-13	-12.417	-12.895	-0.478
FeCl2+	2.962e-14	2.249e-14	-13.528	-13.648	-0.120
FeCl3	8.595e-17	8.896e-17	-16.066	-16.051	0.015
Fe(2)	4.714e-04				
Fe+2	3.132e-04	1.116e-04	-3.504	-3.952	-0.448
FeSO4	1.396e-04	1.445e-04	-3.855	-3.840	0.015
FeHSO4+	1.064e-05	8.082e-06	-4.973	-5.093	-0.120
FeCl+	8.023e-06	6.093e-06	-5.096	-5.215	-0.120
FeOH+	5.442e-12	4.133e-12	-11.264	-11.384	-0.120
Fe(3)	1.494e-11				
FeSO4+	1.120e-11	8.506e-12	-10.951	-11.070	-0.120
Fe(SO4)2-	1.784e-12	1.354e-12	-11.749	-11.868	-0.120
Fe+3	7.191e-13	1.066e-13	-12.143	-12.972	-0.829
FeHSO4+2	5.828e-13	1.939e-13	-12.234	-12.713	-0.478
FeCl+2	3.827e-13	1.273e-13	-12.417	-12.895	-0.478
FeOH+2	2.423e-13	8.059e-14	-12.616	-13.094	-0.478
FeCl2+	2.962e-14	2.249e-14	-13.528	-13.648	-0.120
Fe(OH)2+	4.115e-15	3.125e-15	-14.386	-14.505	-0.120
FeCl3	8.595e-17	8.896e-17	-16.066	-16.051	0.015
Fe(OH)3	4.555e-20	4.714e-20	-19.342	-19.327	0.015
Fe2(OH)2+4	1.428e-23	1.748e-25	-22.845	-24.757	-1.912
Fe(OH)4-	6.630e-27	5.035e-27	-26.178	-26.298	-0.120
Fe3(OH)4+5	1.109e-34	1.141e-37	-33.955	-36.943	-2.988
H(0)	9.910e-16				
H2	4.955e-16	5.129e-16	-15.305	-15.290	0.015
K	1.532e-03				
K+	1.459e-03	1.071e-03	-2.836	-2.970	-0.134
KSO4-	7.265e-05	5.518e-05	-4.139	-4.258	-0.120
KOH	4.201e-16	4.348e-16	-15.377	-15.362	0.015
Mg	1.258e-02				

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

Mg+2	7.833e-03	2.877e-03	-2.106	-2.541	-0.435
MgSO4	4.742e-03	4.908e-03	-2.324	-2.309	0.015
MgOH+	1.611e-12	1.223e-12	-11.793	-11.913	-0.120
Na	6.244e-02				
Na+	6.025e-02	4.573e-02	-1.220	-1.340	-0.120
NaSO4-	2.197e-03	1.668e-03	-2.658	-2.778	-0.120
NaOH	3.419e-14	3.538e-14	-13.466	-13.451	0.015
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-61.818	-61.803	0.015
S(6)	4.342e-02				
SO4-2	2.244e-02	7.279e-03	-1.649	-2.138	-0.489
HSO4-	7.931e-03	6.023e-03	-2.101	-2.220	-0.120
MgSO4	4.742e-03	4.908e-03	-2.324	-2.309	0.015
CaSO4	4.510e-03	4.668e-03	-2.346	-2.331	0.015
NaSO4-	2.197e-03	1.668e-03	-2.658	-2.778	-0.120
AlSO4+	9.433e-04	7.164e-04	-3.025	-3.145	-0.120
Al(SO4)2-	2.171e-04	1.649e-04	-3.663	-3.783	-0.120
FeSO4	1.396e-04	1.445e-04	-3.855	-3.840	0.015
KSO4-	7.265e-05	5.518e-05	-4.139	-4.258	-0.120
FeHSO4+	1.064e-05	8.082e-06	-4.973	-5.093	-0.120
AlHSO4+2	1.625e-06	5.406e-07	-5.789	-6.267	-0.478
FeSO4+	1.120e-11	8.506e-12	-10.951	-11.070	-0.120
Fe(SO4)2-	1.784e-12	1.354e-12	-11.749	-11.868	-0.120
FeHSO4+2	5.828e-13	1.939e-13	-12.234	-12.713	-0.478
Si	4.467e-03				
H4SiO4	4.467e-03	4.623e-03	-2.350	-2.335	0.015
H3SiO4-	1.055e-10	8.009e-11	-9.977	-10.096	-0.120
H2SiO4-2	1.924e-21	6.401e-22	-20.716	-21.194	-0.478

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-9.10	1.70	10.80	Al(OH)3
Albite	-9.23	-4.57	4.66	NaAlSi3O8
Alunite	-6.96	-8.36	-1.40	KAl3(SO4)2(OH)6
Anhydrite	-0.27	-4.63	-4.36	CaSO4
Anorthite	-25.23	0.38	25.62	CaAl2Si2O8
Ca-Montmorillonite	-12.11	-4.33	7.78	Ca0.165Al2.33Si3.67O10(OH)2
Chalcedony	1.22	-2.33	-3.55	SiO2
Chlorite(14A)	-63.99	4.39	68.38	Mg5Al2Si3O10(OH)8
Chrysotile	-32.08	0.13	32.20	Mg3Si2O5(OH)4
Fe(OH)3(a)	-11.66	6.25	17.91	Fe(OH)3
Gibbsite	-6.41	1.70	8.11	Al(OH)3
Goethite	-5.77	6.25	12.02	FeOOH
Gypsum	-0.05	-4.63	-4.58	CaSO4:2H2O
H2(g)	-12.14	-12.14	0.00	H2
Hematite	-9.52	12.51	22.03	Fe2O3
Illite	-16.26	-4.39	11.86	K0.6Mg0.25Al2.3Si3.5O10(OH)2
Jarosite-K	-24.54	5.31	29.85	KFe3(SO4)2(OH)6
K-feldspar	-8.29	-6.20	2.09	KAlSi3O8
K-mica	-15.50	-2.80	12.70	KAl3Si3O10(OH)2
Kaolinite	-8.70	-1.27	7.43	Al2Si2O5(OH)4
Melanterite	-3.89	-6.10	-2.21	FeSO4:7H2O
O2(g)	-58.84	24.28	83.12	O2
Quartz	1.65	-2.33	-3.98	SiO2
Sepiolite	-19.57	-3.81	15.76	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-22.47	-3.81	18.66	Mg2Si3O7.5OH:3H2O
SiO2(a)	0.38	-2.33	-2.71	SiO2
Talc	-25.94	-4.54	21.40	Mg3Si4O10(OH)2

Initial solution 3. North Beverley Groundwater Quality

-----Solution composition-----

Elements	Molality	Moles
Ca	9.500e-03	9.500e-03
S(6)	1.669e-02	1.669e-02

-----Description of solution-----

pH	=	7.000
pe	=	4.000
Activity of water	=	1.000
Ionic strength	=	3.740e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	-6.432e-08
Total carbon (mol/kg)	=	0.000e+00
Total CO2 (mol/kg)	=	0.000e+00
Temperature (deg C)	=	25.000
Electrical balance (eq)	=	-1.438e-02
Iterations	=	5
Total H	=	1.110124e+02
Total O	=	5.557297e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
OH-	1.205e-07	1.001e-07	-6.919	-7.000	-0.081
H+	1.156e-07	1.000e-07	-6.937	-7.000	-0.063
H2O	5.551e+01	9.996e-01	0.000	0.000	0.000
Ca	9.500e-03				
Ca+2	5.756e-03	2.927e-03	-2.240	-2.534	-0.294

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

CaSO4	3.744e-03	3.776e-03	-2.427	-2.423	0.004
CaOH+	5.798e-09	4.855e-09	-8.237	-8.314	-0.077
H(0)	1.404e-25				
H2	7.019e-26	7.079e-26	-25.154	-25.150	0.004
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-42.084	-42.080	0.004
S(6)	1.669e-02				
SO4-2	1.294e-02	6.467e-03	-1.888	-2.189	-0.301
CaSO4	3.744e-03	3.776e-03	-2.427	-2.423	0.004
HSO4-	7.508e-08	6.287e-08	-7.124	-7.202	-0.077

Saturation indices

Phase	SI	log IAP	log KT	
Anhydrite	-0.36	-4.72	-4.36	CaSO4
Gypsum	-0.14	-4.72	-4.58	CaSO4:2H2O
H2(g)	-22.00	-22.00	0.00	H2
O2(g)	-39.12	44.00	83.12	O2

Initial solution 4. Central Beverley Groundwater Quality

Solution composition

Elements	Molality	Moles
Ca	1.526e-02	1.526e-02
S(6)	2.192e-02	2.192e-02

Description of solution

pH	=	7.000
pe	=	4.000
Activity of water	=	0.999
Ionic strength	=	4.968e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	-7.130e-08
Total carbon (mol/kg)	=	0.000e+00
Total CO2 (mol/kg)	=	0.000e+00
Temperature (deg C)	=	25.000
Electrical balance (eq)	=	-1.332e-02
Iterations	=	5
Total H	=	1.110124e+02
Total O	=	5.559390e+01

Distribution of species

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
OH-	1.233e-07	1.001e-07	-6.909	-7.000	-0.091
H+	1.171e-07	1.000e-07	-6.931	-7.000	-0.069
H2O	5.551e+01	9.995e-01	0.000	0.000	0.000
Ca	1.526e-02				
Ca+2	9.090e-03	4.299e-03	-2.041	-2.367	-0.325
CaSO4	6.171e-03	6.242e-03	-2.210	-2.205	0.005
CaOH+	8.683e-09	7.131e-09	-8.061	-8.147	-0.085
H(0)	1.400e-25				
H2	6.999e-26	7.079e-26	-25.155	-25.150	0.005
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-42.085	-42.080	0.005
S(6)	2.192e-02				
SO4-2	1.575e-02	7.276e-03	-1.803	-2.138	-0.335
CaSO4	6.171e-03	6.242e-03	-2.210	-2.205	0.005
HSO4-	8.613e-08	7.074e-08	-7.065	-7.150	-0.085

Saturation indices

Phase	SI	log IAP	log KT	
Anhydrite	-0.14	-4.50	-4.36	CaSO4
Gypsum	0.08	-4.51	-4.58	CaSO4:2H2O
H2(g)	-22.00	-22.00	0.00	H2
O2(g)	-39.12	44.00	83.12	O2

Initial solution 5. South Beverley Groundwater Quality

Solution composition

Elements	Molality	Moles
Ca	2.128e-02	2.128e-02
S(6)	2.611e-02	2.611e-02

Description of solution

pH	=	6.800
pe	=	4.000
Activity of water	=	0.999
Ionic strength	=	6.047e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	-2.464e-07
Total carbon (mol/kg)	=	0.000e+00
Total CO2 (mol/kg)	=	0.000e+00
Temperature (deg C)	=	25.000
Electrical balance (eq)	=	-9.666e-03
Iterations	=	6
Total H	=	1.110124e+02
Total O	=	5.561066e+01

Distribution of species

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	1.874e-07	1.585e-07	-6.727	-6.800	-0.073
OH-	7.909e-08	6.312e-08	-7.102	-7.200	-0.098

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

H2O	5.551e+01	9.993e-01	0.000	0.000	0.000
Ca	2.128e-02				
Ca+2	1.270e-02	5.700e-03	-1.896	-2.244	-0.348
CaSO4	8.579e-03	8.699e-03	-2.067	-2.061	0.006
CaOH+	7.365e-09	5.965e-09	-8.133	-8.224	-0.092
H(0)	3.507e-25				
H2	1.754e-25	1.778e-25	-24.756	-24.750	0.006
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-42.887	-42.881	0.006
S(6)	2.611e-02				
SO4-2	1.753e-02	7.648e-03	-1.756	-2.116	-0.360
CaSO4	8.579e-03	8.699e-03	-2.067	-2.061	0.006
HSO4-	1.455e-07	1.179e-07	-6.837	-6.929	-0.092

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Anhydrite	0.00	-4.36	-4.36	CaSO4
Gypsum	0.22	-4.36	-4.58	CaSO4:2H2O
H2(g)	-21.60	-21.60	0.00	H2
O2(g)	-39.92	43.20	83.12	O2

Initial solution 6. North Beverley - ISL Phase

-----Solution composition-----

Elements	Molality	Moles
Ca	1.371e-02	1.371e-02
S(6)	4.088e-02	4.088e-02

-----Description of solution-----

pH	=	2.250
pe	=	4.000
Activity of water	=	0.999
Ionic strength	=	7.518e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	-1.423e-02
Total carbon (mol/kg)	=	0.000e+00
Total CO2 (mol/kg)	=	0.000e+00
Temperature (deg C)	=	25.000
Electrical balance (eq)	=	-4.012e-02
Iterations	=	6
Total H	=	1.110267e+02
Total O	=	5.566975e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	6.720e-03	5.623e-03	-2.173	-2.250	-0.077
OH-	2.273e-12	1.779e-12	-11.643	-11.750	-0.106
H2O	5.551e+01	9.991e-01	0.000	0.000	0.000
Ca	1.371e-02				
Ca+2	7.184e-03	3.037e-03	-2.144	-2.518	-0.374
CaSO4	6.525e-03	6.639e-03	-2.185	-2.178	0.008
CaOH+	1.123e-13	8.955e-14	-12.950	-13.048	-0.098
H(0)	4.401e-16				
H2	2.200e-16	2.239e-16	-15.658	-15.650	0.008
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-61.088	-61.081	0.008
S(6)	4.088e-02				
SO4-2	2.685e-02	1.096e-02	-1.571	-1.960	-0.389
HSO4-	7.513e-03	5.990e-03	-2.124	-2.223	-0.098
CaSO4	6.525e-03	6.639e-03	-2.185	-2.178	0.008

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Anhydrite	-0.12	-4.48	-4.36	CaSO4
Gypsum	0.10	-4.48	-4.58	CaSO4:2H2O
H2(g)	-12.50	-12.50	0.00	H2
O2(g)	-58.12	25.00	83.12	O2

Initial solution 7. North Beverley - Waste Injection

-----Solution composition-----

Elements	Molality	Moles
Ca	1.369e-02	1.369e-02
S(6)	4.325e-02	4.325e-02

-----Description of solution-----

pH	=	2.070
pe	=	4.000
Activity of water	=	0.999
Ionic strength	=	7.718e-02
Mass of water (kg)	=	1.000e+00
Total alkalinity (eq/kg)	=	-2.111e-02
Total carbon (mol/kg)	=	0.000e+00
Total CO2 (mol/kg)	=	0.000e+00
Temperature (deg C)	=	25.000
Electrical balance (eq)	=	-3.801e-02
Iterations	=	6
Total H	=	1.110335e+02
Total O	=	5.567920e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	1.018e-02	8.511e-03	-1.992	-2.070	-0.078
OH-	1.505e-12	1.175e-12	-11.822	-11.930	-0.108
H2O	5.551e+01	9.990e-01	0.000	0.000	0.000
Ca	1.369e-02				
Ca+2	7.340e-03	3.081e-03	-2.134	-2.511	-0.377
CaSO4	6.347e-03	6.461e-03	-2.197	-2.190	0.008
CaOH+	7.541e-14	6.001e-14	-13.123	-13.222	-0.099
H(0)	1.008e-15				
H2	5.038e-16	5.129e-16	-15.298	-15.290	0.008
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-61.809	-61.801	0.008
S(6)	4.325e-02				
SO4-2	2.597e-02	1.051e-02	-1.586	-1.978	-0.393
HSO4-	1.093e-02	8.698e-03	-1.961	-2.061	-0.099
CaSO4	6.347e-03	6.461e-03	-2.197	-2.190	0.008

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Anhydrite	-0.13	-4.49	-4.36	CaSO4
Gypsum	0.09	-4.49	-4.58	CaSO4:2H2O
H2(g)	-12.14	-12.14	0.00	H2
O2(g)	-58.84	24.28	83.12	O2

Initial solution 8. North Beverley - Alkaline Leach Analysis

-----Solution composition-----

Elements	Molality	Moles
Alkalinity	4.933e-02	4.933e-02
Ca	9.513e-03	9.513e-03

-----Description of solution-----

pH = 6.500
 pe = 4.000
 Activity of water = 0.999
 Ionic strength = 3.920e-02
 Mass of water (kg) = 1.000e+00
 Total carbon (mol/kg) = 7.722e-02
 Total CO2 (mol/kg) = 7.722e-02
 Temperature (deg C) = 25.000
 Electrical balance (eq) = -3.031e-02
 Iterations = 7
 Total H = 1.110617e+02
 Total O = 5.570995e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	3.663e-07	3.162e-07	-6.436	-6.500	-0.064
OH-	3.821e-08	3.161e-08	-7.418	-7.500	-0.082
H2O	5.551e+01	9.986e-01	-0.001	-0.001	0.000
C(4)	7.722e-02				
HCO3-	4.704e-02	3.959e-02	-1.328	-1.402	-0.075
CO2	2.794e-02	2.819e-02	-1.554	-1.550	0.004
CaHCO3+	2.196e-03	1.848e-03	-2.658	-2.733	-0.075
CaCO3	3.577e-05	3.610e-05	-4.446	-4.443	0.004
CO3-2	1.170e-05	5.872e-06	-4.932	-5.231	-0.299
Ca	9.513e-03				
Ca+2	7.281e-03	3.659e-03	-2.138	-2.437	-0.299
CaHCO3+	2.196e-03	1.848e-03	-2.658	-2.733	-0.075
CaCO3	3.577e-05	3.610e-05	-4.446	-4.443	0.004
CaOH+	2.297e-09	1.918e-09	-8.639	-8.717	-0.078
H(0)	1.403e-24				
H2	7.016e-25	7.079e-25	-24.154	-24.150	0.004
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-44.085	-44.081	0.004

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Aragonite	0.67	-7.67	-8.34	CaCO3
Calcite	0.81	-7.67	-8.48	CaCO3
CO2(g)	-0.08	-18.23	-18.15	CO2
H2(g)	-21.00	-21.00	0.00	H2
O2(g)	-41.12	42.00	83.12	O2

Initial solution 9. Central Beverley - Alkaline Leach Analysis

-----Solution composition-----

Elements	Molality	Moles
Alkalinity	4.934e-02	4.934e-02
Ca	1.527e-02	1.527e-02

-----Description of solution-----

pH = 6.500
 pe = 4.000
 Activity of water = 0.999
 Ionic strength = 4.844e-02
 Mass of water (kg) = 1.000e+00
 Total carbon (mol/kg) = 7.611e-02
 Total CO2 (mol/kg) = 7.611e-02

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

Temperature (deg C) = 25.000
 Electrical balance (eq) = -1.879e-02
 Iterations = 7
 Total H = 1.110616e+02
 Total O = 5.570771e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	3.699e-07	3.162e-07	-6.432	-6.500	-0.068
OH-	3.886e-08	3.161e-08	-7.410	-7.500	-0.090
H2O	5.551e+01	9.985e-01	-0.001	-0.001	0.000
C(4)	7.611e-02				
HCO3-	4.589e-02	3.810e-02	-1.338	-1.419	-0.081
CO2	2.683e-02	2.713e-02	-1.571	-1.567	0.005
CaHCO3+	3.318e-03	2.755e-03	-2.479	-2.560	-0.081
CaCO3	5.319e-05	5.379e-05	-4.274	-4.269	0.005
CO3-2	1.190e-05	5.650e-06	-4.925	-5.248	-0.323
Ca	1.527e-02				
Ca+2	1.190e-02	5.667e-03	-1.924	-2.247	-0.322
CaHCO3+	3.318e-03	2.755e-03	-2.479	-2.560	-0.081
CaCO3	5.319e-05	5.379e-05	-4.274	-4.269	0.005
CaOH+	3.609e-09	2.970e-09	-8.443	-8.527	-0.085
H(0)	1.400e-24				
H2	7.001e-25	7.079e-25	-24.155	-24.150	0.005
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-44.086	-44.081	0.005

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Aragonite	0.84	-7.49	-8.34	CaCO3
Calcite	0.99	-7.49	-8.48	CaCO3
CO2(g)	-0.10	-18.25	-18.15	CO2
H2(g)	-21.00	-21.00	0.00	H2
O2(g)	-41.12	42.00	83.12	O2

Initial solution 10. South Beverley - Alkaline Leach Analysis

-----Solution composition-----

Elements	Molality	Moles
Alkalinity	4.935e-02	4.935e-02
Ca	2.129e-02	2.129e-02

-----Description of solution-----

pH = 6.500
 pe = 4.000
 Activity of water = 0.998
 Ionic strength = 5.833e-02
 Mass of water (kg) = 1.000e+00
 Total carbon (mol/kg) = 7.509e-02
 Total CO2 (mol/kg) = 7.509e-02
 Temperature (deg C) = 25.000
 Electrical balance (eq) = -6.776e-03
 Iterations = 7
 Total H = 1.110616e+02
 Total O = 5.570567e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	3.732e-07	3.162e-07	-6.428	-6.500	-0.072
OH-	3.948e-08	3.161e-08	-7.404	-7.500	-0.097
H2O	5.551e+01	9.984e-01	-0.001	-0.001	0.000
C(4)	7.509e-02				
HCO3-	4.482e-02	3.674e-02	-1.348	-1.435	-0.086
CO2	2.581e-02	2.616e-02	-1.588	-1.582	0.006
CaHCO3+	4.368e-03	3.580e-03	-2.360	-2.446	-0.086
CaCO3	6.898e-05	6.992e-05	-4.161	-4.155	0.006
CO3-2	1.207e-05	5.449e-06	-4.918	-5.264	-0.345
Ca	2.129e-02				
Ca+2	1.685e-02	7.638e-03	-1.773	-2.117	-0.344
CaHCO3+	4.368e-03	3.580e-03	-2.360	-2.446	-0.086
CaCO3	6.898e-05	6.992e-05	-4.161	-4.155	0.006
CaOH+	4.929e-09	4.002e-09	-8.307	-8.398	-0.090
H(0)	1.397e-24				
H2	6.985e-25	7.079e-25	-24.156	-24.150	0.006
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-44.087	-44.081	0.006

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Aragonite	0.96	-7.38	-8.34	CaCO3
Calcite	1.10	-7.38	-8.48	CaCO3
CO2(g)	-0.11	-18.26	-18.15	CO2
H2(g)	-21.00	-21.00	0.00	H2
O2(g)	-41.12	42.00	83.12	O2

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

Initial solution 11. North Beverley - Alkaline Leach Analysis					
-----Solution composition-----					
Elements	Molality	Moles			
Alkalinity	4.933e-02	4.933e-02			
Ca	9.513e-03	9.513e-03			
-----Description of solution-----					
pH =		7.200			
pe =		4.000			
Activity of water =		0.999			
Ionic strength =		3.891e-02			
Mass of water (kg) =		1.000e+00			
Total carbon (mol/kg) =		5.463e-02			
Total CO2 (mol/kg) =		5.463e-02			
Temperature (deg C) =		25.000			
Electrical balance (eq) =		-3.031e-02			
Iterations =		7			
Total H =		1.110613e+02			
Total O =		5.566458e+01			
-----Distribution of species-----					
Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
OH-	1.915e-07	1.585e-07	-6.718	-6.800	-0.082
H+	7.305e-08	6.310e-08	-7.136	-7.200	-0.064
H2O	5.551e+01	9.989e-01	0.000	0.000	0.000
C(4)	5.463e-02				
HCO3-	4.671e-02	3.933e-02	-1.331	-1.405	-0.075
CO2	5.536e-03	5.586e-03	-2.257	-2.253	0.004
CaHCO3+	2.155e-03	1.815e-03	-2.667	-2.741	-0.075
CaCO3	1.760e-04	1.776e-04	-3.754	-3.751	0.004
CO3-2	5.814e-05	2.923e-05	-4.236	-4.534	-0.299
Ca	9.513e-03				
Ca+2	7.182e-03	3.616e-03	-2.144	-2.442	-0.298
CaHCO3+	2.155e-03	1.815e-03	-2.667	-2.741	-0.075
CaCO3	1.760e-04	1.776e-04	-3.754	-3.751	0.004
CaOH+	1.138e-08	9.502e-09	-7.944	-8.022	-0.078
H(0)	5.586e-26				
H2	2.793e-26	2.818e-26	-25.554	-25.550	0.004
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-41.285	-41.281	0.004
-----Saturation indices-----					
Phase	SI	log IAP	log KT		
Aragonite	1.36	-6.98	-8.34	CaCO3	
Calcite	1.50	-6.98	-8.48	CaCO3	
CO2(g)	-0.78	-18.93	-18.15	CO2	
H2(g)	-22.40	-22.40	0.00	H2	
O2(g)	-38.32	44.80	83.12	O2	
Initial solution 12. Central Beverley - Alkaline Leach Analysis					
-----Solution composition-----					
Elements	Molality	Moles			
Alkalinity	4.934e-02	4.934e-02			
Ca	1.527e-02	1.527e-02			
-----Description of solution-----					
pH =		7.200			
pe =		4.000			
Activity of water =		0.999			
Ionic strength =		4.799e-02			
Mass of water (kg) =		1.000e+00			
Total carbon (mol/kg) =		5.432e-02			
Total CO2 (mol/kg) =		5.432e-02			
Temperature (deg C) =		25.000			
Electrical balance (eq) =		-1.879e-02			
Iterations =		7			
Total H =		1.110611e+02			
Total O =		5.566389e+01			
-----Distribution of species-----					
Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
OH-	1.947e-07	1.585e-07	-6.711	-6.800	-0.089
H+	7.377e-08	6.310e-08	-7.132	-7.200	-0.068
H2O	5.551e+01	9.989e-01	0.000	0.000	0.000
C(4)	5.432e-02				
HCO3-	4.545e-02	3.775e-02	-1.342	-1.423	-0.081
CO2	5.303e-03	5.361e-03	-2.276	-2.271	0.005
CaHCO3+	3.254e-03	2.703e-03	-2.488	-2.568	-0.081
CaCO3	2.616e-04	2.645e-04	-3.582	-3.578	0.005
CO3-2	5.894e-05	2.806e-05	-4.230	-4.552	-0.322
Ca	1.527e-02				
Ca+2	1.176e-02	5.612e-03	-1.930	-2.251	-0.321
CaHCO3+	3.254e-03	2.703e-03	-2.488	-2.568	-0.081
CaCO3	2.616e-04	2.645e-04	-3.582	-3.578	0.005
CaOH+	1.791e-08	1.474e-08	-7.747	-7.831	-0.084
H(0)	5.575e-26				
H2	2.787e-26	2.818e-26	-25.555	-25.550	0.005
O(0)	0.000e+00				

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

O2	0.000e+00	0.000e+00	-41.286	-41.281	0.005
----	-----------	-----------	---------	---------	-------

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Aragonite	1.53	-6.80	-8.34	CaCO3
Calcite	1.68	-6.80	-8.48	CaCO3
CO2(g)	-0.80	-18.95	-18.15	CO2
H2(g)	-22.40	-22.40	0.00	H2
O2(g)	-38.32	44.80	83.12	O2

Initial solution 13. South Beverley - Alkaline Leach Analysis

-----Solution composition-----

Elements	Molality	Moles
Alkalinity	4.935e-02	4.935e-02
Ca	2.129e-02	2.129e-02

-----Description of solution-----

pH = 7.200
 pe = 4.000
 Activity of water = 0.999
 Ionic strength = 5.774e-02
 Mass of water (kg) = 1.000e+00
 Total carbon (mol/kg) = 5.405e-02
 Total CO2 (mol/kg) = 5.405e-02
 Temperature (deg C) = 25.000
 Electrical balance (eq) = -6.776e-03
 Iterations = 7
 Total H = 1.110610e+02
 Total O = 5.566327e+01

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
OH-	1.978e-07	1.585e-07	-6.704	-6.800	-0.096
H+	7.443e-08	6.310e-08	-7.128	-7.200	-0.072
H2O	5.551e+01	9.988e-01	-0.001	-0.001	0.000
C(4)	5.405e-02				
HCO3-	4.428e-02	3.632e-02	-1.354	-1.440	-0.086
CO2	5.090e-03	5.158e-03	-2.293	-2.287	0.006
CaHCO3+	4.280e-03	3.511e-03	-2.369	-2.455	-0.086
CaCO3	3.390e-04	3.436e-04	-3.470	-3.464	0.006
CO3-2	5.963e-05	2.699e-05	-4.224	-4.569	-0.344
Ca	2.129e-02				
Ca+2	1.667e-02	7.576e-03	-1.778	-2.121	-0.342
CaHCO3+	4.280e-03	3.511e-03	-2.369	-2.455	-0.086
CaCO3	3.390e-04	3.436e-04	-3.470	-3.464	0.006
CaOH+	2.449e-08	1.990e-08	-7.611	-7.701	-0.090
H(0)	5.562e-26				
H2	2.781e-26	2.818e-26	-25.556	-25.550	0.006
O(0)	0.000e+00				
O2	0.000e+00	0.000e+00	-41.287	-41.281	0.006

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Aragonite	1.65	-6.69	-8.34	CaCO3
Calcite	1.79	-6.69	-8.48	CaCO3
CO2(g)	-0.82	-18.97	-18.15	CO2
H2(g)	-22.40	-22.40	0.00	H2
O2(g)	-38.32	44.80	83.12	O2

Initial solution 14. - FLT Background/Native Groundwater Quality

-----Solution composition-----

Elements	Molality	Moles
Al	8.197e-06	8.197e-06
Ca	9.289e-03	9.289e-03
Cl	5.638e-02	5.638e-02
Fe	1.332e-05	1.332e-05
K	1.085e-03	1.085e-03
Mg	8.195e-03	8.195e-03
Na	5.196e-02	5.196e-02
S(6)	1.595e-02	1.595e-02

-----Description of solution-----

pH = 8.310
 pe = 4.000
 Activity of water = 0.998
 Ionic strength = 1.023e-01
 Mass of water (kg) = 1.000e+00
 Total alkalinity (eq/kg) = 5.322e-05
 Total carbon (mol/kg) = 0.000e+00
 Total CO2 (mol/kg) = 0.000e+00
 Temperature (deg C) = 25.000
 Electrical balance (eq) = -2.851e-04
 Iterations = 8
 Total H = 1.110125e+02
 Total O = 5.557011e+01

-----Distribution of species-----						
Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	
OH-	2.685e-06	2.039e-06	-5.571	-5.691	-0.119	
H+	5.942e-09	4.898e-09	-8.226	-8.310	-0.084	
H2O	5.551e+01	9.977e-01	-0.001	-0.001	0.000	
Al	8.197e-06					
Al(OH)4-	8.180e-06	6.377e-06	-5.087	-5.195	-0.108	
Al(OH)3	1.622e-08	1.661e-08	-7.790	-7.780	0.010	
Al(OH)2+	7.099e-10	5.535e-10	-9.149	-9.257	-0.108	
AlOH+2	9.385e-13	3.467e-13	-12.028	-12.460	-0.433	
AlSO4+	2.726e-15	2.125e-15	-14.565	-14.673	-0.108	
Al+3	9.762e-16	1.713e-16	-15.010	-15.766	-0.756	
Al(SO4)2-	3.380e-16	2.635e-16	-15.471	-15.579	-0.108	
AlHSO4+2	2.498e-24	9.228e-25	-23.602	-24.035	-0.433	
Ca	9.289e-03					
Ca+2	7.166e-03	2.778e-03	-2.145	-2.556	-0.412	
CaSO4	2.123e-03	2.174e-03	-2.673	-2.663	0.010	
CaOH+	1.205e-07	9.391e-08	-6.919	-7.027	-0.108	
Cl	5.638e-02					
Cl-	5.638e-02	4.297e-02	-1.249	-1.367	-0.118	
FeCl+	3.603e-10	2.809e-10	-9.443	-9.551	-0.108	
FeCl+2	1.589e-17	5.869e-18	-16.799	-17.231	-0.433	
FeCl2+	1.445e-18	1.127e-18	-17.840	-17.948	-0.108	
FeCl3	4.729e-21	4.842e-21	-20.325	-20.315	0.010	
Fe(2)	1.589e-08					
Fe+2	1.192e-08	4.736e-09	-7.924	-8.325	-0.401	
FeSO4	3.226e-09	3.303e-09	-8.491	-8.481	0.010	
FeOH+	3.913e-10	3.050e-10	-9.408	-9.516	-0.108	
FeCl+	3.603e-10	2.809e-10	-9.443	-9.551	-0.108	
FeHSO4+	1.364e-16	1.063e-16	-15.865	-15.973	-0.108	
Fe(3)	1.331e-05					
Fe(OH)3	1.028e-05	1.053e-05	-4.988	-4.978	0.010	
Fe(OH)4-	2.509e-06	1.956e-06	-5.601	-5.709	-0.108	
Fe(OH)2+	5.146e-07	4.012e-07	-6.289	-6.397	-0.108	
FeOH+2	1.610e-11	5.948e-12	-10.793	-11.226	-0.433	
FeSO4+	2.494e-16	1.945e-16	-15.603	-15.711	-0.108	
Fe+3	2.577e-17	4.522e-18	-16.589	-17.345	-0.756	
Fe(SO4)2-	2.140e-17	1.669e-17	-16.670	-16.778	-0.108	
FeCl+2	1.589e-17	5.869e-18	-16.799	-17.231	-0.433	
FeCl2+	1.445e-18	1.127e-18	-17.840	-17.948	-0.108	
Fe2(OH)2+4	5.114e-20	9.521e-22	-19.291	-21.021	-1.730	
FeCl3	4.729e-21	4.842e-21	-20.325	-20.315	0.010	
Fe3(OH)4+5	4.029e-23	7.981e-26	-22.395	-25.098	-2.703	
FeHSO4+2	6.904e-24	2.551e-24	-23.161	-23.593	-0.433	
H(0)	3.317e-28					
H2	1.659e-28	1.698e-28	-27.780	-27.770	0.010	
K	1.085e-03					
K+	1.056e-03	8.050e-04	-2.976	-3.094	-0.118	
KSO4-	2.867e-05	2.235e-05	-4.543	-4.651	-0.108	
KOH	5.553e-10	5.685e-10	-9.255	-9.245	0.010	
Mg	8.195e-03					
Mg+2	6.012e-03	2.429e-03	-2.221	-2.615	-0.394	
MgSO4	2.181e-03	2.233e-03	-2.661	-2.651	0.010	
MgOH+	2.304e-06	1.796e-06	-5.638	-5.746	-0.108	
Na	5.196e-02					
Na+	5.096e-02	3.980e-02	-1.293	-1.400	-0.107	
NaSO4-	1.003e-03	7.823e-04	-2.999	-3.107	-0.108	
NaOH	5.231e-08	5.356e-08	-7.281	-7.271	0.010	
O(0)	2.810e-37					
O2	1.405e-37	1.439e-37	-36.852	-36.842	0.010	
S(6)	1.595e-02					
SO4-2	1.062e-02	3.922e-03	-1.974	-2.407	-0.433	
MgSO4	2.181e-03	2.233e-03	-2.661	-2.651	0.010	
CaSO4	2.123e-03	2.174e-03	-2.673	-2.663	0.010	
NaSO4-	1.003e-03	7.823e-04	-2.999	-3.107	-0.108	
KSO4-	2.867e-05	2.235e-05	-4.543	-4.651	-0.108	
FeSO4	3.226e-09	3.303e-09	-8.491	-8.481	0.010	
HSO4-	2.395e-09	1.867e-09	-8.621	-8.729	-0.108	
AlSO4+	2.726e-15	2.125e-15	-14.565	-14.673	-0.108	
Al(SO4)2-	3.380e-16	2.635e-16	-15.471	-15.579	-0.108	
FeSO4+	2.494e-16	1.945e-16	-15.603	-15.711	-0.108	
FeHSO4+	1.364e-16	1.063e-16	-15.865	-15.973	-0.108	
Fe(SO4)2-	2.140e-17	1.669e-17	-16.670	-16.778	-0.108	
FeHSO4+2	6.904e-24	2.551e-24	-23.161	-23.593	-0.433	
AlHSO4+2	2.498e-24	9.228e-25	-23.602	-24.035	-0.433	
-----Saturation indices-----						
Phase	SI	log IAP	log KT			
Al(OH)3(a)	-1.64	9.16	10.80	Al(OH)3		
Alunite	-3.95	-5.35	-1.40	KAl3(SO4)2(OH)6		
Anhydrite	-0.60	-4.96	-4.36	CaSO4		
Fe(OH)3(a)	2.69	20.60	17.91	Fe(OH)3		
Gibbsite	1.05	9.16	8.11	Al(OH)3		
Goethite	8.58	20.60	12.02	FeOOH		
Gypsum	-0.38	-4.96	-4.58	CaSO4:2H2O		

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

```
H2(g)          -24.62  -24.62   0.00  H2
Hematite       19.18   41.21  22.03  Fe2O3
Jarosite-K     -0.88   28.97  29.85  KFe3(SO4)2(OH)6
Melanterite    -8.53  -10.74  -2.21  FeSO4·7H2O
O2(g)         -33.88   49.24  83.12  O2
```

End of simulation.

Reading input data for simulation 2.

```
TITLE Mix 10% Leachate, 90% Groundwater.
MIX 1
      14      0.9
      1      0.1
SAVE solution 15
END
```

TITLE

Mix 10% Leachate, 90% Groundwater.

Beginning of reaction calculations.

Reaction step 1.

Using mixture 1.

```
9.000e-01 Solution 14 - FLT Background/Native Groundwater Quality
1.000e-01 Solution 1  Extraction Average
```

```
-----Solution composition-----
Elements      Molality      Moles
Al             1.452e-04     1.452e-04
Ca             9.738e-03     9.738e-03
Cl             5.636e-02     5.636e-02
Fe             5.878e-05     5.878e-05
K              1.130e-03     1.130e-03
Mg             8.632e-03     8.632e-03
Na             5.303e-02     5.303e-02
S              1.846e-02     1.846e-02
Si             4.511e-04     4.511e-04
```

```
-----Description of solution-----
pH = 3.182          Charge balance
pe = 10.915        Adjusted to redox equilibrium
Activity of water = 0.998
Ionic strength = 1.071e-01
Mass of water (kg) = 1.000e+00
Total alkalinity (eq/kg) = -1.177e-03
Total carbon (mol/kg) = 0.000e+00
Total CO2 (mol/kg) = 0.000e+00
Temperature (deg C) = 25.000
Electrical balance (eq) = -6.735e-04
Iterations = 12
Total H = 1.110155e+02
Total O = 5.558195e+01
```

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	7.996e-04	6.575e-04	-3.097	-3.182	-0.085
OH-	2.009e-11	1.519e-11	-10.697	-10.818	-0.121
H2O	5.551e+01	9.976e-01	-0.001	-0.001	0.000
Al	1.452e-04				
ALSO4+	9.888e-05	7.683e-05	-4.005	-4.114	-0.110
Al+3	3.248e-05	5.585e-06	-4.488	-5.253	-0.765
Al(SO4)2-	1.360e-05	1.057e-05	-4.866	-4.976	-0.110
AlOH+2	2.309e-07	8.418e-08	-6.637	-7.075	-0.438
AlHSO4+2	1.229e-08	4.479e-09	-7.911	-8.349	-0.438
Al(OH)2+	1.288e-09	1.001e-09	-8.890	-9.000	-0.110
Al(OH)3	2.183e-13	2.238e-13	-12.661	-12.650	0.011
Al(OH)4-	8.235e-16	6.399e-16	-15.084	-15.194	-0.110
Ca	9.738e-03				
Ca+2	7.355e-03	2.814e-03	-2.133	-2.551	-0.417
CaSO4	2.383e-03	2.443e-03	-2.623	-2.612	0.011
CaOH+	9.119e-13	7.086e-13	-12.040	-12.150	-0.110
Cl	5.636e-02				
Cl-	5.636e-02	4.277e-02	-1.249	-1.369	-0.120
FeCl+	1.051e-06	8.165e-07	-5.979	-6.088	-0.110
FeCl+2	3.844e-07	1.401e-07	-6.415	-6.853	-0.438
FeCl2+	3.445e-08	2.677e-08	-7.463	-7.572	-0.110
FeCl3	1.117e-10	1.145e-10	-9.952	-9.941	0.011
Fe(2)	4.681e-05				
Fe+2	3.526e-05	1.383e-05	-4.453	-4.859	-0.406
FeSO4	1.044e-05	1.070e-05	-4.981	-4.971	0.011
FeCl+	1.051e-06	8.165e-07	-5.979	-6.088	-0.110
FeHSO4+	5.950e-08	4.624e-08	-7.225	-7.335	-0.110
FeOH+	8.540e-12	6.636e-12	-11.069	-11.178	-0.110
Fe(HS)2	0.000e+00	0.000e+00	-165.246	-165.235	0.011

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

Fe (HS) 3-	0.000e+00	0.000e+00	-247.752	-247.861	-0.110
Fe (3)	1.197e-05				
FeSO4+	6.660e-06	5.175e-06	-5.177	-5.286	-0.110
FeOH+2	2.915e-06	1.063e-06	-5.535	-5.974	-0.438
Fe(OH) 2+	6.872e-07	5.340e-07	-6.163	-6.272	-0.110
Fe(SO4) 2-	6.338e-07	4.925e-07	-6.198	-6.308	-0.110
Fe+3	6.310e-07	1.085e-07	-6.200	-6.965	-0.765
FeCl+2	3.844e-07	1.401e-07	-6.415	-6.853	-0.438
FeCl2+	3.445e-08	2.677e-08	-7.463	-7.572	-0.110
FeHSO4+2	2.499e-08	9.112e-09	-7.602	-8.040	-0.438
Fe2(OH) 2+4	1.721e-09	3.041e-11	-8.764	-10.517	-1.753
FeCl3	1.117e-10	1.145e-10	-9.952	-9.941	0.011
Fe(OH) 3	1.018e-10	1.044e-10	-9.992	-9.981	0.011
Fe3(OH) 4+5	1.859e-12	3.392e-15	-11.731	-14.470	-2.739
Fe(OH) 4-	1.859e-16	1.444e-16	-15.731	-15.840	-0.110
H(0)	8.850e-32				
H2	4.425e-32	4.535e-32	-31.354	-31.343	0.011
K	1.130e-03				
K+	1.097e-03	8.322e-04	-2.960	-3.080	-0.120
KSO4-	3.298e-05	2.563e-05	-4.482	-4.591	-0.110
KOH	4.272e-15	4.378e-15	-14.369	-14.359	0.011
Mg	8.632e-03				
Mg+2	6.178e-03	2.466e-03	-2.209	-2.608	-0.399
MgSO4	2.454e-03	2.515e-03	-2.610	-2.599	0.011
MgOH+	1.748e-11	1.359e-11	-10.757	-10.867	-0.110
Na	5.303e-02				
Na+	5.189e-02	4.039e-02	-1.285	-1.394	-0.109
NaSO4-	1.133e-03	8.805e-04	-2.946	-3.055	-0.110
NaOH	3.950e-13	4.049e-13	-12.403	-12.393	0.011
O(0)	3.936e-30				
O2	1.968e-30	2.017e-30	-29.706	-29.695	0.011
S(-2)	0.000e+00				
H2S	0.000e+00	0.000e+00	-80.862	-80.851	0.011
HS-	0.000e+00	0.000e+00	-84.542	-84.663	-0.121
S-2	0.000e+00	0.000e+00	-93.964	-94.399	-0.435
Fe(HS) 2	0.000e+00	0.000e+00	-165.246	-165.235	0.011
Fe(HS) 3-	0.000e+00	0.000e+00	-247.752	-247.861	-0.110
S(6)	1.846e-02				
SO4-2	1.196e-02	4.350e-03	-1.922	-2.362	-0.439
MgSO4	2.454e-03	2.515e-03	-2.610	-2.599	0.011
CaSO4	2.383e-03	2.443e-03	-2.623	-2.612	0.011
NaSO4-	1.133e-03	8.805e-04	-2.946	-3.055	-0.110
HSO4-	3.579e-04	2.781e-04	-3.446	-3.556	-0.110
AlSO4+	9.888e-05	7.683e-05	-4.005	-4.114	-0.110
KSO4-	3.298e-05	2.563e-05	-4.482	-4.591	-0.110
Al(SO4) 2-	1.360e-05	1.057e-05	-4.866	-4.976	-0.110
FeSO4	1.044e-05	1.070e-05	-4.981	-4.971	0.011
FeSO4+	6.660e-06	5.175e-06	-5.177	-5.286	-0.110
Fe(SO4) 2-	6.338e-07	4.925e-07	-6.198	-6.308	-0.110
FeHSO4+	5.950e-08	4.624e-08	-7.225	-7.335	-0.110
FeHSO4+2	2.499e-08	9.112e-09	-7.602	-8.040	-0.438
AlHSO4+2	1.229e-08	4.479e-09	-7.911	-8.349	-0.438
Si	4.511e-04				
H4SiO4	4.511e-04	4.623e-04	-3.346	-3.335	0.011
H3SiO4-	1.334e-10	1.037e-10	-9.875	-9.984	-0.110
H2SiO4-2	2.942e-20	1.073e-20	-19.531	-19.970	-0.438

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-6.51	4.29	10.80	Al(OH)3
Albite	-8.58	-3.92	4.66	NaAlSi3O8
Alunite	-3.08	-4.48	-1.40	KAl3(SO4)2(OH)6
Anhydrite	-0.55	-4.91	-4.36	CaSO4
Anorthite	-19.89	5.73	25.62	CaAl2Si2O8
Ca-Montmorillonite	-9.39	-1.60	7.78	Ca0.165Al2.33Si3.67O10(OH)2
Chalcedony	0.22	-3.33	-3.55	SiO2
Chlorite(14A)	-51.02	17.36	68.38	Mg5Al2Si3O10(OH)8
Chrysotile	-27.60	4.60	32.20	Mg3Si2O5(OH)4
Fe(OH)3(a)	-2.31	15.60	17.91	Fe(OH)3
FeS(ppt)	-82.43	-119.99	-37.56	FeS
Gibbsite	-3.82	4.29	8.11	Al(OH)3
Goethite	3.58	15.60	12.02	FeOOH
Gypsum	-0.33	-4.91	-4.58	CaSO4:2H2O
H2(g)	-28.19	-28.19	0.00	H2
H2S(g)	-79.85	-121.50	-41.64	H2S
Hematite	9.17	31.20	22.03	Fe2O3
Illite	-12.66	-0.80	11.86	K0.6Mg0.25Al2.3Si3.5O10(OH)2
Jarosite-K	-0.40	29.45	29.85	KFe3(SO4)2(OH)6
K-feldspar	-7.70	-5.61	2.09	KAlSi3O8
K-mica	-9.73	2.98	12.70	KAl3Si3O10(OH)2
Kaolinite	-5.52	1.92	7.43	Al2Si2O5(OH)4
Mackinawite	-81.69	-119.99	-38.30	FeS
Melanterite	-5.02	-7.23	-2.21	FeSO4:7H2O
O2(g)	-26.74	56.38	83.12	O2
Pyrite	-127.51	-213.29	-85.78	FeS2
Quartz	0.65	-3.33	-3.98	SiO2

Public Submission on the Proposed Beverley Uranium Project - Gavin M. Mudd, Victoria University of Tech.

Sepiolite	-18.25	-2.49	15.76	Mg ₂ Si ₃ O ₇ .5OH:3H ₂ O
Sepiolite(d)	-21.15	-2.49	18.66	Mg ₂ Si ₃ O ₇ .5OH:3H ₂ O
SiO ₂ (a)	-0.62	-3.33	-2.71	SiO ₂
Sulfur	-57.54	-93.30	-35.76	S
Talc	-23.47	-2.07	21.40	Mg ₃ Si ₄ O ₁₀ (OH) ₂

End of simulation.

End of run.

Appendix Five :

Mines lose valuable staff to fly-in, fly-out

Friday 3 July, 1998 (12:50pm AEST)

© Australian Broadcasting Corporation (ABC)

News Websites :

<http://www.abc.net.au/news/>

Mines lose valuable staff to fly-in, fly-out

Friday 3 July, 1998 (12:50pm AEST)

An international mining conference in North Queensland has heard mines risk losing valuable, trained employees because they are not aware of the pressures of fly-in, fly-out operations.

Delegates from about 200 mining companies from Australia, Canada and Europe are attending the conference in Townsville.

Mick Roche, of BHP Cannington, says fly-in, fly-out operations, where staff work away from their families for long periods, are a concern for companies.

"Whether it's fly-in, fly-out or in the arctic circle - we had a paper from the arctic circle - or fly-in, fly-out from the mines in the Kimberlies, or from here in Queensland, we are all losing people as a result of fly-in, fly-out," he said.

"And we've got a high cost of recruitment. There's a high cost of training people so we've got to make sure we can retain people for as long as we possibly can."

© 1998 Australian Broadcasting Corporation
Updated: Fri Jul 3 13:00:02 1998 (AEST)

AEST = Australian Eastern Standard Time