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Investigation of tailings water leak at the Ranger uranium mine

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Executive summary

During the 1999–2000 Wet season, a leak occurred in the tailings water return pipe at the Ranger uranium mine in the Alligator Rivers Region of the Northern Territory. The first indication to the authorities that a leak had occurred was in a facsimile message from Energy Resources of Australia (ERA), the mine operator, to the Office of the Supervising Scientist (OSS) on the afternoon of Friday 28 April 2000. This message advised that approximately 2000 cubic metres of tailings water (process water) had leaked from a pipe in the Tailings Dam Corridor of the Ranger site between late December 1999 and 5 April 2000. The facsimile message was also sent by ERA to the Northern Territory Department of Mines and Energy (NTDME), Northern Land Council (NLC) and the Department of Industry, Science and Resources (DISR).

Water in the tailings dam at Ranger is pumped from the dam back to the mill through the Tailings Water Return Pipeline for use in the process plant. The primary containment system is the pipeline itself. A secondary containment system is in place to protect the environment from any adverse effects arising from a failure anywhere along the pipeline. This secondary containment system consists of a bunded roadway that collects any spilled water and directs it to a sump, the Tailings Dam Corridor Sump. Water that is collected in this sump is returned to the mill water management system. Should both the primary and secondary containment systems fail, a third barrier for the protection of the environment is in place in the form of constructed wetland filters which are designed to partially remove contaminants from the water as it passes through the filter system.

Although a leak had been reported, no indication was given that the secondary containment system may have been breached. Indeed, the report stated that no infringement of the Ranger General Authorisation had occurred. On receipt of the facsimile, the OSS contacted ERA to clarify the circumstances surrounding the incident. The Department of Industry Science and Resources also sought advice from ERA on the nature and the timing of the leak. During telephone conversations between OSS and ERA staff, information on water quality at a number of sites was provided which indicated that a proportion of the process water had entered the Very Low Grade Corridor Road Culvert (VLGCRC) built under the Tailings Dam Corridor, and hence had escaped the secondary containment system consisting of bunds and a sump, designed to collect any spillages from the pipes in the tailings corridor.

Based on this information, the Supervising Scientist concluded that a breach of the Environmental Requirements had occurred and immediately notified the office of the Minister for the Environment and Heritage. On Sunday 30 April, the Supervising Scientist provided a formal brief to the Minister on the incident. Following receipt of this brief, the Minister requested that the Supervising Scientist investigate the incident and provide a report to him. A similar request was received from the Minister for Industry, Science and Resources who is responsible for the administration of the *Atomic Energy Act 1953* under which approval has been given for ERA to operate the Ranger Mine. This report is in response to these requests.

In preparing this report, the Supervising Scientist has consulted all the major stakeholders including ERA, NTDME, NLC and the Gundjehmi Aboriginal Corporation. On technical aspects of the assessment, a report was prepared by ERA in close cooperation and consultation with staff of the Supervising Scientist and the NTDME. In addition ERA commissioned a report from a specialist pipeline inspection company, Intico, on the condition of pipes in the Tailings Corridor and the Supervising Scientist commissioned a review from

Sinclair Knight Merz on the adequacy of the design, operation and maintenance of the tailings corridor system. NTDME also prepared a report on the incident.

The issues that needed to be addressed were:

- The origin of the leak and the adequacy of remediation measures taken to prevent similar occurrences in the future
- The extent to which the people and the environment of Kakadu National Park have been adversely affected by the leak
- The extent to which Energy Resources of Australia has complied with the reporting requirements specified in the Environmental Requirements that apply to the Ranger operation.

A number of other issues arose in the course of the investigation.

The main findings of the investigation are summarised below.

Origin of the leak and adequacy of remediation measures

It has been established that the volume of water that leaked from the tailings water return pipeline was about 2000 cubic metres during the 1999/2000 wet season. Of this, only a small fraction, about 85 cubic metres, entered the culvert which flows to the Corridor Creek Wetlands. The remainder was collected in the tailings corridor sump and returned to the water management system.

The cause of the leak was corrosion and subsequent failure of three bolts that secure the jointing of two flanges in the pipeline. The principal cause of corrosion was the burial, under moist conditions for up to 6 months of the year, of the relevant section of the pipeline under silt derived from erosion in the vicinity of the tailings corridor roadway. A contributing factor to the failure may have been the use of undersized bolts.

The gradual burial of the pipeline and the absence of measures to remediate the situation are attributable to a reduction in the standard of maintenance carried out by ERA in the pipeline corridor in recent years. The failure of the mine inspection program carried out by the Northern Territory Department of Mines and Energy and, to a lesser extent, that of the Office of the Supervising Scientist, to observe and require remediation of the buried section has also been a contributing factor to the leak.

The failure of the pipeline to contain tailings water would not of itself normally have resulted in the discharge of this water to the external environment. That the leaked water did reach the external environment is due to a failure of the bunded corridor system to fully contain any spilled water. The cause of this failure was that the engineered structure between the roadway and a culvert that drains water from the nearby waste rock dump was not impermeable.

The statutory monitoring program has been found to be deficient in two ways. First, other than visual inspection, it has not been designed to include monitoring locations within secondary containment systems that would indicate the failure of primary containment systems. In the present case, no statutory reporting of the quality of water in the tailings corridor sump is required under the Ranger General Authorisation. If the routine analysis of ammonium ion and manganese in corridor sump water had been required, the existence of a leak in the pipeline may well have been detected several months before it was found and rectified. Second, there is no systematic monitoring program designed to check the integrity of the secondary containment systems. If these monitoring systems had been in place, the current incident could well have been avoided.

The original leak in the pipeline has been repaired and the complete pipeline has been tested to determine its integrity. The system is now operating satisfactorily. The silt that buried the pipeline has been removed and steps implemented to ensure that no build-up of silt will occur in the future. A concrete slab has been installed at the section of roadway that passes over the culvert to prevent infiltration in the future. A full review of the Tailings Dam Corridor has been recommended with particular emphasis on the efficacy with which it performs the task of providing secondary containment.

Impact on people and the environment

Assessments of possible ecological impact arising from the leak have been carried out both using actual monitoring data and by modelling.

An examination of the chemical monitoring data at the gauging station on the Magela Creek upstream of the point at which the Creek enters Kakadu National Park shows that no change occurred during 1999/2000 in the concentrations of the principal constituents of concern compared to similar observations in previous years. The concentrations of all constituents were within the natural range observed previously. Similarly, biological monitoring at the gauging station and at a point upstream from the minesite shows no difference in the response of animals exposed to water at the downstream and the upstream sites. Even at the monitoring site at Georgetown Billabong, which is located on the mine project area downstream from the source of the leak but upstream of the confluence of Georgetown Creek and Magela Creek, no increase in the concentration of any of the principal solutes was detectable.

Modelling of the possible ecological impact was carried out by calculating the likely increase in concentrations at the gauging station using information derived in this study on: the maximum possible volume of leaked tailings water, the most probable value for this volume, the measured concentrations of solutes in tailings water, measured rates of attenuation of solutes in the constructed wetland filter systems and the flow rates in Magela Creek. Even if one ignores the losses in the wetland filters and uses the maximum possible volume of leaked tailings water, the calculated increase in the concentration of all consituents is much lower than the naturally observed concentrations at this point.

We have concluded that the leak of tailings water had no adverse ecological impact on Kakadu National Park.

The radiological impact was assessed using the information derived in this study on the quantity of water released and the concentrations of radionuclides in tailings water together with the results of the past research program of the Supervising Scientist on the dispersion of radionuclides in the surface water system and the uptake of radionuclides in animals and plants. The maximum conceivable dose received by members of the public as a result of the leak is lower than the public dose limit by more than a factor of 1000. The best estimate of the dose received is lower by a further factor of 30. Even these estimates ignore the reduction in dose resulting from absorption of radionuclides in the wetland filter system.

The overall conclusion reached is that the leak of tailings water into the external environment has had a negligible impact on people and the environment.

Compliance with reporting requirements

Under the Environmental Requirements, ERA must directly and immediately report any breach of the Environmental Requirements and any mine-related event which:

(a) result in significant risk to ecosystem health; or

(b) have the potential to cause harm to people living or working in the area; or

(c) are of or could cause concern to Aboriginals or the broader public.

It has been concluded that ERA did not comply with this requirement on two grounds: (i) the leak of tailings water to the external environment is a breach of Environmental Requirement 3.4, and (ii) there should have been no doubt that such a leak would have been of concern to the local Aboriginal people and the broader public.

The reasons for the lack of reporting have been the subject of an internal ERA investigation and the Supervising Scientist has received correspondence from, and has discussed with, the Chief Executive of ERA the outcomes of the review. ERA believes that there was no deliberate intent to deceive or dissemble. Rather, two principal factors are believed to have contributed to the omission. First, recent changes in staffing at Ranger have resulted in the absence of a senior scientist with the ability to effectively identify, interpret and rectify environmental incidents. The lack of interpretive ability was a key factor in the lack of recognition that the data which were available to ERA staff implied that tailings water had reached the external environment. Second, there is a lack of recognition by the Ranger Management Team of the needs and expectations of stakeholders that resulted in emphasis being placed on the absence of environmental impact rather then the issue of whether or not the incident would be of concern to Aboriginal people.

From his discussions with senior ERA personnel, the Supervising Scientist is satisfied that there was no deliberate attempt to deceive the authorities. He accepts the conclusions of ERA and has made recommendations to address the deficiencies identified.

Other issues

In the course of this investigation into the leak of tailings water during the 1999/2000 Wet season, evidence has been obtained that water with the characteristics of tailings water was probably discharged into the same culvert during the 1998/1999 Wet season. Due to time constraints, the cause of this discharge has not been fully established. A possible explanation that is being investigated is that tailings water associated with a leak in the tailings pipeline on 13 December 1998 seeped in to the VLGCRC during the 1998/99 Wet season. While the Supervising Scientist is concerned that the probable presence of tailings water in the VLGCRC went undetected until now and that a full explanation for its origin is not yet available, he is satisfied that the 1998/99 leak caused no harm to people or the environment of Kakadu National Park. ERA should complete a comprehensive investigation of additional sources of contaminants in the VLGCRC, including previous tailings spills in the Tailings Dam Corridor, and provide a report to the Minesite Technical Committee.

During the past few years, there has been an increase in public expressions of concern about the ability of the Supervising Scientist to provide reliable assurances to the public when he has to rely heavily on information and monitoring data provided by ERA and/or by the Department of Mines and Energy which is seen primarily as a proponent of mining. These concerns have heightened following the reporting of the tailings water leak. In particular, the Mirrar, traditional owners of the land containing both the Ranger and the Jabiluka projects, expressed their concerns on this issue at a recent meeting with the Supervising Scientist. We have concluded that, in order to keep pace with these changing expectations on the independent nature of the assessments carried out by the Supervising Scientist, the Supervising Scientist should ensure that there is an adequate and independent on-site audit program, and develop and implement an environmental monitoring program. These programs should focus on the potential off-site environmental consequences arising from operation of the Ranger mine and mill.

There are difficulties with the current requirements for the reporting of incidents at Ranger. First, they often require a judgement by ERA staff on whether or not the incident would give rise to concern by Aboriginal people or the general public. Such judgements may be difficult to make. Second, the demand for a completely open and transparent system of reporting often results in an unjustified but very genuine concern, even fear, on the part of traditional owners. Guidelines need to be developed to clarify the reporting requirements in a way that will, while retaining the transparency of the current system, reduce the element of judgement needed and assist in minimising undue concern for Aboriginal people and the broader community.

Recommendations

The recommendations arising from this investigation are listed below.

Recommendation 1

> ***ERA should undertake a full review of the Tailings Dam Corridor with particular emphasis on the efficacy with which it performs the task of providing secondary containment. The Terms of Reference for the Review should be approved by the Supervising Scientist.***

Recommendation 2

> ***All Recommendations on maintenance procedures in the Tailings Dam Corridor made in the Sinclair Knight Merz Review of the Tailings Dam Corridor should be implemented.***

Recommendation 3

> ***ERA should strengthen the Ranger Management Team to ensure that there is an effective interface with external stakeholders and that decisions are made quickly to meet the expectations of the stakeholders.***

Recommendation 4

> ***ERA should take immediate take steps to put in place an employee training program designed to ensure that all employees appreciate the need to keep the authorities informed of any event that could be perceived to be of concern to the local Aboriginal people or the broader community, not just incidents that are acknowledged infringements of the Ranger General Authorisation or the Environmental Requirements.***

Recommendation 5

> ***The Supervising Scientist should offer to assist ERA in the above training program. In particular, the Supervising Scientist should provide a briefing to ERA employees on issues of significance in this report, and any other issues that are considered to be of concern to members of the public.***

Recommendation 6

> ***ERA should upgrade the environment protection staff structure at Jabiru to ensure that the company has the on site ability to effectively identify, interpret and rectify environmental incidents.***

Recommendation 7

ERA should complete a comprehensive investigation of the additional sources of manganese, including previous tailings spills in the Tailings Dam Corridor, and provide a report to the Minesite Technical Committee.

Recommendation 8

The Minister for Industry Science and Resources should consider what action should be taken in response to the established breach of Environmental Requirements 3.4 and 16.1 taking into account:

- ***The radiological and ecological impact arising from the leak of tailings water to the environment has been negligible***
- ***The leak resulted from poor maintenance practices in the Tailings Dam Corridor***
- ***The view of the traditional owners of the Ranger Project Area is that Aboriginal people will only believe that the Government takes their concerns seriously if substantive action is taken.***

Recommendation 9

The statutory environmental monitoring program should be extended to enhance its capacity to provide early warning of unplanned releases of contaminants. This extension should include the establishment of additional monitoring locations within secondary containment systems that would indicate the failure of primary containment systems.

Recommendation 10

The Minesite Technical Committee should review the inspection and monitoring system at Ranger to establish and implement measures that will detect failures in the secondary containment systems and structures.

Recommendation 11

ERA should provide the Supervising Scientist and the Supervising Authorities with all research data as they become available rather than at the end of research projects. Protocols should be developed for the appropriate use of research data.

Recommendation 12

The Northern Territory Department of Mines and Energy should undertake a comprehensive review of its site inspection regime in the light of deficiencies identified in this report, and design and implement a new proactive inspection regime within a risk management framework.

Recommendation 13

The Supervising Scientist should ensure that there is an adequate and independent on-site audit program related to potential off-site environmental consequences arising from operation of the Ranger mine and mill.

Recommendation 14

The Supervising Scientist should develop and implement a routine environmental monitoring program whose focus should be the provision of advice on the extent of

protection of the people and ecosystems of Kakadu National Park. A component of the program could also provide support to the on-site audit program referred to in Recommendation 13.

Recommendation 15

The Working Arrangements between the Commonwealth and the Northern Territory regarding the regulation of uranium mining activities in the Alligator Rivers Region should be reviewed and amended to take into account changes in the activities of the Supervising Scientist arising from this report.

Recommendation 16

The Mine Site Technical Committee should develop guidelines clarifying requirements for the reporting of incidents which retain the transparency of the current system, are consistent with Environmental Requirement 16.1, reduce the need for the exercise of judgement by staff of ERA and will assist in minimising undue concern for Aboriginal people and the broader community.

Recommendation 17

The Working Arrangements between the Commonwealth and the Northern Territory regarding the regulation of uranium mining activities in the Alligator Rivers Region should be reviewed and amended to require the Department of Mines and Energy and the Supervising Scientist to immediately inform each other of any information they may acquire independently which could be of environmental significance.

Investigation of tailings water leak at the Ranger uranium mine

1 Introduction

During the 1999–2000 Wet season, a leak occurred in the tailings water return pipe at the Ranger uranium mine in the Alligator Rivers Region of the Northern Territory. The first indication to the authorities that a leak had occurred was in a facsimile message from Energy Resources of Australia (ERA), the mine operator, to the Office of the Supervising Scientist (OSS) on the afternoon of Friday 28 April 2000. This message advised that approximately 2000 cubic metres of tailings water (process water) had leaked from a pipe in the Tailings Dam Corridor of the Ranger site between late December 1999 and 5 April 2000. The facsimile message was also sent by ERA to the Northern Territory Department of Mines and Energy (NTDME), Northern Land Council (NLC) and the Department of Industry, Science and Resources (DISR).

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Although a leak had been reported, no indication was given that the secondary containment system may have been breached. Indeed, the report stated that no infringement of the Ranger General Authorisation had occurred. On receipt of the facsimile, the OSS contacted ERA to clarify the circumstances surrounding the incident. The Department of Industry Science and Resources also sought advice from ERA on the nature and the timing of the leak. During telephone conversations between OSS and ERA staff, information on water quality at a number of sites was provided which indicated that a proportion of the process water had entered the Very Low Grade Corridor Road Culvert (VLGCRC) built under the Tailings Dam Corridor, and hence had escaped the secondary containment system consisting of bunds and a sump, designed to collect any spillages from the pipes in the tailings corridor.

Based on this information the Supervising Scientist concluded that a breach of the Environmental Requirements had occurred and immediately notified the office of the Minister for the Environment and Heritage. On Sunday 30 April, the Supervising Scientist provided a formal brief to the Minister on the incident. Following receipt of this brief, the Minister requested that the Supervising Scientist investigate the incident and provide a report to him. A similar request was received from the Minister for Industry, Science and Resources who is responsible for the administration of the *Atomic Energy Act 1953* under which approval has been given for ERA to operate the Ranger Mine. This report is in response to these requests.

In preparing this report, the Supervising Scientist has consulted all the major stakeholders including ERA, NTDME, NLC and the Gundjehmi Aboriginal Corporation. On technical aspects of the assessment, a report was prepared by ERA in close cooperation and consultation with staff of the Supervising Scientist and the NTDME. In addition ERA commissioned a report from a specialist pipeline inspection company, Intico, on the condition of pipes in the Tailings Corridor and the Supervising Scientist commissioned a review from Sinclair Knight Merz on the adequacy of the design, operation and maintenance of the tailings corridor system. NTDME also prepared a report on the incident.

This report describes the outcomes of the investigation and makes recommendations to address deficiencies identified in the environmental management systems at Ranger and in the supervisory and regulatory regimes applied to Ranger by the Supervising Scientist and NTDME. The ERA and NTDME reports are at Appendices 2 and 5 of this report. The SKM report is available on request from the Supervising Scientist.

2 Description of the leak

2.1 Location

The leak occurred at a flange joint in the 250 mm diameter Tailings Water Return Pipeline which transports water from the tailings dam to the processing plant at Ranger. Figure 1 is a photograph of the flange joint after it was repaired. The Tailings Water Return Pipeline (TWRP) is approximately 2.5 km long and runs alongside the Tailings Dam Corridor road within a bunded area on the Ranger site (the Tailings Dam Corridor) designed to collect and contain any spillages that occur. The Tailings Dam Corridor drains to a sump near Pit 1 (the Tailings Dam Corridor Sump). Water collected in this sump is pumped, as required depending on rainfall, to a retention pond on the Ranger site.

Also located in the Tailings Dam Corridor are other pipes for the transport of tailings and tailings water (process water) between the tailings dam, Pit 1 and the process plant. Figure 3 is a schematic representation of the pipelines in the Tailings Dam Corridor.

Between the process plant and a point some 120 m from the tailings dam, the TWRP consists of a steel pipe with a diameter of approximately 250 mm. At this point, the steel pipe joins a steel reinforced flexible ‘plastic’ pipe to accommodate an upward bend in the TWRP, and the pipeline passes under a road culvert (the Access Road Culvert). The flexible section then connects to 250 mm steel pipe which completes the pipeline between the tailings dam and the process plant. It was the flange joint at the eastern end of the flexible section of the TWRP, which was just to the west of the Access Road Culvert under which the TWRP passes, that leaked. At the time, this flange joint was buried at a depth of approximately 50 cm due to silt build-up in the culvert under the road.

Buried by silt near the leaking flange joint, and also passing under the Access Road Culvert, was a disused pipe segment approximately 10 m long. One end of the disused pipe segment was located within one or two metres of the leaking flange. The top of the other end of the disused pipe segment abutted the surface within the Tailings Dam Corridor on the eastern side of the Access Road Culvert. A photograph of this end of the disused pipe segment after it was uncovered is shown in Figure 2. Figure 4 is a schematic representation of the Access Road Culvert showing the TWRP and the disused pipe segment.

Tailings water which escaped from the leaking flange traveled underground for one or two metres, entered one end of the disused pipe segment flowing within it to emerge at the opposite end before upwelling to the surface. Once on the surface, the tailings water joined the surface flow of rainfall runoff within the Tailings Dam Corridor. Surface water within the Tailings Dam Corridor flows to the Tailings Dam Corridor Sump. It has now been established that a proportion of the water seeped into the VLGCRC which flows under the Tailings Dam Corridor, approximately 250 m from the leaking flange. Figures 5 and 6 are schematic representations of the Tailings Dam Corridor at the VLGCRC. Figures 7 and 8 are photographs of the VLGCRC looking south and north respectively.

Figure 1 Photograph of the flange joint in the Tailings Water Return Pipeline that transports water from the tailings dam to the processing plant after it was repaired

Figure 2 End of the disused pipe segment after it was uncovered

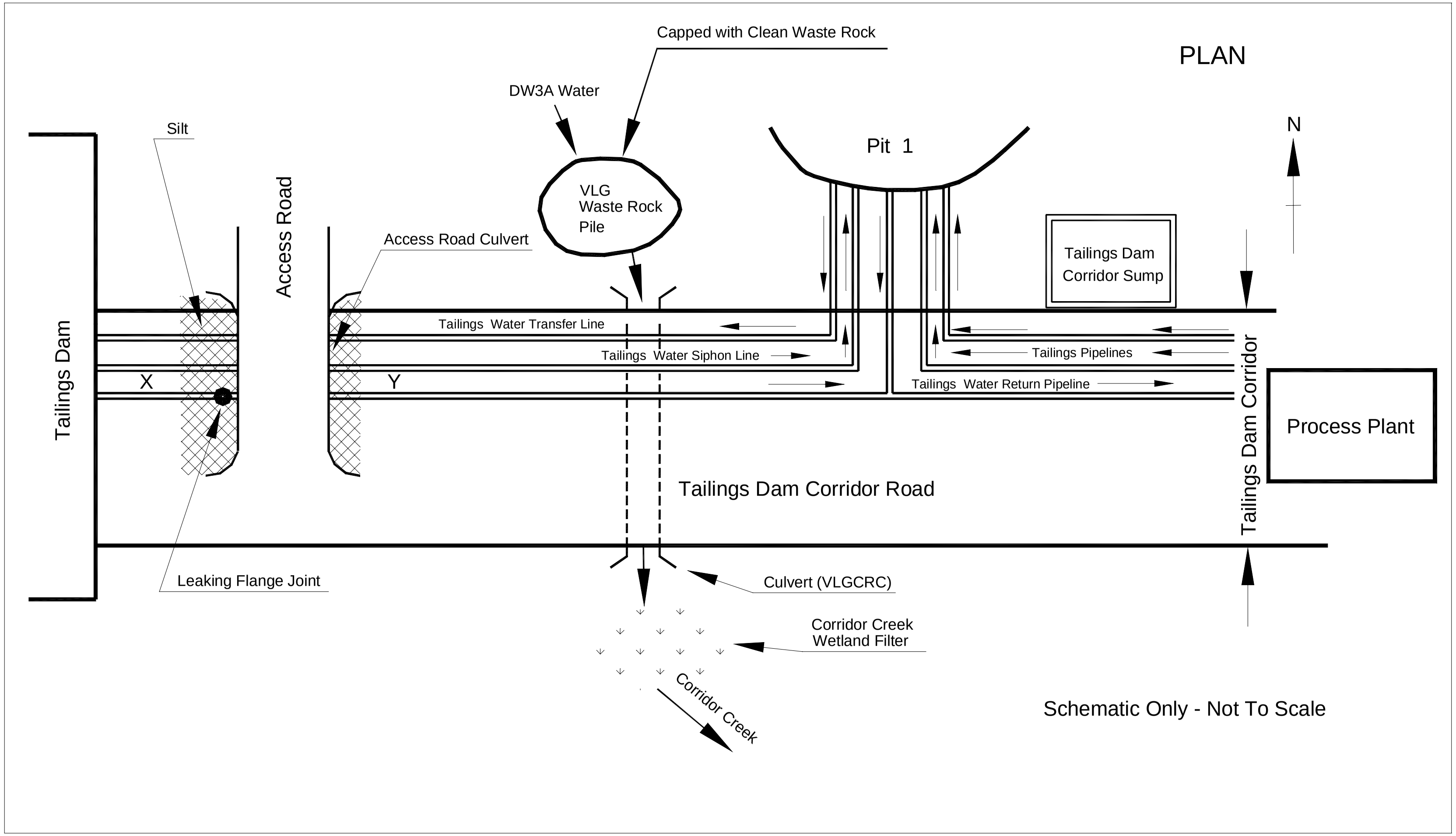

Figure 3 Schematic representation of the pipelines in the Tailings Dam Corridor

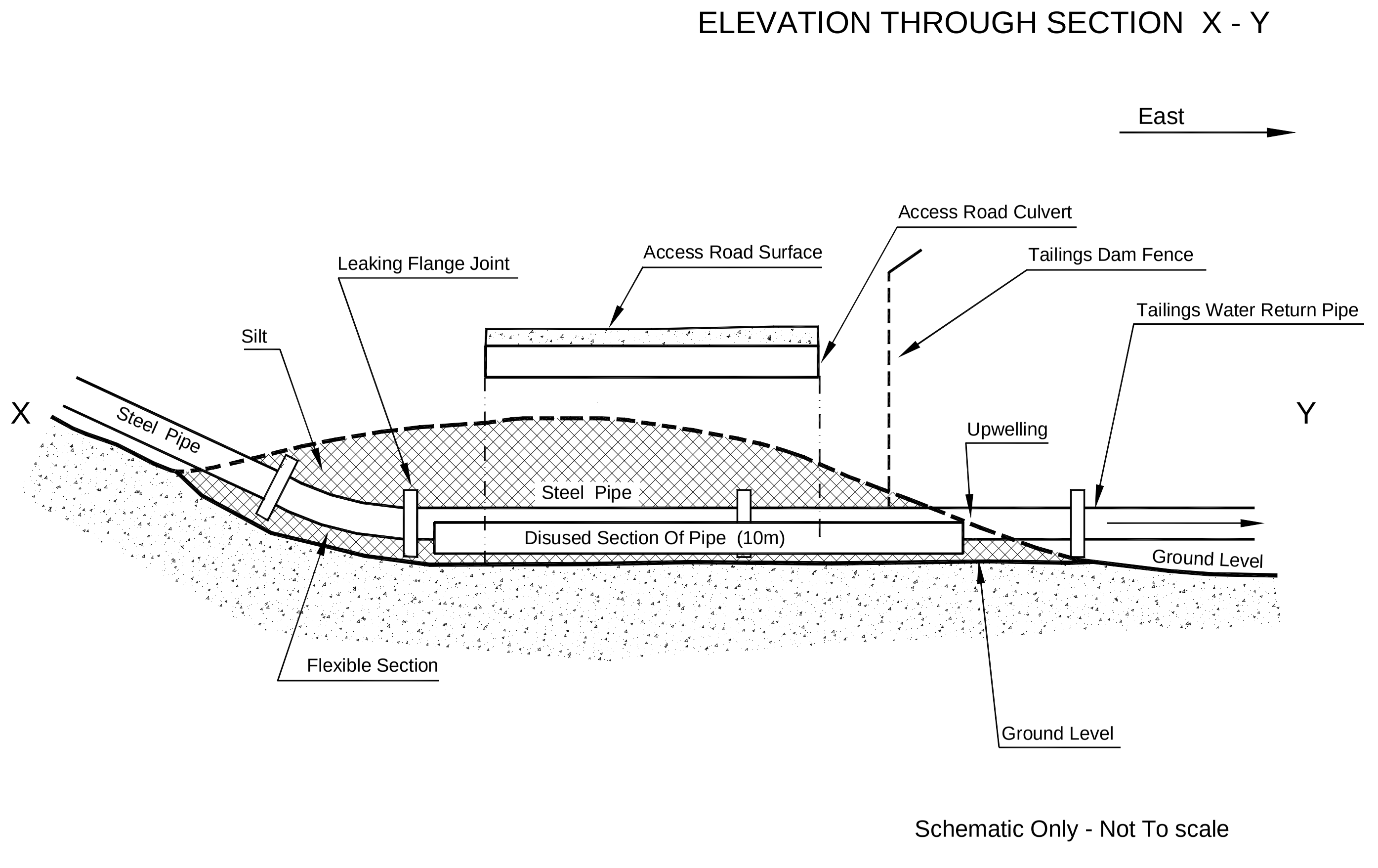

Figure 4 Schematic representation of the Access Road Culvert showing the TWRP and the disused pipe segment

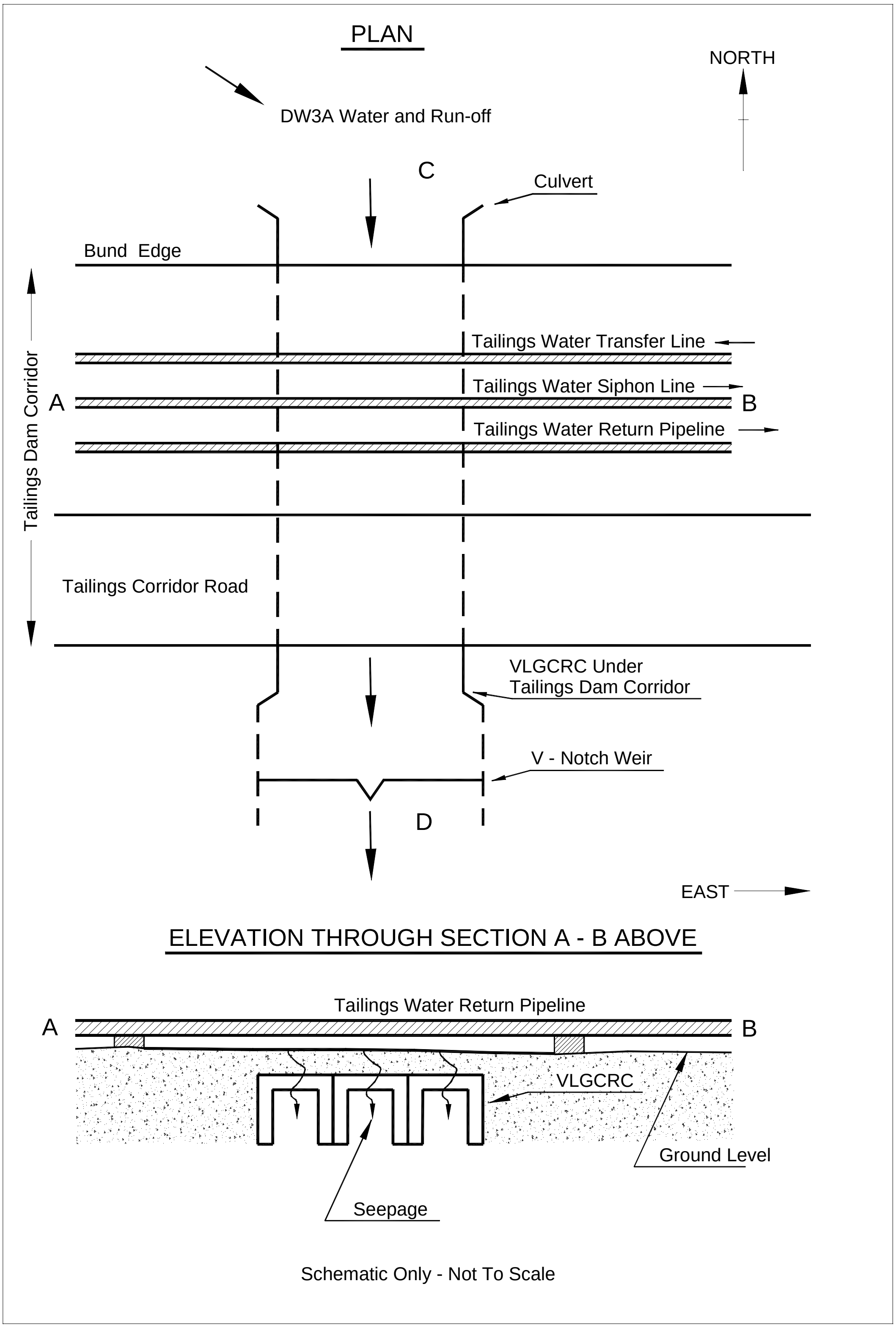

Figure 5 Schematic representation of the Tailings Dam Corridor at the VLGCRC

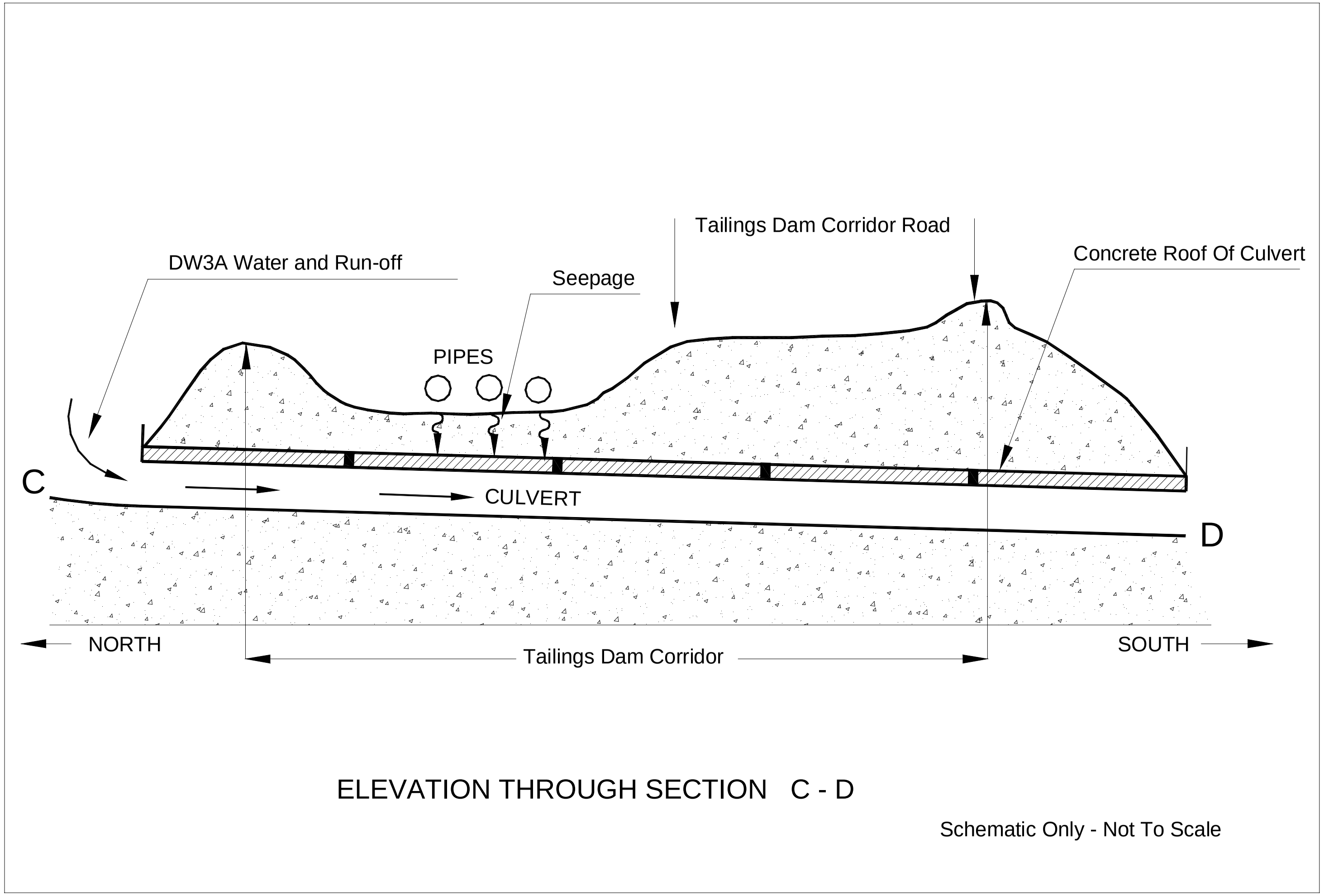

Figure 6 Schematic representation of the Tailings Dam Corridor at the VLGCRC (elevation through section C – D)

Figure 7 VLGCRC looking south

Figure 8 VLGCRC looking north

2.2 Duration

ERA has advised the Supervising Scientist that remedial work on the TWRP was completed on 4 April 2000, and that the leak was confirmed to have stopped on 5 April 2000. It is more difficult to determine precisely when the leak commenced, however, there is strong evidence to suggest that it commenced in February 2000. Monitoring undertaken by ERA in the VLGCRC during the course of a research project identified manganese concentrations of 751 μgl^{-1} and 6077 μgl^{-1} on 25 January and 2 February 2000 respectively. These data represent an abrupt increase in the concentration of manganese measured in the VLGCRC. Manganese is present in relatively high concentrations in tailings water, approximately 1 000 000 μgl^{-1}, making it a useful indicator of the presence of tailings water. However, during the course of this investigation, further information has emerged that indicates that there are additional sources of manganese that contribute to the total load of manganese in the VLGCRC. These additional sources are briefly discussed in section 2.6.

Because of the presence of other sources of manganese, alternative indicator solutes were considered to trace the movement of tailings water. Ammonium is present in tailings water at high concentrations (530 mgl^{-1}). There is no significant natural source of ammonium on the Ranger site making it a very reliable indicator of the presence of tailings water. Water samples taken by ERA from the VLGCRC, and from points downgradient of the VLGCRC had not been analysed for ammonium as it is not one of the standard suite of analytes. ERA identified archived samples taken from the VLGCRC between January and April 2000 and analysed them for the presence of ammonium. The sample taken on 9 February 2000 contained ammonium at typical background concentrations, 0.009 mgl^{-1} (milli grams per litre). The sample, taken on 23 February 2000 contained ammonium at a much higher concentration of 0.3 mgl^{-1}. This is strong evidence that no detectable quantities of tailings water entered the VLGCRC prior to 9 February 2000. This leads to the conclusion that the elevated concentrations of manganese measured in the VLGCRC prior to 9 February 2000 originated from a source other than the tailings water leak.

During rainfall events, the flow of water in the Tailings Dam Corridor would be significant and tailings water which leaked from the TWRP would reach the VLGCRC quickly, certainly in less than one hour. After a day or so without rain, the flow would be expected to stop as the water in the Tailings Dam Corridor formed a series of isolated pools. Examination of the rainfall record reveals that 34 mm of rain was recorded at Ranger on 7 February 2000. Rainfall on 8, 9 and 10 February 2000 was 9 mm, 4 mm and 34 mm respectively. Had the TWRP been leaking significantly on 7 February, ammonium would probably have been present in the sample of water taken from the VLGCRC on 9 February 2000. Given the relatively low rainfall on 8 February, it is possible that the TWRP was leaking on this date and that the tailings water had not reached the VLGCRC by 9 February 2000. These data lead to the conclusion that the TWRP started leaking on or after 8 February 2000.

There is also evidence that the TWRP was not leaking during the 1999 Dry season. The pipelines in the Tailings Dam Corridor are inspected by ERA staff three or four times per shift. Had the leak commenced prior to the onset of the wet season in November 1999, the moist patch of earth resulting from the leak would have been clearly visible in contrast to the dry earth surrounding it. An examination of ERA inspection records by the OSS indicated that the pipelines in the Tailings Dam Corridor were inspected as required. Considering the frequency of inspections, it is very unlikely that the leak commenced in the Dry season and was not identified.

2.3 Water Volume

ERA estimated (Appendix 2) that 2000 m^3 (cubic metres) of tailings water leaked from the TWRP based upon the water flow measured at the end of the disused pipe segment after it was exposed. That flow, measured by ERA on 29 March 2000, was 0.3 ls^{-1} (litres per second). The flow measured by ERA at the exposed end of the disused pipe may be used to estimate with a reasonable level of confidence the volume of tailings water which entered the surface flow within the Tailings Dam Corridor via the disused pipe segment. Assuming that the flow through the disused pipe segment was 0.3 ls^{-1} between 8 February 2000 and 5 April 2000, the total volume emerging from the disused pipe over the period of the leak was approximately 1500 m^3.

However, ERA did not measure the flow rate at the source of the leak, that is the flange in the TWRP. This leads to uncertainty in estimating the total volume of the leak as some of the tailings water may not have entered the disused pipe segment, and thus may not have been included in the flow rate measured by ERA.

The leak occurred at a point in the TWRP where there was a depression in the ground surface. That depression acted as a silt trap and, over a period of eighteen months to two years, filled with silt, burying the TWRP. When the TWRP started leaking, the silt would have become saturated and the depression would have approximated a silt-filled bath. Rainfall runoff would also have contributed to the saturation of the silt. The end of the disused pipe segment rested on or near the natural ground surface at the base of the depression. The disused pipe segment was certainly the primary conduit for the drainage of water from the saturated silt. Considering the proximity of the end of the disused pipe segment to the source of the leak, and its extremely high hydraulic conductivity compared to the ground, it has been concluded that effectively all of the tailings water which leaked from the TWRP would have drained through it. Nevertheless, for the purposes of making conservative estimates of potential environmental impact, a slightly higher figure of 2000 m^3 has been assumed in this report. It is assumed that the additional 500 m^3 of tailings water moved through the silt covering the leaking flange and entered the surface flow within the Tailings Dam Corridor.

2.4 Identification of the leak

In December 1999, ERA commenced the DW3A water disposal trial to test the capability of the Corridor Creek constructed wetlands to remove contaminants from the water column. This trial, endorsed by the Minesite Technical Committee, involves the pumping of water from a de-watering bore (DW3A) located between Retention Pond 2 and Pit 3 onto the Very Low Grade (VLG) waste rock stockpiles to the east of the tailings dam. The water then flows within a drain across the VLG waste rock stockpiles, and under the Tailings Dam Corridor through the VLGCRC. ERA commenced weekly monitoring of water in the VLGCRC on 22 December 1999. These data were collected as part of a research project and were not reported to the authorities.

On 25 January and 2 February 2000, analysis of water samples collected by ERA from the VLGCRC revealed manganese concentrations of 751 and 6077 μgl^{-1} respectively. The concentration of manganese in the sample collected by ERA on 9 February was 504 μgl^{-1}, which is still significantly elevated compared to samples collected between 22 December 1999 and 25 January 2000. Elevated manganese concentrations of between 1827 μgl^{-1} (sample collected 16 February) and 9532 μgl^{-1} (sample collected 8 March) persisted throughout February and March. On 13 March 2000 ERA staff held initial internal discussions regarding the elevated manganese concentrations and determined the need to identify its source. Table 1 summarises the actions taken by ERA in the investigation and the repair of the leak, as subsequently reported to the Supervising Scientist.

Table 1 Summary of actions taken by ERA in the identification of the leak

Date	ERA Action
28 March 2000	ERA staff observed a small upwelling of water in the western end of the Tailings Dam Corridor. A sample of this water was collected by ERA and subsequent analysis showed manganese concentrations of 840 000 μgl^{-1}.
29 March 2000	Minor excavation at the site of the upwelling identified a disused pipe segment as the source of the water. The flow of water from the end of the disused pipe segment was measured at 0.3 ls^{-1}. ERA staff closely inspected the Tailings Dam Corridor between the tailings dam and the VLGCRC. A water logged area to the west of the end of the disused pipe segment from which the water was flowing was identified and found to contain high conductivity water. ERA staff concluded that the leak was associated with the syphon line between the tailings dam and pit 1. The syphon break valve was removed completely. Water samples were taken from the water logged area, the VLGCRC, a pool of water upstream of the VLGCRC, and the Tailings Dam Corridor to the east of the VLGCRC. The Ranger Management Team was notified of a suspected leak of process water from the syphon line.
30 March – 2 April 2000	On 30 March, water samples were taken from the water logged area, the VLGCRC, drips from the roof of the VLGCRC, a pool of water upstream of the VLGCRC, and downstream of the VLGCRC. The flow from the disused pipe segment was observed not to have abated. The complete removal of the syphon break valve was confirmed indicating that the syphon line was not the source of the leak.
3 April 2000	The TWRP was identified as the only possible source of the water. Work orders were lodged for the excavation of the TWRP. The TWRP was shut down. Water samples were taken from the pool of water upstream of the VLGCRC, and from the drain in the top of the VLG waste rock stockpiles in which DW3A water was flowing.
4 April 2000	The TWRP was excavated. Three bolts in a flange of the TWRP were observed to have corroded and pulled through the bolt holes. The bolts were replaced.
5 April 2000	The TWRP was returned to service and the leak was confirmed to have stopped.

2.5 Cause of the leak

A significant aspect of the leak is that it occurred in a section of the TWRP that had become buried over a period of approximately 18 months to two years under about half a metre of silt. The leak was not immediately identified because the buried section of the TWRP was not able to be inspected. Also buried at the same point in the Tailings Dam Corridor were the syphon line which transfers tailings water from the tailings dam to pit 1, and the Tailings Water Transfer line which transfers tailings water from pit 1 to the tailings dam. The buried sections of these pipes were also not able to be inspected.

In addition to preventing the rapid identification of the leak in the TWRP, its burial is likely to have contributed towards the corrosion of the bolts, and consequently the initiation of the leak itself. The buried section of the pipe would have been in contact with water present in the silt which covered it. It is reasonable to assume that the silt was moist throughout the 1998/99 and 1999/00 wet seasons. Hence, the buried section of the TWRP is likely to have been in contact with water, and consequently in an environment conducive to corrosion, for at least six months since mid 1998. In comparison, the remainder of the TWRP on the surface would have only been in contact with water during rain and for the relatively short period after rain required for water on the pipeline to evaporate.

The burial of the TWRP is also likely to have played a role in the development of the leak. The leak probably started as a very low flow weep. The tailings water would have saturated the silt surrounding the flange and, given its acidity (pH of 4 to 4.4) and high conductivity (15 000 to 18 000 micro Siemens per centimetre), exacerbated any corrosive processes already underway resulting in the failure of three flange bolts.

The report on the Review of the Tailings Dam Corridor by Sinclair Knight Merz commissioned by the OSS notes the use of undersized bolts and concludes that their use may have been a contributing factor in the the leak. Undersized bolts would be more prone to failure than correctly sized bolts, especially if their integrity was compromised by corrosion.

The leak was caused by the failure of three bolts in a flange joint due to corrosion. The burial of the TWRP at the point of the leak is likely to have been a significant contributing factor to the initiation and progression of the corrosion of the bolts. The use of undersized bolts may have been a contributing factor.

2.6 Additional sources of manganese

During the course of this investigation, additional information has emerged which indicates that there are two other sources which have contributed to the total solute load in the VLGCRC. Research data collected by ERA during the 1998/99 Wet season show manganese concentrations in the VLGCRC of over 20 000 μgl^{-1} in December 1998. Re-analysis of archived water samples taken from the VLGCRC in 1998/99 by ERA show significantly elevated concentrations of ammonium. The presence of ammonium in the VLGCRC is evidence that tailings water was present in the VLGCRC at the time. A review of records has identified spills of tailings and tailings water within the Tailings Dam Corridor upgradient of the VLGCRC. It has been concluded from these data that tailings water probably seeped into the VLGCRC from the Tailings Dam Corridor in 1998/99 as well as in 1999/00.

However, preliminary analysis indicates that tailings water could not account for the concentrations of manganese measured in the VLGCRC in 1998/99. The ERA report (Appendix 2) presents data which indicate that seepage through the VLG waste rock stockpiles is the other principal source of manganese.

Monitoring data for the 1998/99 wet season demonstrates that these additional sources of manganese have not had any detectable impact on Kakadu National Park. Concentrations of contaminants are all consistent with historic levels and within natural variability. The analysis of environmental impact associated with the 1999/2000 leak presented in section 3 of this report is also applicable to any discharges that may have taken place during the 1998/1999 Wet season. The clear conclusion is that the environmental impact was negligible.

This report focuses on the leak of tailings water from the TWRP which was repaired on 4 April 2000. While the Supervising Scientist is concerned that the 1998/99 research data were not reported and the issues investigated at the time, to include a substantive examination of the additional sources of manganese would have resulted in an unacceptable delay in the production of the report on the 1999/2000 tailings water leak. These additional sources of manganese are the subject of ongoing investigations and will be the subject of further reports to the Minesite Technical Committee.

3 Assessment of Environmental Impact

3.1 Contaminant Transport Pathway

The surface water pathway between the source of the tailings water leak at the Ranger Mine and the entry point to Kakadu National Park is shown in figure 9.

Tailings water which escaped from the TWRP entered a disused pipe segment, one end of which was buried within one or two metres of the leaking flange. It flowed within this disused pipe segment emerging at the surface within the Tailings Dam Corridor. Tailings water is also assumed to have moved through the silt covering the leaking flange, reaching the surface within the Tailings Dam Corridor. The tailings water then joined the surface flow of rainfall runoff within the Tailings Dam Corridor, which reports to the Tailings Dam Corridor Sump. A proportion of the water in the Tailings Dam Corridor seeped into the VLGCRC which runs underneath the Tailings Dam Corridor.

Water in the VLGCRC flows into the Corridor creek artificial wetlands, then into Corridor creek which is bunded with spillways in three locations creating ponds on the upstream side of each bund. The purpose of the artificial wetlands is to remove contaminants from the water which passes through them. The bunds, and their associated ponds are the Brockman Bund, the Mine Bore L Bund, and the Sleepy Cod Dam Bund. Corridor Creek flows into Georgetown creek incorporating Georgetown Billabong and then into Magela creek. Magela creek enters Kakadu National Park approximately 7000 m downstream of this point. The total length of the transport pathway between the leaking flange joint in the TWRP and Kakadu National Park is approximately 12 km.

3.2 Ecological impact assessment based on monitoring

The principal monitoring point for the Ranger mine is at the gauging station (GS8210009) located on Magela Creek just before the creek enters Kakadu National Park (Figure 9). At this point a statutory chemical monitoring program is conducted by ERA and a non-statutory biological monitoring program (which was developed and conducted by ***eriss*** until 1996) is conducted by ERA in cooperation with ***eriss***. The results obtained in these programs have been used to assess the ecological impact of the leak of tailings water on Kakadu National Park.

The water chemistry data for the principal constituents of interest (Manganese, Uranium, Sulphate, Magnesium) and electrical conductivity at GS8210009 are shown as time series data in figures 10–14. The data clearly demonstrate that no discernable change in water quality occurred during the 1999/2000 wet season compared with any previous year.

A summary of comparisons between upstream and downstream sites and between the 1999–2000 wet season and previous wet seasons is given in table 2. The following conclusions can be drawn:

- there is no evidence that as a result of the process water leak there was any deterioration of water quality in Magela Creek downstream of Ranger.
- the relatively high rainfall of the 1999–2000 wet season resulted in a lower dissolved solids content in Magela Creek water compared to the average.

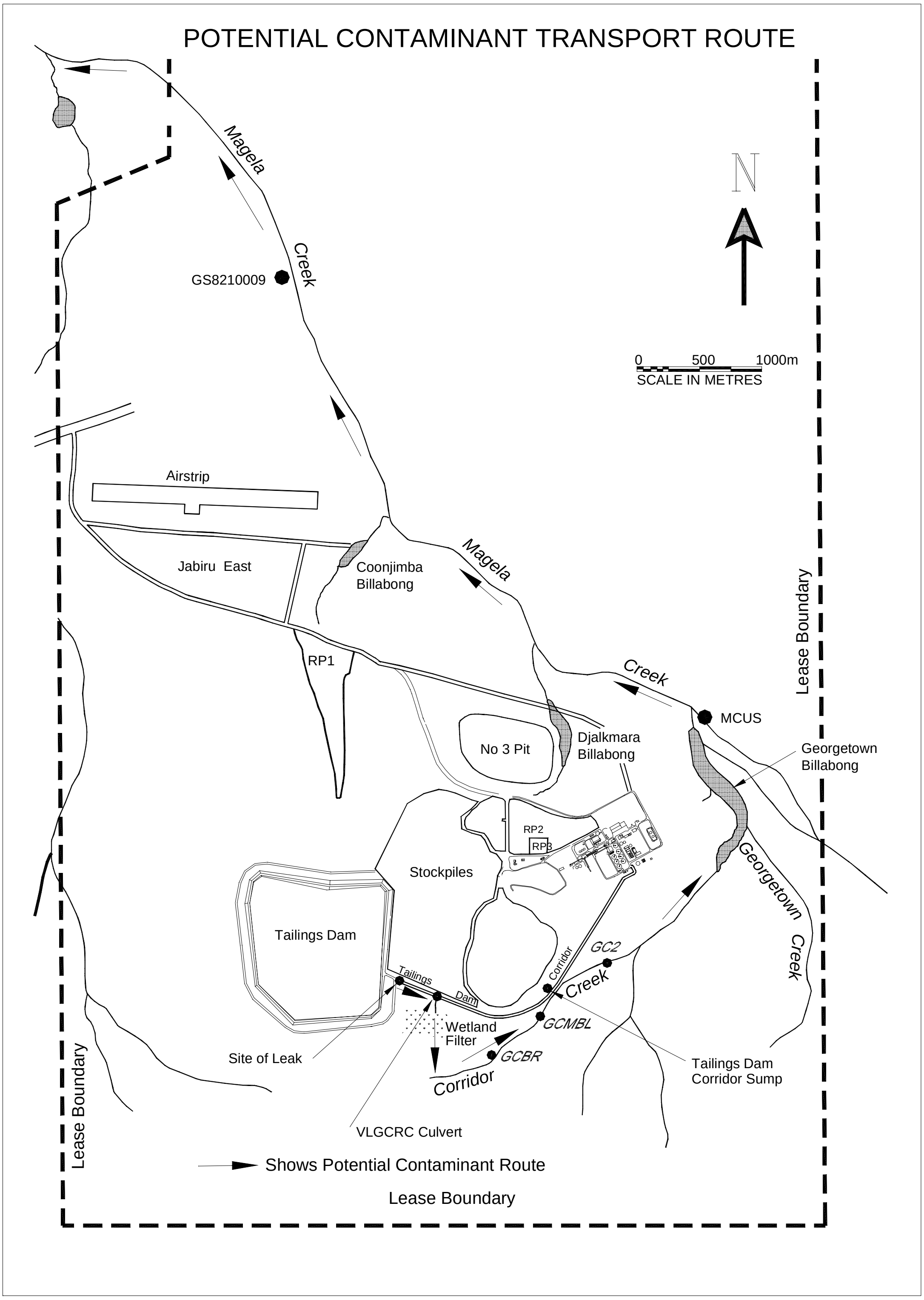

Figure 9 Potential transport pathway between the source of the leak and Kakadu National Park

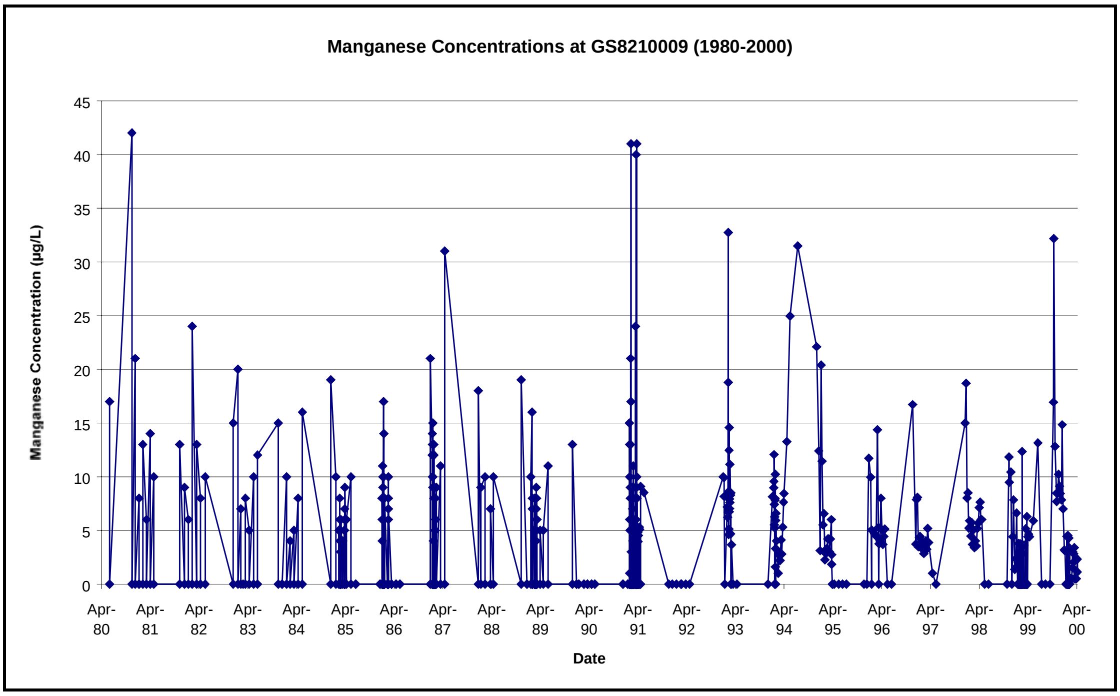

Figure 10 Manganese concentrations at GS8210009 (1980–2000)

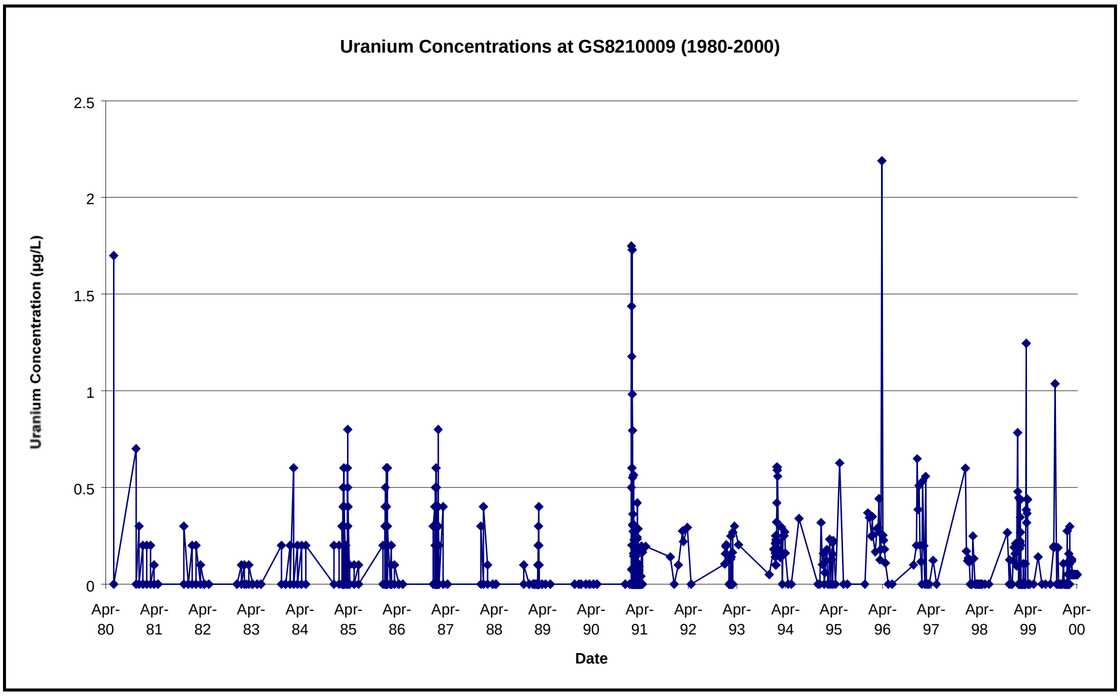

Figure 11 Uranium concentrations at GS8210009 (1980–2000)

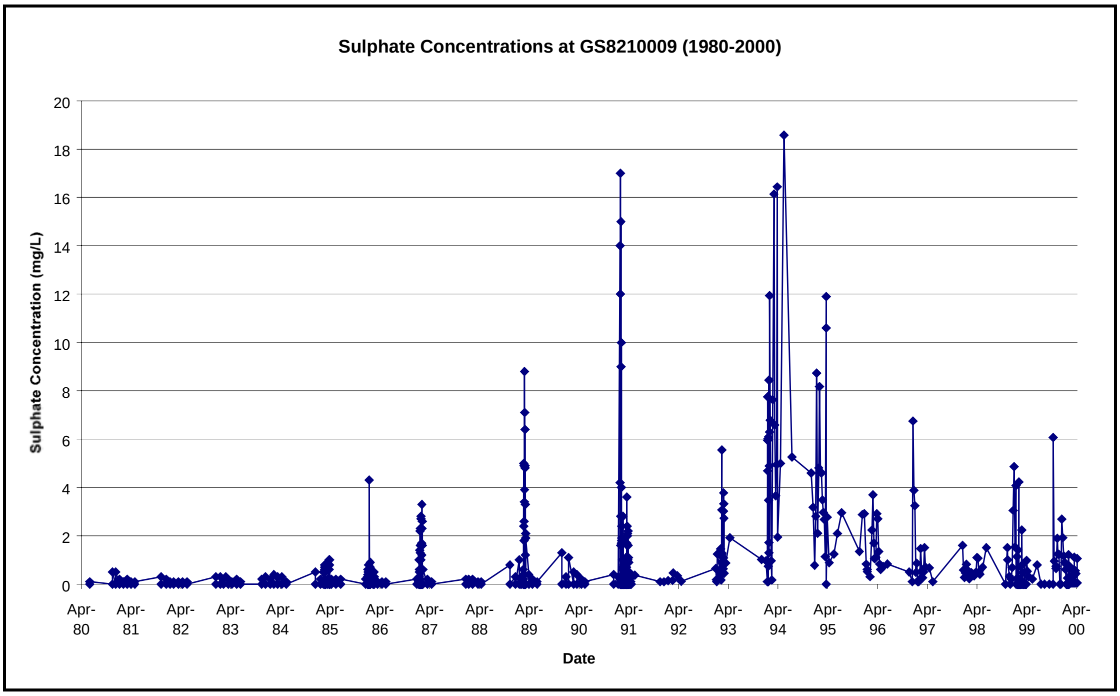

Figure 12 Sulphate concentrations at GS8210009 (1980–2000)

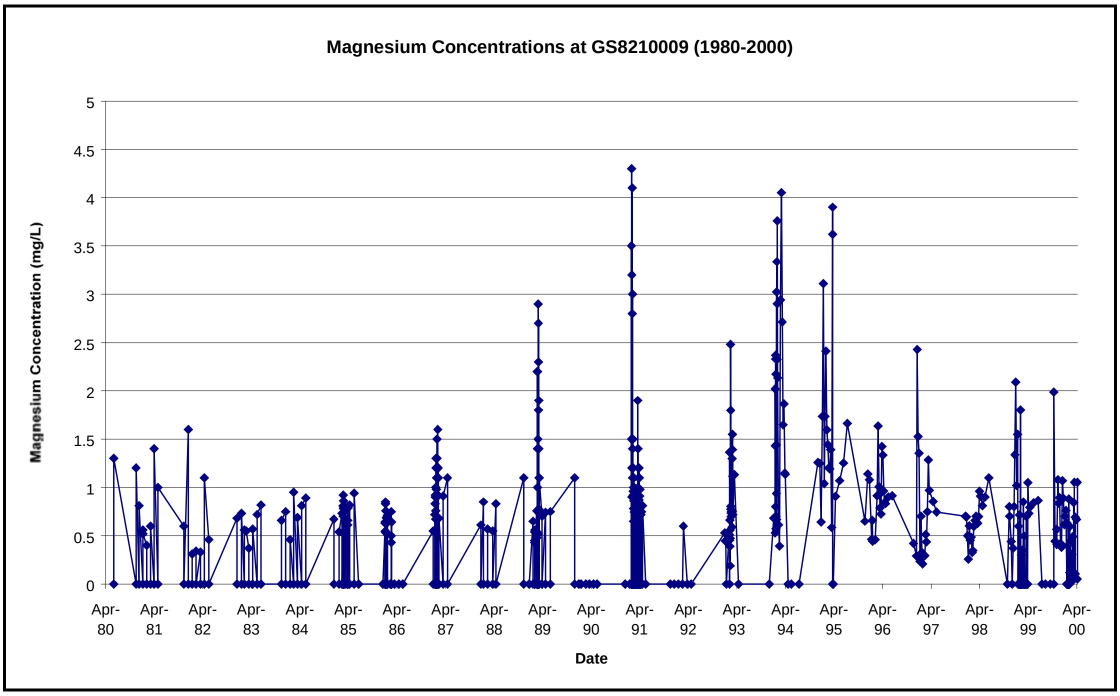

Figure 13 Magnesium concentrations at GS8210009 (1980–2000)

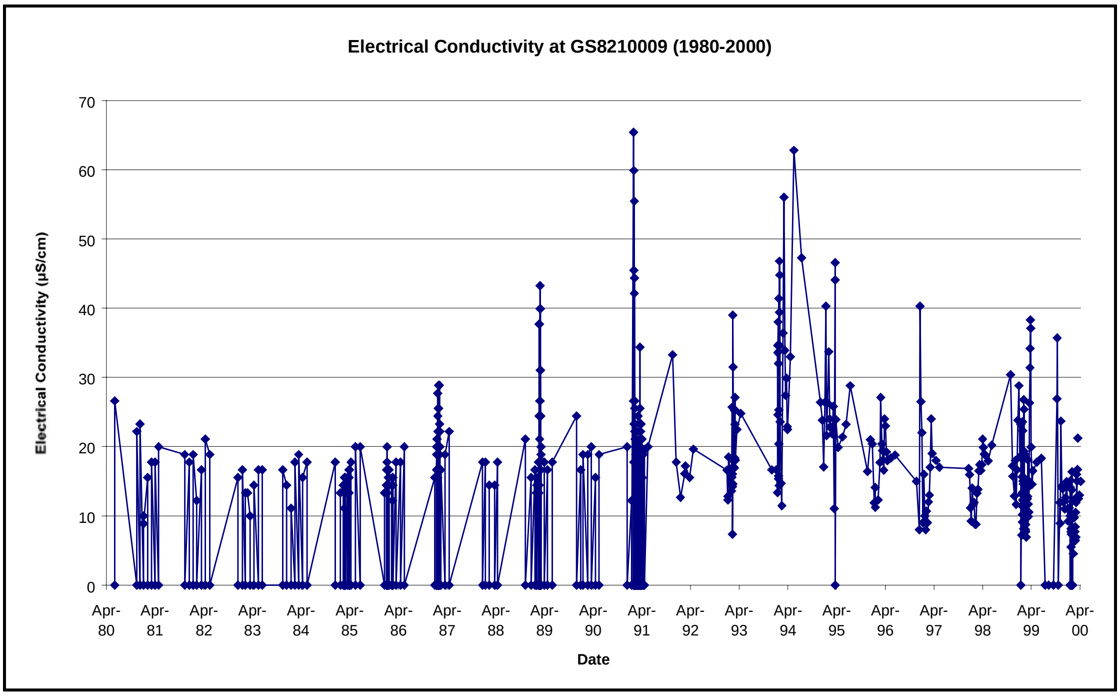

Figure 14 Electrical conductivity at GS8210009 (1980–2000)

Table 2 Summary statistics for the compositions of waters in Magela Creek upstream and downstream of Ranger

Site/Time	Statistic	pH	EC (µS/cm)	Mg (mg/l)	SO_4 (mg/l)	Mn (µg/l)	U (µg/l)
Upstream 1999–00	Mean±σ	5.99±0.48	9.6±2.9	0.39±0.24	0.34±0.58	4.57±7.24	0.06±0.03
	Median	6.00	9.7	0.41	0.22	2.08	0.05
Downstream 1999–00	Mean±σ	5.99±0.48	12.1±5.6	0.53±0.41	0.78±1.10	4.79±6.19	0.09±0.14
	Median	6.10	11.1	0.47	0.56	2.93	0.05
Upstream 1980–99	Mean±σ	6.18±0.33	16.1±1.4†	0.63±1.51†	0.62±1.16	5.76±1.9†2	0.62±2.35
	Median	6.20	16.0	0.64	0.27	5.6	0.10
Downstream 1980–99	Mean±σ	6.13±0.38	20.2±13.3	0.98±0.65	1.68±2.59	9.20±9.20	0.26±0.71
	Median	6.10	18.0	0.80	0.79	6.70	0.13

† Derived from log values

Creekside monitoring is used by ***eriss*** and, in the past three years, by ERA to provide early detection of adverse effects in Magela Creek arising from dispersion of mine waste waters from Ranger. In this form of monitoring, effects of mining are evaluated using lethal and sub-lethal responses of captive organisms exposed to effluent waters. The responses of two test species are measured over a four-day period:

- reproduction (egg production) in the freshwater snail, *Amerianna cumingii*, and
- survival of black-striped rainbowfish, *Melanotaenia nigrans*, larvae.

Lewis (1992) and Humphrey et al (1995) report on the relatively high sensitivity of snails of the genus *Amerianna* to uranium and Ranger retention pond (2) waters. Fish larvae are generally not as sensitive to uranium as invertebrates (such as snails) although Bywater et al

(1991) found that larval black-striped rainbowfish were about as sensitive as other fish species tested.

The principle of the creekside tests is to expose test species simultaneously to a continuous flow of either control (upstream of the mine site) or test (downstream of the mine site, GS8210009) waters for four days. During this time, pairs of snails are free to lay ‘egg masses’ upon their holding chambers while the numbers of fish in replicate tanks are observed on a daily basis. At the end of each 4-day trial, the mean number of egg cases per snail pair and mean number of fish surviving per replicate, are noted for each of the upstream and downstream sites.

In the 1999–2000 wet season, a number of creekside trails were conducted collaboratively by ERA and ***eriss***. The timing of these trials is listed in table 3.

Table 3 Dates of creekside trials conducted in the 1999-2000 wet season

Dates of creekside trials	
Freshwater snails	*Larval fishes*
9-13/12/99	4-8/1/00
24-27/2/00	21-25/2/00
29/2-3/3/00	6-10/3/00
16-19/3/00	14-18/3/00

The results of the creekside trials are plotted as part of a continuous time series of such data in figure 15A for fish survival data, and in figure 15B for snail egg production. When data from the upstream site are subtracted from those at the downstream site, a set of ‘difference’ values can be derived – as shown in figure 15. These difference values may be compared statistically for different parts of the time-series. For example, the 1999–2000 difference data may be compared with those from previous years; if they differ significantly, using a Student’s *t* test, it may indicate a mine-related change (Humphrey et al 1995). Such statistical tests were conducted on the data shown in figure 15. The results showed no significant difference in the ‘difference’ values of 1999–2000 data compared with data from previous years ($P>0.05$). (Note that in the first fish trial (fig 15a), there is poor survival at the upstream control site. The data for this trial are included to illustrate the high survival at the downstream site (and hence no adverse effects arising from mine waste waters at this time.) The data for this trial were not included in the statistical analyses referred to above.)

From these results, it is concluded that there were no adverse effects of mine waste waters on any of the test species over the 1999–2000 wet season. This finding is consistent with the chemical results presented previously.

Given the absence of any detectable impact at GS8210009, it is worthwhile examining the chemical monitoring data collected at Georgetown Billabong which is located on the mine project area downstream from the source of the leakage (Figure 9) but upstream of the Georgetown Creek confluence with Magela Creek. At this point the dilution of leak derived solutes by runoff waters from undisturbed catchments would be less by at least factor of ten. The monitoring results for all the solutes of concern are provided in the attached ERA report (Appendix 2, Figures 11, 12, 13 and 14). Again no increase in the concentrations of any of the solutes was detectable in Georgetown Billabong. It can be concluded that, even this close to the mine, no environmental impact arose as a result of the leak of tailings water during the 1999/2000 wet season.

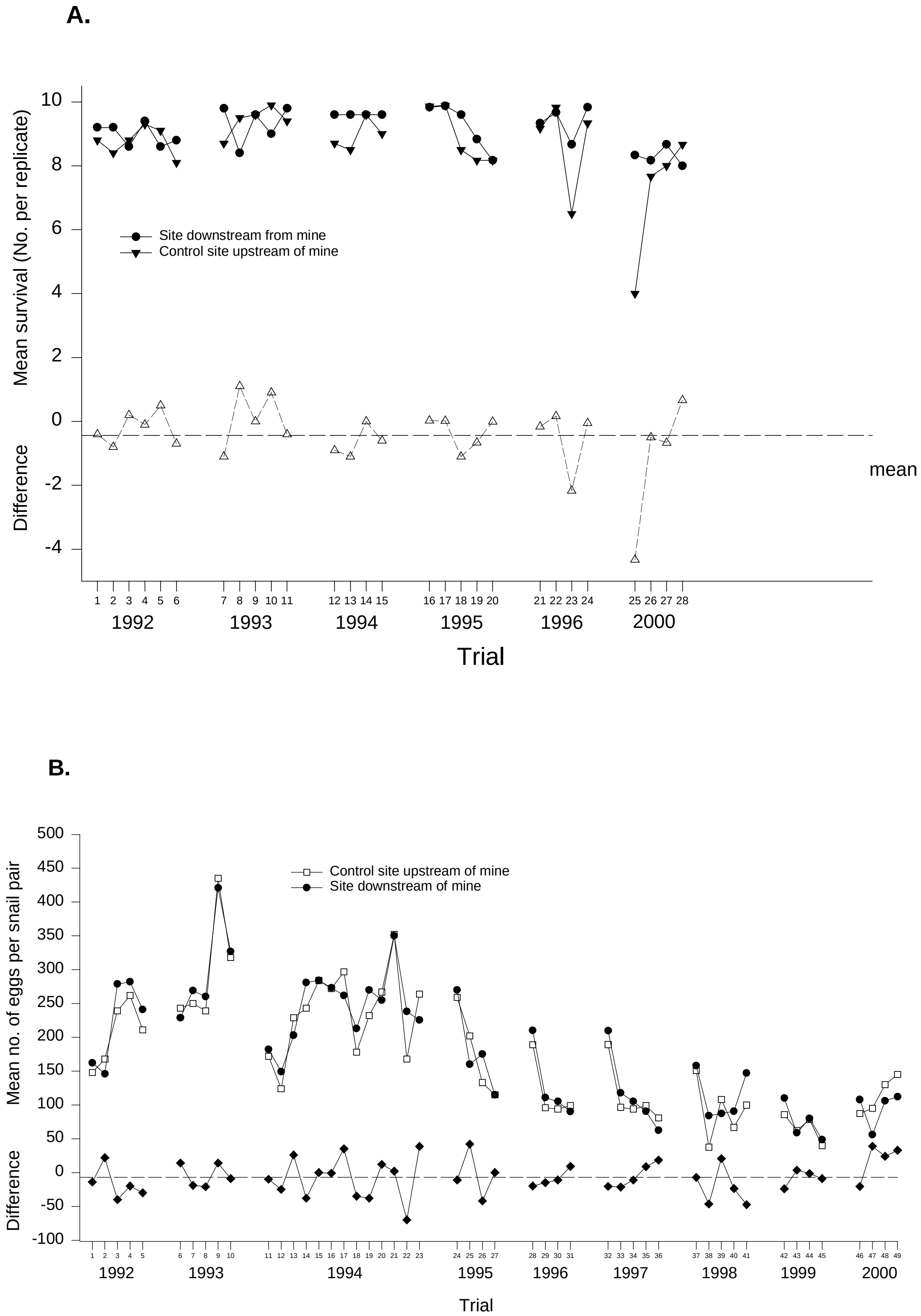

Figure 15 Creekside monitoring results for A larval black-striped rainbowfish survivial, and B freshwater snail egg production, for wet seasons between 1992 and 2000

3.3 Ecological impact assessment based on modelling

The potential ecological impact of the leak of tailings water can also be assessed by estimating the increase in concentrations of tailings associated solutes at gauging station GS8210009 as a result of the leak. This has been done using the following information:

- the volume of tailings water which leaked from the TWRP and entered the Tailings Dam Corridor (2000 m^3)
- estimates of the contaminant loads which seeped from the Tailings Dam Corridor into the VLGCRC
- estimates of the reduction in contaminant loads which reached GS8210009 as a result of processes which remove contaminants from water as it passes through wetlands
- calculation of the increase in concentration of each contaminant at GS8210009 based upon the calculated contaminant load and the volume of water in which it would have been diluted.

3.3.1 Seepage into the Culvert

The ammonium concentration data measured in the VLGCRC have been used to estimate the volume of water that seeped into the VLGCRC. The concentration of ammonium in tailings water is known (530 mgl^{-1}), as is the volume of water that flowed through the VLGCRC. The ratio of the concentration of ammonium in tailings water to the concentration of ammonium in the VLGCRC water represents the dilution of tailings water by DW3A water and rainfall runoff. If the total flow through the VLGCRC is divided by the dilution, the result is an estimate of the volume of tailings water in the VLGCRC.

The relevant data are presented in table 4, taken from ERA 2000.

Table 4 Calculation of Tailings Water Load in the VLGCRC

Date	Ammonium concentration in the VLGCRC (mgl^{-1})	Dilution factor (530 / ammonium concentration in VLGCRC)	Total flow through the VLGCRC over the 24 hour period (m^3)	Calculated flow of Tailings Water through the VLGCRC over the 24 hour period (Flow/Dilution Factor) (m^3)
9 Feb 2000	0.009	Background		
23 Feb 2000	0.3	1767	266	0.15
8 Mar 2000	1.5	353	289	0.82
29 Mar 2000	1.3	408	421	1.03
19 Apr 2000	1.5	353	420	1.18
5 May 2000	0.36	1472	456	0.31

The data show the increase of seepage of tailings water into the VLGCRC during February, reaching a steady state in March and April, then falling in May. Although the leak was repaired on 4 April 2000, tailings water was not completely flushed from the system by 5 May 2000.

There are only six data points over a four month period so the data must be interpreted with caution. However, the data enable a reasonable estimate to be made of the total volume of tailings water which seeped into the VLGCRC using conservative assumptions. The data in table 4 indicate that tailings water seeped into the VLGCRC at a rate of approximately 1 m^3

per day between 8 March 2000 and 19 April 2000. Assuming that tailings water seeped into the VLGCRC at this rate over the entire 85 day period between 9 February 2000 and 5 May 2000, the total volume of tailings water which seeped into the VLGCRC is 85 m^3. This may well be an overestimate of the volume since the data indicate that the seepage rate of tailings water was significantly less than 1m^3 per day during February, early March and early May.

3.3.2 Sources of solutes in Corridor Creek

There are a number of sources of water which enter the constructed wetlands of Corridor Creek. At the entry point to the wetlands, water is derived from:

- overland flow and subsurface seepage from the southern catchment of the very low grade (VLG)/low grade (LG) and waste rock stockpiles, and
- DW3A bore (ie Pit #3 dewatering water) discharge which drains from the top of the waste rock stockpile mainly by surface flow.

Downstream of this entry point, flow within the wetlands is augmented by Pit #1 dewatering water from mine bore L (MBL). The typical compositions of DW3A, MBL and mixed DW3A and waste rock seepage waters during January–May 2000 are summarised in table 5. The volume contribution from waste rock seepage and its composition is not known and is currently being investigated by ERA. However, the largest contribution to flow within the wetland catchment comes as runoff of high water quality from the surrounding undisturbed catchment.

Table 5 The composition of waters considered in the environmental impact assessment

Parameter	DW3A	MBL	Process water
pH	8.1–8.5	7.8–7.9–4.	4.0–4.4
EC (µS/cm)	1100–1200	440–460	15 000–18 000
Mg (mg/l)	150–280	59–68	2400–3700
Mn (µg/l)	<1–7.3	<1	710 000–1 100 000
Ra (Bq/l)			~11
SO_4 (mg/l)	390–1000	10–24	13 000–14 000
U (µg/l)	14–18	200–220	900–1300

3.3.3 Dilution and attenuation of contaminants within the wetlands

Changes in the concentration of Mn, SO_4 and U in response to distance traveled through the wetlands subsequent to process water entering Corridor Creek are shown in figure 16. Sulphate behaves conservatively[1] in wetland systems at Ranger. That is, sulphate is not lost from the water column (attenuated) due to chemical or biological processes. The relative change in the concentration of sulphate can be used as an estimate of dilution during transport through a surface water system. Figure 16 shows that over a 2.6 km path length down Corridor creek, the concentration of sulphate reduces by a factor of approximately 25. This can all be assumed to be due to dilution. The decrease in concentration of the other contaminants beyond a factor of 25 is due to attenuation.

[1] Previous work (Klessa et al 1998) on the RP1 constructed wetland filter has shown that the possible removal of SO_4 by reduction, adsorption or by plant uptake has a negligible effect on concentration.

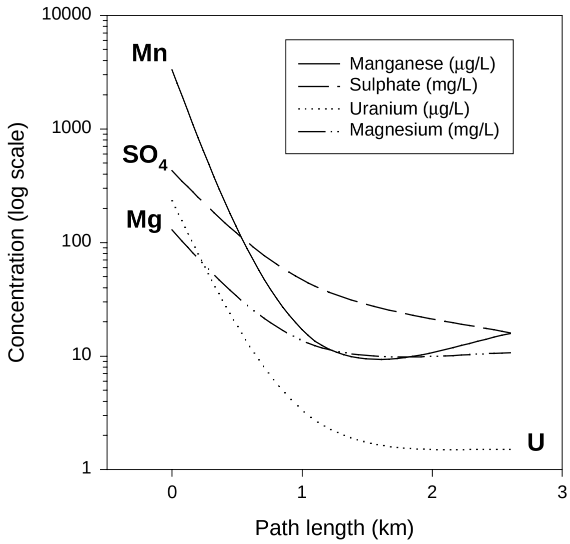

Figure 16 Mean changes (March–April 2000) in the concentration of contaminants as a function of path length through the Corridor Creek wetlands (note the logarithmic scale)

Considering that dilution accounts for a reduction in the concentration of all contaminants by a factor of 25 over a distance of 2.6 km down Corridor creek, Mn and U are indicated to be attenuated by 90% and 80% respectively. That is, approximately 90% of the Mn and 80% of the U are removed from the water column as the water travels through a distance of 2.6 km down Corridor creek. These estimates are in good agreement with previous studies at Ranger[2] which have shown that around 70–90% of Mn and 50–80% of U are attenuated when mine water is passed through wetland filters.

In the absence of data for ^{226}Ra (radium 226), research[3] in two different wetland systems suggests an attenuation factor of 2. Hence over a 2.6 km distance, the activity of ^{226}Ra would be expected to fall by around a factor of 50; a factor of 25 due to dilution and a factor of 2 due to attenuation.

It should be noted that further attenuation of the non-conservative contaminants (Mn, U, Ra) would be expected prior to the water reaching Kakadu National Park. At a distance of 2.6 km downstream of VLGCRC, Corridor creek flows into Georgetown creek. The water has yet to travel approximately another 9 km in the Georgetown and Magela creeks before it enters Kakadu National Park. Consequently, significantly less than 10% of the Manganese, 20% of the Uranium and 50% of the Radium which entered the VLGCRC would have entered Kakadu National Park.

3.3.4 Estimates of the concentration of contaminants in Magela Creek

Since there is some uncertainty on the volume of process water which entered Corridor Creek, the following exercise provides a series of predicted concentration increases at GS8210009 *assuming conservative behaviour for all contaminants*. In it, the volumes of process water used to calculate the export of contaminants are 85 m^3 (ie the estimated volume which entered Corridor Creek) and 2000 m^3 (ie the total volume of process water which leaked into the

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2 LeGras & Klessa 1997; Klessa et al 1998 –based on the RP1 constructed wetland system.

3 Akber et al 1992; Ryan (pers comm) based on work at Djalkmara Billabong and the RP1 constructed wetland filter respectively.

Tailings Dam Corridor). Catchment areas on route downstream from Corridor Creek, Georgetown Billabong (4.6 km from source) and GS8210009 (10 km from source) were used to calculate dilution effects. Results are given in table 6.

Table 6 Average predicted increases in concentration of dissolved contaminants at GS8210009 based upon scenarios of no chemical attenuation of contaminants and process water leaks of 85 m^3 and 2000 m^3, compared to the historical mean during mining at Ranger (1980–1999)[4]

Contaminant	85 m^3	2000 m^3	Historical mean at GS8210009 ±standard deviation (number of samples)
Mg	0.8 µg/l	18 µg/l	985±650 µg/l (n = 545)
Mn	0.15 µg/l	3.5 µg/l	9.2±9.2 µg/l (n = 489)
NH_4	0.1 µg/l	2.4 µg/l	28±66 µg/l (n = 142)
^{226}Ra	0.003 mBq/l	0.064 mBq/l	7.1±8.7 mBq/l (n = 237)
SO_4	3.8 µg/l	90 µg/l	1680±2587 µg/l (n = 417)
U	0.0002 µg/l	0.006 µg/l	0.26±0.71 µg/l (n = 564)

For the purposes of these calculations, it has been assumed that no attenuation of contaminants has taken place. This conservative approach has been taken as there is limited data on the attenuation which occurred in the wetlands. This allows an assessment of the absolute worst case scenario described by all 2000 m^3 of tailings water entering the VLGCRC and no attenuation taking place.

Of particular note are the relatively small effects of the process water leak on the composition of Magela Creek at GS8210009 despite the adoption of the most conservative approach (ie the worst case scenario with all 2000 m^3 of process water entering Magela Creek and no attenuation of contaminants). Additionally, predicted increases fall well within historical variation and therefore can not be detected.

In summary, even assuming a completely unrealistic worst case scenario, the predicted increases in the concentration of contaminants upstream of the point where Magela Creek enters Kakadu National Park are small compared to historical average concentrations and are well within natural variation.

3.3.5 Comparison with toxicological data

Based on existing laboratory toxicological data, the maximum (conservative) predicted increase in manganese downstream of Ranger (at GS8210009) of 3.5 µg/l above background concentrations, would have no adverse impact on aquatic biota. The draft ANZECC & ARMCANZ water quality guideline trigger value for manganese, to be applied to areas of high conservation value, is 200 µg/l (ANZECC & ARMCANZ in press), well above manganese concentrations reported at GS8210009 and those predicted as a result of the process water leak. The trigger value was derived from toxicity data for over ten aquatic species, with toxicity values ranging from 440 µg/l to 4,540,000 µg/l. The fact that the predicted increase in manganese concentration at GS8210009 fell well within the natural temporal variation also indicates that adverse biological impacts are not of concern.

The other major chemical contaminants of concern, uranium, magnesium and sulphate, were also not elevated sufficiently to elicit adverse biological impacts. As stated above, the predicted increases in all major contaminants were well within the natural temporal variation, and thus,

[4] Klessa DA (2000)

biological impacts would not be expected. A site-specific uranium trigger value of 3 µg/l has been derived for Magela Creek downstream of Ranger, based on local species toxicity data. As with manganese, this value is well above recorded uranium concentrations at GS8210009 and those predicted as a result of the process water leak. Limited local species toxicity data has been gathered for magnesium, indicating that toxic effects would not be observed below around 7000 µg/l (Rippon et al 1998), while local and overseas toxicity data for sulphate have shown no adverse effects below 100 000 µg/l (Goetsch & Palmer 1997, Rippon et al 1998). Again, both values are well well above the respective magnesium and sulphate concentrations reported at GS8210009 and those predicted as a result of the process water leak.

In summary, based on toxicological data, the predicted minor elevations in the concentrations of the major chemical contaminants as a result of the process water leak would not result in adverse biological impacts.

3.4 Radiological impact assessment

The critical group for a radiological impact assessment of the incident is the group of Aboriginal people living near Mudginberri billabong (downstream of Ranger) and deriving food and water from the Magela creek system. The principal assessment method for radiological assessment uses the results of past research on radionuclide dispersal and uptake in local aquatic species to calculate of the maximum dose which could have been received by members of the critical group. While this method is scientifically sound, the NLC and the Gundjehmi Aboriginal Corporation have requested further reassurance in the form of measurements of radionuclide content in the edible flesh of fish and freshwater mussels collected from Mudginberri billabong in May 2000. These measurements are underway.

3.4.1 Calculation of the maximum dose which could have been received

Considerable research has been carried out by the Supervising Scientist over the past two decades to enable a reliable assessment of radiation dose received in such a situation. This includes research carried out on the transport of radionuclides in the Magela Creek system and bioaccumulation into the aquatic food chain. This research has been recently reviewed (Martin 2000), and the methods for calculation of dose recommended in that review have been used here.

Estimates have been made of the amount of radioactivity which reached the Magela Creek system as a result of the incident. It is estimated that the amount of tailings water which was discharged into the Tailings Dam Corridor was 2000 m^3 over approximately two months. Based upon Ranger's monitoring data for tailings water over the past two years, the average concentrations of each of U-238 (uranium 238) and Ra-226 (radium 226) have been estimated to be 11 Bq/litre (Becquerels per litre). Routine monitoring of the other naturally occurring radionuclides is not carried out for tailings water but ***eriss*** research data are available for samples collected prior to 1992. These data were used to give estimates of 0.2 Bq/litre for Th-230 (Thorium 230), 12.0 Bq/litre for Pb-210 (Lead 210) and Po-210 (Polonium 210), and 4.9 Bq/litre for Ac-227 (Actinium 227).

Based on the above, and the assumption that no radionuclides were removed in the wetland filter, the estimated doses to a member of the critical group at Mudginberri for the year following the release are:

- 0.8 µSv (micro Sieverts) for an adult and 0.9 µSv for a 10-year old child averaged over the year following the incident, for a release of 2000 m^3 of water.

- 0.03 μSv for an adult and 0.04 μSv for a 10-year old child averaged over the year following the incident, for a release of 85 m^3 of water.

Thus the maximum conceivable dose received by members of the critical group as a result of the leak is lower than the public dose limit of 1000 μSv per year by more than a factor of 1000. The best estimate of the dose received, based upon the released volume of 85 m^3 of tailings water, is lower by a further factor of 30. Even these estimates ignore the reduction in dose resulting from absorption of radionuclides in the wetland filter system.

It can be concluded, therefore, that radiation exposure of members of the public as a result of the leak of tailings water during the 1999/2000 Wet season was negligible.

3.4.2 Measurements of radionuclides in fish and mussels from Mudginberri billabong

Following notification that the incident had occurred, collections of fish and freshwater mussels from Mudginberri billabong were carried out by ***eriss*** personnel. Samples of the edible flesh have been processed for radionuclide analysis. The results obtained will be compared with analyses carried out previously by ***eriss*** and other researchers. Because of the time-consuming nature of such analyses, only preliminary results for Ra-226 and Po-210 for a few samples are available at this stage. These results are summarised in table 7.

Table 7 Results of the Preliminary Analysis of Fish taken from Mudginberri Billabong

Sample	Ra-226 (mBq/kg[1] flesh)	Po-210 (mBq/kg flesh)
Fork-tailed catfish #2	14 ± 40	210 ± 20
Fork-tailed catfish #3	–	480 ± 50
Fork-tailed catfish #4	90 ± 20	–
Fork-tailed catfish #5	160 ± 50	–

1 milli Becquerel per kilogram

Results from a study carried out by ***eriss*** in the 1980s of flesh of Mudginberri fork-tailed catfish gave mean concentrations for Ra-226 of 100 mBq/kg (standard deviation 50; 5 samples) and for Po-210 of 280 mBq/kg (standard deviation 120; 6 samples). Based on these results, there is no indication of a significant change in concentrations of either Ra-226 or Po-210 between the two sets of samples.

To give an indication of the relevance of these figures, the expected dose resulting from ingestion of fish flesh based upon the highest concentrations recorded in the above table have been calculated. The total annual consumption of fish assumed for an adult in the diet of the critical group is 40 kg per year. Consumption of 40 kg of flesh containing 160 mBq/kg Ra-226 and 480 mBq/kg Po-210 would result in a radiation exposure of 24 μSv. This is a factor of 40 below the internationally agreed limit for exposure members of the public. It should also be noted that this exposure is of natural origin and not as a result of the leak of tailings water.

4 Review of the Tailings Dam Corridor

The Supervising Scientist contracted Sinclair Knight Merz Pty Ltd (SKM) to review the Tailings Dam Corridor at the Ranger Mine. The objective of the review was to:

- assess the suitability of key aspects of the design,
- assess the suitability of current operating, maintenance and system development regimes and responsibilities, and

- make recommendations as appropriate.

The SKM Report is available from the Supervising Scientist on request.

4.1 Suitability of the design of the tailings dam corridor

The SKM Report concluded that the fundamental design and operation of the Tailings Dam Corridor was appropriate at the time of initial construction and operation, and is still appropriate. However, the report made a number of recommendations related to the design of the Tailings Dam Corridor. Those recommendations are summarised below.

- Investigate the widening of the western end of the Tailings Dam Corridor to reduce the risk of a pipe leak resulting in contaminated water falling outside of the Tailings Dam Corridor.
- Investigate the effect on the Tailings Dam Corridor of the presence of the 500 mm polyethylene pipes in regard to the possible impedance of flow in the drain, and the progressive erosion and degeneration of the drain due to thermal movement of the polyethylene pipes.
- The specifications of the overflow pipe installed between the Tailings Corridor Sump and pit 1 should be reviewed to ensure that overflow capacity is adequate considering the design storm event.
- Investigate the permeability of the Tailings Dam Corridor.
- All locations where the original Tailings Dam Corridor has been significantly altered should be reviewed to determine whether those alterations have compromised the integrity of the Tailings Dam Corridor.
- The design of the concrete slab installed by ERA in the Tailings Dam Corridor over the VLGCRC as a remedial measure should be reviewed to confirm that it is properly keyed and will not result in undermining of the slab by storm flow in the drain.

The last three of these recommendations are the most significant. Up to 85 m^3 of tailings water is calculated to have seeped from the Tailings Dam Corridor into the VLGCRC between 9 February and 5 May 2000. In addition to tailings water for which ammonium has been used as a tracer, rainfall runoff would have also seeped into the VLGCRC. Assuming that 2000m^3 of tailings water leaked from the TWRP into the Tailings Dam Corridor, 4.25% of the tailings water seeped into the VLGCRC. It is reasonable to assume that the same proportion of the rainfall runoff that entered the Tailings Dam Corridor upgradient of the VLGCRC would also have seeped into the VLGCRC.

The total rainfall at Ranger between 9 February and 5 May 2000 was 850.2 mm. The catchment of the Tailings Dam Corridor upgradient of the VLGCRC is 1.25 ha. Using an average runoff coefficient of 0.3 for this catchment, the volume of rainfall runoff which would have entered the Tailings Dam Corridor upgradient of the VLGCRC was 3200 m^3. Assuming that 4.25% of this water also seeped into the VLGCRC, the total volume of water which seeped onto the VLGCRC between 9 February and 5 May, including tailings water was 220 m^3.

The uncertainties associated with this figure are relatively high. Regardless of those uncertainties, seepage rates of this order of magnitude justify a full review of the Tailings Dam Corridor with particular emphasis on the efficacy with which it performs the task of providing secondary containment.

4.2 Suitability of the operation and maintenance of the Tailings Dam Corridor

The principle finding of the SKM Report regarding the operation and maintenance of the Tailings Dam Corridor is that the maintenance of the Tailings Dam Corridor, in terms of cleaning and grading etc, has not in latter years been to the same standards which prevailed during the early stages of mine development. Figure 17 is a photograph of the Tailings Dam Corridor taken from above the VLGCRC looking in an easterly direction. However the Report notes that ERA has recognised the need to improve the maintenance of the Tailings Dam Corridor and is putting measures in place to rectify the situation. Figure 18 shows the same section of the Tailings Dam Corridor after remedial works had been completed including the installation of a concrete pad over the culvert. Figures 19 and 20 show the area of the leak before and after remedial works.

Significant issues detailed in the SKM Report are summarised below.

- Responsibility for maintaining pipelines in the Tailings Dam Corridor is split between the Mill Maintenance group and the Engineering Services Group. The Mill Maintenance group wishes to pass its responsibility for maintenance of the tailings pipeline to the Engineering Services Group.
- The ultrasonic inspection of the TWRP and the tailings pipelines by Intico has not found any evidence of metal wall thickness reduction. However, the method employed does not allow the examination of the ends of the pipes near joints or the examination of the polyethylene lining in the tailings lines. Evidence presented to SKM indicates that degradation of the lining in the tailings lines is not likely to be an issue at present. The condition of pipe ends in the tailings lines is thought to be good. The condition of pipe ends in the TWRP is suspect.
- Some flange guards in the tailings pipelines and the TWRP are not correctly fitted and at places in the TWRP, are not fitted at all.
- Some recently installed sections of the TWRP have been painted on the outside instead of the inside.
- The most vulnerable aspect of the pipelines are the joints.
- Undersized bolts are suspected to have been used at the flange joint in the TWRP that failed.
- Redundant pipework remains in the Tailings Dam Corridor from previous operations.
- Grading of the Tailings Corridor Road has resulted in material being pushed into the pipetrack area causing the pipelines to be partially or fully buried in places (grading was not a significant contributor to the burial of the TWRP at the point of the leak).
- The maintenance practice of applying herbicides to the Tailings Dam Corridor to prevent the growth of grass around the pipelines has ceased resulting in the extensive growth of grass and weeds around the pipelines. Some cold burning has been used to control grass however this practice carries with it a risk of damaging the internal linings of pipes, compromising their integrity.
- There is some evidence that the side embankment heights/integrity might in a few locations not be as originally designed.
- The pipelines in the Tailings Dam Corridor are located very close to waste rock stockpiles in places. There is a risk of falling rocks from the stockpile damaging the pipelines.

Figure 17 Tailings Dam Corridor looking east before remedial works

Figure 18 VLGCRC culvert after remedial works had been completed showing concrete pad over the culvert (looking east)

Figure 19 Tailings Dam Corridor pipelines in the vicinity of the leak before remedial works (looking west)

Figure 20 Tailings Dam Corridor pipelines in the vicinity of the leak after remedial works (looking west)

The recommendations made in the SKM Report relevant to the operation and maintenance of the Tailings Dam Corridor are summarised below.

- Prepare a formal maintenance program and procedures covering all aspects of the Tailings Dam Corridor including grading of the Tailings Dam Corridor Road.
- Review the roles and responsibilities of ERA departments regarding maintenance of the Tailings Dam Corridor.
- Review technical drawings, and the procedures for the amendment of technical drawings of the Tailings Dam Corridor to ensure an up to date set is always available.
- Based on a review of all available information on the tailings pipelines, determine if the investigation of the tailings lines polyethylene lining is justified.
- Progressively strip and paint the pipe ends on the TWRP to prevent deterioration and reduce the risk of joint failures.
- Inspect all flange joints to ensure that all bolts are of the correct size.
- Visually inspect all joints which have been buried for signs of corrosion.
- Check and properly fit guards on all flange joints.
- Emphasise in procedures, and to maintenance staff, the importance of carefully handling pipe ends during assembly of Victualic coupling joints. Provide documentation and training to staff.
- Ensure that Victualic couplings of an appropriate quality continue to be supplied.
- Identify all pipework not currently being used and establish whether or not it should be made permanently redundant. Establish a program to remove all redundant pipework as soon as practical.
- Inspect bunds at the perimeter of the Tailings Dam Corridor to confirm that they are consistent with the original design intent.
- Ensure that the Tailings Dam Corridor clean up operation recently undertaken has returned all corridor levels, drainage and other features as appropriate to original specifications.
- Safely remove all grass which has developed in the Tailings Dam Corridor.
- Initiate a regular supervised herbicide application program to prevent re-growth of grass in the Tailings Dam Corridor.
- Investigate options to reshape/cut back the waste rock stockpile at the western end of the Tailings Dam Corridor in order to reduce the risk of falling rocks damaging the adjacent pipelines.
- Consider the installation of magnetic flowmeters in pipelines to detect major leaks which could have a significant impact if they occurred some time before the next inspection.

It is clear from the SKM Report that the maintenance of the Tailings Dam Corridor by ERA has not been adequate in recent years. The degeneration of the standard of maintenance must be considered a contributing factor to the leak in the TWRP.

The pipelines in the Tailings Dam Corridor were installed above ground so that they may be readily inspected and maintained. Where an access road was required to cross these pipelines, the Access Road Culvert was installed through which the pipelines pass, and over which the access road is built. The purpose of the culvert is to allow rainfall runoff to pass under the access road, and also to maintain the integrity of the Tailings Dam Corridor. It also retains access to the pipelines which would otherwise have been buried under the access road.

Over a period of 18 months to two years, silt was allowed to build up in the Access Road Culvert burying a small part of these pipelines. The maintenance and inspection regime applied by ERA to the pipes in the Tailings Dam Corridor includes a visual inspection three or four times per shift. The gradual covering of a section of the pipelines should have been identified by these visual inspections. Action should then have been taken by ERA to prevent any further siltation of the pipelines, and to remove any silt which prevented visual inspections of the pipelines. These actions were not taken representing a failure of the ERA maintenance and inspection regime for the pipelines in the Tailings Dam Corridor. Had these actions been taken, the leak, if it occurred at all, would have been identified and repaired before significant quantities of tailings water had escaped the TWRP.

An examination of the Tailings Dam Corridor inspection records maintained by ERA indicates that inspections were made as required. It is interesting to note however the entry recorded on 4 April 2000, the date on which the TWRP was being repaired. The entry was “All lines OK”. Whilst this may be technically correct in that the TWRP was not leaking, the entry does not reflect the significant deviation from normal operation of the TWRP which applied at that time. Such minimalist record keeping renders such inspection records of limited use.

5 Discussion on issues arising from the investigation

This investigation of the leak from the Tailings Water Return Pipeline has demonstrated that the environmental consequences of the leak were negligible both for the health of people living downstream from the mine and for the ecosystems of Kakadu National Park. Nevertheless, the investigation has raised a number of issues that need to be addressed if the standard of environmental performance which has been achieved in the past at Ranger is to be maintained in the future. These issues are addressed in this section.

5.1 Design and Maintenance of the Tailings Dam Corridor

As part of this investigation the Supervising Scientist conducted a review, through Sinclair Knight Merz Pty Ltd (SKM), of the design of the tailings dam corridor and of the adequacy of ERA’s operation and maintenance program in the corridor.

The SKM Report concluded that the fundamental design and operation of the Tailings Dam Corridor was appropriate at the time of initial construction and operation, and is still appropriate. However, the report made a number of recommendations related to the design of the Tailings Dam Corridor. The principal issue raised is the extent to which the corridor fulfills its role as an impermeable secondary containment system. A full review of the Tailings Dam Corridor is required to determine the extent to which the Corridor meets this requirement.

Recommendation 1

> ***ERA should undertake a full review of the Tailings Dam Corridor with particular emphasis on the efficacy with which it performs the task of providing secondary containment. The Terms of Reference for the Review should be approved by the Supervising Scientist.***

The principal conclusion of the SKM review on the operation and maintenance of the Corridor is that the standard of maintenance has deteriorated and does not meet the standard achieved in earlier years of the operation. A number of recommendations were made for improvements in the maintenance regime. The same conclusion has been reached in ERA's internal management review "Significant Incident Investigation Report – Process Water Pipe Leak at ERA" (Appendix 3). The latter report concluded that, when the tailings lines were decommisioned at the western end of the corridor (the location of the leak) and tailings were pumped directly to Pit 1, the perceived hazard and the response to it by ERA reduced. This reduced perception of the hazard led to a poorer maintenance regime and was a direct contributor to both the leak itself and to the delayed identification of the source of the leak.

Recommendation 2

> ***All Recommendations on maintenance procedures in the Tailings Dam Corridor made in the Sinclair Knight Merz Review of the Tailings Dam Corridor should be implemented.***

5.2 ERA response to the incident

The Ranger Management Team was aware on 29 March 2000 that there was a significant probability that tailings water had escaped to a surface water system which flows to the environment. ERA now recognises that this was a reportable incident but, for some reason, the Management Team considered the issue at the time and chose not to report it. ERA has conducted a review of management actions throughout the period of this incident. It concluded that there was no deliberate intent to deceive or dissemble. Rather, the underlying reason is likely to have been a lack of recognition by the Ranger Management Team of the needs and expectations of stakeholders.

Recommendation 3

> ***ERA should strengthen the Ranger Management Team to ensure that there is an effective interface with external stakeholders and that decisions are made quickly to meet the expectations of the stakeholders.***

This lack of recognition of the needs of stakeholders appears to permeate down through the organisation at ERA Ranger mine. There appears to be a considerable reluctance on the part of staff to pass on information that could be of importance not only to the NTDME and the OSS but also to senior management at ERA. This may stem from a perception, somewhat justified by past experience of public responses, that the reporting of incidents produces a primarily political response rather than an objective assessment of significance. ERA needs to take steps to improve the awareness of all of its staff to ensure that the open and transparent system of reporting to which it is committed is implemented.

Recommendation 4

> ***ERA should take immediate take steps to put in place an employee training program designed to ensure that all employees appreciate the need to keep the authorities informed of any event that could be perceived to be of concern to the local Aboriginal people or the broader community, not just incidents that are acknowledged infringements of the Ranger General Authorisation or the Environmental Requirements.***

Recommendation 5

> ***The Supervising Scientist should offer to assist ERA in the above training program. In particular, the Supervising Scientist should provide a briefing to ERA employees on issues of significance in this report, and any other issues that are considered to be of concern to members of the public.***

An issue of concern in the ERA response to its discovery of enhanced concentrations of manganese in the culvert is that it does not appear to have been appreciated by the staff involved that the principal source of manganese on the mine site is the tailings circuit. This observation should have immediately triggered a concern that there could be a failure not only in the process water/tailings circuit but also a failure of the secondary containment system. Similar deficiencies in interpretative ability was demostrated in other ways until much later in the investigation when senior scientific staff from EWL (Earth Water Life Sciences, ERA's environmental consultants) were consulted on the problem.

ERA has advised that notification of stakeholders was prepared on 10 April 2000 but was not sent until 28 April due to "a sequence of internal delays (the Easter and ANZAC day break and the assumption that no process water had escaped off site)". How ERA came to the conclusion that no process water had escaped off site, (which we interpret as loose wording referring to contaminants in the process water, which is the issue) considering the monitoring data in the VLGCRC available to it, is not well established. Whilst ERA would have been aware at the time that only a small proportion of the contaminants in the process water could have reached Kakadu National Park, it should not have assumed that no contaminants had escaped off site.

The notification which was provided on 28 April 2000 (Appendix 1) was inadequate. It made no mention of the elevated manganese concentrations in the VLGCRC nor did it allude to the possibility that process water was the cause of those elevated concentrations. Had OSS not made further inquiries of ERA by phone that afternoon, it is possible that the most important aspects of this incident would never have been revealed.

There is a clear need for ERA to strengthen its scientific interpretative capacity. The ERA management review (Appendix 3) supports this conclusion.

Recommendation 6

> ***ERA should upgrade the environment protection staff structure at Jabiru to ensure that the company has the on site ability to effectively identify, interpret and rectify environmental incidents.***

From the date of the public announcement of the occurrence of the incident, 2 May 2000, ERA has cooperated to the fullest extent possible with the authorities. The scientific rigour of the investigation of the incident led by EWL has been patently obvious and ERA has taken up all of the suggestions of the Supervising Scientist to undertake new and different analyses of archived samples in an attempt to understand some of the complicated processes that had clearly taken place during the 1989/1999 and 1999/2000 wet seasons. The report provided by ERA (Appendix 2) has been invaluable to the OSS in preparing this report.

While we now have a sufficient understanding of the leak of tailings water during the 1999/2000 wet season to prepare this report, there remain some outstanding issues. Principal among these is the need to continue work on the other sources of Mn in the Tailings Dam Corridor and the culvert during the 1998/1999 wet season. Work reported to date indicates that tailings affected waters were present in the culvert during that year. While this report has concluded that this would not have given rise to harm to people or ecosystems downstream, the issue needs to be fully investigated and resolved.

Recommendation 7

> ***ERA should complete a comprehensive investigation of the additional sources of manganese, including previous tailings spills in the Tailings Dam Corridor, and provide a report to the Minesite Technical Committee.***

5.3 Breach of the Commonwealth's Environmental Requirements

An assessment is required of whether or not ERA has been in breach of the Commonwealth's Environmental Requirements (ERs) for the Ranger uranium mine. The relevant ER for the control of process water is reproduced below.

3.4 Process water must be totally contained within a closed system except for:

(a) losses through natural or enhanced evaporation;

(b) seepage of a quality and quantity that will not cause detrimental environmental impact outside the Ranger Project Area; and

(c) subject to clauses 3.1, 3.2 and 3.3, process water which has been treated to achieve a quality which:

i) conforms to a standard practice or procedure recommended by the Supervising Scientist; and

ii) is not less than that of the water to which it is to be discharged.

It is clear that the tailings water escaped the Tailings Dam Corridor as seepage into the VLGCRC. Section 3 of this report discusses the environmental impact of this seepage. The conclusions drawn in that section would certainly support the view that the seepage was of a quantity and quality that will not cause detrimental impact outside of the Ranger Project Area. So a cursory review of the leak may, considering ER 3.4(b), lead to the conclusion that it is not a breach of the ERs.

However, the intent ER 3.4(b) is to acknowledge that the large water retaining structures such as the retention ponds and the tailings dam on the Ranger site were designed and constructed in a manner which can not absolutely prevent seepage from occurring. Seepage which is monitored from these large water retaining structures does not represent a failure of any kind as long as the seepage remains below acceptable levels, which these water retaining structures were designed to achieve.

The leak of tailings water from the TWRP is quite different to the situation described above. In this case, the TWRP failed, spilling tailings water into the Tailings Dam Corridor. Containment in the Tailings Dam Corridor also failed, allowing a significant quantity of the tailings water to enter the VLGCRC. ER 3.4(b) is therefore not applicable as it is not intended to allow failures of infrastructure designed to contain process water. Consequently, this incident constitutes a breach of ER 3.4.

The relevant ER on reporting of incidents is:

16.1 The company must directly and immediately notify the Supervising Authority, the Supervising Scientist, the Minister and the Northern Land Council of all breaches of any of these Environmental Requirements and any mine-related event which:

(a) results in significant risk to ecosystem health; or

(b) which has the potential to cause harm to people living or working in the area; or

(c) which is of or could cause concern to Aboriginals or the broader public.

Whether ERA should have formally reported the increased concentrations of manganese in the VLGCRC to OSS, NTDME, ISR and the NLC in early February 2000 is debatable. It would have been prudent to at least informally advise OSS of the observed concentrations by telephone as soon as the results of the analysis were known to ERA. However, on 29 March 2000, the Ranger Management Team was informed of a suspected leak of tailings water (process water) in the Tailings Dam Corridor which was known by ERA at the time to be a likely source of elevated concentrations of manganese measured in the VLGCRC since early February 2000, which eventually flows to the environment.

Thus, the Ranger Management Team was aware on 29 March 2000 that there was a significant probability that tailings water had escaped to a surface water system which flows to the environment. Even considering the environmental insignificance of the event which has now been demonstrated, any reasonable person should have judged the release of process water to the VLGCRC which eventually flows to the environment to be an issue that could cause concern to Aboriginal people living downstream of the Ranger uranium mine. Therefore, ERA was required by ER 16.1 to immediately report the incident to the OSS, NTDME, ISR and NLC. The fact that such a notification was not made immediately puts ERA in breach of ER 16.1.

The Supervising Scientist has concluded, therefore, that ERA has been in breach of Enviromental Requirements 3.4 and 16.1.

The views of the Mirrar are important in the context of this discussion. The Supervising Scientist consulted the Mirrar at a meeting of the Gundjehmi Aboriginal Corporation on 13 June 2000. The purpose of the meeting was to enable to Mirrar to be advised of the details of the leak investigation, particularly the effects on people and the environment, and to seek feedback from the Mirrar on their concerns and expectations.

The Mirrar advised that what mattered to the Aboriginal people was that tailings water is dangerous, they had been promised that it would be contained and that this promise had been broken. All the assurances of the scientists did not matter to the people - what they care about is that dangerous water has been allowed to leak. They further advised that they want the Government to demonstrate that it takes the concerns of the Aboriginal people seriously.

Recommendation 8

The Minister for Industry Science and Resources should consider what action should be taken in response to the established breach of Environmental Requirements 3.4 and 16.1 taking into account:

- ***The radiological and ecological impact arising from the leak of tailings water to the environment has been negligible***
- ***The leak resulted from poor maintenance practices in the Tailings Dam Corridor***
- ***The view of the traditional owners of the Ranger Project Area is that Aboriginal people will only believe that the Government takes their concerns seriously if substantive action is taken.***

5.4 Statutory Environmental Monitoring Program

An important issue in the assessment of the tailings water leak is the the fact that the data that initiated investigations were research data, not routine monitoring data. These data were not provided to the OSS or other members of the Minesite Technical Committee. As described earlier in this report, the statutory monitoring data which were provided to the authorities did not provide any indication of the leak.

The statutory environmental monitoring program is designed to quantify the loads and concentrations of contaminants which leave the Ranger Project Area and are attributable to mining operations on the site. They enable the comparison of water quality data with appropriate standards and also enable the identification of trends in water quality which, long before standards might be exceeded, would allow appropriate management action to be taken where trends of concern become evident. The program has not been designed to detect leaks in pipelines on the site. This incident has demonstrated that there is a need to improve the scope of the statutory environmental monitoring program.

The philosophy underlying the environment protection systems in place at Ranger is that it is recognised that a major industrial operation cannot operate without failures of plant and equipment at some time during the operational period and that, to ensure that the environment beyond the minesite is protected, barriers must be in place to contain contaminants in the event of failure. Wherever possible, therefore, significant potential sources of contaminants at the Ranger Uranium mine are managed using multiple levels of containment. For example, tailings water is transported within the TWRP (primary containment). The TWRP runs within the Tailings Dam Corridor (secondary containment). The Tailings Dam Corridor is designed so that water within it, including water which may have leaked from the TWRP, reports to the Tailings Dam Corridor Sump. The Tailings Dam Corridor Sump is designed to overflow into Pit 1. Any potentially contaminated water which escapes the Tailings Dam Corridor and enters Corridor Creek passes through wetlands (tertiary containment) which polish the water. This system of environment protection is illustrated in the schematic diagram in figure 21.

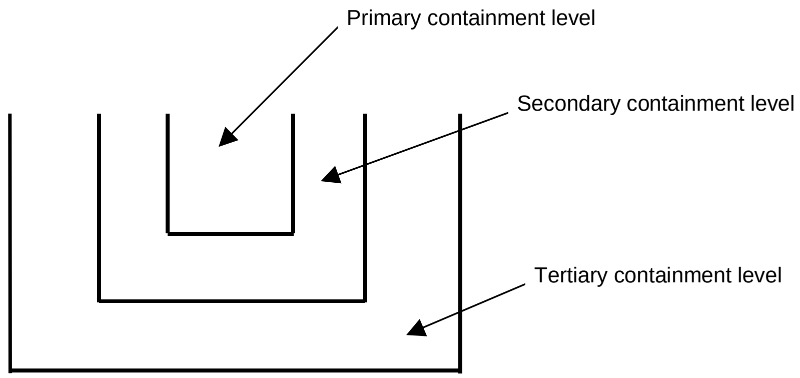

Figure 21 Schematic diagram illustrating the environment protection philosophy at Ranger

The current statutory monitoring program involves sampling of water at Georgetown Billabong, at a point upstream of Ranger (MCUS), and at GS8210009 upstream from the point at which the Magela Creek enters Kakadu National Park. These points are beyond the last level of containment. This is appropriate considering the purpose for which the Statutory Monitoring Program was designed. However, one of the lessons to be learned from this investigation is that it is now necessary to review the statutory monitoring program to determine the practicality of including appropriate monitoring within the secondary and tertiary levels of containment. For example, in the case considered in this report, monitoring of ammonium ion and manganese in the Tailings Dam Corridor Sump would have provided an early warning of failure of a primary containment structure in the Corridor. Similarly, the research data which first indicated that there may have been a leak of tailings water were data for water beyond the second level of containment (the Tailings Dam Corridor) but within the third level of containment (upstream of the Corridor creek wetlands). This incident has demonstrated the value of environmental monitoring closer to potential sources of contamination. Such an extension to the Statutory Environmental Monitoring Program would provide an additional early warning capability within a formal reporting framework.

Recommendation 9

> ***The statutory environmental monitoring program should be extended to enhance its capacity to provide early warning of unplanned releases of contaminants. This extension should include the establishment of additional monitoring locations within secondary containment systems that would indicate the failure of primary containment systems.***

A second issue that arises in this context is the question of how failures in the secondary containment structures are to be detected prior to failure of the relevant primary containment structure. In the current case, the engineered structure between the tailings dam road and the culvert had clearly been permeable for some time, possibly since its installation. This failure was not detectable until the primary barrier (the pipeline) failed because no system is in place to detect failures in the secondary containment system. This needs to be rectified.

Recommendation 10

> ***The Minesite Technical Committee should review the inspection and monitoring system at Ranger to establish and implement measures that will detect failures in the secondary containment systems and structures.***

The use of research data collected by ERA and its consultants requires assessment. Had the research data been provided to the OSS and the other members of the Minesite Technical Committee when they became available, OSS would have been in a position to commence its own inquiries. This may have led to the identification of the source in a more timely manner.

There are sensitivities associated with the provision and use of research data. Research scientists are inclined to guard research data closely until it has been fully analysed and published, with appropriate discussion, in the scientific literature or in a report to the client in the case of research completed under contract. The primary concerns are the misinterpretation of an incomplete dataset, and the loss of intellectual property. These are valid concerns. Nonetheless, the provision of research data to the OSS as it becomes available should be required. Protocols can be developed on the use of such data to ensure the protection of IP rights.

Recommendation 11

> ***ERA should provide the Supervising Scientist and the Supervising Authorities with all research data as they becomes available rather than at the end of research projects. Protocols should be developed for the appropriate use of research data.***

It should be noted that ERA has identified this issue and, in his letter to the Supervising Scientist of 19 May 2000 (Appendix 4), the Chief Executive of ERA has undertaken to provide research data to the authorities as it becomes available.

5.5 Inspection of the Ranger Uranium Mine

The Ranger uranium mine is subject to a regulatory system which is unique in Australia. The mine operates under an authority issues pursuant to Section 41 of the Atomic Energy Act 1953. The Environmental Requirements for the mine are stipulated in that authority. The Northern Territory Department of Mines and Energy (NTDME), as the regulatory authority for mining activities in the Northern Territory, is responsible for administering regulatory processes underpinned by Northern Territory Legislation. Those regulatory processes include the issue of the Ranger General Authorisation (RGA) which defines regulatory requirements, the assessment and approval of various operational manuals, compliance audits and inspections of Ranger operations by Inspectors appointed under relevant Northern Territory legislation, and check monitoring. In summary, NTDME is responsible for the day to day regulation of the Ranger uranium mine.

The Supervising Scientist is responsible for supervising the environmental aspects of mining operations at Ranger with particular reference to the Commonwealth's Environmental Requirements (ERs) for the Ranger Uranium Mine. The ERs address all potential environmental hazards associated with the Ranger operations but, unlike the RGA issued by NTDME do not constitute detailed regulatory requirements. Rather, the ERs focus on environmental protection outcomes, and stipulate in broad terms the processes which must be followed to meet defined Primary Environmental Objectives. Whereas NTDME undertakes site inspections and compliance audits to determine whether requirements under its legislation are being met, the Supervising Scientist undertakes Environmental Performance Reviews (EPRs) to determine whether requirements under the ERs are being met.

Working Arrangements agreed by the Commonwealth and Northern Territory Governments delineate the responsibilities of NTDME and the Supervising Scientist and establish consultative processes which allow both parties to meet their responsibilities without significant duplication of effort. The Working Arrangements were revised in 1995 following the expression of concern that the Supervising Scientist was duplicating the work of the NTDME. Prior to this revision, staff of the Supervising Scientist conducted regular inspections of the mine site and provided reports to ERA. Thus, the current Working Arrangements reflect the then government's view that the Supervising Scientist should focus on environmental outcomes and that the Northern Territory should be responsibile for all day to day aspects of regulating of uranium mining activities in the ARR.

Despite the level of government scrutiny to which Ranger is subject, as is very briefly described in the preceding paragraphs, the gradual burial of the TWRP by silt was not identified as an issue requiring remedial action. Compliance inspections of the Ranger site undertaken by NTDME should have recognised the burial of the TWRP, and resulted in an instruction to ERA to undertake appropriate remedial work. NTDME inspections should also have identified shortcomings in the maintenance of the Tailings Dam Corridor, such as the presence of disused pipe segments, partial burial of pipelines, and some vegetation growing around the pipelines which should have been removed. NTDME has both the responsibility and the authority to require ERA to improve performance when required.

NTDME inspectors visit the Ranger site regularly but NTDME does not have in place a regular program of inspection specific to the Tailings Dam Corridor. Inspections of the Tailings Dam Corridor are made by NTDME inspectors on an exceptions basis. That is, the Tailings Dam Corridor is inspected in response to issues which arise such as following a reported leak from a pipeline. The lack of a structured proactive inspection regime for the

Tailings Dam Corridor is identified as a deficiency in the NTDME regulatory system which compounded the deficiencies in the ERA inspection and maintenance program.

It is recognised, however, that the Ranger Uranium mine is a large industrial facility, and that detailed and frequent inspections of every part of every unit of infrastructure on site would require resources that are not available to Government regulators. Consequently, the inspection regime should be based on the risk to the environment and human health posed by the failure of site infrastructure. In relation to the Tailings Dam Corridor, this incident and previous incidents over the last twenty years have demonstrated that those risks are very small. Hence it is appropriate that the Tailings Dam Corridor not be subject to the same level of scrutiny as, for example, is the tailings dam.

Recommendation 12

> ***NTDME should undertake a comprehensive review of its site inspection regime in the light of deficiencies identified in this report, and design and implement a new proactive inspection regime within a risk management framework.***

OSS and NTDME undertake joint inspections of the Tailings Dam once per year. The most recent Tailings Dam Inspection prior to the occurrence of the leak was in August 1999. These inspections address the operation, integrity and stability of the Tailings Dam and also involve consultants as required. Whilst these joint NTDME/OSS inspections focus on the Tailings Dam in significant detail, they also include a cursory inspection of the Tailings Dam Corridor. The environmental risk associated with a failure of a pipeline in the Tailings Dam Corridor is negligible compared to the risk associated with a failure of the Tailings Dam itself. This has been clearly demonstrated by the TWRP leak which, as discussed in section 3, has not had any adverse impact on Kakadu National Park. Considering the need to allocate resources within a risk management framework, it is appropriate that the Tailings Dam component of these inspections are far more rigorous than the Tailings Dam Corridor component. Nonetheless, the burial of the TWRP was not noted by officers of either the OSS or NTDME during these inspections.

Environmental Performance Reviews (EPRs) undertaken by OSS focus on environmental protection outcomes and are not designed to address in detail the maintenance of on-site infrastructure. Consequently, it is not surprising that the EPRs did not reveal the burial of the TWRP. However, each EPR includes an inspection of key sites on the Ranger Project Area and OSS officers would have driven over the Access Road Culvert and the buried section of TWRP. Even taking into account the OSS focus on environmental protection outcomes rather than the maintenance of on-site infrastructure, the failure of OSS to observe the burial of the TWRP, and to raise the issue with NTDME and ERA must be considered a shortcoming.

The above delineation of the supervisory and regulatory responsibilities between the Supervising Scientist and NTDME appears to have met the expectations of key stakeholders and the general public for a number of years after its introduction in 1995. During the past few years, however, perhaps because of the recent focus on Jabiluka, there has been an increase in the expressions of concern about the ability of the Supervising Scientist to provide reliable assurances to the public when he has to rely heavily on information provided by the mining company and/or by the Department of Mines and Energy which is seen primarily as a proponent of mining. These concerns have heightened following the reporting of the tailings water leak and will, no doubt, heighten again following the release of the information contained in this report.

In order to keep pace with these changing expectations on the independent nature of the assessments carried out by the Supervising Scientist, the Supervising Scientist should ensure that there is an adequate and independent on-site audit program related to potential off-site environmental consequences arising from operation of the Ranger mine and mill.

Recommendation 13

> ***The Supervising Scientist should ensure that there is an adequate and independent on-site audit program related to potential off-site environmental consequences arising from operation of the Ranger mine and mill.***

5.6 Environmental monitoring programs

Similar concerns to those described above have been expressed by the public about the reliance by the Supervising Scientist on data from ERA in the provision of assessments to the Parliament and the public on the extent to which the environment and people are protected from the effects of uranium mining at Ranger. In simple but blunt terms, the public does not trust the mining company. This has been made abundantly clear in public statements by various interested parties following the announcement of the leak of tailings water. Importantly, the Mirrar made this point strongly to the Supervising Scientist at his meeting with the Gundjehmi Aboriginal Corporation on 13 June 2000.

The primary reason for the existence of the Supervising Scientist is to enable credible and independent assurance to be given, when justified, to the Australian community on the extent to which the environment of the Alligator Rivers Region is being protected from the effects of uranium mining. The independence of the Supervising Scientist is enshrined in the provisions of the EP(ARR) Act. However, under the current monitoring regime, the Supervising Scientist is often unable to provide the level of credibility demanded by the public because the primary data used in environmental assessments are provided by ERA. For these reasons, it has been concluded that the Supervising Scientist should develop and implement a routine environmental monitoring program. The program should not simply duplicate that required of ERA. The focus of the program should be the provision, within the context of the Environmental Requirements, of advice on the extent of protection of the people and ecosystems of Kakadu National Park. A component of the program could also provide support to the on-site audit program referred to above. No amendments to the *Environment Protection (Alligator Rivers Region) Act 1978* would be required to enable the implementation of this monitoring program.

Recommendation 14

> ***The Supervising Scientist should develop and implement a routine environmental monitoring program whose focus should be the provision of advice on the extent of protection of the people and ecosystems of Kakadu National Park. A component of the program could also provide support to the on-site audit program referred to in Recommendation 13.***

Recommendation 15

> ***The Working Arrangements between the Commonwealth and the Northern Territory regarding the regulation of uranium mining activities in the Alligator Rivers Region should be reviewed and amended to take into account changes in the activities of the Supervising Scientist arising from this report.***

5.7 Reporting of Incidents

There are acknowledged difficulties with the current reporting system for incidents at the Ranger Mine. As outlined in section 5.3, ERA is required to report all breaches of the Environmental Requirements and any mine-related event which

(a) results in significant risk to ecosystem health; or

(b) which has the potential to cause harm to people living or working in the area; or

(c) which is of or could cause concern to Aboriginals or the broader public.

One difficulty is that where there has been no clear breach of the ERs, staff of ERA are required to make a judgement on whether an issue could be of concern to Aboriginal people or the broader community. There is always a risk that ERA's judgement will not be consistent with the that of other stakeholders. This appears to have been a contributing factor to the lack of reporting of the current incident.

A further difficulty arises from competing interests in the reporting objectives. On the one hand, the importance of the environment that surrounds the Ranger mine, Kakadu National Park, has resulted in the Commonwealth Government's demand that a completely open and transparent system of reporting exists. This has resulted in the formal reporting of more than one hundred incidents over the life of the mine. An assessment of these incidents by the Supervising Scientist has shown (Johnston and Needham 1999) that only one of these incidents was of ecological significance.

On the other hand, the very reporting of the incidents has, independent of their environmental significance, given rise to genuine concerns for members of the public, particularly the local Aboriginal population. In the case of the incident that is the subject of this report, it has been clearly demonstrated that no harm to people or downstream ecosystems occurred. Nevertheless, the Supervising Scientist has been advised that Aboriginal people in the region are "fearful" of contamination in water due to the TWRP leak and that they will not consume foods obtained from Mudginberri Billabong.

A possible approach that will retain the transparency of the current system but not give rise to undue but genuinely felt concern is one that is based upon the environmental protection philosophy discussed in section 5.4 and depicted schematically in figure 21. Provided Recommendation 10 is implemented, that is the integrity of secondary containment structures is assured, the failure of a primary containment structure clearly cannot give rise to an environmental impact nor should such a possible impact be of concern to Aboriginal people or the broader community. Such an incident need not, therefore, be formally reported under ER 16.1 and need not be recorded by the Supervising Scientist in his Annual Report to Parliament.

However, all such incidents should be reported, outside the framework of ER 16.1, to the members of the Mine Site Technical Committee to ensure that the regulator and the Supervising Scientist can assess the adequacy of remedial action taken to correct the failure and to ensure that the integrity of the primary containment structure has been restored. This would be an improvement on the current system from the regulatory perspective because many incidents in this category have not been reported, quite legitimately, over life of the mine.

Recommendation 16

> ***The Mine Site Technical Committee should develop guidelines clarifying requirements for the reporting of incidents which retain the transparency of the***

current system, are consistent with Environmental Requirement 16.1, reduce the need for the exercise of judgement by staff of ERA and will assist in minimising undue concern for Aboriginal people and the broader community.

When considering reporting arrangements it is important not to overlook reporting between NTDME and OSS. The Working Arrangements state that there should be frequent and detailed communication between the Supervising Scientist and NTDME. They also state that NTDME is responsible for ensuring that the mining company directly and immediately notify NTDME, the Supervising Scientist, DISR and the NLC of any environmental event or incident which has the potential to cause concern to Traditional Owners or the broader public. The Working Arrangements do not, however, require NTDME or the Supervising Scientist to inform each other of any information they may acquire independently which could be of environmental significance. This is a deficiency in the Working Arrangements.

In this instance, NTDME officers observed black precipitate indicative of the presence of manganese in the VLGCRC on 2 February 2000. The officers recognised this to be unusual prompting them to collect water samples from the VLGCRC for analysis. This information was not passed by NTDME to the Supervising Scientist until investigations commenced after ERA notified OSS of the incident on 28 April 2000. Had the Working Arrangements required NTDME to report this observation to the OSS, OSS would have been in a position to commence its own inquiries and the leak may have been identified in a more timely manner.

Recommendation 17

The Working Arrangements between the Commonwealth and the Northern Territory regarding the regulation of uranium mining activities in the Alligator Rivers Region should be reviewed and amended to require the Department of Mines and Energy and the Supervising Scientist to immediately inform each other of any information they may acquire independently which could be of environmental significance.

6 Conclusions

This report has been prepared in reponse to requests from the Minister for the Environment and Heritage and the Minister for Industry Science and Resources. Its purpose has been to investigate and report on the leak of water from the Tailings Water Return Pipe at the Ranger uranium mine during the 1999/2000 wet season with specific reference to:

- The origin of the leak and the adequacy of remediation measures taken to prevent similar occurrences in the future
- The extent to which the people and the environment of Kakadu National Park have been adversely affected by the leak
- The extent to which Energy Resources of Australia has complied with the reporting requirements specified in the Environmental Requirements that apply to the Ranger operation.

6.1 Origin of the leak and adequacy of remediation measures

It has been established that the volume of water that leaked from the tailings water return pipeline was about 2000 cubic metres during the 1999/2000 wet season. Of this, only a small fraction, about 85 cubic metres, entered the culvert which flows to the Corridor Creek Wetlands. The remainder was collected in the tailings corridor sump and returned to the water management system.

The cause of the leak was corrosion and subsequent failure of three bolts that secure the jointing of two flanges in the pipeline. The principal cause of corrosion was the burial, under moist conditions for up to 6 months of the year, of the relevant section of the pipeline under silt derived from erosion in the vicinity of the tailings corridor roadway. A contributing factor to the failure may have been the use of undersized bolts.

The gradual burial of the pipeline and the absence of measures to remediate the situation are attributable to a reduction in the standard of maintenance carried out by ERA in the pipeline corridor in recent years. The failure of the mine inspection program carried out by the Northern Territory Department of Mines and Energy and, to a lesser extent, that of the Office of the Supervising Scientist, to observe and require remediation of the buried section has also been a contributing factor to the leak.

The failure of the pipeline to contain tailings water would not of itself normally have resulted in the discharge of this water to the external environment. That the leaked water did reach the external environment is due to a failure of the bunded corridor system to fully contain any spilled water. The cause of this failure was that the engineered structure between the roadway and a culvert that drains water from the nearby waste rock dump was not impermeable.

The statutory monitoring program has been found to be deficient in two ways. First, other than visual inspection, it has not been designed to include monitoring locations within secondary containment systems that would indicate the failure of primary containment systems. In the present case, no statutory reporting of the quality of water in the tailings corridor sump is required under the Ranger General Authorisation. If the routine analysis of ammonium ion and manganese in corridor sump water had been required, the existence of a leak in the pipeline may well have been detected several months before it was found and rectified. Second, there is no systematic monitoring program designed to check the integrity of the secondary containment systems. If these monitoring systems had been in place, the current incident could well have been avoided.

The original leak in the pipeline has been repaired and the complete pipeline has been tested to determine its integrity. The system is now operating satisfactorily. The silt that buried the pipeline has been removed and steps implemented to ensure that no build-up of silt will occur in the future. A concrete slab has been installed at the section of roadway that passes over the culvert to prevent infiltration in the future. A full review of the Tailings Dam Corridor has been recommended with particular emphasis on the efficacy with which it performs the task of providing secondary containment.

6.2 Impact on people and the environment

Assessments of possible ecological impact arising from the leak have been carried out both using actual monitoring data and by modelling.

An examination of the chemical monitoring data at the gauging station on the Magela Creek upstream of the point at which the Creek enters Kakadu National Park shows that no change occurred during 1999/2000 in the concentrations of the principal constituents of concern compared to similar observations in previous years. The concentrations of all constituents were within the natural range observed previously. Similarly, biological monitoring at the gauging station and at a point upstream from the minesite shows no difference in the response of animals exposed to water at the downstream and the upstream sites. Even at the monitoring site at Georgetown Billabong, which is located on the mine project area downstream from the source of the leak but upstream of the confluence of Georgetown Creek and Magela Creek, no increase in the concentration of any of the principal solutes was detectable.

Modelling of the possible ecological impact was carried out by calculating the likely increase in concentrations at the gauging station using information derived in this study on; the maximum possible volume of leaked tailings water, the most probable value for this volume, the measured concentrations of solutes in tailings water, measured rates of attenuation of solutes in the constructed wetland filter systems and the flow rates in Magela Creek. Even if one ignores the losses in the wetland filters and uses the maximum possible volume of leaked tailings water, the calculated increase in the concentration of all consituents is much lower than the naturally observed concentrations at this point.

We have concluded that the leak of tailings water had no adverse ecological impact on Kakadu National Park.

The radiological impact was assessed using the information derived in this study on the quantity of water released and the concentrations of radionuclides in tailings water together with the results of the past research program of the Supervising Scientist on the dispersion of radionuclides in the surface water system and the uptake of radionuclides in animals and plants. The maximum conceivable dose received by members of the public as a result of the leak is lower than the public dose limit by more than a factor of 1000. The best estimate of the dose received is lower by a further factor of 30. Even these estimates ignore the reduction in dose resulting from absorption of radionuclides in the wetland filter system.

The overall conclusion reached is that the leak of tailings water into the external environment has had a negligible impact on people and the environment.

6.3 Compliance with reporting requirements

Under the Environmental Requirements, ERA must directly and immediately report any breach of the Environmental Requirements and any mine-related event which:

(a) results in significant risk to ecosystem health; or

(b) which has the potential to cause harm to people living or working in the area; or

(c) which is of or could cause concern to Aboriginals or the broader public.

It has been concluded that ERA did not comply with this requirement on two grounds: (i) the leak of tailings water to the external environment is a breach of Environmental Requirement 3.4 and (ii) there should have been no doubt that such a leak would have been of concern to the local Aboriginal people and the broader public.

The reasons for the lack of reporting have been the subject of an internal ERA investigation and the Supervising Scientist has received correspondence from, and has discussed with, the Chief Executive of ERA the outcomes of the review. ERA believes that there was no deliberate intent to deceive or dissemble. Rather, two principal factors are believed to have contributed to the omission. First, recent changes in staffing at Ranger have resulted in the absence of a senior scientist with the ability to effectively identify, interpret and rectify environmental incidents. The lack of interpretive ability was a key factor in the lack of recognition that the data which were available to ERA staff implied that tailings water had reached the external environment. Second, there is a lack of recognition by the Ranger Management Team of the needs and expectations of stakeholders that resulted in emphasis being placed on the absence of environmental impact rather than the issue of whether or not the incident would be of concern to Aboriginal people.

From his discussions with senior ERA personnel, the Supervising Scientist is satisfied that their was no deliberate attempt to deceive the authorities. He accepts the conclusions of ERA and has made recommendations to address the deficiencies identified.

6.4 Other issues

In the course of this investigation into the leak of tailings water during the 1999/2000 Wet season, evidence has been obtained that water with the characteristics of tailings water was probably discharged into the same culvert during the 1998/1999 Wet season. Due to time constraints, the cause of this discharge has not been fully established. A possible explanation that is being investigated is that tailings water associated with a leak in the tailings pipeline on 13 December 1998 seeped in to the VLGCRC during the 1998/99 Wet season. While the Supervising Scientist is concerned that the probable presence of tailings water in the VLGCRC went undetected until now and that a full explanation for its origin is not yet available, he is satisfied that the 1998/99 leak caused no harm to people or the environment of Kakadu National Park. ERA should complete a comprehensive investigation of additional sources of contaminants in the VLGCRC, including previous tailings spills in the Tailings Dam Corridor, and provide a report to the Minesite Technical Committee.

During the past few years, there has been an increase in public expressions of concern about the ability of the Supervising Scientist to provide reliable assurances to the public when he has to rely heavily on information and monitoring data provided by ERA and/or by the Department of Mines and Energy which is seen primarily as a proponent of mining. These concerns have heightened following the reporting of the tailings water leak. In particular, the Mirrar, traditional owners of the land containing both the Ranger and the Jabiluka projects, expressed their concerns on this issue at a recent meeting with the Supervising Scientist. We have concluded that, in order to keep pace with these changing expectations on the independent nature of the assessments carried out by the Supervising Scientist, the Supervising Scientist should ensure that there is an adequate and independent on-site audit program, and develop and implement an environmental monitoring program. These programs should focus on the potential off-site environmental consequences arising from operation of the Ranger mine and mill.

There are difficulties with the current requirements for the reporting of incidents at Ranger. First, they often require a judgement by ERA staff on whether or not the incident would give rise to concern by Aboriginal people or the general public. Such judgements may be difficult to make. Second, the demand for a completely open and transparent system of reporting often results in an unjustified but very genuine concern, even fear, on the part of traditional owners. Guidelines need to be developed to clarify the reporting requirements in a way that will, while retaining the transparency of the current system, reduce the element of judgement needed and assist in minimising undue concern for Aboriginal people and the broader community.

A full set of recommendations has been made to address the issues identified above.

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Appendices

Appendix 1

Notification of the tailings water leak from ERA

ERA Energy Resources of Australia Ltd – Ranger Mine
ACN 008 550 865

FACSIMILE TRANSMISSION

TO	:	Mr Tony McGill (Director of Mines)	FAX NO 8999 6527
		Mr Peter Waggit (OSS Darwin)	8981 4316
		Mr Steve Roeger (NLC Darwin)	8920 5177
		Director, Uranium Industry Section (ISR Canberra)	02 6272 4309
FROM	:	Mal Wedd, Manager Environment, Safety & Health	TEL.NO 08 8938 1237
REF	:		FAX NO 08 8938 1211
SUBJECT	:	Notification (Non-Infringement)	
DATE	:	28 April 2000	NUMBER OF PAGES: 1 (including this page)

This facsimile is to inform you that tailings water has reported to the tailings corridor drain from the tailings dam – Mill pipeline. The leak occurred within the fenced tailings dam area. There is no infringement and no environmental detriment involved.

It is estimated that approximately 2000m^3 of tails water leaked into the corridor road drain from late December 1999 up to 5 April. The corridor road drain flows into the corridor road sump. Water contained within the drain would undergo significant dilution from rainfall prior to entering the sump.

The effect on water quality in the corridor road sump has been minimal, with only slight increases in magnesium and sulphate concentrations apparent. The water quality of the corridor road sump is better than that of RP2, therefore based on quality criteria under the new Authorization, pumping of this water to RP2 will continue.

Average Feb. Conc.	Corridor Rd Sump	RP2
Magnesium (mg/L)	18	140
Sulphate (mg/L)	76	560
Uranium (µg/L)	2.2	3400

Seepage from the pipeline was not visible detectable during wet-season run-off. The leak was detected once dry conditions were experienced, with repairs being undertaken and completed as soon as possible.

Although not an infringement, ERA has committed to advise the main stakeholders of unplanned events.

Should you have any further information requirements please contact me on (08) 8938 1239, or fax (08) 8938 1203.

Yours sincerely

MWedd

Mal Wedd, Manager – Environment, Safety and Health

Sydney Office Level 18, Gateway, 1 Macquarie Place, Sydney NSW 2000 Australia Tel: (02) 9256 8900 Fax: (02) 9251 1817
Ranger Mine Locked Bag 1, Jabiru NT 0886 Australia Tel: (08) 8938 1211 Fax: (08) 8938 1203
Web Site www.energyres.com.au
A Member of the North Group

Appendix 2

Ranger Mine Incident Investigation:
Second Report on Technical Issues prepared for Supervising Scientist by ERA of Australia Pty Ltd

ERA **Energy Resources of Australia Ltd**
ACN 008 550 865

Ranger Mine Incident Investigation: Second Report on Technical Issues

for

Supervising Scientist

June 12, 2000

Sydney Office **120 Christie Street**, St Leonards NSW 2065 Australia Tel: (02) 9467 9811 Fax: (02) 9467 9800
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1 EXECUTIVE SUMMARY

On April 28th, 2000, Energy Resources of Australia (ERA), the operator of the Ranger Uranium Mine, notified key stakeholders that it had discovered, and on April 4th repaired, a leak from the pipeline carrying process water from the tailings dam to the mill. The notification advised that up to 2,000 cubic metres of process water had been estimated to have leaked from the pipe and that this water had been retained in the tailings corridor road drain and the corridor road sump.

On May 2nd, ERA launched a comprehensive investigation into the incident. On May 11th a special meeting of the Ranger Minesite Technical Committee was held to clarify the scope of the investigation. An Interim Report that examined the technical issues and drew tentative conclusions based on available data was prepared by ERA and submitted for discussion at a second meeting in Darwin on May 19th. A separate report from a management systems and organisational perspective was also prepared by a North Limited review team.

It subsequently emerged that some of this water had in fact seeped through the bunded corridor drain into a concrete box culvert beneath. This culvert was designed to channel runoff from the capped and excised VLG/LG stockpile and adjacent waste rock stockpile into a series of artificial wetland filters in the upper reaches of Corridor Creek. These artificial wetland filters are part of the water management system at Ranger.

The interim technical investigations identified three sources of water contributing to the chemical composition of surface water samples at the key monitoring site downstream of the culvert, prior to entering the constructed wetland filters, namely:

- runoff and seepage from the capped area of the southern VLG/LG and waste rock stockpile that reports to the culvert;
- water from bore DW3A being discharged across the top of the waste rock stockpile; and
- seepage of process water through the roof of the culvert underlying the tailings pipeline corridor.

The available data were summarised in the Interim Report that was tabled at the MTC meeting on May 19th. A number of requests were made by stakeholders during discussions at the meeting. Relevant investigations were initiated and the results obtained thus far are discussed in this Second Technical Report.

A map has been produced to show the location of historical tailings spills and process water leaks along the tailings corridor road and drain back to 1988. Scrutiny of ERA files has indicated that some tailings spills and process water leaks were recorded in 1998 in the vicinity of the ramp and culvert on the eastern wall of the tailings dam. Although not an infringement of the environmental requirements because it was contained within the corridor drain, notification to the stakeholders of one such spill (December 13, 1998) was made by ERA on December 14, 1998.

In light of this information (which was not recognised at the time the Interim Report was being written), the high Mn concentrations at a monitoring site about 20 metres downstream from the culvert in 1998/99 are a potential indicator of process water seepage from the corridor drain through the culvert. Analysis of NH_4-N and sulfur isotopes in the few archived samples that exist confirms this assessment and further investigations have been initiated.

In relation to the leak notified on April 28th, 2000, estimates of dilution of process water by rainfall and runoff in the low flow culvert drain through the relevant time period can be made from NH_4-N, ^{226}Ra and sulfur isotope data. Ammonium ion concentration data were used to calculate a dilution factor for the process water reporting to the VLGCRC monitoring site. The daily volume of process water equivalent was then estimated by multiplying the dilution factor by the measured daily flow. If it is assumed that the seepage occurred for a maximum period of 85 days (from February 9 to May 5, 2000, based on ammonium ion data), and that the average daily seepage rate through the culvert was $1m^3$ of process water, then a maximum total volume of $85m^3$ of process water may have seeped through the culvert and reported to the VLGCRC monitoring site. During this same 85 day period a total of approximately 1,900,000 m^3 of water flowed past monitoring site GC2.

Analysis of monitoring data in the artificial wetland filters, and downstream in Georgetown Billabong and Magela Creek, shows conclusively that there was no environmental impact, and that contaminants were trapped in the first of the artificial wetland filters on the minesite.

Significant works have been implemented or planned to prevent a repeat of this type of incident. For example, a concrete spoon drain has been constructed above the VLG/LG culvert beneath the tailings corridor drain to ensure that it does not leak. Investigations have been also initiated to ensure that the tailings corridor drain and bund system operates effectively as a total containment system.

Protocols and procedures for observing, locating, describing, repairing and assessing tailings and process water leaks have been refined and additional training has been implemented to ensure that all relevant information is recorded appropriately. Work has also commenced on a reporting protocol that clarifies ERA's requirements relating to reporting to stakeholders.

ERA's ability to continue to protect the surrounding environment from the impacts of uranium mining cannot continually rely on the backup protection systems designed into the Ranger operation. The changes, procedures and practices resulting from this investigation are aimed at ensuring that the primary protection systems perform to expectations.

2 BACKGROUND

An incident occurred at the ERA Ranger Mine in which a leak from a process water pipe within a bunded containment area became an issue of concern to Traditional landowners and Commonwealth and Territory Ministers. The incident was damaging to the reputation of ERA and North Limited and to its relationship with key stakeholders.

Investigations in progress have considered in detail the chain of events giving rise to the incident. A chronological account of these events is as follows.

The physical location of the process water leak (Figures 1, 2) was the western section of the tailings corridor bund, a bunded corridor connecting the mill and tailings dam, designed to act as a secondary containment system for pipes carrying tailings to the dam and return process water to the mill. This infrastructure dates back to the beginning of mill operations (although the pipelines have been variously replaced over time due to normal wear and tear) and while the tailings pipes are no longer in use in the section where the leak occurred, the steel process water pipe still carries process water from the tailings dam.

In December 1999 a trial (the DW3A Trial) was initiated to test the ability of the Corridor Creek constructed wetland south of the Tailings corridor bund to attenuate solutes including heavy metals and nitrate. Water from a mine dewatering bore (DW3A) was pumped to the capped very low grade waste stockpile (VLG waste stockpile) to the north of the tailings corridor bund. From here it flowed across and through adjacent waste rock, under the tailings corridor via a concrete box culvert (the VLG tailings corridor culvert), and into the constructed wetlands. Weekly samples were taken at the south end of the culvert to monitor the levels of various solutes in water entering the wetland system.

On 2 February, the DW3A trial sample showed abnormally high manganese (Mn) levels (6,100 ppb). The following week the Mn level had dropped but was elevated again in the samples from February 16th to March 8th.

On March 13th an investigation was initiated and various samples were collected both upstream and downstream of the VLGCRC to track down the source of the elevated Mn.

On March 28th, towards the end of the wet season, a small upwelling of water was found in an area to the west of the VLG tailings corridor culvert. At this point, where the process water pipe passed beneath a road culvert adjacent to the fence around the tailings dam, the pipe had become buried under silt. Excavation revealed the source of the upwelling to be a disused length of tailings pipe from which water flow was measured at 0.3 l/sec. By April 4th the source of the water was identified as the flange joint between fixed and flexible sections of the process water pipe on the other side of the road culvert. These pipes were also buried in silt and the leaking water was draining below the surface, into the disused section of pipe, to emerge on the other side of the road culvert. The leak was repaired immediately.

A notification for the incident was prepared on April 10th in accordance with a commitment to advise main stakeholders of unplanned events. However, due to a sequence of internal delays (the Easter and Anzac day break and the assumption that no process water had escaped off-site) the notification was not sent to stakeholders until April 28th. In summary the notification advised that:

- an estimated 2000 m^3 of process water leaked into the tailings corridor drain over approximately three months, from where it would have flowed to a sump after considerable dilution by rainwater;
- there was minimal impact on water quality measured at the sump, which was pumped into the lower quality RP2 during the period when the leak was unidentified;
- the delay in repairing the pipeline was due to an inability to identify the seepage during the wet season; and that
- there was no infringement or environmental damage involved.

Unfortunately, the notification did not include an assessment of water quality data, the potential significance of the elevated Mn levels at VLGCRC not being recognised by ERA, and hence was not reported to stakeholders. Discussion with OSS on April 28th following issue of the notification resulted in recognition of stakeholder concerns about the possibility that some process water had contributed to the solute concentrations measured at the water quality monitoring site VLGCRC. The regulators notified ERA and North of their concerns with the lack of detail in the notification and a press release was generated by ERA acknowledging these concerns.

On May 3rd monitoring data from another trial conducted by EWL Sciences a year earlier emerged which showed even higher levels of manganese at the same monitoring point. This cast further doubt over whether the abnormal readings were due to the process water leak or could instead have been associated with leaching from the VLG and waste rock stockpiles. A separate investigation has been initiated in relation to these data.

By May 5th, water quality sampling within the culvert, in conjunction with a hydraulic load test, demonstrated that water in the tailings corridor drain could slowly seep through the roof of the culvert beneath the tailings corridor drain. This confirmed the possibility that a small volume of process water had seeped into the VLG drain and reported to the VLGCRC monitoring site.

Actions resolved at a special meeting of the Ranger Minesite Technical Committee on Thursday May 11th to clarify the scope of the investigations were as follows:

OSS to provide an independent assessment of pipeline integrity (SKM report);

ERA to provide stakeholders with an information memorandum on earthworks being undertaken on the process water pipeline (reported in the Interim Report);

ERA to supply a discussion paper on clarifying reporting requirements to stakeholders (this report);

ERA to produce a preliminary report compiling the data from current and past studies relevant to assessing the incident by 18th May 2000 (reported in the Interim Report);

ERA to produce a proposal by 18th May 2000, in consultation with stakeholders, on investigating potential impacts to edible species in the Georgetown and Magela systems (in progress);

Stakeholders to compile relevant data from 1998 – present for inclusion in the report on the outcomes of 1998/99 Corridor Creek research project (in progress);

ERA to produce a preliminary interpretative report on the incident by 18th May 2000 (reported in the Interim Report);

ERA to provide raw data to stakeholders by 18th May 2000 (actioned); and

MTC to meet on 19th May 2000 to discuss ERA's interpretative report (actioned).

The Interim Report summarised and evaluated all data available to the date of the Special MTC meeting on May 19th. A number of investigations were initiated following discussions at that meeting and as a result of requests made by stakeholders, including:

- determination, if possible, of the maximum amount of process water that leaked from the pipe into the tailings corridor bund;
- identification of the source of Mn leached from the waste rock stockpiles;
- evidence that might rule out the possibility that there has been a continuing leak of process water over the past couple of years (potentially indicated by high Mn at VLGCRC in 1998/99);
- historical data on the location (and size) of process water and tailings leaks along the tailings corridor road;
- information on the predictable future behaviour of waste rock stockpiles if high Mn (as observed at VLGCRC) is to be leached out of them;
- evaluation of data to determine the extent of any environmental impact from the leak;
- attempt to unravel unequivocally the source of waters at VLGCRC through S-isotope analyses of archived samples (if they exist); and
- establishment of a technical specialists group to meet separately from the MTC and guide the investigations and data evaluation.

The results of these investigations to date are summarised and evaluated in this Second Report.

3 INCIDENT REVIEW

The Interim Report (May 19th, 2000) examined the technical issues surrounding the process water leak incident in April 2000 and drew conclusions from the available data. The report also identified further investigations that would clarify a number of issues of concern to stakeholders.

A parallel investigation had been initiated to examine the incident from a management systems and organisational perspective. This has been completed and a report submitted to the Chief Executive Officers of North Limited and ERA Limited.

4 IMPACT ASSESSMENT

4.1 Retention and retardation of Runoff Water at Ranger Mine

Figure 1 is a map of the water management system at Ranger Mine, showing the wetland filters and retention basins that have been constructed to protect the surrounding lease areas from minesite runoff. They include:

- Retention Pond 1 (runoff from native woodlands and waste rock stockpiles);
- RP1 wetland filter (for treatment of RP2 water);
- Retention Pond 2 (runoff from mine areas and ore stockpiles, and water from Pit #3);
- Djalkmara Billabong (runoff from low grade ore stockpiles and seepage from RP2);
- Brockman wetland filter (runoff from native woodlands and Gravel Pit);
- MBL wetland filter (runoff from native woodlands and Brockman Pond); and
- Sleepy Cod wetland filter (runoff from native woodlands and MBL Pond).

As can be seen, ecosystems such as Georgetown Billabong and Magela Creek are substantially protected by this complex of artificial wetland filters, by design, from minesite runoff through the VLG drain. Monitoring sites at VLGCRC, GCBR, GCMBL, GC2 and SCD provide data on water quality throughout the artificial wetland filter system. Downstream and control sites are at Georgetown Billabong and in a natural tributary creek to the south.

4.2 Characterisation of Potential Source Waters at the VLGCRC Site

4.2.1 Overview

There are a number of potential sources of water that can report to the VLGCRC monitoring point, and each of these must be considered in the context of the levels of manganese that were measured. These sources are:

- runoff and seepage from the capped area of the southern VLG/LG and waste rock stockpiles that reports to the culvert via the drain at the base of the waste rock;
- water from bore DW3A being discharged across the top of the waste rock stockpile; and
- seepage of tailings process water through the roof of the culvert underlying the tailings pipeline corridor.

The locations of each of these sources are marked on Figure 2.

The different chemical compositions of each of these source waters can potentially be used to partition the loads of solutes (including Mn) between each of the contributing sources. In particular the presence of high concentrations of particular solutes, or the presence or absence of one or more chemically conservative trace solutes, can be used to fingerprint a source and hence derive its contribution to the total load. Quantitative ICPMS scan data for samples of each of the possible source waters collected late in March and in the first week of May are presented for reference in Table 1.

4.2.2 Process Water

A typical major and minor ion composition of tailings/process water is provided in Table 2 for reference purposes. A full ICPMS scan has also been done for a sample of water from the tails dam (site TDWW) and the results are reported in Table 1. Process water is characterised by high concentrations of magnesium, sulfate, manganese, and ammonium ion. Manganese, and especially ammonium, are considered to be signature analytes for process water. ^{226}Ra is also relatively enriched in process water.

4.2.3 DW3A Water

A trial involving wetland treatment of water from bore DW3A was in progress at the time that the elevated levels of Mn were detected at the VLGCRC sampling point. Bore DW3A is the main dewatering bore for Pit#3 and is located between RP2 and the edge of Pit#3. The bore water was pumped to a sump located near the RP1 wetland filter and onto the recently capped and revegetated area of VLG/LG stockpiles, and bounding waste rock, that integrates the eastern wall of the tailings dam with the adjacent waste rock stockpiles. This water ultimately reported as a combination of surface runoff and seepage through the stockpiles to the culvert underlying the tailings pipeline corridor drain. A typical major and minor ion composition of DW3A water is given in Table 2.

This source is characterised by alkaline pH (8.1-8.5) and substantial bicarbonate alkalinity. Magnesium and sulfate are the major ions. The concentration of Mn in this water is usually close to analytical detection limit (<1 µg/L) and U values are low (~15 µg/L). The major effect of DW3A water contacting the waste rock was an increase in U concentrations measured at VLGCRC. This occurred before any elevation in Mn levels was detected and is probably a result of the leaching of U from the waste rock by the higher pH, higher bicarbonate regime induced by the DW3A water. The DW3A trial was started in December 1999. Monitoring of this trial, prior to the detection of elevated Mn, indicated that 50-100 fold attenuation of U was occurring in the Brockman wetland filter (GCBR- Figures 1 and 2), with further substantial attenuation in the MBL wetland filter (GCMBL).

4.2.4 Monitoring Site VLGCRC, downstream of the corridor drain culvert

VLGCRC data for the 1999/00 wet season

The detailed water quality data produced to date for the 1999/00 wet season are recorded in Table 3. The most salient data are the time series for pH, conductivity and manganese. The data for pH and conductivity data for VLGCRC for the 1999/00 wet season are compared with data over the two earlier wet seasons (for monitoring site GCSR) in Graph 1. It can be seen that there is a fundamental difference in the characteristics of the plots for each of the three wet seasons represented. During the first wet season that data are available (1997/98) the pH remained above 6 and the electrical conductivity remained close to 400 µS/cm. During the 1998/99 wet season, quite different behaviour was observed. The pH declined from 7 to 5 at the start of the wet season and this coincided with a rise in conductivity from 400 to 1600 µS/cm. Despite the persistence of these lower pH values, the electrical conductivity subsequent to January maintained a steady decrease downwards to 200 µS/cm at the end of the wet season. This behaviour strongly suggests a "washout" of soluble salts initially mobilised by contact with lower pH water. These data are being investigated further.

The behaviour of pH and conductivity was very different during the 1999/00 wet season. The pH was on average almost 2 units higher than in 1998/99 and the electrical conductivity did not show the steep rise and fall seen in the preceding year. Instead, the conductivity rose to attain a steady plateau value. The observed behaviour is undoubtedly a function of the effect of the large volumes of the high pH and bicarbonate alkalinity DW3A water being discharged across the surface of the landform. The consequence of this substantially higher pH would be to reduce the extent of leaching of Mn from the waste rock.

The time series data for Mn in 1998/99 and 1999/00 are overlain in Graph 2. It can be seen that not only are the concentrations of Mn much lower during 1999/00, but the shape of the graphs for the time series data are very different. There is also a much longer lag from the start of the wet season until concentrations do start to rise. The rise that does occur presumably reflects the start of seepage of process water through the roof of the culvert overlying the stockpile drain.

A preliminary analysis of correlations between the major and minor ion components has been examined for the VLGCRC site to see if the slope of these lines can provide an indication of the extent of contributions from different source waters. Examples are provided of scatter plots of sulfate against manganese for each of the 1998/99 and 1999/00 data sets (Graphs 3 and 4). The two plots are quite different in character. For the 1998/99 data, most of the points are tightly clustered around a straight line relationship, implying a constant composition of source water throughout the wet season. The plot for 1999/00 is very different with the majority of points scattered in the upper left hand quadrant of the graph. However, a number of points do lie close to the same linear relationship seen in 1998/99. The overlay of the two data sets (Graph 5) reinforces the point that multiple sources were contributing to the composition of water determined at VLGCRC during 1999/00. The scattering of points in the upper left hand quadrant is probably a function of differential dilution of seepage water by water from DW3A. The higher pH and alkalinity of the DW3A water would further act to reduce the dissolved concentration of Mn by both facilitating its adsorption on rock surfaces as well as accelerating oxidation of the soluble Mn(II) to produce insoluble Mn(IV) oxides.

Measurements to identify the source of the process water seepage

Investigations were initiated during April and May to obtain more detailed chemical fingerprint data for the sources of water reporting to VLGCRC. The specific sites sampled for this investigation in the vicinity of the road culvert and associated pipeline corridor included the DW3A discharge on top of the capped and excised VLG/LG stockpile, the VLG stockpile drain upstream of the culvert, “drips” of water falling from the roof of the culvert into the VLG stockpile drain, the bunded pipeline corridor itself, and the VLG stockpile drain downstream of the culvert to where it enters the wetland created by the Brockman bund.

The complete ICPMS data and major ion chemistry obtained for samples collected from each of these sites on or about May 5th are compiled in Tables 1 and 4 respectively. It was hoped that the ICPMS data might provide a clear distinction between the water sources and readily enable the volume of process water that entered the stockpile drain to be determined. However, it is apparent that many of the most potentially useful indicators were substantially attenuated during passage through the clay and cement layers underlying the culvert. The adsorption of metals by clays are well documented, and substantial attenuation of otherwise conservative ions such as magnesium have been observed in recent testwork on cemented paste tailings.

Ammonium Ion Concentration Data

The most characteristic signature solute for process water is ammonia. This species has no natural origin of significance on the site. The detection of ammonia (in the form of ammonium ion at the prevailing pH) is an absolute indicator of process water. The fact that elevated levels of ammonia were measured in the seepage dripping from the roof of the culvert, and that ammonia was measured downstream of the culvert, confirms that a small amount of process water did seep through the pipeline corridor.

No ammonia was detected in the stockpile drain at the base of the waste rock stockpile. This suggests that it is unlikely that this source was impacted by process water seepage. Hence the elevated concentrations of Mn measured at this location are likely to have originated from waste rock.

Concentrations of ammonium ion have been measured in water samples collected from VLGCRC during January to April 2000 (Table 5). The data prior to February 9th are similar to the concentrations measured in November and early December 1998 and are consistent with those expected from leaching of waste rock containing blasting residues. Starting at February 23rd, 2000 the values rise to a plateau of about 1.5 mg/L NH_4-N. The rise, and ultimate decline, in concentrations of ammonium ion exactly match the behaviour of Mn at VLGCRC.

The ammonium concentration data in Table 5, relative to its concentration in process water, can be used to provide an estimate of the contribution of process water to the solute load at VLGCRC. This dilution factor can then be used to predict the expected concentration of Mn at VLGCRC due to process water seepage, as set out in Table 6.

The results of the calculations show that on and before February 9th, 2000 there was no contribution of process water to the solute load at VLGCRC. Between February 23rd and March 29th, process water could have accounted for about one third to one quarter of the Mn concentration, and up to two thirds on April 19th. However, it must be recognised that the actual contribution will be a combined function of the driving head for seepage into the culvert from the corridor drain and the flow of water through the VLG drain. These factors are likely to vary substantially as a result of the exact timing and intensity of rainfall and catchment runoff.

Sulfur Isotope Data

Previous work on sulfur isotope signatures at Ranger Mine had shown a very clear distinction between the δ^{34} value for S in the process circuit and that derived from waste rock sources (leGras *et al*. 1991). Available archived samples of water collected from the VLGCRC from a range of strategic locations between February and May 2000 were submitted to CSIRO Exploration & Mining for sulfur isotope analysis. The results (Table 7) indicate that water derived primarily from DW3A (TDSite13) has the lowest isotope ratio of approximately 6.1. Previous studies of S isotopes (leGras *et al* 1991) had found that the water retention ponds receiving runoff and seepage from waste rock also had a δ^{34}S value of about 6. Thus, sulfate derived primarily from a waste rock source can be assigned an end member value of 6.0. In contrast, process water from the tailings dam has a very different $\delta^{34}S$ value of 9.8.

The water seeping from the roof of the culvert into the VLG drain is clearly of process water origin. The three data points for the VLGCRC monitoring site in February, March and May 2000 indicate a declining contribution from process water, and that in May there is unlikely to be any process water contributing to the solute load at this site.

The Mn and NH_4^+ data indicate that seepage of process water through the culvert commenced after the process water pipeline started leaking sometime after February 9th and before February 23rd, allowing for transit time between the site of the leak and the culvert 250m downgradient from this location. Although the pipeline was shut down on April 3rd, and repair work was initiated the following day, some residual solutes in the corridor drain were evidently transported across the culvert during rainfall events and contributed to the solute load at VLGCRC until late April or early May 2000 (Tables 5 and 6).

Earlier Wet Season data for the VLG/waste rock drain

Data for 1997/1998 wet season

The earliest data for the composition of water in the VLG/waste rock drain was obtained during the 1997/98 wet season. A limited range of analytes was measured, but Mn was not included in the suite of elements (Table 8).

Data for 1998/99 wet season

A very comprehensive dataset was acquired at monitoring site GCSR (adjacent to VLGCRC, which was located at a V-notch weir constructed and instrumented in December 1999; Figures 1 and 2) during the 1998/99 wet season. This was part of a research project to evaluate the ability of constructed sentinel wetland systems downgradient of the rehabilitated landform to absorb the load of solutes contained in runoff and seepage. The area of the capped VLG/LG stockpile and bounding waste rock stockpile was considered to provide the best example available on site. Water samples were obtained from GCSR to characterise the source. The attenuation of solutes through the artificial wetland filters in the upper reaches of Corridor Creek was also studied by collecting frequent water samples from three monitoring sites (GCBR, GCMBL, and GC2; see Figures 1 and 2). A reference site (GCC) located on a tributary of Corridor Creek was also included as part of the study. This site is away from the area of potential impact by mining operations.

Water samples were collected initially twice weekly from all sites for chemical analysis, whilst continuous measurements of pH, conductivity and water depth were made by a chemistry datasonde installed at GCSR. All chemical analysis data acquired during the 1998/99 wet season are compiled in Table 9.

An estimate of flow at the GCSR site was provided by the depth of water in the channel recorded by the pressure sensor in the chemistry datasonde (Graph 6). The highest flows were recorded the beginning of February and April. The continuous pH trace for the 1998/99 wet season is shown in Graph 7. Whilst the pH generally ranges between 6 and 6.5 for the majority of the wet season, it is very important to note that there are many transient events during which the pH decreased to as low a value as 5. These low pH episodes occur predominantly in the second half of January and through February.

The time series data for Mn during the 1998/99 wet season are shown in Graph 10. The concentrations can be seen to rise rapidly from a low base in early December to a plateau peak of about 23,000 µg/L through the second half of December 1998 and into January 1999. The transient steep decrease in manganese concentrations at the end of January coincides with the high flow event at this time. The level then decreased steadily after January, to a low value at the end of the wet season.

Investigations to determine the source of the solutes

Subsequent to tabling of the Interim Report on May 19th, 2000 it was discovered that there had been a spill of tailings into the corridor containment drain at the ramp on the eastern wall of the tailings dam, upstream of the VLG drain culvert, in December 1998. The spill occurred at about the same time as the steep rise in Mn concentration at monitoring site GCSR shown in Graph 10.

A number of filtered and acidified water samples that had been collected at GCSR at this time were located in storage and analysed for ammonium ion (Table 10). Prior to the middle of December, ammonium concentrations were low, presumably reflecting the baseline signature in leachate from waste rock containing blasting residues. However, from December 10th onwards, substantially elevated levels of ammonium were present. This finding unambiguously shows that some water of process origin had seeped into the VLG drain, presumably through the culvert beneath the tailings corridor drain, as in February 2000.

The ammonium ion concentrations can be used to estimate the likely contribution of process water to the solute load at GCSR, and hence derive a value for the concentration of Mn that should have been present, using values of 800,000 µg/L Mn and 530 mg/L NH_4-N for process water (TDWW, Table 2). The highest value of 4.7 mg/L NH_4-N in Table 10 yields a predicted value of 7,080 µg/L Mn (dilution factor of 113). This is substantially less than the peak value of 22,000 µg/L measured at GCSR at this time.

Ammonium ion is a chemically non-conservative entity, being susceptible to adsorption and biological uptake/transformation. In addition, the water samples analysed for ammonium ion had been stored at room temperature for a year before being analysed for this species. Despite samples having been filtered and acidified, there is the possibility that ammonium could have been degraded by microbiological activity and thus the levels measured may be lower than originally present, thus yielding an overestimation of the dilution factor.

It is also possible to use ^{226}Ra to estimate the contribution of process water to the solute load at GCSR, since ^{226}Ra is enriched in process water (approximate activity 15 Bq/L). Reference to Table 9a shows that the activity of ^{226}Ra rose steeply from about 100 mBq/L in early December 1998 to an average plateau of 520 mBq/L between December 14th, 1998 and January 11th, 1999. Between January 11th and February 22nd, 1999, the activity declined to 344 mBq/L and this value was maintained to the end of the wet season. If the assumption is made that the average value of ^{226}Ra activity (350 mBq/L) between February 22nd and May 6th, 1999, represents a system 'background', derived primarily from a waste rock source, then the maximum contribution from process water would have been 520 – 350 = 170 mBq/L between December 14th, 1998 and January 11th, 1999. This equates to a dilution factor of 88. Using this factor yields a predicted Mn concentration of 9,000 µg/L. This is only 30% higher than the maximum value calculated using the ammonium dilution factor, and is still much less than the Mn values measured during much of December and January.

Thus, the evidence suggests a mixed waste rock and process water source for the Mn that was measured at GCSR, downstream of the culvert, with the majority of the Mn coming from waste rock. Closer examination of the time series data for site GCSR in Table 9a shows that a value of 7,099 µg/L Mn was measured on December 10th, 1998, three days prior to the tailings spill at the tailings dam wall ramp, about 250m hydraulically upstream of the culvert.

The rainfall record from nearby on the tailings dam shows a regular daily pattern of rainfall prior to December 10th, 1998 (Graph 8). Thus, soluble salts that may have been present in the tailings corridor drain should have been dissolved and reported to the VLG drain via seepage through the culvert, prior to this date. The depth of water in the culvert was continuously recorded by a datasonde with the cease-to-flow depth being approximately 0.5m. A low level of base flow at GCSR stared on the morning of December 9th, 1998, with no significant periods of sustained flow having been recorded since the sonde was commissioned on December 2nd. The first significant flow event occurred on December 9th, with a peak of 0.1m, and the second event (peak 0.11m) was on December 13th. Thus, the drain was flowing prior to and after the tailings spill and yet no process water signature was recorded until December 16th (NH_4-N 2.6 mg/L).

The portion of the pH trace between December 11th, 1998 and January 1st, 1999 is overlain on the rainfall data in Graph 9. It is immediately apparent from this trace that the transient decreases in pH to values close to 5 correspond exactly with flow events in the culvert and drain. This response is consistent with a waste rock source for this water since substantially increased flow can only have been caused by surface runoff and seepage coming from the waste rock catchment upstream of the culvert.

4.2.5 Stockpile seepage in drain upstream of the VLG stockpile drain culvert

Several measurements have been made of the stockpile seepage water in the drain upstream of the culvert during the 1999/00 wet season. These data are of special importance since they clearly prove that this seepage source upstream of the culvert does contribute substantial concentrations of Mn (Table 11). In the absence of flow induced by the DW3A trial, which was initiated during the 1999/2000 wet season, this source would have comprised the major flow reporting to GCSR in 1997/98 and 1998/99.

The first measurement was made on a water sample collected on December 2nd, 1999 from a discrete seepage flow at the base of the waste stockpile by a student from ANU who is working on a PhD project[1]. Subsequent samples were collected from March to May, 2000 as part of the investigation to locate the source of Mn being measured at VLGCRC. The value measured in December 1999 is consistent with that recorded for the first half of December in 1998. The values from March 2000 onwards are also of a similar order to those measured in the latter part of the 1998/99 wet season.

4.2.6 Leaching characteristics of waste rock

Additional information about the composition of potential leachate from waste rock is provided by the results of a low grade ore and waste rock leach characterisation study carried out in the first half of 1999 (Jones & Hughes 1999). The three lowest grades of waste

[1] Greg Shirtliff – 'Weathering of waste rock at Ranger uranium mine, Northern Territory, Australia: Mineralogy, element mobility and chemical processes'.

rock representing each of three types of ore (lateritic (L), transition (T) and primary (P) from Pits #1 and #3 were screened for their leaching potential. A batch leach procedure was employed using a 5:1 liquid to solid ratio with distilled water and pH 4.5 acetic acid/sodium acetate buffer as the leach media. A pH value of 4.5 was selected to simulate the effect of the acidic wet season rainfall (pH 4-5) in the Kakadu region (Noller *et al*. 1990).

Finely ground samples of rock were used to promote maximum contact and the suspensions were mixed for 24h prior to taking a sample of the supernatant for analysis. The concentrations of Mn present in each of the leachate solutions for the 18 samples of waste rock that were screened are summarised in Table 12. These data illustrate that little Mn is likely to be leached at a pH of 7.5 to 8.5. This is the pH of the slurries when distilled water is used. However, reduction of pH could lead to substantial concentrations of Mn reporting to the leachate. The fact that a 5:1 liquid to solid ratio is high relative to the ultimate contact ratio achieved as water percolates downwards through very low grade ore/waste rock indicates that higher concentrations could be achieved. The sensitivity of the extent of Mn leaching to a decrease in pH is not known since only the two end member values (pH 8 and pH 4.5) have been investigated so far. However Mn(II) is one of those solutes that is most easily mobilised as the pH decreases in waste rock. An investigation of the solubility of Mn as a function of pH for a selection of the waste rock types used for the batch leach work is currently in progress and the results will be presented in a subsequent report.

4.2.7 Preliminary Conclusions

Based on all the available evidence it is concluded that a small amount of process water seeped through the roof of the corridor drain culvert and mixed with the stockpile plus DW3A water that reported to site VLGCRC. This water then flowed into the first of the artificial wetland filters constructed in the upper reaches of Corridor Creek to treat non-RRZ runoff water from the minesite.

The ammonium ion concentration data measured for several samples at the leading edge, through the peak, and at the receding end of the seepage period (end of wet season and following repair of the leaking pipe) can be used to calculate a dilution factor for the process water reporting to the VLGCRC monitoring site. The daily volume of process water equivalent can then be estimated by multiplying the dilution factor by the daily flow measured at VLGCRC. These data are summarised in the Table below. The ammonia concentration measured on December 9th, 2000 is provided as evidence that process water was not seeping through the culvert on, or prior to, this date

Calculated volume of process water leaking through culvert[a]

Date	NH_4-N mg/L	Dilution factor [a]	Flow m^3 [b]	Volume Process Water m^3
09-Feb-00	0.009			
23-Feb-00	0.3	1767	266	0.15
08-Mar-00	1.5	353	289	0.82
29-Mar-00	1.3	408	421	1.03
19-Apr-00	1.5	353	420	1.18
05-May-00	0.36	1472	456	0.31

[a] calculated using concentrations of 530 mg/L NH_4-N in process water. [b] total flow over 24h period

The calculated volumes of process water rise through the end of February as the leading edge of the leak travelled along the tailings corridor drain and reached the culvert. The data through March and April indicate that a near steady state rate of seepage was maintained through this period. The lower value on May 5th corresponds to the onset of the dry season (consequent removal of the rainfall transport medium) and repair of the leak. Assuming that the seepage occurred for a maximum period of 85 days (February 9th to May 5th, 2000), and that the average daily seepage rate through the culvert was 1m^3 of process water, then a maximum total volume of 85m^3 of process water may have seeped through the culvert and reported to the VLGCRC monitoring site. During this same 85 day period a total of approximately 1,900,000 m^3 of water flowed past monitoring site GC2.

4.2.8 Further investigations

A number of investigations have been foreshadowed as a result of the technical overview, including:

- ongoing monitoring of solute concentrations in seepage from the waste rock landform to cessation of flow this dry season and 'first flush' at the start of next wet season;
- inclusion of ammonia and nitrate in the routine analysis suite for VLGCRC and VLG stockpile seepage;
- inclusion of an upstream part of the VLG stockpile drain site as a routine sampling point during the 00/01 wet season; and
- definition of the pH dependence of Mn leaching from waste rock.

4.3 Attenuation of Solutes by Treatment Wetland Systems

Of key import to the question of whether the escape of a small volume of process-derived water had any significant impact on Georgetown Billabong, or Magela Creek, is the ability of constructed wetland filters systems surrounding Ranger Mine to attenuate solutes in site water. Many years of performance data have been acquired for the RP1 constructed wetland system. In addition, performance data is available for the past two years for the constructed wetland filters in the upper reaches of Corridor Creek.

A number of relevant research projects have been undertaken on these issues[2]. Some projects are still in progress as part of the 1999/2000 R&D program[3]. Evaluation of relevant

[2]JONES, D R (1998) Performance of the RP1 catchment constructed wetland filter - 1997. Report for ERA Ranger Mine. - *April 1998*. 27 pp.

JONES, D R, FARRAR, V A, TOOHEY, D & WADE, A (1999) Prognosis for RP1 following inputs of U from the upper catchment. Report to ERA Ranger Mine. - *June 1999*. 19pp plus 3 appendices.

JONES, D R & JUNG, R (1999) Removal of uranium and sulfate in the RP1 constructed wetland. Report to ERA Environmental Services Pty Ltd. CSIRO Minesite Rehabilitation Research Program Report No. CET/IR 79R, July 1999. 85pp plus 4 appendices.

BATTERHAM, R & OVERALL, R (1999) Trophic pathways of heavy metals in Ranger water bodies. Internal discussion paper for ERA Ranger Mine. - *August 1999*. 28pp plus 14 plates and 2 appendices.

JONES, D R & HUGHES, L (1999) Leaching characteristics of Ranger low grade ore. Report to ERA Ranger Mine. - *August 1999*. 33pp plus 4 appendices.

[3]JONES, D R 'Fate of mobilised solutes in the Corridor Creek catchment'

BATTERHAM, R. "Chemical limnology of RP1 following seepage from the low grade stockpile'

OVERALL, R 'Modelling the evolution of water quality in runoff and seepage from the waste rock dumps'

STOCKTON, D "Development (design, progressive construction and monitoring the behaviour) of the final landform'

CORBETT, L K 'Review and evaluation of all data on ecosystem health of trophic groups at key monitoring locations'

BATTERHAM, R 'Impacts of contaminants in Ranger waterbodies on fauna' data in all projects is underway as part of the normal reporting process in the R&D program each financial year and reports will be available to stakeholders in due course.

To ensure maximum protection of the Magela Creek system downstream of the mine, a new reporting system is being implemented. This involves comparing the measured levels at 009 with the historical dataset for a water quality monitoring station upstream of the mine. Trigger levels have been set for when specified measured values are exceeded and investigative action is required. A similar procedure can be applied to the historical data record for Georgetown Billabong. This site has been regularly sampled since 1990. The data for Mn, U, Mg and SO_4 are plotted on Graphs 11 to 14, with the 80th and 95th percentile lines overlaid for reference. These time series plots of data can be assessed in light of the procedures now implemented for Magela Creek monitoring and reporting. If the measured value exceeds the 80th percentile of the dataset, then an increased frequency of monitoring will be implemented to determine the rate at which the concentration value is changing. If the 95th percentile value is exceeded, then a report will be made to stakeholders, and corrective action taken by the company.

Graph 11 shows the time series data for filterable concentrations of manganese. Most of the data over the past ten years falls well below the 80th percentile line. In particular, the data for January to May 2000 lies below this threshold. Thus, the small leak of process water into the constructed wetland filters in the upper reaches of Corridor Creek has not impacted on Georgetown Billabong.

Graph 12 shows the U concentration data measured since the beginning of 1990. All of the values measured over the past two and a half years are below the 80th percentile threshold. There is a very similar situation with magnesium, with only one measured value over the past two years having exceeded the 80th percentile (Graph 13).

4.4 *Assessment of Potential for Impact on Magela Floodplain*

It has been shown above that the seepage of a small volume of process water containing elevated concentrations of Mn has had no impact on water quality impact at either site GC2 in Corridor Creek or at the sampling point in Georgetown Billabong. It follows that there could therefore be no impact further downstream and there is clear evidence that Magela Creek was not impacted. The results of the analysis of the monitoring data for the 99/00 wet season are presented below.

4.4.1 Chemical Monitoring Data for 009

Monitoring of Magela Creek is performed by ERA on a weekly basis upstream of the minesite (MCUS) and at gauging station GS8210009 (downstream of mine) during periods of flow.

Manganese levels downstream of the mine have been monitored since 1980 (Graph 15). As can be seen from the graph, manganese levels are elevated during the first flush events, with a rapid decrease once consistent creek flow is established. The data for 1999/2000 shows no deviation from historic trends.

A single water sample collected on November 3rd, 1999 had a manganese concentration of 32 µg/L. The first significant rains for the wet season occurred late in October, with 66.8 mm being recorded at Jabiru Airport on October 31st, 1999. The concentrations of solutes (including Mn) in this sample are indicative of the 'first flush'.

Mn concentrations for the remainder of the wet season remain below 10 µg/L, with the exception of one reading taken on January 5th, 2000 of 15 µg/L. A sample collected on the same date from Magela Creek Upstream monitoring site had a manganese concentration of 41 µg/L, indicating that the slight elevation in manganese recorded at the downstream site was not due to mining activities.

Graph 16 shows filterable uranium concentrations measured at 009. As with manganese, a first flush high is recorded at the beginning of each wet season, followed by a rapid decrease. No deviation from historic trends is evident.

Table 13 summarises statistical data available for both the upstream (MCUS) and downstream (009) sites. No variation from historic trends is evident, indicating no impact of water from the VLG drain at VLGCRC.

4.4.2 Biological Monitoring Data for 009

Creekside monitoring has been conducted by *eriss* and ERA for a number of years to investigate the relative toxicity of Magela Creek up and downstream of any mine related inputs. The program was established to serve as a validation of the laboratory based pre-release screening tests. The creekside stations are established immediately downstream of the confluence of Georgetown Billabong with Magela Creek (upstream of mine related inputs) and near gauging station 009. Analysis and interpretation of results has been provided by *eriss*.

Fish larval survival was higher in the down stream site (Graph 17). The snail egg production test showed similar survival levels between the two monitoring stations (Graph 18). It should be noted that the creek side monitoring system experienced problems such as the water becoming supersaturated with oxygen during the 1999/2000 test period. Both *eriss* and Ranger tests experienced these problems. Poor fish survival in some test tanks can be correlated with the supersaturation of these waters.

General conclusion only can be drawn from these data due to the abovementioned technical difficulties. However, it is clear that there were no adverse effects of mine operations on any of the test species over the 1999/2000 wet season.

5 UPDATED OPERATIONAL PROCEDURES FOR TAILS AND PROCESS WATER SPILLAGES

5.1 Tails pipeline inspection procedure (draft)

- Tailings lines are to be checked at least three times per shift as a minimum requirement.
- The results of the checks and the frequency of the checks are to be logged.
- All the tails lines are to be included in the checks, i.e.
    - ✓ A tails line along corridor road;
    - ✓ A tails line from corridor road to the top of Pit # 1

- ✓ A tails line around the side of Pit # 1
- ✓ B tails line along the corridor road
- ✓ B tails line from the corridor road to the discharge point at Pit #1
- ✓ Tails return water line from the tails return pumps to the process head tank
- ✓ Siphon line from the tailings dam to Pit #1 along the corridor road and into the pit
- ✓ Dewatering lines from Pit #1 to the tailings dam – on top of Pit #1 and along the corridor road

- The procedure for checking is to drive slowly along beside the pipelines and observe any water pooling around the pipes or any mud slurry leaking from the pipes.
- Special attention should be given to victaulic couplings, sections of mine hose, and any bends.
- If the view of the pipe is impeded in any way, the operator should leave the vehicle for closer inspection.
- On night shift, the vehicle spotlights may need to be adjusted so as to illuminate the pipelines.
- Sections of the pipelines that cannot be checked from the vehicle may need to be walked.

5.2 *In the event of identifying a leak*

- In the event of identifying a leak, **action must be taken to stop the spill as soon as possible**. That is, if a tails line is leaking, change the tails pumps.
- Any leak **must be contained in the corridor road drain**.
- Maintenance **must be advised and repairs implemented as soon as possible**.
- The mill coordinator and/or mill superintendent **must be informed as soon as possible**.
- In the event of a leak to the containment drain**, the flyght pump in the turkey's nest sump must be stopped immediately**.

5.3 *Formal ERA Operational Procedure*

The formal Operational Procedure for Tails/Process Water Spillage is being updated. The principal objective of the procedure is "to ensure that the spillage of tailings and process water is effectively managed and reported". Personal protection equipment requirements are stated. A number of specific actions (with comments, explanations and instructions) are described.

6 INCIDENT NOTIFICATION AND REPORTING TO EXTERNAL STAKEHOLDERS

The length of time it took to formally report the incident to appropriate stakeholders is recognised by ERA as unacceptable. This is a matter of internal and external investigation and revised procedures have been implemented. To this end, ERA is working with the OSS, NTDME and the NLC through the Ranger Minesite Technical Committee to develop a protocol that details the threshold or trigger levels for formally reporting environmental incidents.

To initiate discussion on this process, ERA has proposed that a reporting regime similar to that being developed for 009 be adopted for locations within the purpose-built surface water retention systems that are part of the mining operations upstream of Magela Creek and both Coonjimba and Georgetown Billabongs. Thus the reporting trigger regime could be applied to existing statutory monitoring sites at the weir on RP1 and at GC2 above the Sleepy Cod wetland filter on Corridor Creek. Potential variables and trigger thresholds are set out in the following tables.

Key variable	**Relevance**
pH	Stipulated under ER 3.3 as a master variable influencing speciation and toxicity of potential contaminants and ecosystem character (i.e. structure and function)
EC	As above
U concentration	Stipulated under ER 3.3 as the principal contaminant of public concern and has potential ecological impact
Turbidity	No evidence of mine effect but becomes increasingly important as a physico-chemical indicator of potential ecological impact from disturbance and erosion of surfaces during mining operations and rehabilitation
Mg concentration	Evidence of mine impacts (e.g. accelerated weathering of waste rock) and potential impacts on potability of water. Ecological impacts unclear.
SO_4 concentration	As above
Mn concentration	Evidence of effects of mining. Arises primarily from the use of pyrolusite in mineral processing, although also derived from leaching of waste rock. Potential ecological impact
Ca concentration	No direct effect envisaged but potentially has an ecological impact through Mg imbalance (i.e. Ca:Mg ratio)
NH_4	Process water indicator

Type of data	**Level of Action**	**Value**
Normal distribution	Focus level	$\pm\ \delta$
	Report trigger	$\pm\ 2\delta$
Non-normal distribution	Focus level	$x>80^{th}$ percentile
	Report trigger	$x>95^{th}$ percentile

Further clarification may be possible using the approach developed by OSS in relation to the significance of environmental incidents. A paper along these lines will be tabled at the next MTC meeting.

7 CORRECTIVE ACTIONS

The following remedial works have been completed:

- realigned and contoured the pipeline pipeline bund from the Tailings Dam toe to the crest;
- re-established the pipeline bund subgrade material in the above section;
- renewed and replaced the steel pipeline on concrete support blocks within the above section;
- reinstated the 450 mm diameter HPDE pipeline within the above section;
- regraded and contoured the tailings corridor road to ensure minimal sediment wash towards the pipeline bund;
- excavated the underside of the steel pipeline within the tailings corridor bund for the entire length (approximately 2.5 km);
- removed vegetation over the entire pipeline bund length and the Tailings Dam crest area to the decant pump pontoon;
- installed a concrete barrier over the top of the Very Low Grade Corridor Road Culvert (VLGCRC) within the tailings corridor pipeline bund;
- non-destructive testing of 4.5 km length of steel pipeline utilising INTICO Pty Ltd[4];
- SKM have completed a draft report reviewing the design and operational functionality of the pipeline corridor for the Office of the Supervising Scientist;
- a review of the process water system;
- declared the tailings corridor bunded area a part of the closed water system;
- appointed a Manager, Public Relations (Scott Walker); and
- restructured the ESH Department.

Other strategies under consideration include:

- extending the DW3A trial outlet to the culvert beneath the tailings corridor drain;
- investigations of a methodology for the non-destructive testing of 450mm HDPE and pit tailings line;
- updating the monitoring program in the constructed wetland filters in the upper reaches of Corridor Creek to consolidate additional barriers of protection to the offsite environment;
- developing trigger values and locations for mandatory reporting; and
- developing plans to improve the clarity of reporting to external stakeholders

[4] INTICO (VIC) Pty Ltd. "Ultrasonic thickness survey of tailsline steel and polyethylene PE 808 grade piping". Report to ERA Limited. June 1, 2000.

8 CONCLUSIONS

This incident and subsequent investigations have highlighted deficiencies in the hazard recognition and reporting process at Ranger Mine. While the water quality and toxicological data shows that there has been no impact of the process water leak on the external environment, ERA is committed to working with external stakeholders to address all identified issues and implement remedial actions arising from investigations of the incident.

9 REFERENCES

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10 TABLES OF DATA

Table 1. ICPMS scan results for samples of source waters

Sample number	Site Code	Date sampled	Ag ug/L	Al ug/L	As ug/L	Au ug/L	B ug/L	Ba ug/L	Be ug/L	Bi ug/L	Br ug/L	Ca ug/L	Cd ug/L	Ce ug/L	Co ug/L	Cr ug/L	Cs ug/L	Cu ug/L	Dy ug/L	Er ug/L	Eu ug/L	Fe ug/L	Ga ug/L	Gd ug/L
74926	Corridor Creek wetland site GC2	29-Mar-00	<0.01	24.2	<0.05	0.01	20	4.82	<0.1	<0.01	4	1253	<0.02	0.08	0.08	0.4	0.03	0.86	0.01	<0.01	<0.01	123	<0.01	0.01
74930	Corridor Creek wetland site GCBR	29-Mar-00	<0.01	6.9	<0.05	<0.01	21	3.48	<0.1	<0.01	4	1654	<0.02	0.03	0.08	0.3	0.03	0.19	<0.01	<0.01	<0.01	75	<0.01	<0.01
74977	DW3A drain SITE7	30-Mar-00	<0.01	29.5	0.13	<0.01	50	89.48	1	<0.01	19	46505	0.23	290.3	13.22	0.8	2.26	3.11	13.63	5.74	3.61	1600	<0.01	21.65
74978	DW3A drain SITE8	30-Mar-00	<0.1	458	<0.5	<0.1	61	90.7	2	<0.1	26	489090	0.7	331.6	7.5	37	22.35	8.3	11.7	5.5	3.2	6533	1.3	20.2
74995	DW3A drain SITE9	31-Mar-00	<0.01	72.6	0.27	<0.01	54	27.26	0.2	<0.01	18	13419	0.03	1.81	0.96	1.6	0.21	4.08	0.16	0.08	0.04	117	0.08	0.21
74996	DW3A drain SITE10	31-Mar-00	<0.01	64.1	0.26	<0.01	47	28.21	0.2	<0.01	17	18554	0.06	8.93	2.29	1.3	0.46	3.14	0.59	0.28	0.14	258	0.14	0.8
74997	DW3A drain SITE11	31-Mar-00	<0.2	4831	<1	<0.2	755	44.2	11	<0.2	32	732480	6.7	244.4	1168.2	3	69.1	1480.2	406.8	166.3	60.9	46284	14.5	296
75771	Drain SITE9	05-May-00	<0.01	29.6	0.23	<0.01	55	19.24	0.2	<0.01	20	13577	<0.02	0.39	0.19	2.6	0.09	2.85	0.07	0.04	0.01	<20	0.01	0.08
75774	DW3A drain SITE13 - outlet pipe DW3A	05-May-00	0.02	15.7	<0.05	0.02	77	23.26	0.2	0.01	25	12023	<0.02	0.05	0.25	5.5	0.07	0.43	0.01	<0.01	<0.01	<20	0.03	0.01
75777	VLG tailings corridor culvert - V-notch weir site VLGCRC	05-May-00	<0.01	24.9	0.07	<0.01	50	21.12	<0.1	<0.01	19	15467	<0.02	0.6	0.22	2.6	0.12	2.54	0.07	0.04	0.02	29	0.02	0.09
75779	Corridor Creek wetland GCBR	05-May-00	<0.01	4	0.07	<0.01	20	6.67	0.1	<0.01	6	1518	<0.02	0.03	0.2	0.3	0.05	0.07	<0.01	<0.01	<0.01	71	<0.01	<0.01
75785	DW3A drain SITE6	05-May-00	<0.01	29.5	0.27	<0.01	47	19.07	0.2	<0.01	19	13766	0.02	0.28	0.16	2.2	0.08	2.62	0.06	0.03	0.01	<20	0.02	0.06
75788	DW3A drain SITE20	05-May-00	<0.01	15.1	0.16	<0.01	53	18.09	0.1	<0.01	19	15173	<0.02	0.15	0.13	1.7	0.26	2.09	0.03	0.01	<0.01	27	0.03	0.03
75798	DW3A drain SITE22	05-May-00	<0.01	18.3	0.36	<0.01	41	28.11	0.3	<0.01	18	16181	<0.02	1.06	0.23	1.9	0.15	1.9	0.06	0.03	0.02	36	0.02	0.09
75803	DW3A drain SITE8	05-May-00	<0.1	42	<0.5	<0.1	351	28.5	<1	<0.1	<10	528150	0.2	0.5	2	3	1.25	5	<0.1	<0.1	<0.1	4095	1.9	<0.1
75806	DW3A drain SITE7	05-May-00	<0.02	20	<0.1	<0.02	31	34.44	0.5	<0.02	15	21987	0.09	62.62	2.8	0.5	1.8	1.2	2.28	1.02	0.62	443	<0.01	3.86
75810	Mine bore L water	05-May-00	<0.01	15.4	0.1	<0.01	114	32	0.1	<0.01	5	6537	0.02	0.02	0.45	4	0.02	0.48	<0.01	<0.01	<0.01	<20	<0.01	<0.01
75818	Corridor Creek wetland GC2	05-May-00	<0.01	37.5	<0.05	0.02	33	4.5	<0.1	<0.01	6	1225	<0.02	0.11	0.1	1	0.02	0.21	<0.01	<0.01	<0.01	220	<0.01	0.01
75820	Process water Tails Dam WW	05-May-00	<0.2	4688	<1	<0.2	861	43.5	3	<0.2	33	743820	6.8	244.2	1149.2	<2	70.08	1429	414	170.4	61.9	47348	14.1	298.8

Table 1. ICPMS scan results for samples of source waters (continued)

Sample number	Site Code	Date sampled	Ge	Hf	Hg	Ho	I	In	La	Li	Lu	Mg	Mn	Mo	Nb	Nd	Ni	Os	PbTot	Pd	Pr	Pt
74926	Corridor Creek wetland site GC2	29-Mar-00	<0.05	0.04	<0.02	<0.01	<5	<0.01	0.05	0.5	<0.01	8359	7.8	0.06	<0.02	0.04	0.68	<0.1	0.11	<0.01	0.01	<0.01
74930	Corridor Creek wetland site GCBR	29-Mar-00	<0.05	0.02	<0.02	<0.01	6	<0.01	0.01	1.3	<0.01	11506	7.99	0.03	<0.02	0.02	<0.05	<0.1	<0.01	<0.01	<0.01	<0.01
74977	DW3A drain SITE7	30-Mar-00	<0.05	0.08	<0.02	2.53	35	<0.01	218.4	12.8	0.37	490930	76693.5	0.46	<0.02	127.3	40.18	<0.1	0.19	<0.01	35.14	<0.01
74978	DW3A drain SITE8	30-Mar-00	<0.1	<0.1	0.2	2.3	<50	<0.1	272.4	13	0.5	2095500	307325	37.9	<0.2	152.1	20.7	<1	0.8	<0.1	42.8	<0.1
74995	DW3A drain SITE9	31-Mar-00	<0.05	0.07	<0.02	0.03	34	<0.01	1.48	32.8	<0.01	178750	4882.05	0.69	<0.02	1.03	2.95	<0.1	0.26	<0.01	0.28	<0.01
74996	DW3A drain SITE10	31-Mar-00	<0.05	0.04	<0.02	0.11	37	<0.01	9.58	23.9	0.02	201740	11542.5	0.59	<0.02	4.45	5.83	<0.1	0.15	<0.01	1.25	<0.01
74997	DW3A drain SITE11	31-Mar-00	1.3	0.3	0.1	70	<100	<0.2	82.8	1638	12.2	6872800	2348400	0.7	<0.4	258.4	1854	<2	1524.6	<0.2	47.1	<0.2
75771	Drain SITE9	05-May-00	<0.05	0.03	<0.02	0.02	38	<0.01	0.38	35.3	<0.01	202070	577.89	0.6	<0.02	0.3	0.73	<0.1	<0.01	<0.01	0.08	<0.01
75774	DW3A drain SITE13 - outlet pipe DW3A	05-May-00	0.06	0.03	<0.02	<0.01	38	<0.01	0.06	51	<0.01	210100	2.11	0.37	<0.02	0.06	0.32	<0.1	0.02	<0.01	0.02	<0.01
75777	VLG tailings corridor culvert - V-notch weir site VLGCRC	05-May-00	<0.05	0.02	<0.02	0.02	39	<0.01	0.7	32.9	<0.01	202400	1059.25	0.62	<0.02	0.43	0.84	<0.1	0.02	<0.01	0.11	<0.01
75779	Corridor Creek wetland GCBR	05-May-00	<0.05	0.01	<0.02	<0.01	8	<0.01	0.01	0.7	<0.01	9237	14.83	0.05	<0.02	0.02	<0.05	<0.1	<0.01	<0.01	<0.01	<0.01
75785	DW3A drain SITE6	05-May-00	<0.05	0.02	<0.02	0.02	37	<0.01	0.31	37.8	<0.01	206910	433.01	0.6	<0.02	0.26	0.66	<0.1	0.01	0.01	0.07	<0.01
75788	DW3A drain SITE20	05-May-00	<0.05	0.05	<0.02	<0.01	30	<0.01	0.19	17.7	<0.01	163790	823.84	0.55	<0.02	0.12	0.67	<0.1	<0.01	0.01	0.03	<0.01
75798	DW3A drain SITE22	05-May-00	<0.05	0.02	<0.02	0.02	38	<0.01	0.95	26.6	<0.01	198440	1273	0.53	<0.02	0.52	0.83	<0.1	0.04	0.01	0.14	<0.01
75803	DW3A drain SITE8	05-May-00	0.2	0.1	<0.1	<0.1	<50	<0.1	0.3	3	<0.1	914980	194750	6.5	<0.2	0.2	4.7	<1	<0.1	<0.1	<0.1	<0.1
75806	DW3A drain SITE7	05-May-00	<0.05	0.02	<0.02	0.43	26	<0.02	43.44	2.5	0.07	234740	19722	0.26	<0.04	23.16	6.4	<0.2	0.13	<0.01	6.48	<0.02
75810	Mine bore L water	05-May-00	<0.05	0.03	<0.02	<0.01	<5	<0.01	0.02	18.1	<0.01	64328	84.14	1.07	<0.02	0.01	0.67	<0.1	0.53	<0.01	<0.01	<0.01
75818	Corridor Creek wetland GC2	05-May-00	<0.05	0.04	<0.02	<0.01	5	<0.01	0.05	0.3	<0.01	8330	17.61	0.05	<0.02	0.05	0.06	<0.1	0.04	<0.01	0.02	<0.01
75820	Process water Tails Dam WW	05-May-00	1.3	0.2	0.2	70.3	<100	<0.2	82.3	1726	12.4	7194000	2420600	0.4	<0.4	263	1808	<2	1513.8	<0.2	47	<0.2

Table 1. ICPMS scan results for samples of source waters (continued)

Sample number	Site Code	Date sampled	Rb	Re	Ru	Sb	Sc	Se	Sm	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
74926	Corridor Creek wetland site GC2	29-Mar-00	3.09	0.55	<0.01	0.01	<0.5	<0.2	0.01	3.68	<0.01	<0.01	<0.1	<0.01	<2	<0.01	<0.01	1.394	<0.5	0.02	0.03	<0.01	3.9	<0.05
74930	Corridor Creek wetland site GCBR	29-Mar-00	3.37	1.74	<0.01	<0.01	0.5	<0.2	<0.01	4.66	<0.01	<0.01	<0.1	<0.01	<2	<0.01	<0.01	3.517	<0.5	<0.01	0.01	<0.01	0.6	<0.05
74977	DW3A drain SITE7	30-Mar-00	66.13	19.31	<0.01	0.07	2.2	2.6	19.94	98	<0.01	2.63	<0.1	<0.01	4	0.17	0.57	157.5	0.8	0.03	124.8	2.56	8.5	<0.05
74978	DW3A drain SITE8	30-Mar-00	625.1	32.6	<0.1	0.5	8	4	20.5	804.2	<0.1	2.3	<1	<0.1	32	1	0.6	13.15	<5	0.2	109.8	3	37	<0.5
74995	DW3A drain SITE9	31-Mar-00	9.65	20.68	<0.01	0.04	2.8	1.4	0.17	24.76	<0.01	0.03	<0.1	<0.01	2	0.03	0.01	288.6	1.6	0.04	1.33	0.05	5.2	<0.05
74996	DW3A drain SITE10	31-Mar-00	15.49	18.21	<0.01	0.06	2.6	1.3	0.66	43.95	<0.01	0.11	<0.1	<0.01	3	0.04	0.03	286.9	1	0.02	5.46	0.15	5	<0.05
74997	DW3A drain SITE11	31-Mar-00	673.6	108	<0.2	<0.2	20	<4	174.5	1455.6	<0.2	64	<2	<0.2	53	7.5	20.1	1739.8	<10	<0.2	1591.4	110.3	585	<1
75771	Drain SITE9	05-May-00	4.84	23.73	<0.01	0.02	3.1	1.2	0.06	23.84	<0.01	0.01	<0.1	<0.01	3	0.01	<0.01	259.3	1.6	0.02	0.7	0.02	12.7	<0.05
75774	DW3A drain SITE13 - outlet pipe DW3A	05-May-00	2.12	24.09	<0.01	0.03	3.6	1.1	<0.01	17.41	<0.01	<0.01	<0.1	<0.01	4	<0.01	<0.01	11.08	<0.5	0.03	0.08	<0.01	<0.5	<0.05
75777	VLG tailings corridor culvert - V-notch weir site VLGCRC	05-May-00	7	22.92	<0.01	0.02	3.1	1.1	0.07	31.05	<0.01	0.01	<0.1	<0.01	3	0.02	<0.01	285.1	2.5	0.02	0.8	0.02	0.7	<0.05
75779	Corridor Creek wetland GCBR	05-May-00	4.06	1.31	<0.01	<0.01	0.6	0.2	<0.01	4.07	<0.01	<0.01	<0.1	<0.01	<2	0.02	<0.01	1.237	<0.5	<0.01	0.01	<0.01	1.4	<0.05
75785	DW3A drain SITE6	05-May-00	4.86	23.53	<0.01	0.02	3.3	1.3	0.05	24.16	<0.01	<0.01	<0.1	<0.01	3	0.01	<0.01	273.1	2	0.02	0.6	0.02	1.1	<0.05
75788	DW3A drain SITE20	05-May-00	11.63	18.35	<0.01	0.01	2.2	1	0.02	35.71	<0.01	<0.01	<0.1	<0.01	2	0.02	<0.01	239.5	1.1	0.03	0.31	<0.01	<0.5	<0.05
75798	DW3A drain SITE22	05-May-00	7.99	21.08	<0.01	0.01	3	1.2	0.08	35.58	<0.01	0.01	<0.1	<0.01	3	0.02	<0.01	291.8	1.5	0.01	0.69	0.02	2.5	<0.05
75803	DW3A drain SITE8	05-May-00	58.9	12.9	<0.1	0.5	11	3	<0.1	492	<0.1	<0.1	<1	<0.1	31	<0.1	<0.1	144.6	<5	<0.1	<0.1	<0.1	12	<0.5
75806	DW3A drain SITE7	05-May-00	66.22	14.69	<0.02	<0.02	2.2	1.8	3.43	38.76	<0.02	0.44	<0.2	<0.02	<4	0.13	0.11	76.3	<1	<0.01	21.92	0.45	6	<0.1
75810	Mine bore L water	05-May-00	2.06	1.9	<0.01	0.03	2.3	1.7	<0.01	18.69	<0.01	<0.01	<0.1	<0.01	2	<0.01	<0.01	764.8	2.7	0.28	0.03	<0.01	16.8	<0.05
75818	Corridor Creek wetland GC2	05-May-00	1.91	0.75	<0.01	0.12	<0.5	<0.2	0.01	3.67	<0.01	<0.01	<0.1	0.01	<2	<0.01	<0.01	1.57	0.6	0.02	0.03	<0.01	0.6	<0.05
75820	Process water Tails Dam WW	05-May-00	685.6	106	<0.2	<0.2	21	6	175.2	1500.8	<0.2	64.8	<2	<0.2	56	7.2	20.2	1733.2	<10	<0.2	1622.8	116	571	<1

Table 2. Typical major and minor ion composition (range of values) of source waters

	Process water - Tailings dam **5/1/00-29/3/00 (13 samples)**	**DW3A water** **5/1/00-29/3/00 (13 samples)**	**Mine Bore L water** **5/1/00-1/3/00 (3 samples)**	**Retention Pond 2 water** **5/1/00-29/3/00 (13 samples)**
pH	4.0-4.4	8.1-8.5	7.8-7.9	7.1-7.6
Conductivity µS/cm	15,000-18,000	1,100-1,200	440-460	820-950
HCO_3 mg/L	below detection	230 (1/12/99)	nm	23*
Turbidity NTU	1.2-8	0.1-0.83	below detection*	1.6-7
Na mg/L	53*	8.9*	nm	6.7*
K mg/L	84*	1.3*	nm	2.8*
Mg mg/L	2,400-3,700	150-280	59-68	100-160
Ca mg/L	440*	12*	nm	15*
Cl mg/L	nm	nm	nm	nm
NO_3 mg/L	nm	nm	nm	nm
NH_4-N mg/L	530*	nm	nm	0.5*
SO_4 mg/L	13,000-14,000	390-1,000	10-24	410-670
Pb µg/L	980*	nm	nm	0.92*
Zn µg/L	nm	below detection*	below detection*	nm
Mn µg/L	710,000-1,100,000	below detection - 7.3	below detection*	1,200-22,000
U µg/L	900-1,300	14-18	200-220	2,500-3,800
Fe µg/L	460*	below detection*	below detection*	4.8*
Al µg/L	490*	below detection*	below detection*	below detection*

*Single analysis result
nm = not measured

Table 3. Water quality data for site VLGCRC, 1999/2000 wet season DW3A trial

Sample	Site	Date sampled	pH	Cond	Co3	Hco3	Turb	Al	Ca	Cl	Cu	Fe	K	Mg	Mn	Na	NH4-N	NO3	Pb	PO4	Ra-226	SO4	U	Zn
				uS/cm	mg/L	mg/L	NTU	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L		mg/L	ug/L	ug/L
71440	VLGCRC	03-Nov-99	6.6	274	-1.0	8.7	6.4	45	4.0		-2.0		2.5		186	1.4						104.8	23.1	-2
71802	VLGCRC	17-Nov-99	6.5	320	-1.0	12.8	4.9							32.7								106.5	15.2	
71975	VLGCRC	24-Nov-99	7.0	308	-1.0	44.1	2.1							33.5								107.2	50.0	
72082	VLGCRC	01-Dec-99	7.0	281	-1.0	14.7	8.4		4.1				2.2	28.1								109.2	148.5	
72240	VLGCRC	08-Dec-99	7.3	315	-1.0	34.5	3.4	15	7.7		-2.0	21	3.6	31.8	48	2.4						92.3	104.3	-2
72307	VLGCRC	15-Dec-99	7.6	304																		84.8	155.5	
72467	VLGCRC	22-Dec-99	6.9	327			5.0							34.8	77							121.1	140.1	
72602	VLGCRC	29-Dec-99	7.7	365			6.8							40.0	104							142.9	222.3	
72729	VLGCRC	05-Jan-00	7.3	377			6.4							41.9	145							120.0	116.9	
72881	VLGCRC	12-Jan-00	7.6	470			9.2							54.2	98							163.5	297.6	
72992	VLGCRC	19-Jan-00	8.1	645			5.7							93.7	202							178.4	513.5	
73226	VLGCRC	25-Jan-00	7.4	573			23.2							18.2	751							106.4	102.2	
73408	VLGCRC	02-Feb-00	7.3	689			4.4							78.6	6077							298.2	59.8	
73661	VLGCRC	09-Feb-00	8.1	852			3.0							114.4	504							376.3	917.3	
73831	VLGCRC	16-Feb-00	7.4	458			12.2							48.3	1827							185.3	193.9	
74044	VLGCRC	23-Feb-00	7.6	855			3.0							102.4	2111							368.1	364.3	
74240	VLGCRC	01-Mar-00	7.3	608			4.0							99.6	3730							374.8	183.4	
74449	VLGCRC	08-Mar-00	7.5	1081			5.0							138.0	9532							538.0	320.3	
74645	VLGCRC	15-Mar-00	7.6	530			13.0							60.9	2589							220.4	154.2	
74814	VLGCRC	22-Mar-00	8.0	954			2.0							133.8	1845							395.7	403.8	
74931	VLGCRC	29-Mar-00	7.3	663			6.0							79.3	5941							299.6	103.9	
74996	VLGCRC	31-Mar-00																						
75091	VLGCRC	05-Apr-00	7.9	1089			1.0							148.9	2691							462.5	332.7	
75227	VLGCRC	12-Apr-00	8.3	1089			1.0							141.0	3540							495.6	288.9	
75479	VLGCRC	19-Apr-00	7.5	905			2.0							119.3	3622							410.9	223.8	
75570	VLGCRC	26-Apr-00	7.6	1091			1.0							146.2	1085							452.8	207.2	
75681	VLGCRC	03-May-00	8.1	1039			1.0																253.4	
75776	VLGCRC	05-May-00	7.6	1100																				
75777	VLGCRC	05-May-00												150.0	840		0.36					470.0		

Table 4. Compilation of major ion data for samples from sites relating to the process water leak incident in late March-early May, 2000

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
71420	DW3A	03-Nov-99	8.2	1092	210.3	-10	11.5	5.3	-2.00			5	8.0		0.39		427.0	11.9	-2.00				
74940	DW3A	29-Mar-00	8.2	1085							199.1	-1					389.0						
75105	DW3A	05-Apr-00	8.2	1089							153.8	-1					441.6						
75236	DW3A	12-Apr-00	8.1	1089							153.5	1					434.8	13.2					
75488	DW3A	19-Apr-00	8.2	1089							150.3	11					441.5	12.0					
75579	DW3A	26-Apr-00	7.6	1089							149.6	-1					436.6	11.6					
75695	DW3A	03-May-00	8.1	1094														11.6					
74926	GC2	29-Mar-00	7.1	81							9.1	7					13.9	1.5		0.00	0.04	0.02	0.05
74926	GC2	29-Mar-00				24	1.3		0.86	123						0.11		1.4	3.90				
75086	GC2	05-Apr-00	7.3	94							10.3	26					17.4	1.6					
75222	GC2	12-Apr-00	7.2	107							11.9	10					15.3	1.7					
75474	GC2	19-Apr-00	7.0	98							10.7	21					18.6	1.3					
75565	GC2	26-Apr-00	6.8	107							11.5	20					17.2	1.3					
75676	GC2	03-May-00	7.2	88														2.3					
75818	GC2	05-May-00																		0.00	0.04	0.00	0.00
75818	GC2	05-May-00				38	1.2		0.21	220						0.04		1.6	0.60				
75819	GC2	05-May-00																					
74930	GCBR	29-Mar-00	6.9	112							11.1	7					37.1	3.6		0.00	0.00	0.00	0.00
74930	GCBR	29-Mar-00				7	1.7		0.19	75						<0.01		3.5	0.60				
75090	GCBR	05-Apr-00	6.8	112							12.2	37					38.6	2.4					
75226	GCBR	12-Apr-00	7.0	128							13.0	4					43.8	2.8					
75478	GCBR	19-Apr-00	6.9	107														2.5					
75569	GCBR	26-Apr-00	6.5	128							12.8	6					43.8	2.0					
75680	GCBR	03-May-00	6.7	99														1.7					
75779	GCBR	05-May-00	6.3	96							9.4	14		<0.05			24.0			0.00	0.00	0.00	0.00
75779	GCBR	05-May-00				4	1.5		0.07	71						<0.01		1.2	1.40				
75780	GCBR	05-May-00																					
75120	Georgetown Billabong	05-Apr-00	6.6	21																			
75707	Georgetown Billabong	03-May-00	6.2	31														0.3					
75810	Mine Bore L water	05-May-00	7.4	480							61.0	80		<0.05			32.0			0.01	0.14	0.12	0.26
75810	Mine Bore L water	05-May-00				15	6.5		0.48	<20						0.53		764.8	16.80				
75811	TDSITE31	05-May-00	4.8	2500																			
75812	TDSITE31	05-May-00									290.0	71000		52			1600.0						
74244	TDWW - process water	01-Mar-00	4.4	16064	-1.0		443.4	22.0			2425.4	830731	53.3	532.00	1.44	980.00	12969.5	1001.4					
74935	TDWW - process water	29-Mar-00	4.4	16044																			
75095	TDWW - process water	12-Apr-00	4.3	16107																			
75231	TDWW - process water	12-Apr-00	4.4	15392																			
75256	TDWW - process water	12-Apr-00																					

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
75483	TDWW - process water	19-Apr-00	4.4	15392																			
75574	TDWW - process water	26-Apr-00	3.9	15392																			
75685	TDWW - process water	03-May-00	4.4	16064																			
75820	TDWW - process water	05-May-00																		0.44	1325.98	166.19	21.24
75820	TDWW - process water	05-May-00				4688	743.8		1429.00	47348						1513.80		1733.2	571.00				
75821	TDWW - process water	05-May-00																					
74971	VLG drain SITE1 - 100m east of TD wall, upstream of leak	29-Mar-00	5.9	217							20.0	301					84.0						
74996	VLG Drain SITE10	31-Mar-00				64	18.6		3.14	258						0.15		286.9	5.00				
	VLG drain SITE11 - TD Gate	28-Mar-00									2600.0	840000					14000.0						
74997	VLG drain SITE11 - TD Gate	31-Mar-00				4831	732.5		1480.20	46284						1524.60		1739.8	585.00				
74997	VLG drain SITE11 - TD Gate	31-Mar-00									2200.0	730000					12000.0			0.49	1333.69	168.49	21.88
74998	VLG Drain SITE12 - pond 800m downstream of VLGCRC	31-Mar-00									80.0	440					230.0						
75782	VLG Drain SITE12 - pond 800m downstream of VLGCRC	05-May-00									110.0	23		<0.05			360.0						
75783	VLG Drain SITE12 - pond 800m downstream of VLGCRC	05-May-00																					
75781	VLG Drain SITE12 - pond 800m downstream of VLGCRC	05-May-00	8.0	860																			
75052	VLG drain SITE13 - waste rock	03-Apr-00									150.0	4					470.0						
75053	VLG drain SITE13 - waste rock	03-Apr-00	8.1	1070																			
75774	VLG drain SITE13 - waste rock	05-May-00				16	12.0		0.43	<20						0.02		11.1	<0.5				
75775	VLG drain SITE13 - waste rock	05-May-00																					
75773	VLG drain SITE13 - waste rock	05-May-00	7.7	1100																			
75774	VLG drain SITE13 - waste	05-May-00												<0.05						0.00	0.02	0.00	0.00

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
	rock																						
75054	VLG drain SITE14 - water over stockpile	03-Apr-00									150.0	4					480.0						
75055	VLG drain SITE14 - water over stockpile	03-Apr-00	8.6	1022																			
75767	VLG drain SITE14 - water over stockpile	05-May-00	8.3	1100																			
75769	VLG drain SITE14 - water over stockpile	05-May-00																					
75768	VLG drain SITE14 - water over stockpile	05-May-00									150.0	440		<0.05			440.0						
75056	VLG drain SITE15 - DW3A water sump prior to pumping to stockpile	03-Apr-00																					
75057	VLG drain SITE15 - DW3A water sump prior to pumping to stockpile	03-Apr-00	7.5	1076																			
75058	VLG drain SITE16 - DW3A on waste rock stockpile	03-Apr-00																					
75059	VLG drain SITE16 - DW3A on waste rock stockpile	03-Apr-00	8.4	1054																			
75628	VLG drain SITE16 - DW3A on waste rock stockpile	02-May-00																					
75629	VLG drain SITE16 - DW3A on waste rock stockpile	02-May-00									130.0	280					460.0						
75060	VLG drain SITE17 - waste rock	03-Apr-00									22.0	<0.1					57.0						
75061	VLG drain SITE17 - waste rock	03-Apr-00	9.1	212																			
75630	VLG drain SITE18 - 5m due south of central culvert	02-May-00	7.8	28																			
75631	VLG drain SITE18 - 5m due south of central culvert	02-May-00									150.0	11					500.0						
75791	VLG drain SITE18 - 5m due south of central culvert	05-May-00									150.0	520		<0.05			460.0						
75792	VLG drain SITE18 - 5m due south of central culvert	05-May-00																					

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
75796	VLG drain SITE18 - 5m due south of central culvert	05-May-00	7.4	1100							150.0	1300		0.89			460.0						
75797	VLG drain SITE18 - 5m due south of central culvert	05-May-00																					
75798	VLG drain SITE18 - 5m due south of central culvert	05-May-00	7.4	1100							140.0	970		0.46			450.0			0.00	0.03	0.01	0.00
75798	VLG drain SITE18 - 5m due south of central culvert	05-May-00				18	16.2		1.90	36						0.04		291.8	2.50				
75799	VLG drain SITE18 - 5m due south of central culvert	05-May-00																					
75790	VLG drain SITE18 - 5m due south of central culvert	05-May-00	7.6	1100																			
75635	VLG drain SITE19 - 200m south of culvert	02-May-00									52.0	690					180.0						
75634	VLG drain SITE19 - 200m south of culvert	02-May-00	7.5	29																			
74972	VLG drain SITE2 - site of pipe joint leak	29-Mar-00	4.4	15414							2600.0	890000					13000.0						
75636	VLG drain SITE20 - 500m south of culvert	02-May-00	8.1	31																			
75637	VLG drain SITE20 - 500m south of culvert	02-May-00									37.0	19					130.0						
75787	VLG drain SITE20 - 500m south of culvert	05-May-00	8.0	970																			
75788	VLG drain SITE20 - 500m south of culvert	05-May-00				15	15.2		2.09	27						<0.01		239.5	<0.5				
75789	VLG drain SITE20 - 500m south of culvert	05-May-00																					
75788	VLG drain SITE20 - 500m south of culvert	05-May-00									130.0	620		<0.05			430.0			0.00	0.00	0.00	0.00
74973	VLG drain SITE3 - overflow from pond at base of waste rock stockpile	29-Mar-00	7.3	651							84.0	5900					320.0						
74974	VLG drain SITE4 - small	29-Mar-00	6.6	717							78.0	10000					340.0						

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
	upwelling 5m south of culvert																						
74975	VLG drain SITE5 - water in pipeline bund, 200m east of culvert	29-Mar-00	4.2	14910							2400.0	830000					13000.0						
74976	VLG drain SITE6 - 1m due north of central culvert	29-Mar-00	6.8	691																			
75784	VLG drain SITE6 - 1m due north of central culvert	05-May-00	7.7	1100																			
75785	VLG drain SITE6 - 1m due north of central culvert	05-May-00									150.0	360		<0.05			460.0			0.00	0.01	0.00	0.00
75785	VLG drain SITE6 - 1m due north of central culvert	05-May-00				30	13.8		2.62	<20						0.01		273.1	1.10				
75786	VLG drain SITE6 - 1m due north of central culvert	05-May-00																					
75793	VLG drain SITE6 - 1m due north of central culvert	05-May-00	7.6	1100																			
75794	VLG drain SITE6 - 1m due north of central culvert	05-May-00									150.0	31		<0.05			440.0						
75795	VLG drain SITE6 - 1m due north of central culvert	05-May-00																					
75800	VLG drain SITE6 - 1m due north of central culvert	05-May-00	7.6	1100																			
75801	VLG drain SITE6 - 1m due north of central culvert	05-May-00									150.0	400		<0.05			460.0						
75802	VLG drain SITE6 - 1m due north of central culvert	05-May-00																					
74977	VLG drain SITE7 - still water at base of western culvert	30-Mar-00									370.0	63000					1600.0			0.00	0.11	0.03	0.05
74977	VLG drain SITE7 - still water at base of western culvert	30-Mar-00				30	46.5		3.11	1600						0.19		157.5	8.50				
75632	VLG drain SITE7 - still water at base of western culvert	02-May-00	6.7	27																			
75633	VLG drain SITE7 - still water at base of western culvert	02-May-00									180.0	15000					800.0						
75806	VLG drain SITE7 - still water at base of western	05-May-00	7.0	1400							180.0	17000		12			720.0			0.00	0.09	0.02	0.02

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
	culvert																						
75806	VLG drain SITE7 - still water at base of western culvert	05-May-00				20	22.0		1.20	443						0.13		76.3	6.00				
74978	VLG drain SITE8 - drips from roof of culvert	30-Mar-00									1800.0	320000					11000.0			0.01	0.35	0.17	0.31
74978	VLG drain SITE8 - drips from roof of culvert	30-Mar-00				458	489.1		8.30	6533						0.80		13.2	37.00				
75803	VLG drain SITE8 - drips from roof of culvert	05-May-00				42	528.2		5.00	4095						<0.1		144.6	12.00				
75803	VLG drain SITE8 - drips from roof of culvert	05-May-00	7.3	5800							650.0	160000		8.3			2700.0			0.00	0.00	0.00	0.00
74995	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	31-Mar-00									140.0	4000					460.0			0.00	0.07	0.06	0.12
74995	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	31-Mar-00				73	13.4		4.08	117						0.26		288.6	5.20				
75050	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	03-Apr-00									130.0	6100					450.0						
75051	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	03-Apr-00	7.1	31																			
75626	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	02-May-00	6.6	26																			
75627	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	02-May-00									140.0	3200					470.0						
75770	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	05-May-00	7.5	1100																			
75771	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	05-May-00									150.0	450		<0.05			460.0			0.00	0.01	0.00	0.00
75771	VLG drain SITE9 - pool at base of waste rock stockpile 15m west culvert	05-May-00				30	13.6		2.85	<20						<0.01		259.3	12.70				
75772	VLG drain SITE9 - pool at base of waste rock	05-May-00																					

Sample	Site	Date sampled	pH	Cond	Hco3	Al	Ca	Cl	Cu	Fe	Mg	Mn	Na	NH4-N	NO3	Pb	SO4	U	Zn	Pb204	Pb206	Pb207	Pb208
				uS/cm	mg/L	ug/L	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
	stockpile 15m west culvert																						
74931	VLGCRC - V notch weir	29-Mar-00	7.3	663							79.3	5941					299.6	103.9					
74996	VLGCRC - V notch weir	31-Mar-00																		0.00	0.07	0.03	0.05
75091	VLGCRC - V notch weir	05-Apr-00	7.9	1089							148.9	2691					462.5	332.7					
75227	VLGCRC - V notch weir	12-Apr-00	8.3	1089							141.0	3540					495.6	288.9					
75479	VLGCRC - V notch weir	19-Apr-00	7.5	905							119.3	3622					410.9	223.8					
75570	VLGCRC - V notch weir	26-Apr-00	7.6	1091							146.2	1085					452.8	207.2					
75681	VLGCRC - V notch weir	03-May-00	8.1	1039														253.4					
75777	VLGCRC - V notch weir	05-May-00									150.0	840		0.36			470.0			0.00	0.02	0.00	0.00
75777	VLGCRC - V notch weir	05-May-00				25	15.5		2.54	29						0.02		285.1	0.70				
75778	VLGCRC - V notch weir	05-May-00																					
75776	VLGCRC - V notch weir	05-May-00	7.6	1100																			

Table 5. Concentrations of NH_4-N and Mn at VLGCRC (1999/2000 wet season)

Date	NH_4-N mg/L	Mn µg/L
12-Jan-00	0.035	97.6
19-Jan-00	0.02	202
27-Jan-00	0.062	751
09-Feb-00	0.009	504
23-Feb-00	0.3	2110
08-Mar-00	1.5	9530
29-Mar-00	1.3	5940
19-Apr-00	1.5	3620
05-May-00	0.36	840

Table 6. Calculated dilution factor and predicted Mn concentration[a]

Date	NH_4-N mg/L	Dilution factor	Predicted Mn µg/L	Measured Mn µg/L
12-Jan-00	0.035	15143	53	97.6
19-Jan-00	0.02	26500	30	202
27-Jan-00	0.062	8548	94	751
09-Feb-00	0.009	58889	14	504
23-Feb-00	0.3	1767	453	2110
08-Mar-00	1.5	353	2264	9530
29-Mar-00	1.3	408	1962	5940
19-Apr-00	1.5	353	2264	3620
05-May-00	0.36	1472	543	840

[a] calculated using concentrations of 530 mg/L NH_4-N and 800 mg/L Mn in process water

Table 7. Sulfur isotope data for water samples

SITE ID	Description	DATE SAMPLED	$\delta^{34}S$ CDT	SO4 mg/L
TDSITE13	DW3A bore water	05-May-00	6.1	440
TDSITE6	Upstream of road culvert	05-May-00	6.3	460
TDSITE9	Pool at base of waste rock in stockpile drain	03-Apr-00	7.6	450
TDSITE9		05-May-00	6.2	460
TDSITE8	Water on culvert roof	05-May-00	9.3	2700
TDWW	Tails Dam	05-May-00	9.8	13000
VLGCRC	V-notch weir downstream of road culvert	09-Dec-98	8.9	580
VLGCRC		23-Dec-98	8.9	300
VLGCRC		20-Jan-99	8.6	600
VLGCRC		24-Feb-99	8.7	460
VLGCRC		02-Feb-00	9.2	300
VLGCRC		08-Mar-00	7.6	540
VLGCRC		05-May-00	6.5	470

Table 8. Composition of water in VLG stockpile drain downstream of culvert during 1997/98 wet season

Sample	Site	Date sampled	Comments	pH	Cond uD/cm	Turb NTU	Mg mg/L	NO3 mg/L	SO4 mg/L	U-1 ug/L
55692	VLGCRC	16-Dec-97	F	6.5	289	178	23		98	13.1
55733	VLGCRC	17-Dec-97		7.2	262		22		90	0.1
55941	VLGCRC	24-Dec-97	F	6.7	349		38		143	15.1
56164	VLGCRC	07-Jan-98	F	6.8	358		37		110	12.9
56318	VLGCRC	14-Jan-98	F	6.5	371		39		115	10.8
56595	VLGCRC	21-Jan-98	F + Nutrients	6.5	448		47	43	144	12.9
56718	VLGCRC	28-Jan-98	F	6.2	346		35		95	34.5
57038	VLGCRC	04-Feb-98	F	6.2	519		59		189	11.5
57105	VLGCRC	11-Feb-98	F	6.3	562		63		197	11.1
57249	VLGCRC	18-Feb-98	F	6.2	488		53		169	16.9
57424	VLGCRC	25-Feb-98	F	6.3	469		55		165	10.3
57724	VLGCRC	04-Mar-98	F	6.3	390		37		153	19.4
57888	VLGCRC	11-Mar-98	F	6.2	415		41		171	10.5
58142	VLGCRC	18-Mar-98	F	6.1	413		43		167	10.6
58208	VLGCRC	25-Mar-98	F No overflow ex culvert	6.2	355		37		117	13.4
58353	VLGCRC	06-Apr-98	F Flowing after rain event	6.4	329		32		115	12.9
58564	VLGCRC	22-Apr-98	F	5.4	458		48		174	10.7

Table 9a. Water quality data for site GCSR, 1998/99 R&D project

SITE	Date	Sample	pH	Condy	Cl	N-NO3	K	Ca	Mg	Mn	Na	SO4	U	Ra-226
				uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	ug/L	mBq/L
GCSR	27-Nov-98				-	10.5	6.5	17.10	71.7	124.7	4.9	271.3	11.6	141
GCSR	30-Nov-98	62726	7.73	613	-	9.6	7.4	18.80	64.4	66.3	5.2	252.9	14.5	89
GCSR	03-Dec-98	62806	7.22		-	16.2	7.2	30.00	136.4	549	6.6	541.9	8.0	101
GCSR	07-Dec-98	62830	7.14	1113	-	13.1	8.7	29.40	127.6	634	7.5	513.3	10.5	
GCSR	10-Dec-98	62982	6.59	936	-	10.0	4.9	19.30	106.7	7099	4.1	433.0	46.1	185
GCSR	14-Dec-98	63068	6.32	1468	-	17.2	7.4	31.80	190.9	23211	6.2	808.3	122.9	640
GCSR	17-Dec-98	63278	6.33	687	-	16.6	4.4	13.40	73.3	7542	3.3	312.9	38.3	432
GCSR	21-Dec-98	63388	7.01	1299	-	17.4	7.4	27.70	163.6	21238	6.1	687.4	82.5	460
GCSR	22-Dec-98	63626	6.14	1161	-		6.3	23.00	139.1	18723	5.2	592.6	108.3	440
GCSR	30-Dec-98	64068	5.82	1295	<5	14.4	7.3	27.30	155.8	21866	6.4	674.3	114.1	550
GCSR	04-Jan-99	64140	6.50		-	13.2	7.7		160.2	23058	6.1	704.0	122.8	551
GCSR	07-Jan-99	64131	6.29	1280	<5	14.5	7.9		163.3	22731	6.3	641.9	124.7	544
GCSR	11-Jan-99	64233	5.97	898	<5	9.0	6.4	17.90	105.0	13499	4.6	431.3	80.8	530
GCSR	13-Jan-99	64287	6.01	1174	-	12.5	7.1	23.70	135.3	18238	5.4	564.4	106.1	
GCSR	18-Jan-99	64520	6.25	1204	5.0	12.2	7.9	25.30	147.2	20153	6.1	611.5	110.9	
GCSR	21-Jan-99	64678	5.86	1053	-	11.3	6.7	22.40	126.6	15913	4.9	523.8	97.9	
GCSR	25-Jan-99	64734	6.01	1022	2.6	7.87	6.9	20.70	122.4	16337	5.3	497.4	82.4	
GCSR	28-Jan-99	64910	6.81	415	1.1	3.51	3.6	8.50	43.0	3104	2.5	161.1	38.2	
GCSR	01-Feb-99	65066	7.22	595	1.8	5.32	4.6		66.3	6074	3.8	262.0	43.6	
GCSR	04-Feb-99	65488	6.49	538	1.4	4.40	4.2		57.4	5689	3.1	228.1	38.2	
GCSR	08-Feb-99	65493	6.44	514	1.6	4.12	4.6	10.20	54.0	5556	3.2	215.9	39.8	
GCSR	11-Feb-99	65840	6.55	635	2.1	5.04	5.4		68.5	7274	3.7	277.2	44.6	
GCSR	22-Feb-99	66146	6.56	799	3.3	3.55	6.6	15.60	86.0	11097	4.5	381.1	47.2	344
GCSR	26-Feb-99	66462	6.60	777	2.3	5.75	6.7	15.00	84.5	11277	4.4	375.1	47.5	354
GCSR	08-Mar-99	66779	6.42	679	2.5	3.19	5.4	12.80	72.1	9125	3.7	311.7	47.6	
GCSR	11-Mar-99	66901	6.54	676	2.4	2.65	5.9	12.60	72.1	9232	4.0	315.0	40.5	
GCSR	22-Mar-99	67364	6.30	505	-	-	4.7	8.90	50.3	5741	2.8	214.7	47.1	
GCSR	25-Mar-99	67576			1.9	1.47	4.3	6.50	39.7	4716	2.3	166.8	44.2	314
GCSR	29-Mar-99	67774	6.37	538	1.50	4.21	4.8	9.60	54.2	6218	3.1	216.5	37.0	
GCSR	01-Apr-99	67777	6.56	349	1.00	1.90	3.4	7.40	34.9	1934	2.4	128.5	20.9	
GCSR	06-Apr-99	67806	6.52	444	1.70	3.03	4.8	8.10	44.7	4618	2.8	178.4	40.7	
GCSR	07-Apr-99	67870	6.52	481			4.9	8.90	49.3	5382	3.0	200.1	37.4	
GCSR	16-Apr-99	68226	6.96	486	2.00	2.38	5.9	10.40	48.8	4452	3.4	196.1	33.1	
GCSR	23-Apr-99	68444			2.40	1.07	7.1	11.40	30.5	1300	3.2	102.1	50.0	
GCSR	29-Apr-99	68446	7.60	321	2.20	0.83	7.9	13.60	26.2	808	3.6	79.2	76.4	
GCSR	06-May-99	68587			2.60	0.76	7.2	26.00	32.9	447	4.9	124.3	186.6	370

Table 9b. Water quality data for site GCBR, 1998/99 R&D project

SITE	Date	Sample	pH	Condy	Cl	N-NO3	K	Ca	Mg	Mn	Na	SO4	U	Ra-226
				uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	ug/L	mBq/L
GCBR	27-Nov-98	62690.00	7.51	43.8	-	-	2.4	1.10	2.9	4.06	1.3	4.6	1.938	
GCBR	30-Nov-98	62724.00	7.36	45.2	-	-	2.7	1.00	2.9	5.17	1.6	4.9	3.828	
GCBR	03-Dec-98	62808.00	7.12		<5	<0.05	2.0	0.90	2.6	8.55	1.5	4.0	2.854	
GCBR	03-Dec-98	62810.00			-	-	2.0	0.90	2.6	7.75	1.5	4.0	3.172	
GCBR	07-Dec-98	62822.00	6.81	32.3	-	-	1.4	0.80	2.3	9.57	1.7	2.8	2.177	
GCBR	10-Dec-98	62978.00	7.01	27.4	-	-	1.0	0.60	1.7	1.94	1.5	2.7	1.772	
GCBR	14-Dec-98	63066.00	7.08	33.3	-	-	1.2	0.80	2.1	1.00	1.5	5.1	2.434	
GCBR	17-Dec-98	63276.00	6.39	27	-	-	1.2	0.80	1.7	4.34	1.1	3.6	1.991	
GCBR	21-Dec-98	63389.00	7.51		-	-	1.1	1.00	2.5	3.57	1.4	7.4	3.439	
GCBR	22-Dec-98	63632.00	6.83	37	-	-	1.0	1.00	2.6	6.37	1.3	7.4	1.048	
GCBR	30-Dec-98	63482.00	6.75	34.4	19	<0.05	0.9		2.2	3.48	1.2	6.2	4.178	
GCBR	30-Dec-98	63722.00	6.32	33.8	-	-	0.9		2.2	3.91	1.2	6.2	5.244	
GCBR	04-Jan-99	64099.00	6.74	3.49	-	-	0.8		1.8	1.18	1.3	4.4	1.814	
GCBR	07-Jan-99	64133.00	6.58	31.4	<5	<0.05	1.0		2.4	4.35	1.5	5.7	2.699	
GCBR	11-Jan-99	64231.00	6.71		<5	<0.05	0.7	0.70	1.8	3.52	1.1	5.8	6.000	
GCBR	13-Jan-99	64273.00	6.74	29.8	5	<0.05	0.7		1.7	1.33	1.1	4.5	2.434	
GCBR	13-Jan-99	64293.00	6.83	25.7				0.70						
GCBR	18-Jan-99	64519.00	7.28	29.8	<5	<0.05	0.7	0.60	2.0	1.54	1.5	5.9	2.031	
GCBR	21-Jan-99	64677.00	6.41	28	<5	<0.05	0.6	0.60	1.8	4.17	1.5	4.7	2.236	
GCBR	25-Jan-99	64733.00	6.31	32.1	1.0	-	0.6	0.70	2.2	7.42	1.5	6.5	1.352	
GCBR	28-Jan-99	64908.00	6.85	17.01	0.9	-	0.5	0.40	1.0	2.46	1.0	1.7	0.708	
GCBR	01-Feb-99	65064.00	6.75	27.4	0.6	-	0.6		2.0	1.14	0.8	6.0	2.182	
GCBR	04-Feb-99	65489.00	6.35	19.24	1.0	-	0.7		1.2	3.55	0.9	2.3	1.589	
GCBR	08-Feb-99	65494.00	6.40	22.2	0.9	-	0.6	0.50	1.5	5.23	1.0	3.4	1.575	
GCBR	11-Feb-99	65692.00	6.51	19.48	1.2	-	0.6	0.50	1.2	0.83	1.0	2.4	1.804	
GCBR	26-Feb-99	66464.00	6.62	20.5	-	-	0.4	0.40	1.3	3.24	1.4	3.9	1.345	
GCBR	11-Mar-99	66903.00	6.82	28	1.3	-	0.5	0.50	2.0	1.60	1.5	6.3	0.938	
GCBR	25-Mar-99	67582.00	6.76	24.1	-	-	0.6	0.50	1.8	3.02	1.1	4.4	5.311	
GCBR	01-Apr-99	67779.00	6.54	23			0.9	0.50	1.5	0.75	0.9	3.9	0.922	
GCBR	07-Apr-99	67868.00	6.45	26.1			0.7	0.50	1.8	0.63	1.3	4.0	1.574	
GCBR	23-Apr-99	68440.00	6.84	19.48			0.5	0.30	1.1	1.00	1.6	1.8	0.346	
GCBR	06-May-99	68516.00	6.90	46.7			0.6		1.1	0.74	1.9	2.4	1.193	

Table 9c. Water quality data for site GCMBL, 1998/99 R&D project

SITE	Date	Sample		pH	Condy	Cl	N-NO3	K	Ca	Mg	Mn	Na	SO4	U	Ra-226
					uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	ug/L	mBq/L
GCMBL	30-Nov-98	-	-	0.4	5.8	6.63	2.3	2.2	1.441						
GCMBL	03-Dec-98	-	-	0.6	7.9	5.37	2.1	3.2	1.221						
GCMBL	07-Dec-98	-	-	0.3	6.9	2.89	2.1	2.7	0.831						
GCMBL	10-Dec-98	-	-	0.5	7.8	2.40	1.9	3.1	1.036						
GCMBL	14-Dec-98	-	-	0.5	8.5	3.63	1.5	2.5	1.601						
GCMBL	17-Dec-98	-	-	0.7	4.2	2.30	1.4	4.4	0.846						
GCMBL	22-Dec-98	-	-	0.6	3.8	9.84	1.7	3.8	0.877						
GCMBL	30-Dec-98	<5	<0.05	0.4	4.8	2.20	1.7	6.8	1.690						
GCMBL	04-Jan-99	-	-	0.6	5.5	1.90	1.7	6.0	1.148						
GCMBL	07-Jan-99	11	<0.05	0.4	4.5	1.93	1.7	4.7	0.691						
GCMBL	11-Jan-99	-	-	0.5	3.0	3.00	1.4	4.6	1.130						
GCMBL	13-Jan-99	<5	<0.05	0.4	3.4	1.80	1.4	5.4	0.665						
GCMBL	**13-Jan-99**	**-**	**-**	**0.4**	**3.5**	**2.08**	**1.4**	**5.5**	**0.666**						
GCMBL	18-Jan-99	<5	<0.05	0.3	3.4	0.81	1.6	6.0	0.533						
GCMBL	21-Jan-99	<5	<0.05	0.4	4.0	7.42	1.7	5.8	0.524						
GCMBL	25-Jan-99	1.2	-	0.3	4.0	1.50	1.6	6.9	0.649						
GCMBL	28-Jan-99	0.9	-	0.6	2.0	2.22	1.2	3.9	1.060						
GCMBL	01-Feb-99	0.7	-	0.4	2.5	1.55	0.9	5.7	2.480						
GCMBL	04-Feb-99	1.0	-	0.5	2.9	4.17	1.1	6.1	1.536						
GCMBL	08-Feb-99	0.9	-	0.4	3.8	3.92	1.2	9.1	0.705						
GCMBL	11-Feb-99	1.2	-	0.5	3.1	1.03	1.2	6.9	1.975						
GCMBL	26-Feb-99	-	-	0.3	3.0	3.91	1.5	4.2	1.379						
GCMBL	11-Mar-99	1.1	-	0.3	3.4	2.09	1.5	6.1	0.701						
GCMBL	11-Mar-99	1.2	-	0.2	3.4	2.35	1.5	5.3	0.713						
GCMBL	25-Mar-99	1.1	-	0.4	3.5	3.56	1.2	8.5	0.762						
GCMBL	01-Apr-99			0.7	3.0	2.17	0.9	6.8	0.760						
GCMBL	07-Apr-99			0.4	3.6	1.94	1.4	6.5	0.413						
GCMBL	23-Apr-99			0.5	3.7	0.99	1.5	2.1	0.448						
GCMBL	06-May-99			0.3	3.7	1.34	1.6	1.2	0.363						

Table 9d. Water quality data for site GC2, 1998/99 R&D project

SITE	Date	Sample	pH	Condy	Cl	N-NO3	K	Ca	Mg	Mn	Na	SO4	U	Ra-226
				uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	ug/L	mBq/L
GC2	27-Nov-98	62694.00	8.26	131.7	-	-	0.4	1.90	14.1	5.01	2.3	27.8	5.220	
GC2	30-Nov-98	62722.00	8.32	118	-	-	0.4	1.70	12.1	6.42	2.5	23.8	4.113	
GC2	03-Dec-98	62804.00	8.07		-	-	0.5	2.00	14.0	6.44	2.2	23.8	4.137	
GC2	07-Dec-98	62824.00	7.51	113.8	-	-	0.4	1.90	12.1	8.60	2.4	18.5	4.930	
GC2	10-Dec-98	62887.00	6.97	102.8	-	-	0.6		13.0	7.60	2.0	24.3	3.686	
GC2	14-Dec-98	63067.00	7.70	108	-	-	0.6	1.70	11.0	4.29	1.9	21.4	3.095	
GC2	17-Dec-98	63147.00	7.11	119.2	-	-	0.6		8.6	4.82	1.6	20.0	3.552	
GC2	21-Dec-98	63282.00	7.59	90.1	-	-	0.3	1.50	10.5	4.68	1.9	20.2	3.372	
GC2	22-Dec-98	63628.00	7.39	75.5	-	-	0.5	1.20	7.3	6.77	1.7	13.5	3.247	
GC2	22-Dec-98	63478.00	6.82	81.6	-	-	0.4		7.3	4.87	1.7	13.4	2.229	
GC2	30-Dec-98	63718.00	7.08	90.6	<5	<0.05	0.4		9.2	8.00	1.6	21.5	3.157	
GC2	04-Jan-99	64071.00	7.55	71.1	-	-	0.3	1.30	7.2	0.52	1.6	12.5	2.380	
GC2	07-Jan-99	64129.00	7.33	83.1	<5	<0.05	0.2		8.4	5.11	1.7	15.8	2.578	
GC2	11-Jan-99	64234.00		81.1	<5	<0.05	0.4	0.60	7.8	8.94	1.5	15.5	4.400	
GC2	13-Jan-99	64269.00	7.25	91.2	6.0	<0.05	0.3		8.3	3.50	1.5	18.5	2.615	
GC2	18-Jan-99	64295.00	7.37	85.6	<5	<0.05	0.3	1.40	8.0	6.41	1.7	17.9	3.887	
GC2	17-Jan-99	64522.00	7.38	82.2				1.40						
GC2	21-Jan-99	64675.00	7.06	65.2	<5	<0.05	0.3	1.10	6.2	4.40	1.6	10.2	4.351	
GC2	25-Jan-99	64731.00	7.01	73.8	0.7	-	0.3	1.30	7.4	5.27	1.6	12.6	2.599	
GC2	28-Jan-99	64904.00	7.17	71.6	0.8	-	0.4	1.20	6.6	3.19	1.2	16.7	3.215	
GC2	01-Feb-99	65062.00	7.32	70.5	0.8	-	0.3		6.7	3.89	1.2	15.5	4.129	
GC2	04-Feb-99	65490.00	6.86	59.6	1.0	-	0.3		5.5	4.26	1.1	12.4	2.517	
GC2	08-Feb-99	65495.00	7.25	69.5	1.2	-	0.4	1.20	6.7	4.42	1.2	14.5	2.636	
GC2	26-Feb-99	66460.00	6.90	57.3	-	-	0.2	1.00	5.5	7.70	1.6	6.1	1.714	
GC2	11-Mar-99	66893.00	7.50	67.7	1.1		0.2	1.10	6.6	13.35	1.6	9.1	2.275	
GC2	25-Mar-99	67580.00	7.09	91.9	1.7	-	0.7	1.70	9.0	13.30	1.3	23.1	3.731	
GC2	01-Apr-99	67775.00	7.00	66.7			0.6	1.10	6.4	3.52	1.2	12.3	2.692	
GC2	07-Apr-99	67866.00	7.05	67.4			0.5	1.10	6.6	9.27	1.4	9.4	1.395	
GC2	16-Apr-99	68228.00	7.00	58.3			0.4		5.8	9.71	1.6	3.1	2.255	
GC2	23-Apr-99	68441.00	7.40	58.4			0.3	1.10	5.8	9.78	1.6	3.0	2.115	
GC2	06-May-99	68508.00	7.13	69.1			0.4		6.6	1.89	1.7	3.0	2.528	

Table 9e. Water quality data for control site GCC, 1998/99 R&D project

SITE	Date	Sample ID	pH	Condy	Cl	N-NO3	K	Ca	Mg	Mn	Na	SO4	U	Ra-226
				uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	ug/L	mBq/L
GCC	27-Nov-98	62686.00	7.04	23.9	-	-	0.5	0.70	1.1	4.44	2.1	<0.1	0.887	
GCC	30-Nov-98	62718.00	7.01	25.2	-	-	0.7	0.80	1.1	6.62	2.2	<0.1	0.086	
GCC	03-Dec-98	62800.00	6.97		-	-	0.9	0.80	1.3	1.72	2.1	<0.1	0.156	
GCC	07-Dec-98	62820.00	7.03	27.1	-	-	0.9	0.80	1.4	15.55	2.1	<0.1	0.126	
GCC	10-Dec-98	62980.00	6.98	26.7	-	-	0.9	0.70	1.3	6.41	1.9	<0.1	0.096	
GCC	14-Dec-98	63065.00	7.11	5.9	-	-	0.9	0.70	1.3	5.79	2.0	<0.1	0.132	
GCC	17-Dec-98	63274.00	6.73	23.6	-	-	0.8	0.60	1.2	4.40	1.8	<0.1	0.196	
GCC	21-Dec-98	63390.00		22.5	-	-	0.5	0.60	1.1	3.15	1.9	<0.1	0.129	
GCC	22-Dec-98	63634.00	6.74	23	-	-	0.7	0.60	1.2	6.67	1.8	<0.1	0.336	
GCC	30-Dec-98				<5	<0.05	0.5		1.1	1.53	1.7	<0.1	0.098	
GCC	04-Jan-99	64070.00	6.85	20.4	-	-	0.7	0.50	1.1	0.61	1.7	<0.1	0.176	
GCC	07-Jan-99	64135.00	6.93	19.45	5	<0.05	0.6		1.1	2.40	1.7	<0.1	0.192	
GCC	13-Jan-99	64297.00	6.64	17.48	<5	<0.05	0.6	0.40	0.9	1.99	1.4	<0.1	0.276	
GCC	21-Jan-99	64676.00	6.92	19.89	<5	<0.05	0.4	0.40	1.1	3.87	1.6	<0.1	0.128	
GCC	28-Jan-99	64912.00	6.93	18.96	1.7	-	0.5	0.40	1.0	2.11	1.6	<0.1	0.133	
GCC	04-Feb-99	65486.00	6.82	18.86	1.8	-	0.5		1.0	1.86	1.5	<0.1	0.106	
GCC	11-Feb-99	65841.00	6.58	17.48	1.5	-	0.6		1.0	3.38	1.4	<0.1	0.922	
GCC	26-Feb-99				-	-	0.4		1.4	5.42	1.8	0.4	0.473	
GCC	26-Feb-99	66454.00	6.65	23.1	-	-	0.4	0.50	1.4	5.18	1.8	0.5	0.449	
GCC	11-Mar-99	66899.00	6.72	24.7	2.2	-	0.3	0.60	1.5	10.52	1.9	0.3	1.082	
GCC	26-Mar-99	67521.00	6.77	23.3	2.0	-	0.3	0.60	1.6	5.82	1.9	1.0	0.138	
GCC	01-Apr-99	67776.00	6.73	22.3			0.5	0.60	1.4	2.13	1.6	<0.1	0.055	
GCC	07-Apr-99	67872.00	6.73	25.4			0.5	0.60	1.7	2.15	1.8	<0.1	0.059	
GCC	23-Apr-99	68445.00	7.05	34			0.5	0.80	2.1	3.81	2.5	<0.1	0.055	
GCC	06-May-99						0.3		1.9	3.33	2.9	<0.1	0.055	
													? Possible U contamination	

Table 10. Concentrations of NH_4-N at GCSR (1998/99 wet season)

Date	NH_4-N mg/L
18-Nov-98	0.0044
02-Dec-98	0.077
09-Dec-98	0.084
16-Dec-98	2.6
06-Jan-99	4.7
20-Jan-99	4.4
03-Feb-99	2.7
10-Feb-99	2.1
17-Feb-99	2.7

Table 11. Concentrations of Mn measured in the VLG stockpile drain upstream of the road culvert (1999/00 wet season)

Date	pH	Mg µg/L
2/12/99	6.18	410
29/3/00	6.5	5900
30/3/00	--	4000
3/4/00	7.05	6100
2/5/00	--	3700

Table 12. Leaching of Mn from Ranger#1 low grade ore and waste rock (5:1 L/S ratio batch leach)

Sample	Distilled Water		pH 4.5 acetate buffer	
	pH	Mn µg/L	pH	Mn µg/L
Lateritic waste				
R1 L1	7.4	1.5	4.6	6104
R1 L2	7.5	1.0	4.6	14336
R1 L3	8.0	1.5	4.6	11320
Transitional (partly weathered) waste				
R1 T1	8.0	1.3	4.6	7992
R1 T2	7.9	12.2	4.6	4764
R1 T3	7.9	22.5	4.6	8968
Primary (unweathered) rock waste				
R1 P1	8.4	0.3	4.6	4112
R1 P2	8.6	0.6	4.6	3644
R1 P3	8.5	1.3	4.6	5472

Table 13. Data summary for parameters measured downstream of the mine at GS009 (MG009) and upstream of the mine at MCUS

Parameter	**Site**	**Historical Data 1980 – 1998***		**1999/2000 Reporting Period**	
		10 – 90 Percentile	Median / Mean	10 – 90 Percentile	Median / Mean
Conductivity (µS/cm)	MG009	12.0 – 30.3	17.9 / 19.9	6.9 – 16.7	11.9 / 13.4
	MCUS	8.8 – 22.2	13.3 / 14.8	6.0 – 13.2	9.8 / 10.2
Manganese (Filterable) (µg/L)	MG009	3.1 – 14.5	6.0 / 8.1	0.5 – 13.4	4.5 / 6.6
	MCUS	2.4 – 10.0	4.7 / 5.8	0.5 – 10.6	4.1 / 6.4
Uranium (Filterable) (µg/L)	MG009	<0.1 – 0.4	0.2 / 0.3	<0.1 – 0.2	<0.1 / 0.1
	MCUS	<0.1 – 1.1	<0.1 / 0.8	<0.1 – 0.1	<0.1 / <0.1
Magnesium (mg/L)	MG009	0.5 – 1.8	0.8 / 1.0	0.4 – 1.1	0.7 / 0.8
	MCUS	0.2 – 1.1	0.5 / 0.6	0.4 – 0.8	0.5 / 0.5
Sulfate (mg/L)	MG009	0.1 – 4.8	0.8 / 1.8	0.3 – 1.9	0.7 / 1.1
	MCUS	<0.1 – 1.2	0.3 / 0.6	0.2 – 0.7	0.3 / 0.4

* = Data for Magela Creek Upstream (MCUS) for the period 1991 - 1998

11 APPENDIX

11.1 Timeline of Events relating to the process water leak incident

Date	Details
03 Nov 1999	Monthly monitoring of culvert water for manganese commenced. This was introduced as part of a standard monitoring suite. Previously, manganese was not routinely analysed at this site by the Environment Laboratory. Previous analyses at the culvert concentrated on magnesium, sulfate and uranium concentrations in connection with capped/re-vegetated area run-off.
22 Dec 1999	Weekly monitoring for manganese undertaken at the culvert in line with the commencement of the DW3A water trial.
02 Jan 2000 **03 Jan 2000**	Heavy rainfall on-site resulted in culvert being largely blocked.
17 Jan 2000	First attempt to clear culvert unsuccessful
24 Jan 2000 - **26 Jan 2000**	Central culvert cleared by external contractors
02 Feb 2000	First water sample containing higher than expected manganese levels was collected. Manganese reading of 6100 µg/L was obtained.
09 Feb 2000	Manganese reading of 500 µg/L for water collected at the culvert
16 Feb 2000 - **01 Mar 2000**	Manganese concentration observed to increase from 1800 µg/L (16/2) to 3700 µg/L (1/3)
08 Mar 2000	High reading of 9500 µg/L obtained.
13 Mar 2000	Initial discussion between Andre De Waal (Technical Officer) and David Toohey (Senior Environmental Chemist) at which the unusual occurrence was discussed. Initiation of investigation project.
16 Mar 2000	Further discussions between David Toohey and Andre De Waal regarding the manganese levels recorded at the culvert. Project incorporated into goals of performance management system (Corridor Road Project) Mill Foreman's log recorded pumping from the corridor road sump to RP2 occurred prior to leak detection on 16 Mar 2000. Since leak detection, pump to RP2 was turned on 15 Apr 2000 and turned off 16 Apr 2000. (via Lotus notes – Glen Sauer)
17 Mar 2000 – **28 Mar 2000**	Data collation and review. Weekly monitoring continued. Persistence of elevated results, although manganese concentrations observed to decrease – 2600 µg/L (15/3) and 1800 µg/L (22/3)
28 Mar 2000	Andre De Waal reviews area on foot. Initial leak site discovered. (morning) Trevor Spedding (Hydrographer) and Geoff Mackenzie (Technical Officer) from Water Resources and Glen Sauer from the Mill inspected the area and collected a water sample. (afternoon)
29 Mar 2000	Analysis of sample collected 28 Mar 2000 completed. Flow of water from the leak measured at 0.3 L/sec. The area from the Tails Dam wall to the VLGCRC was walked and inspected by David Toohey and Don Pidsley. A water logged area containing high conductivity water was located and marked. Water samples were collected at several sites including the culvert. The boggy area surrounding the poly pipe identified as a high conductivity source was initially thought to be associated with the syphon pipeline. Wayne Hunter of the Mill was advised to remove the syphon break valve entirely.

Date	Details
	Ranger Management Team informed of a process water spill at meeting attended by David Toohey @ 1100 hrs. Team informed of suspected leak of the syphon line.
30 Mar 2000	Samples collected 29 Mar 2000 analysed.
30 Mar 2000 – 02 Apr 2000	Area was inspected over the weekend up to and including 02 Apr 2000. Assessed the strength of the flow from the area and defined that it was not a leak from the syphon pipe. As the leak had continued without any noticeable reduction in flow over the weekend as observed by Water Resources and Chemistry staff, it was suggested by Don Pidsley (via Lotus notes 3 Apr 2000 @ 9000 hrs) that the leak was due to the steel mill decant line.
31 Mar 2000	It was confirmed that the syphon break had been removed entirely by Don Pidsley. Wayne Hunter of the Mill was requested to look at the "leak" over the weekend to check if the leak flow reduced, thereby confirming or otherwise if the "leak" was in the syphon line (Lotus notes 31 Mar 2000 @ 1600 hrs)
03 Apr 2000	Don Pidsley contacted Wayne Hunter (Mill Services Supervisor) and agreed to urgent repair. Work orders were scheduled and identified the pipe source. Arrangements made for Mill to shut down the main source for repairs. (Lotus notes 3 Apr 2000 @ 1120 hrs – Don Pidsley requested seeking the exposure of the pipe and requested a site inspection of the area with Wayne. Diary note of the meeting 1400 – 1430 hrs on 3 Apr 2000, but no further notes of meeting outcome.)
04 Apr 2000	"Work started on water leak. Excavations started and found that bolts were corroded and had pulled through bolt holes on flange. Bolts were replaced and system brought back on line. Back filling was to take place on 05 Apr 2000, but was postponed, this job was put off (the backfilling) and completed approx 1 week Later" Albert Price (Mechanical Workshop Supervisor)
05 Apr 2000	Leak had stopped and reporting considerations commenced. This was not considered to be a breach of the authorization at this point.

11.2 *Rainfall record (mm) for the period September 1999 – May 2000*

Days	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	0.00	0.00	8.00	0.00	0.00	0.00	8.60	0.00	
2	0.00		2.00	30.40	0.00	5.20	43.60	19.00	0.00
3	0.00		31.20	4.40	112.60	0.00	41.60	0.00	6.20
4		0.00	4.80		0.10	4.80	18.40	0.00	0.00
5		0.00	5.80		0.00	0.20	1.00	0.00	0.00
6	0.00	0.00		14.20	0.00	36.20	0.00	3.00	
7	0.00	0.00		0.00	0.80	33.80	7.80		
8	0.00	0.00	22.00	0.00	0.00	9.40	0.60	21.20	0.00
9	0.00		30.40	0.00	10.40	3.60	0.00	2.60	0.00
10	0.00		30.20	0.40	29.60	34.20	30.80	13.20	9.60
11		0.00	6.40		68.20	11.80	6.80	11.20	0.00
12		0.00	0.00		0.10	3.80		1.00	0.40
13	0.00	0.00		2.40	1.40	22.20	12.40	6.00	
14	0.00	1.20		0.00	0.00	26.00	3.40	23.80	
15	0.00	0.00	0.00	1.80	12.80	41.60	31.80	32.60	
16	0.00			0.00	16.80	54.40	29.00		
17	0.00		8.00	0.00	55.20	29.00	3.40	1.00	
18		1.00	0.00		8.20	20.80	10.80	0.80	
19		0.00	0.00		5.20	4.60		0.00	
20	0.00			11.80	1.20	0.00	13.20	5.00	
21		8.00		32.80	4.60	0.00	3.40	0.00	
22						36.60			
22	0.00	0.00	23.80	23.00	18.00		11.60		
23	0.00	88.60	2.20	2.40		0.00	0.00		
24	0.00		2.40	0.00	18.80	21.20	0.00	0.20	
25		0.40	2.60	14.20	6.00	5.00	0.00	28.00	
26		0.00	11.40	0.20	2.00			0.00	
27	0.00			11.40	0.00	19.40	9.40	0.00	
28	0.00	0.00		11.20	0.00	33.20	0.00	0.00	
29	0.00	0.00	0.00	34.40		7.60	11.80		
30	0.00		44.80	3.60	10.40		1.00	0.00	
31		66.80		0.10	0.00		0.00		

11.3 Summary of leaks and spills in tailings corridor drain from available mine records

Mill Department Work Order records (Berglund, May 2000)

Location on map (Figure 2)	Work Order reference	Pipeline	Date	Location	Material/Cause
	4754	A/B-tails	06/02/1988	?	Leak at coupling
	10542	C/D-tails	29/04/1988	?	Poly pipe
	21402	A/B-tails	05/11/1988	Tails dam	Leaking flange
	23239	A/B/C/D-TAILS	03/12/1988	?	Leaking flange
	27729	A/B-tails	23/02/1989	Tails dam	Mine Hose
	36312	A/B-tails	12/07/1989	?	Leak at coupling
	47103	C/D-tails	11/12/1989	?	Patch hole
6	B3692-1	C/D-tails	13/06/1994	Bridge to pit	Coupling apart
7	B8044	Tails Return Water	31/10/1994	Tails Dam Ramp	?
	B2584	B-tails	17/11/1994	?	PE-lined pipe
	C4234-1	C/D-tails	17/05/1995	Dam wall	Pipe section
	E5107-1	A/B-tails	14/01/1997	Pit 1/Haul road	Steel pipe
	E6144-1	A/B-tails	11/02/1997	Pit 1/Haul road	Steel pipe
	E7135-1	A/B-tails	10/03/1997	Pit 1/Haul road	Steel pipe
	E7169-1	A/B-tails	11/03/1997	Pit 1/Haul road	Elbow
	E8402	A/B-tails	16/04/1997	?	Broken pipe
8	E9219-1	C/D-tails	08/05/1997	Dam wall	Mine Hose
	E9602-1	A/B-tails	21/05/1997	Pit 1	Elbow
	F1009-1	C/D-tails	26/06/1997	?	Leaking coupling
	F-2980-1	C/D-tails	20/08/1997	Corridor	Victualic coupling
	F4004-1	A/B-tails	17/09/1997	Pit 1	Elbow?
	A8910	Tails Return Water	19/01/1998	?	Mine Hose Flange
	F9757	Tails Return Water	18/02/1998	South Dam Wall	Valve leaking
9	G2419	Tails Return Water	05/05/1998	Tails dam gate	Mining hose
	F3105	Tails Return Water	26/08/1998	North Dam Wall	Victualic coupling
10	G6685	Tails Return Water	30/08/1998	Tails dam gate	Mining hose
	2624	Tails Return Water	29/12/1998	Tails dam	Steel/Victualic coupling
	5098	A-tails	05/03/1999	Pit 1	Poly
11	10031	Pit 1/Tails dam	09/08/1999	?	Poly (Fire damage)
12	10706	Pit 1/Tails dam	26/08/1999	Corridor/Pit 1?	Poly
	10709	B-tails	30/08/1999	Pit 1	Mine hose joint
	12387	B-tails	21/10/1999	Corridor/Pit 1?	Bend
	12720	Tails Return Water	29/10/1999	?	Steel
13	16886	B-tails	06/03/2000	Turkeys Nest	Rubber lined steel
14	17866	Tails Return Water	04/04/2000	Bottom of dam ramp	Flange to mine hose
15	19098	B-tails	15/05/2000	Turkeys Nest	Rubber lined steel

Recorded Catchment Condition Reports: Water Resources File w28-0012 (Pidsley, May 2000)

Location on map (Figure 2)	Catchment	Date	Location	Material/Cause
	Tailings dam	1/9/98	Pipe culvert adjacent corridor road	Culver blocked
	Corridor/Pit #1	10/9/98	At tails crossover	RRZ drain from tails dam wall under road looks blocked

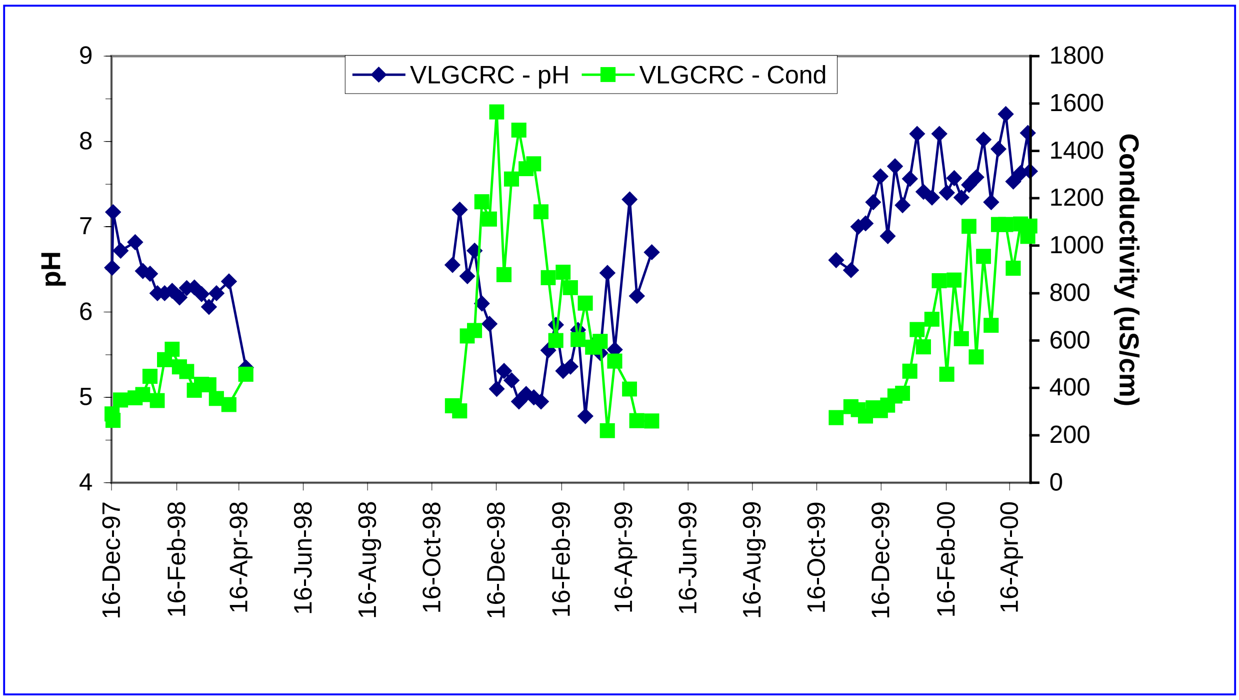
Infringement notifications: Water Resources File I25-0001 (Pidsley, May 2000)

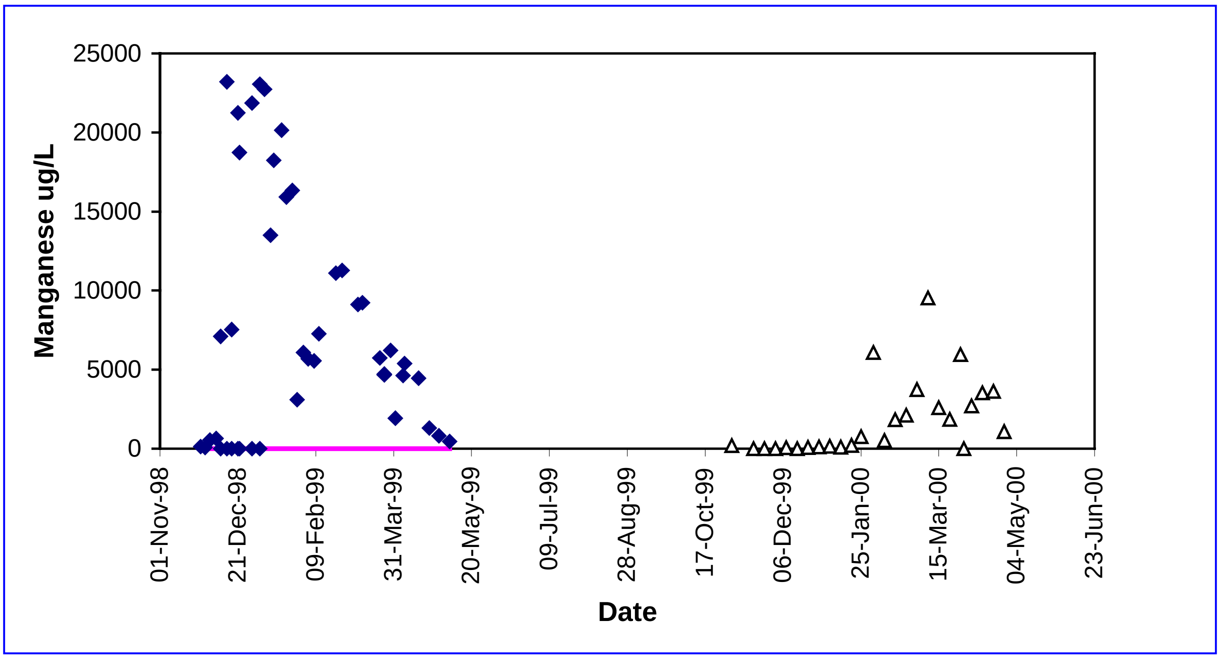
Location on map (Figure 2)	Type	Date	Location	Material/Cause
	Infringement	23/1/96	?	Tailings spillage on A/B tailings line. Larox Pinch valve 0415h Tuesday 23/1. Rubber flange on valve failed. 2-3m^3 of tails sprayed outside RRZ; ~20m^3 tails within RRZ.
	Infringement	19/2/96	East wall of TD	Tailings spillage. HDPE pipe joint failure, 2200h Sunday 18/2. 0.25m^3 spray outside RRZ.
5	Infringement	19/12/97	Between main CD tailings line and corridor sump	Failure in side line between main CD tailings line and corridor sump at 1650h. Rubber lining failure caused non-return failure and spray of tails ~1m^3 outside RRZ bund.
4 (two locations)	Notification (non-infringement)	2/11/98	Areas at corridor sump and mill side of the sump	Tailings line became bogged Saturday 31/10and was cleared at two locations. Possible small quantity of tails and process water washed into corridor sump
3	Notification (non-infringement)	14/12/98	At ramp between TD wall crest and fence gate	Siphon break valve on dredge tails line at the top of the tails dam ramp. Small quantity of tails spilled. Sunday 13/12.
	Infringement	6/8/99	?	RP2 water used for firefighting 5/8/99. ~5m^3 used to extinguish fire east of southeastern corner of tails dam. Damage to flexible join in tailings line noted. Join failure allowed small quantity of tailings to escape to the tails corridor.
	Notification (non-infringement)	28/4/00	Ramp at east wall of TD	Current incident

12 GRAPHS

Graph 1. Conductivity and pH data for VLGCRC over three wet seasons

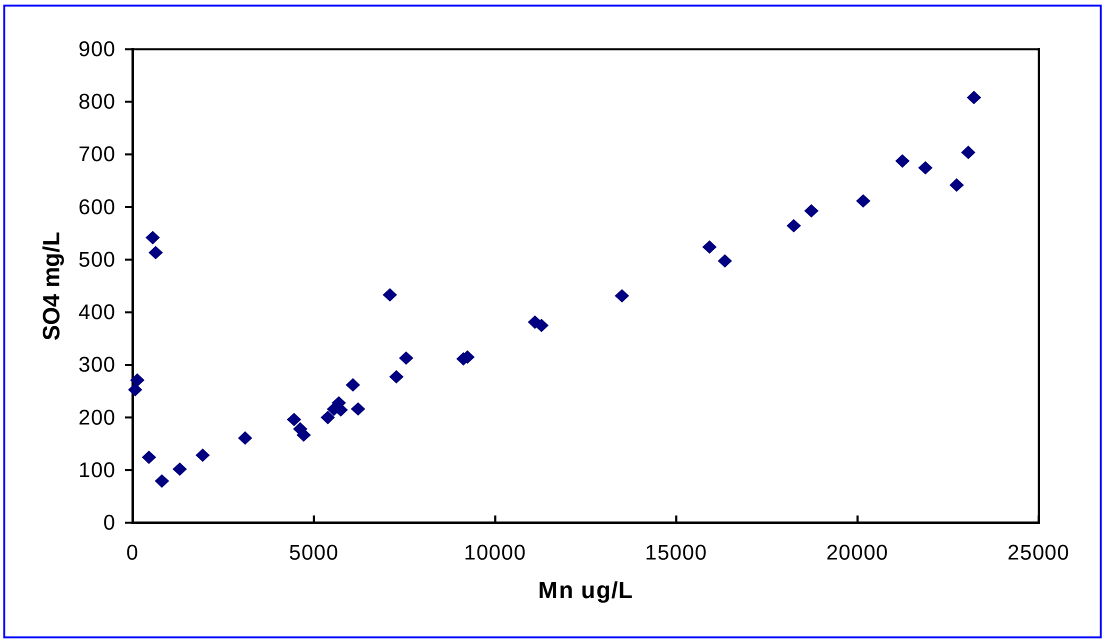
Graph 2. Comparison of Mn time series data between 1998/99 and 1999/00 wet seasons

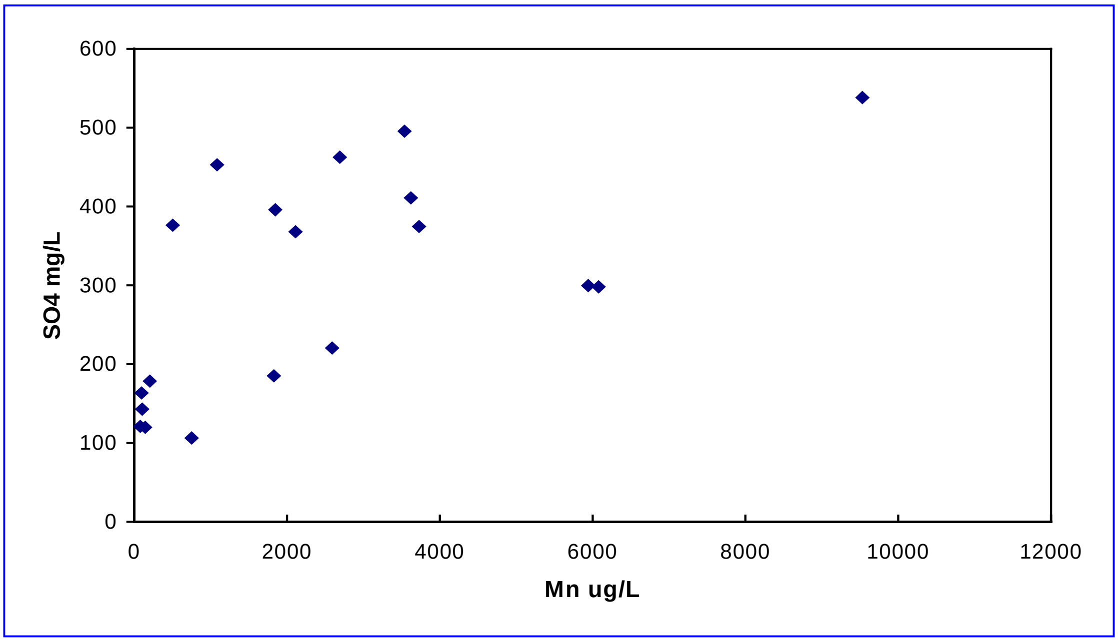




Graph 3. Sulfate-manganese scatter plot for GCSR (1998/99)

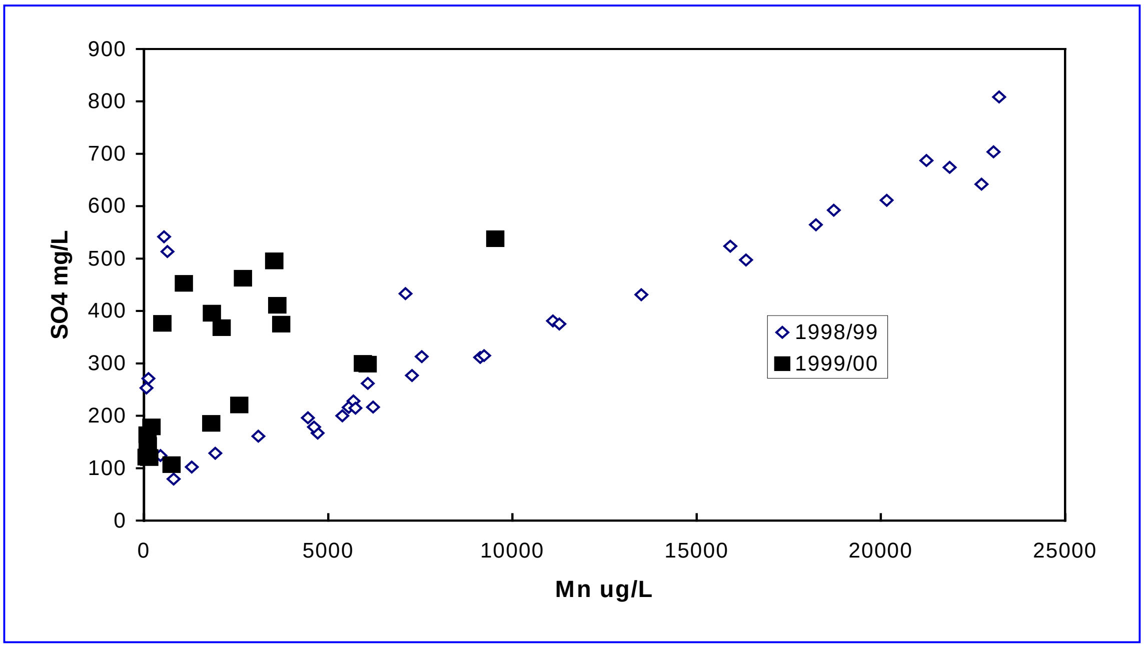
Graph 4. Sulfate-manganese scatter plot for VLGCRC (1999/00)

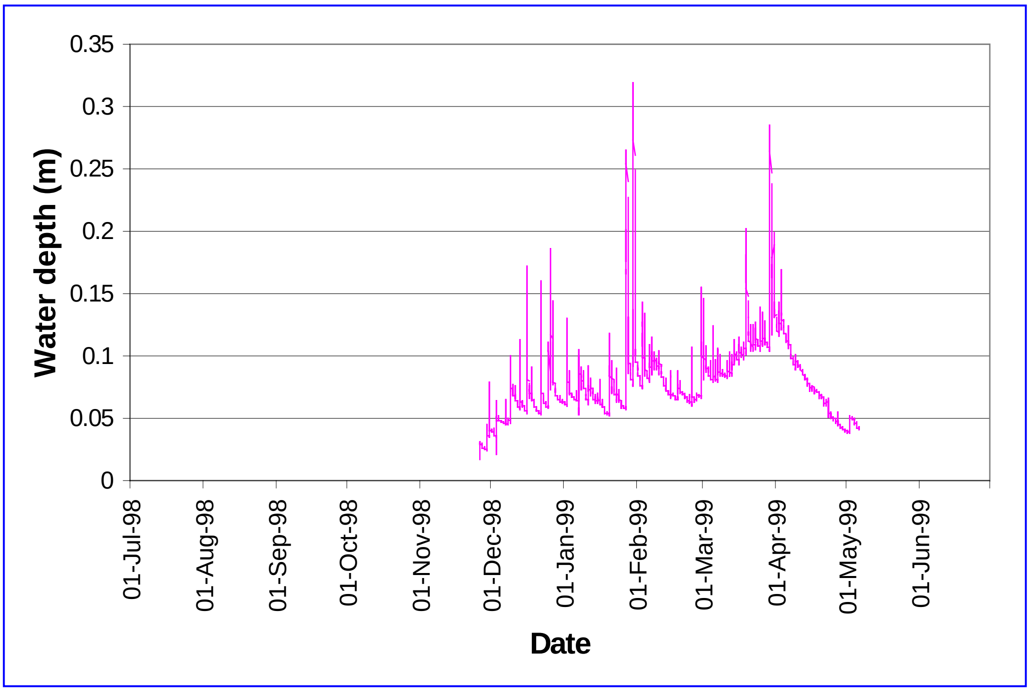




Graph 5. Overlay of 1998/99 and 1999/00 scatterplot data for sulfate and manganese

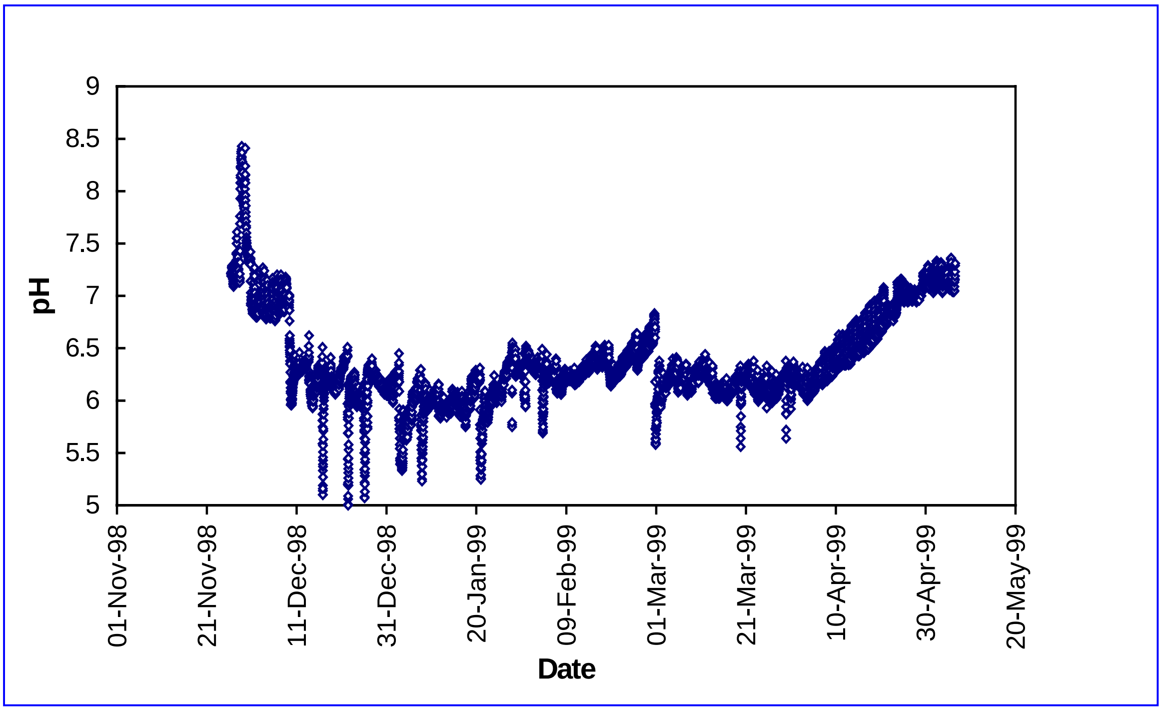
Graph 6. Depth of water at site GCSR (1998/99)

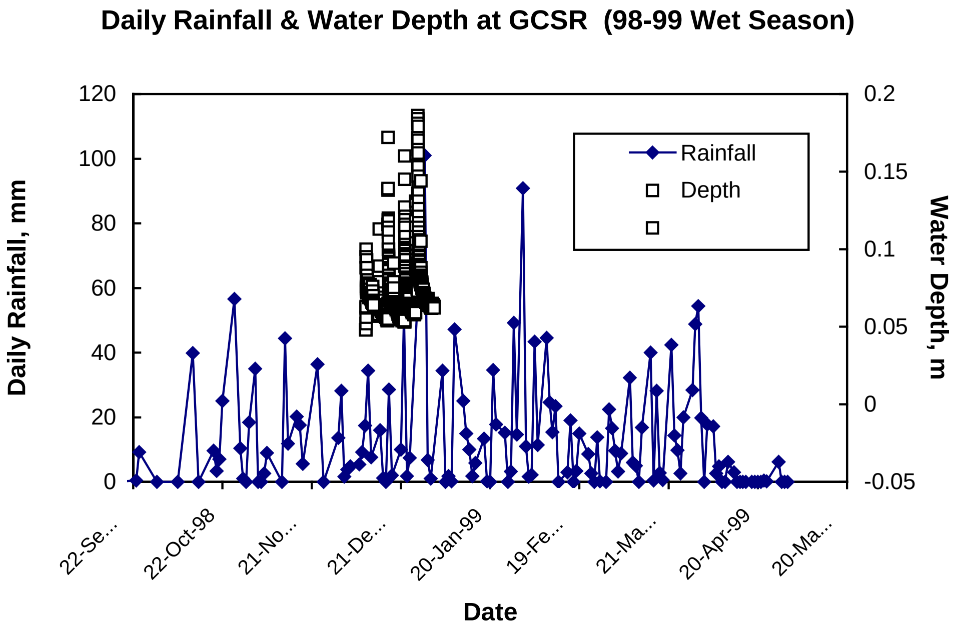




Graph 7. Continuous datasonde record for pH at GCSR (1998/99)

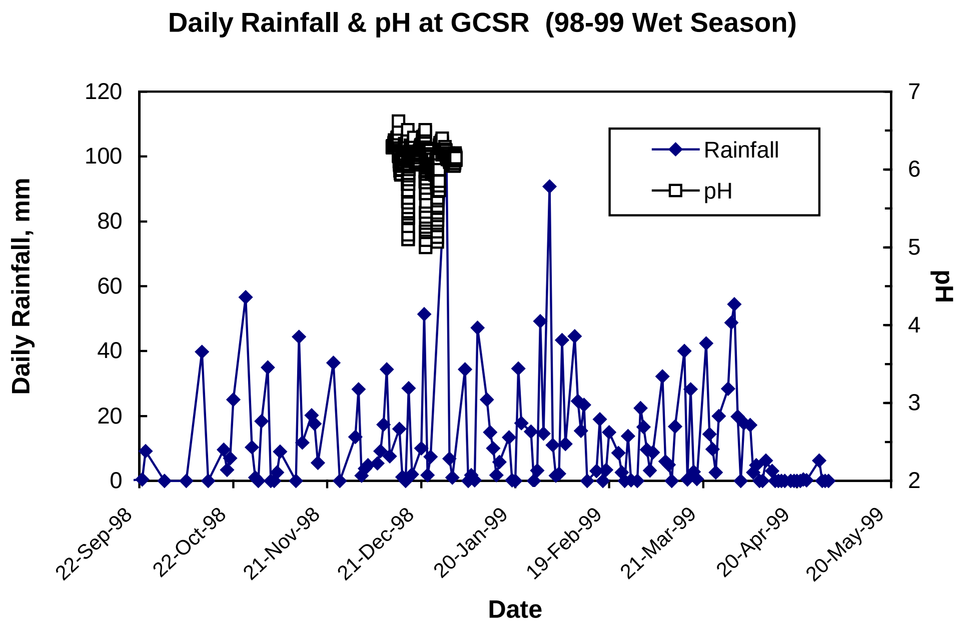
Graph 8. Daily rainfall at tailings dam and water depth at GCSR (1998/99)

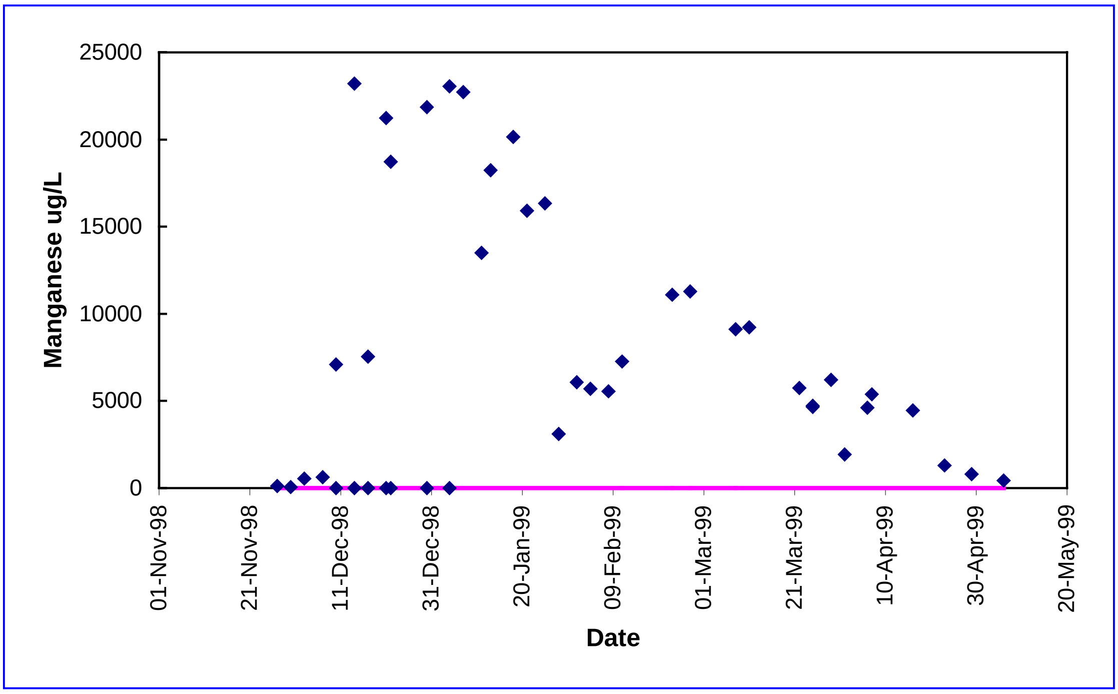




Graph 9. Daily rainfall at tailings dam and pH at GCSR (1998/99)

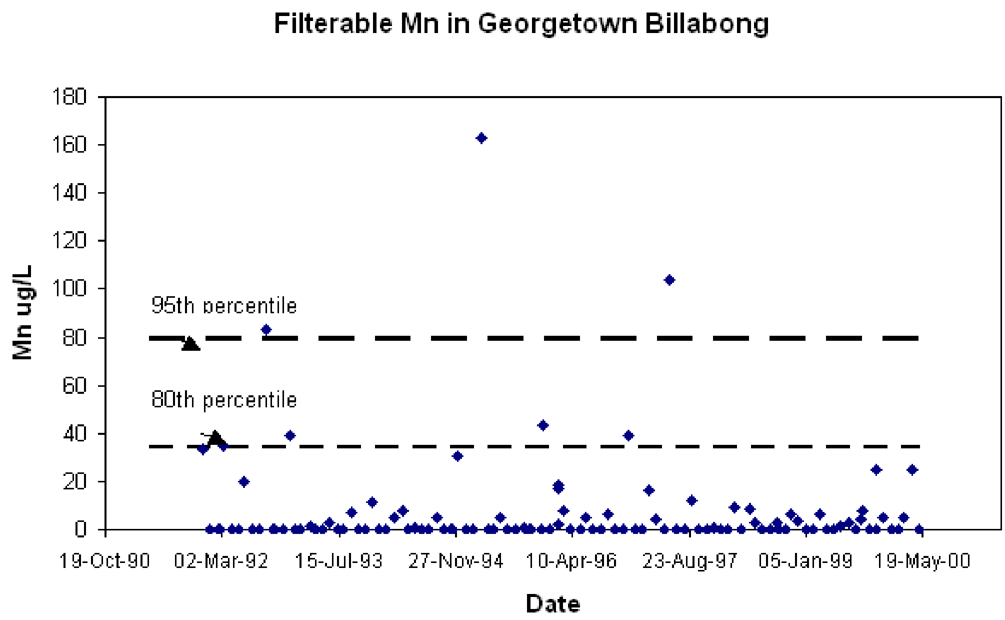
Graph 10. Manganese time series data for GCSR (1998/99)

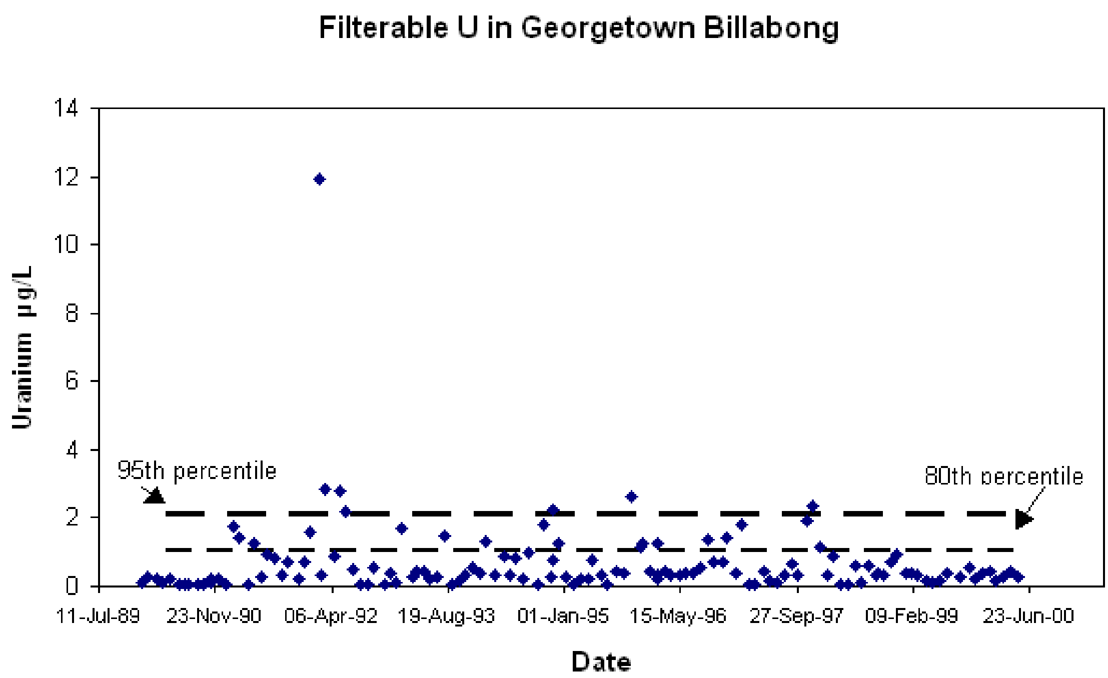




Graph 11. Filterable Mn in Georgetown Billabong since 1990

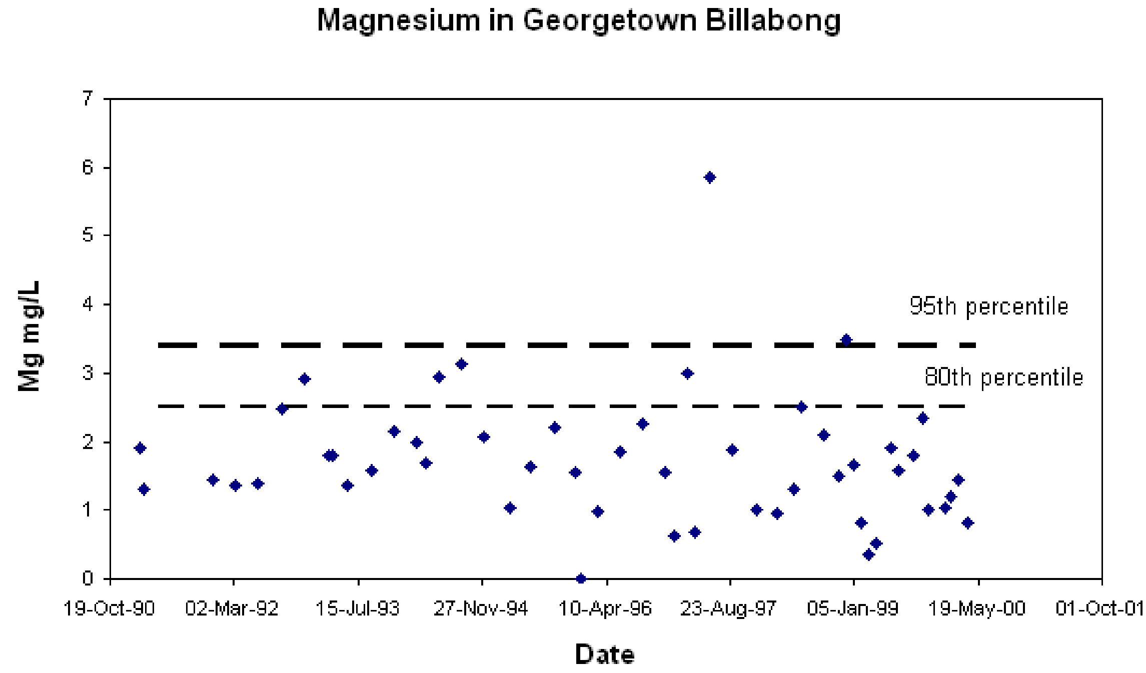
Graph 12. Filterable U in georgetown Billabong since 1990

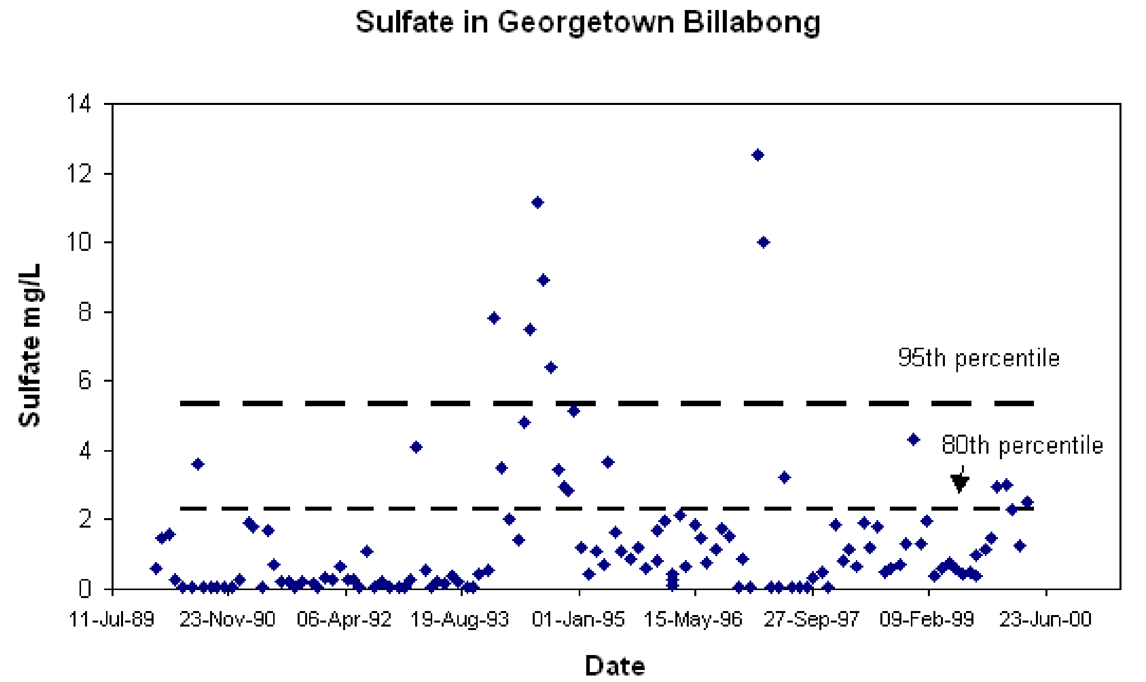




Graph 13. Magnesium in Georgetown Billabong since 1990

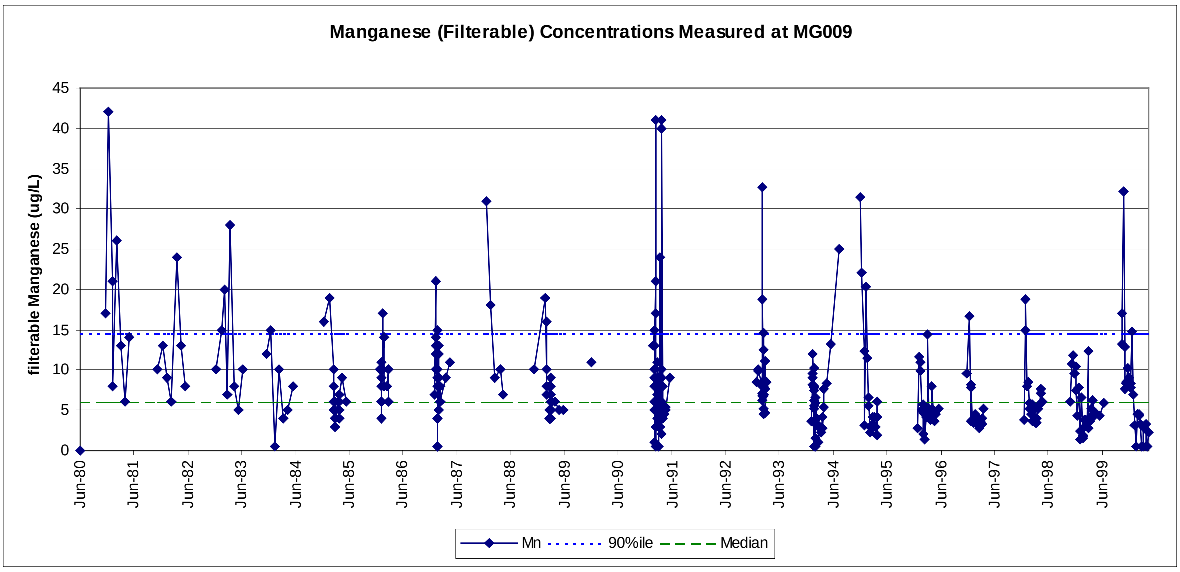
Graph 14. Sulfate in Georgetown Billabong since 1990

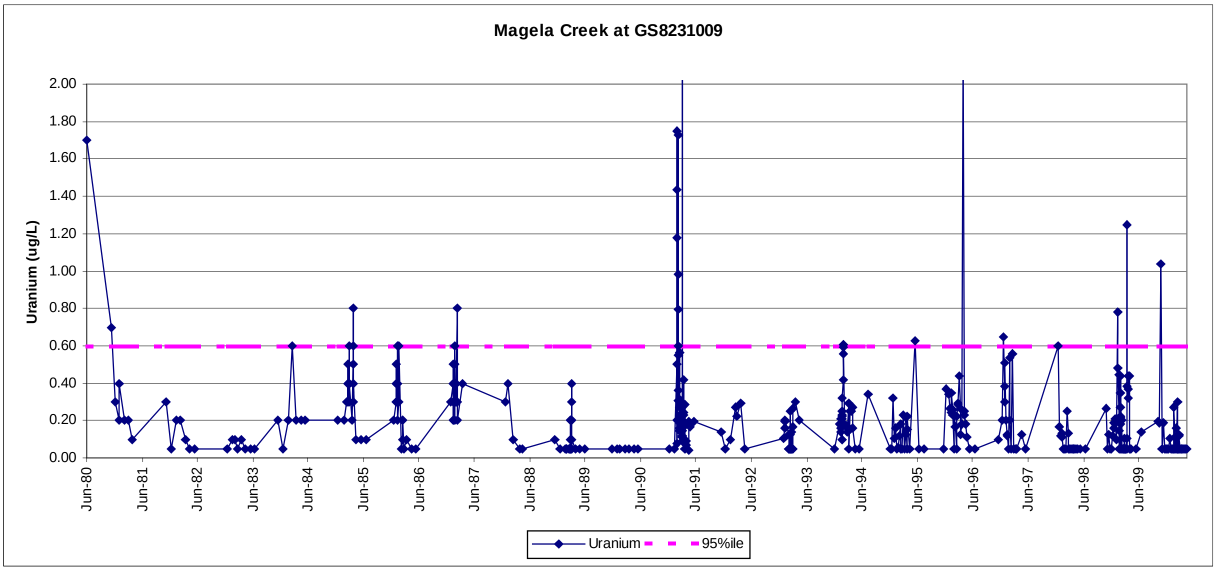




Graph 15. Manganese levels at 009, downstream of Ranger Mine, since 1980.

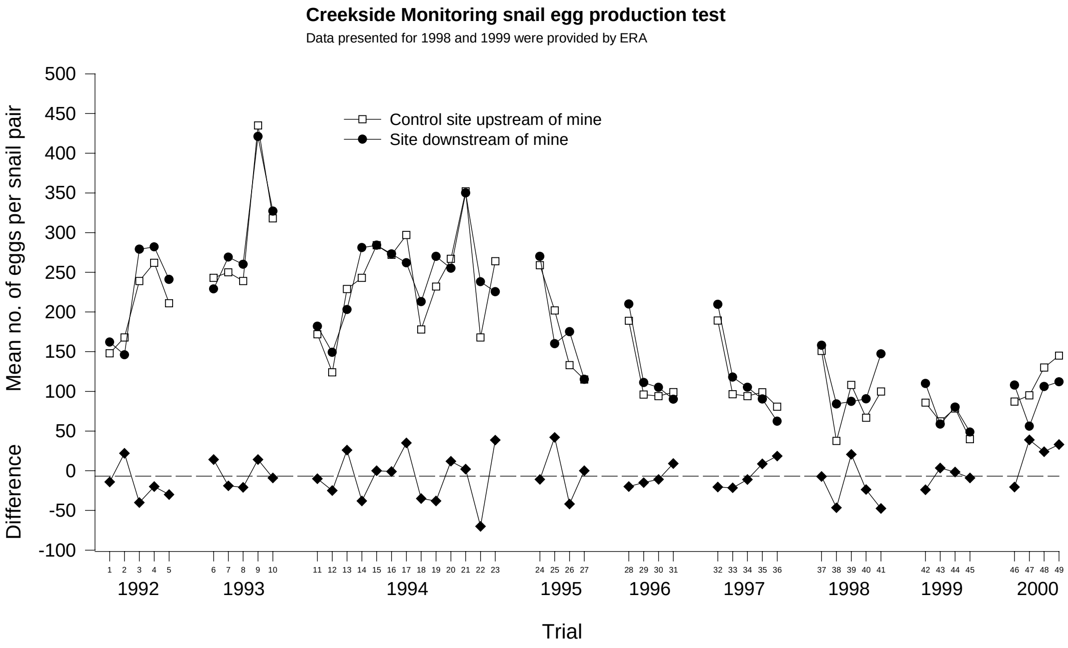
Graph 16. U concentrations measured at 009, downstream of Ranger Mine, since 1980.

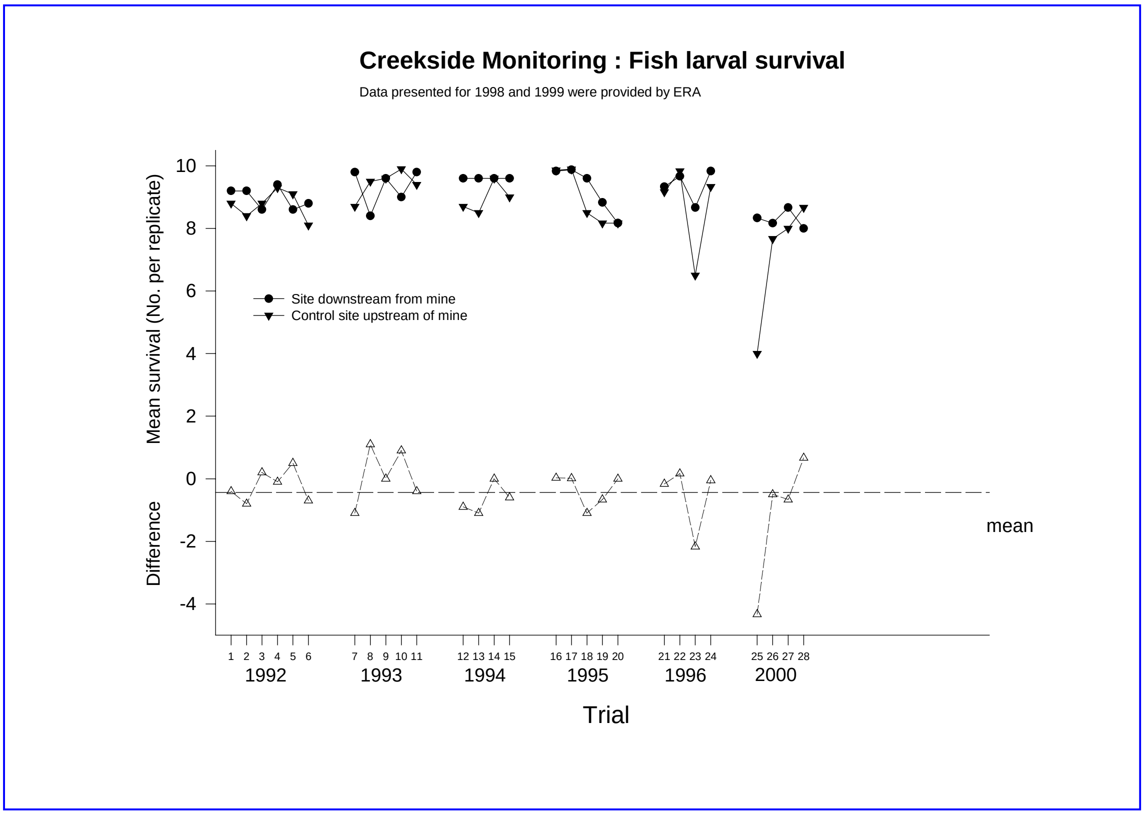




Graph 17. Creekside monitoring at 009 – fish larval survival

Graph 18. Creekside monitoring at 009 – snail egg production





13 FIGURES

Figure 1. Ranger Mine Map water management system, May 2000.

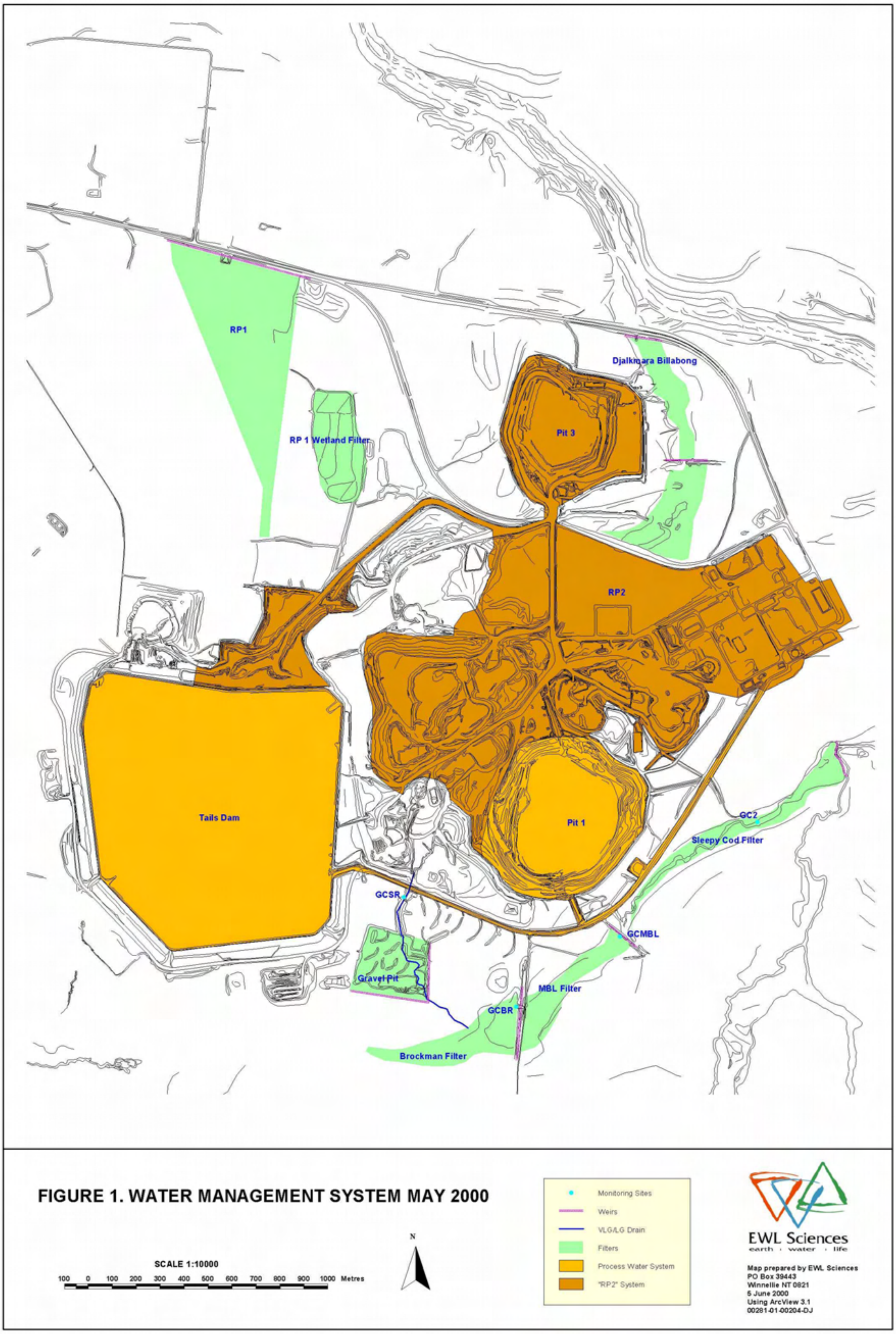
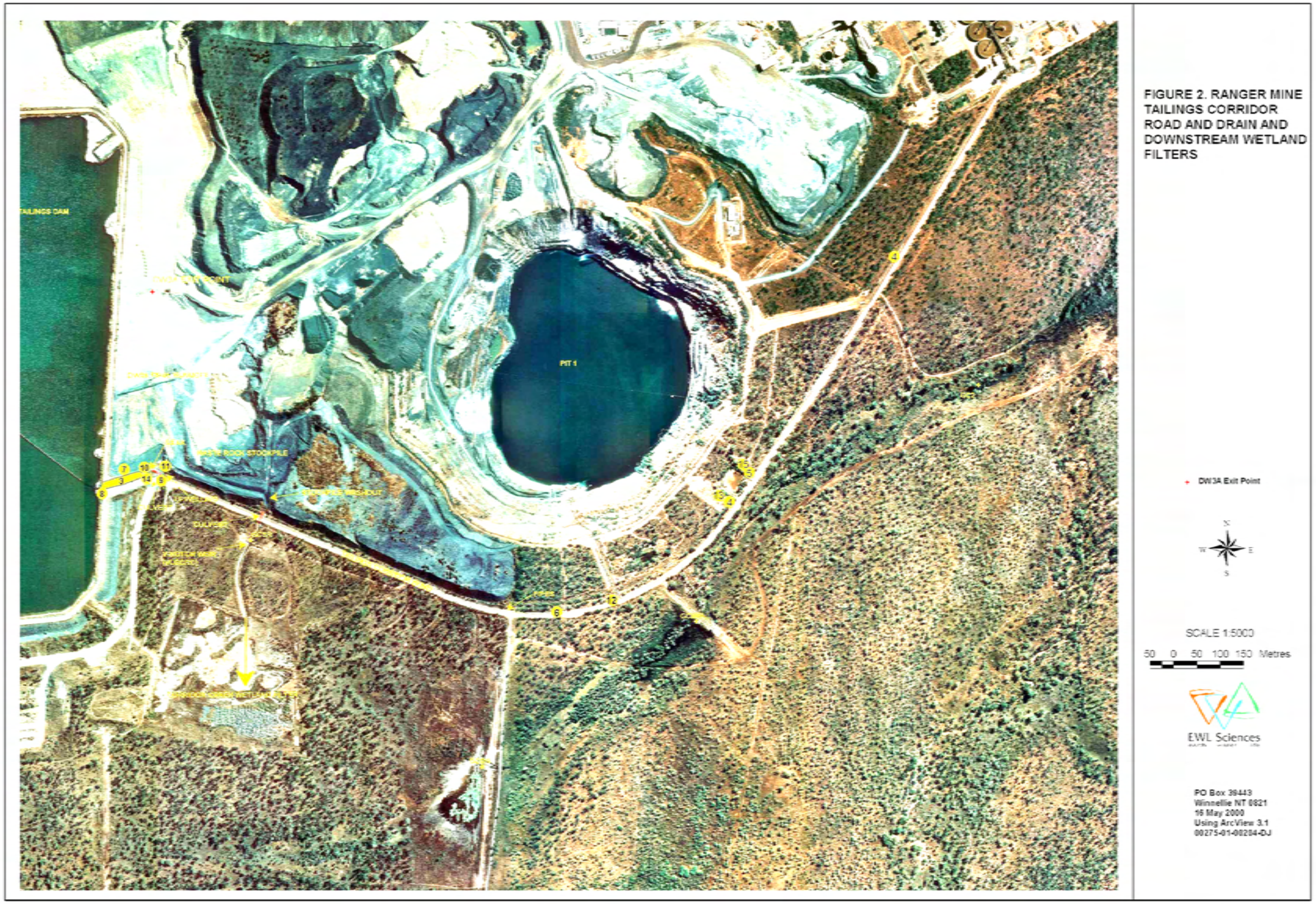


Figure 2. Ranger Mine tailings corridor road and drain and downstream wetland filters.



14 ATTACHMENTS

INTICO (VIC) Pty Ltd. "Ultrasonic thickness survey of tailsline steel and polyethylene PE 808 grade piping". Report to ERA Limited. June 1, 2000. (Part copy)

Precis from report.

1. "An ultrasonic thickness survey was carried out on approximately 5km of carbon steel tailsline piping[5] performing two circumferential A-scans to record minimum and maximum wall thickness on every pipe length. Three lines were examined: A and B (PE SO lined) and Water Return (epoxy paint lined). Each scan was carried out approximately 150mm adjacent to each clamped connection on all pipes. All full strength butt weld splices in these lines were scanned on the downstream side. All butt welded fittings to pipeline were also scanned. No areas of underside corrosion or laminations were detected except pipe n. 296. All bend and elbows along pipeline were examined 100%." The results were tabulated.
2. "Thirty eight pipes were scanned 100%, except where concrete pipes supports 300mm wide restricted access. No areas of underside corrosion or laminations were detected except for pipe no. 296 (end of line at tailings dam end) where some thinning was detected adjacent to valve."
3. "Circumferential A-scans were undertaken on the bends of two polyethylene pipes, the tailings dam to pit no. 1 water line A and the dredge tailings line B. No areas of thinning were detected. However, areas of thicker than nominal (29.6mm) were detected around location no. 5 of pipe A. It was noted at the time of inspection that thicknesses varied greatly with temperature variations: expansion where hot and contraction where cool."
4. "At the request of the ERA – Ranger Mine client representative, a 100% circumferential A-scan was undertaken on the polyethylene transfer line B, down stream of the third elbow. Line A was not accessible." The minimum reading was 22.0mm and the maximum reading was 23.0mm.

[5] Map supplied showing extent of pipe including Line A from mill to eastern side of Pit #1; Line B from mill to southern side of Pit #1, and water return from tailings dam to mill.

Appendix 3

ERA Internal Review
Significant Incident Investigation Report
Process Water Pipe Leak at ERA

Significant incident investigation report: process water pipe leak at ERA

Introduction

An incident occurred at the ERA Ranger Mine in which a leak from a process water pipe within a bunded containment area became elevated to an issue of concern to Aboriginals, Commonwealth and Territory ministers and the national and international press. The incident was damaging to the reputation of North Limited and to its relationship with key stakeholders.

The purpose of this investigation was to examine the incident from a management systems and organisational perspective to identify improvements which will minimise the possibility of a recurrence of this type of event. A parallel study will be conducted to investigate the technical aspects of the incident.

Incident Summary

The investigation considered in detail the chain of events giving rise to the incident. A summary of these events is as follows.

The physical location of the process water leak (figure 1) was the western section of the tailings corridor bund, a bunded corridor connecting the mill and tailings dam, designed to act as a secondary containment system for pipes carrying tailings to the dam and return process water to the mill. This infrastructure dates to the beginning of mill operations and while the tailings pipes are no longer in use in the section where the leak occurred, the steel process water pipe still carries process water from the tailings dam.

In December, 1999 an approved trial (the DW3A Trial) was initiated to test the ability of the Corridor Creek constructed wetland south of the Tailings corridor bund to attenuate solutes including heavy metals and nitrate. Water from a mill dewatering bore (DW3A) was pumped to the capped very low grade waste dump (VLG waste dump) to the north of the tailings corridor bund. From here it flowed through adjacent waste rock, under the tailings corridor via a concrete box culvert (the VLG tailings corridor culvert) and on to the wetland. Weekly samples were taken at the south end of the culvert to monitor the levels of various solutes in water entering the wetland system.

On 2 February, the DW3A trial sample showed abnormally high manganese (Mn) content at 6,100 parts per billion (ppb). Various hypotheses were entertained to explain this but high Mn was most usually associated with the presence of process water. The following week the Mn level had dropped but was elevated again in the samples from 16 February to 8 March.

On 13 March an investigation was formalised and various samples were taken to track down the source of the elevated Mn.

On 28 March, towards the end of the wet season, a small upwelling of water was found in an area to the west of the VLG tailings corridor culvert. At this point, where the process water pipe passed beneath a road culvert adjacent to the fence around the tailings dam, the pipe had become buried under silt. Excavation revealed the source to be a disused length of tailings pipe from which water flow was measured at 0.3 l/sec. By 4 April the source of the water was identified as the flange joint between fixed and flexible sections of the process water pipe on the other side of the road culvert. These pipes were also buried in silt and the leaking water was draining below the surface, into the disused section of pipe, to emerge on the other side of the road culvert. The leak was repaired the next day.

Ranger ESH staff evaluated the incident as not breaching the Commonwealth Environmental Requirements for the mine (ERs) on the basis that the leak was contained within the tailings corridor bund. This analysis overlooked the fact that the search for the process water leak had been initiated in response to elevated Mn concentrations measured outside of the containment system.

A notification for the incident was prepared on 10 April in accordance with a commitment to advise main stakeholders of unplanned events. However, a sequence of delays (editing, absence from work due to sickness, and the Easter and Anzac day break) resulted in the fax (attachment 1) not being sent to stakeholders until 28 April. In summary the notification advised the following:

- An estimated 2000 m^3 of process water leaked into the tailings corridor bund over approximately three months, from where it would have flowed to a sump after considerable dilution by rainwater.
- There was minimal impact on water quality measured at the sump, which was pumped into the lower quality RP2 during the period when the leak was unidentified.
- The delay in repairing the pipeline was due to inability to identify the seepage during the wet season.
- There was no infringement or environmental damage involved.

The Office of the Supervising Scientist (OSS) found the information in the fax and the delay puzzling and thought there must be more to it. They called Ranger to discuss the incident and, after discussions, advised their belief that a regulatory breach had occurred. In a subsequent discussion with another Ranger staff member the fact emerged that the search for the leak was in response to the high Mn levels at the VLG tailings corridor culvert.

The OSS concluded that this was a breach of the ERs and were concerned that early recognition of the issues had not occurred. They were incensed at the delay in reporting and what they perceived as a failure to be forthcoming with all of the facts. The possibility was even entertained of a deliberate attempt to conceal the full extent of the incident. Over the weekend the OSS sent a briefing note on the issue to the Minister's office at Environment Australia, copied to the Department of Industry Science and Resources (DISR).

The DISR were similarly incensed and on Tuesday 2 May brought the issue to the attention of ERA's parent, North Limited, and raised the possibility of cancelling the export license for Ranger's next shipment. This very quickly caught the attention of North, at the most senior level.

North could not allow any suggestion of a cover up of the incident and on 2 May initiated a press release acknowledging that the delay in reporting the incident was unacceptable. The media interpreted this as a significant environmental incident. It was reported as far away as the *London Times*. The incident elavated ERA's operations in both the public and political arenas and provided opportunities for its critics to undermine its environmental management record.

On 3 May monitoring data from another trial conducted by EWL Services a year earlier emerged which showed even higher levels of heavy metals at the same sampling point. This cast some doubt over whether the abnormal readings were due to the process water leak or could instead have been associated with leaching from the VLG waste dump. However, it also raised the question of why this data had not been reported to stakeholders or followed up when reported to site in April 1999.

On 5 May 2000 a trial was conducted that demonstrated that water in the tailings corridor bund could slowly seep through the roof of the VLG tailings corridor culvert, confirming the possibility that process water sitting in the drain for a prolonged period could escape to the natural drainage system.

Gap Analysis Summary

Where did our handling of these events fall short of the standard required for managing Australia's most environmentally and politically sensitive mine? A detailed gap analysis was conducted to answer this question, applying a yardstick of *best practice* to determine the expected response at each key decision point.

The analysis is summarised by reference to four critical periods in the sequence of events:

1. The conditions existing prior to the leak
2. The *detection period* between the first anomalous sample result and the locating and repair of the leak
3. The *reporting period* between fixing the leak and the reporting to stakeholders
4. The *crisis period* during which the outrage had to be managed

Pre-Existing Conditions

The tailings corridor bund and piping had been engineered with the objective of managing the environmental risk from possible pipe leakage. The tailings lines and process water return were all steel pipes and were set on concrete blocks to minimise corrosion and facilitate identification of any leakage. In the one location where the tailings dam road passed over the pipes, a concrete box culvert protected them. The corridor in which the pipes lay was carefully designed to contain any spillage.

It appears that for many years the pipes were managed with careful maintenance and regular three hourly inspections. However, when the tailings lines were decommissioned in 1997 (tailings were pumped direct to Pit #1) the perceived hazard and the response to it reduced. The pipes had become buried in several locations by sediment deposition as they approached the tailings dam resulting in corrosion, which ultimately appears to have given rise to the leak (or perhaps vice versa) and prevented the identification of the leak throughout the wet season.

The VLG tailings corridor culvert was installed in 1997. It has now been demonstrated that its construction allows seepage of water from the tailings drain and as such is a compromise to the original design integrity of the tailings secondary containment structure.

Whilst we understand that the risk of process water leakage is less than that for tailings, best practice would have recognised and responded to the combination of technical and political sensitivity surrounding water management issues to a greater extent than that which is apparent. It should be noted, however, that in the course of the rigorous inspection and audit regime many experienced observers failed to identify the potential environmental hazard of the buried process water pipe.

The response to the 1998 EWL trial data also warrants review. The consensus now is that when these results were reported to Ranger in April 1999, they were sufficiently anomalous that they should have triggered follow up to better understand the situation. Follow up did not occur due in part to the fact that there are no established action trigger points for managing discretionary monitoring data and that investigation into elevated uranium levels in RP1 assumed a higher priority at that time.

Ideally, the 1998 EWL trial data would also have warranted consultation with the OSS and NT Department of Mines and possibly the NLC. Standing in the way of this approach is a concern that sharing information which is of interest but not critical to environmental protection is more likely to generate a political response than a technical one.

The Detection Period

The period of time between the first anomalous reading at the VLG tailings corridor culvert and detection of the leak was almost eight weeks. While pursuit of the issue might have been somewhat more vigorous, in practice there may have been very little that could have been done during the wet season in the area of the buried pipes without causing more environmental harm than would have been saved. However, once the leak of process water was identified, more vigorous followup would have located and addressed the source in less than the almost one week taken.

In relation to reporting, we should aspire to a relationship with the regulators in which test results which are anomalous could be discussed with the regulators in an open and timely way.

The Reporting Period

The correct interpretation of the situation, having identified the leak, was that a significant volume of process water had escaped the primary containment system to the secondary containment system *and* that there was some evidence that smaller volumes may have seeped or flowed from the secondary containment system to the environment.

The Commonwealth Environmental Requirements for the mine require reporting of any breach of the regulations or of any mine related event which:

(a) results in significant risk to ecosystem health; or

(b) which has the potential to cause harm to people living or working in the area; or

(c) which is of or could cause concern to Aboriginals or the broader public.

The Requirements also provide that process water must be contained within a closed system except for, *inter alia*, seepage of a quality and quantity that will not cause detrimental environmental impact outside the Ranger Project Area.

Whether or not a regulatory breach occurred is not the subject of this report. A best practice model would demand under these circumstances early discussion with Aboriginals, the NLC and the regulators.

Written notification, sent with considerable delay and without prior verbal warning and all relevant facts, invited misinterpretation and concern.

North's internal incident reporting procedure and "no surprises" culture also demanded notification upon finding the leak, if not before.

It is important to note however, the firm conclusion that there was no deliberate intent by Ranger management to deceive or dissemble in relation to this matter.

The Crisis Period

The response at Ranger to the crisis was proportionate to their evaluation that from an environmental perspective there was no impact from the event as measured at the statutory monitoring point.

The appropriate evaluation was that since the event had triggered ministerial interest and concern it was a crisis of considerable dimensions, regardless of one's perception of the underlying facts.

The expected response is that relevant personnel would give the issue the very highest priority and within a matter of hours have to hand a detailed account of the sequence of events and all data and information which might be related to the issue. The management team would be expected to make every effort to understand what is generating the concern and be proactive in relation to developing an appropriate management response. In this case that would include immediately restoring the integrity of the mill process water containment system.

The actual response fell short of this expectation.

Summary of Causal and Contributing Factors

1. Over recent years the original design integrity of the mill process water pipe and containment system was changed.
2. No systematic process existed to address anomalous monitoring data to ensure that the possible concerns of stakeholders are addressed.
3. Decision making in relation to consultation, notification and remediation was based on assessment of *environmental impact*, focussing on statutory compliance. This approach stems from a concern of ERA management that release of information beyond the required minimum will generate a political rather than a technical response. It does not place adequate weight on *political risk* or address the need to manage stakeholder relationships by understanding and servicing their differing expectations on reporting and consultation.
4. Differing messages were received by the regulators from Ranger personnel due to a lack of a single contact point with both the complete picture and consistent messages.
5. There has been a long-term issue with the management and ultimate disposal of water on the lease that has not been adequately addressed. The Ranger staff face an increasingly intractable water management problem which is becoming the primary driver behind operational and environmental decision making.
6. Substantial and rapid change in the management structure and personnel occurred without adequate consideration of the impact on the overall competence of the management team to deal with both commercial and stakeholder issues.

Discussion of Organisational Issues arising from this Incident

The following discussion of organisational issues attempts to identify the root causes where performance fell short of expectations and the issues which will need to be addressed.

ERA Structure

- The establishment of the Jabiluka Project Team and the elimination of the General Manager Operations position have reduced the exposure of management at Ranger to the political environment in which the mine must operate.
- Without adequate planning, after the Jabiluka Project Team has fulfilled its purpose, there is the potential for an unacceptable gap in the relationships management function which needs to be managed.

Site Management Structure

Since August 1999 the General Manager's role at Ranger has been replaced with a self-directed team made up from the senior functional managers. The enthusiasm, energy and commercial focus of that team is evident. This is important for a mine in mid-life, operating under commercially and politically difficult circumstances and must be preserved. However, the organisational structure needs review against the following:

- The fact that the responsibilities of some individual team members is so broad that they cannot adequately focus on relationship management.
- That the structure has no effective redundancy to deal with performance or competency gaps of individual members or to provide continuity through operations management changes.
- Functional managers need to continue the focus on commercial imperatives whilst at the same time ensuring understanding of the big picture against which those imperatives must be balanced.
- Some stakeholders find difficulty interacting with Ranger where the area of responsibility for their issue is not clear or where they have a need to go beyond the functional management role.
- When crises arise the relevant functional manager takes responsibility. There is a need to ensure that in such situations the required level of expertise and experience, which may not yet have been developed by the functional manager, is brought to bear.

The Environment Safety and Health Department

- While the ESH Department has maintained its numerical strength, there is a need to ensure that its *depth* of capability is also sustained. The relocation of ERAES to Darwin and more recently the promotion of the Senior Scientist to Department Manager without a replacement of similar capability in his former position have opened up a potential gap in this area.
- There is considerable tension between the role of acting as Ranger's "environmental conscience" and level of involvement in the pursuit of difficult commercial objectives.
- Managing the increasing excess of process and RP2 water has become an all consuming task at Ranger which appears to be a major distraction from the task of achieving site-wide best possible environmental outcomes and relationships with key stakeholders.

Conclusion

This incident has highlighted a number of opportunities for improvement at ERA in the areas of its management systems and in taking a broader view of its consultation and notification obligations. However, underlying all of the issues is the need to change the dynamics of relationships between ERA, Aboriginals and regulators so that each party's expectations can be met through more positive and open interactions.

Appendix 4

ERA investigations into the Process Water Spill Incident: Letter from ERA

ERA Energy Resources of Australia Ltd
ACN 008 550 865

19 May 2000
rac:kp:mkg0558ltr

Dr Arthur Johnston
Supervising Scientist
ERISS
PO Box 461
DARWIN NT 0801

By facsimile: (08) 8981 4316

Dear Dr Johnston

ERA Investigations into the Process Water Spill Incident

As you are aware, following the concerns raised about the spill itself and the way in which it was handled, ERA undertook several investigations. One involved looking at the technical aspects of the process water spill and the extent of any environmental impact an investigation in which members of a number of external bodies, including the OSS, were invited to participate and review all available data. An interim report on that investigation and its findings will be forwarded to you on Friday 19 May 2000.

The other investigation focussed on the management and reporting of the incident. The intent of this investigation was to examine the personnel, organisation, practices and procedures at the Ranger mine in order to determine whether any or all of these factors were significant contributors to the unsatisfactory way in which this incident arose and was handled. This letter summarises the findings and actions that ERA proposes to take as a result of those findings.

Key factors contributing to the incident and the way it was handled were:

1. Organisational changes, resulting in a lack of external focus by site management.

2. Turnover of key personnel, resulting in loss of site experience and detailed familiarity with ER's.

3. Revision of Ranger ER's and ambiguity associated with the reporting process.

4. Very recent appointment of the Manager – ES&H, prior to the incident.

5. Complication of R&D trials in the near vicinity, leading to a degree of masking of the data.

6. A lack of assessment and interpretation of all relevant data prior to notifying external stakeholders.

7. Significant changes in site tailings management practices, leading to a departure from the original pipeline integrity monitoring criteria.

8. Unclear requirements on incident reporting within the Company, and consequent failure to trigger internal questioning.

9. Reliance on environmental impact potential at 009 sampling station, for assessment of seriousness, rather than trigger points within the operating site to initiate early investigations and remedial actions.

I would like to comment on the actions that ERA has taken or has planned in relation to the points listed above, in order to ensure improvement of Ranger's future performance.

Changes resulting in deposition of tailings in the disused Ranger #1 pit changed the focus on tailings spill prevention and retention in the vicinity of the tailings dam. Hence the inspection regime which encompassed the return process water line fell away when tailings were no longer being pumped through that part of the pipeline systems. This in turn meant that the significance of part of the process water line being buried under silt and rock debris during high rainfall run off over recent years, and the external corrosion of the buried flange bolts was missed.

Since repairing the leak, all of the process water line has been fully exposed, an access culvert across the line which was trapping silt has been totally removed, and sections of the process water line which were showing signs of external corrosion have been replaced. The value of being able to see any incipient problems at all joins in the line has been reinforced, and a procedure to slash grasses along the entire 2.5km of the pipeline has been introduced.

Organisational changes that have been made at Ranger and within ERA have been aimed at both addressing the changing expectations and aspirations of our employees, while at the same time meeting the expectations of our stakeholders in terms of the Ranger site performance. This has led to a broadening of job responsibilities, but also an inward focus which has tended to underscore the importance of the working relationships with external stakeholders, and led to uncertainty with a number of external bodies regarding effective interface with Ranger and ERA.

I have already commenced a process to strengthen the management team, specifically to address and facilitate effective interface with external stakeholders key to ERA's future.

Ranger's ability to effectively identify, interpret and rectify environmental incidents in a way which not only continues to protect the environment, but does it in a way which satisfies traditional owners, regulators and supervisory authorities is dependent to a large extent on the calibre and experience of its senior environmental scientists. A Senior Environmental Scientist will be recruited as a matter of urgency to support the Manager – Environment, Safety and Health in fulfilling his responsibilities.

An important part of a flatter organisational structure being effective is that people throughout the structure are fully conversant with the requirements of their jobs. For this reason we will be documenting training sessions with all environmental staff on the new ER's, to ensure they are well understood. An important precursor to this will be clarification of interpretation of any part of the ER's that may be unclear. A meeting of the MTC has been proposed to commence this process.

Research and Development projects being undertaken at Ranger are vital in both better understanding ongoing impacts of our operations on the environment and demonstrating the effectiveness of proposed rehabilitation strategies. However, it is important that these projects don't mask or complicate the job of protecting the environment from Ranger's processing operations.

It is proposed that current and future R&D projects be openly discussed with external stakeholders, both in the intent and nature of the projects, and access to ongoing data as it is accumulated. This will ensure that any anomalous results are identified, discussed, reviewed and investigated when warranted.

The fact that the Ranger environmental performance is assessed at the 009 sampling station, and that Ranger has been assessed as having no detrimental impact on the environment outside the Ranger project area, has not served to give comfort to local Aboriginal people that their country is being protected.

In order to address this concern, discussions are proposed with a number of key external groups aimed at identifying a number of monitoring sites within the Ranger operating area which can serve as early sentinels of something untoward happening within the site. Agreement needs to be reached regarding appropriate trigger levels for notification at these various sites in order to ensure that transient situations which can be shown to have only localised impact to not serve to heighten rather than alleviate Aboriginal concern when they are reported.

The actions taken and planned by ERA in response to the investigation of this incident are extensive and far reaching, and will hopefully satisfy your Minister that the Company has treated this matter seriously and has responded accordingly.

Yours sincerely

RA Cleary
Chief Executive

Appendix 5

Ranger Mine Incident Investigation:
Northern Territory Department of Mines and Energy

NORTHERN TERRITORY SUPERVISING AUTHORITIES
ALLIGATOR RIVERS REGION

RANGER URANIUM MINE REPORTED LEAK IN PROCESS WATER RETURN PIPELINE

REPORT ON INVESTIGATION OF INCIDENT
MAY 2000

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1 EXECUTIVE SUMMARY

Operations at the Ranger Uranium Mine have recently received scrutiny from a variety of sources following an alleged leak of contaminated water into the surrounding Kakadu National Park. Officers of the Northern Territory Department of Mines and Energy (DME) have undertaken a thorough investigation of this incident. This comprised review of the available relevant data, site inspections and interviews of Ranger and DME staff.

Concern has centred around elevated manganese levels in water, measured in an internal mine road culvert. This culvert permits run-off from a partially rehabilitated area of the waste rock dump to enter the wetland filter zone (the wetland filter is designed to remove water-borne contaminants prior to discharge into Magela Creek, and has behaved precisely as designed). Manganese is considered to be ubiquitous in nature and the elevated levels found at the road culvert (approximately 5000 µg/L) do not represent a significant threat to the wetlands environment, as concentrations of this order are readily attenuated by the natural system. In fact at the first downstream monitoring point manganese levels are well below the Australian Drinking Water Guidelines levels.

The source of the manganese contamination is most likely to have come from a water return pipeline (which carries water from the tailings repository back to the mill for re-use) which started to leak around January this year. Although the pipeline is in a bunded containment corridor, the bund itself is an earthen design and is not impermeable to water. Therefore it has allowed seepage of some of the elevated manganese process water into the underlying culvert.

The above investigation has found no evidence to suggest that any significant environmental harm has occurred from this incident. There is no indication that the elevated manganese levels have had any impact either on the biota present in the wetland filter or on the associated flora. As the seepage has not caused environmental detriment it is not considered an infringement of ERA's licence to operate.

Since the levels of manganese contamination were below drinking water standards downstream, and there was no environmental detriment, there is no reason for it to be of public concern. The reporting of this incident, although tardy in some respects, does not constitute an infringement of reporting requirements as a leak of this nature, into a containment bund, is not usually given special priority in reporting.

Considering that there has been no environmental harm as a result of this leak, there appears to be no case for infringement. Environmental Requirement 16 states:

> "The company must directly and immediately notify the Supervising Authority, the Supervising Scientist, the Minister and the Northern Land Council of all breaches of any of these Environmental Requirements and any mine-related event which:
>
> (a) results in significant risk to ecosystem health; or

(b) which has the potential to cause harm to people living or working in the area; or

(c) which is of or could cause concern to Aboriginals or the broader public."

Since the contamination has not caused environmental harm and there is no related ecosystem risk, items a) and b) cannot be considered as breached.

Since there has been no environmental harm and there is no potential for harm to health, there is no basis for this incident to be of concern to the Aboriginals and broader public. Therefore item c) is not considered by the DME as having been breached .

1.0 Introduction

On 25 January 2000 and 2 February 2000, water samples taken from site VLGCRC (from Very Low Grade Corridor Road Culvert) below the tailings dam road corridor culvert (Figure 1) indicated that manganese from a source other than the rehabilitated waste rock dump may have been present. Data prior to 25 January did not indicate the presence of any other source of contamination. At this time (2 February) DME officers reported a discolouration ("sediment/precipitate") in the area of the culvert and consequently sampled the culvert water for analysis.

Table 1: Data which indicated manganese contamination.

Site	Date sampled	pH	Cond	Turb	Mg	SO4	Mn	U
			µS/cm	NTU	mg/l	mg/l	µg/l	µg/l
DW3A	25/01/2000				211.5	713.6	7.3	13.8
DW3A	02/02/2000	8.2	1168.0	0.2	151.3	492.2	-1.0	16.6
VLGCRC	25/01/2000	7.4	573.0	23.2	18.2	106.4	751.5	102.2
VLGCRC	02/02/2000	7.3	689.0	4.4	78.6	298.2	6,076.9	59.8
GCBR	25/01/2000	7.0	85.5	1.6	3.5	8.5	11.9	5.8
GCBR	02/02/2000	7.0	49.0	1.6	4.2	7.4	16.7	3.5
GC2	25/01/2000	7.3	95.5	2.7	10.9	17.5	5.6	2.2
GC2	02/02/2000	7.3	78.1	4.1	8.2	7.9	-1.0	1.8

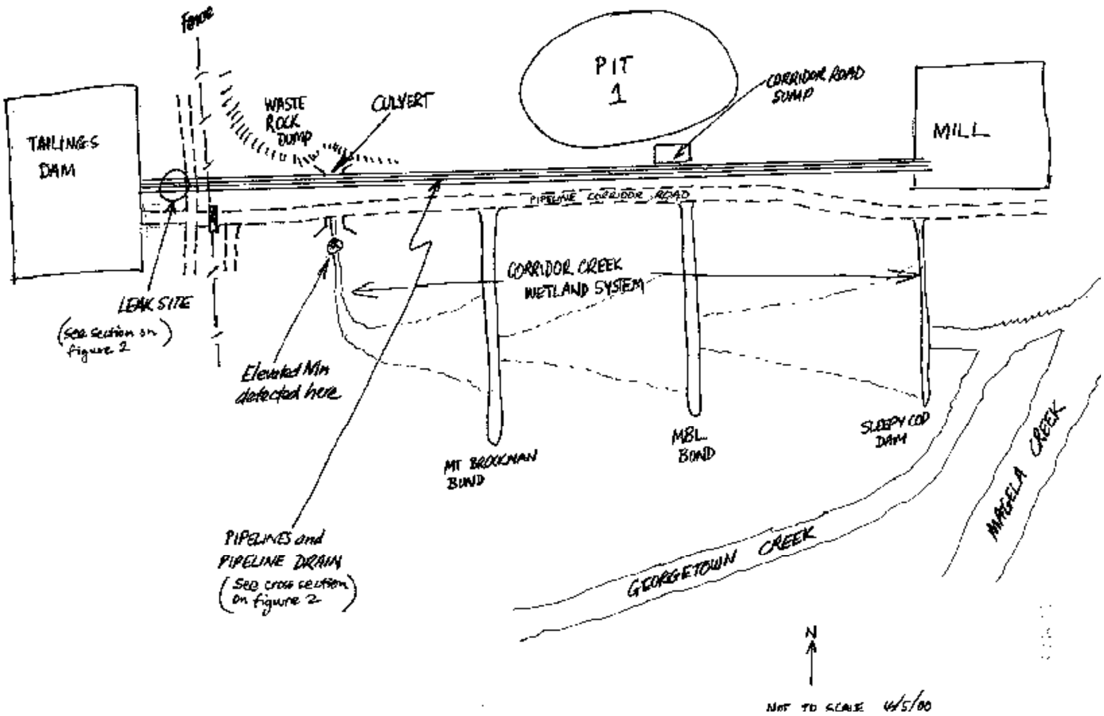
In response to these elevated levels, Energy Resources of Australia Ltd. (ERA) initiated an investigation to determine the source of the manganese. On 3 April, a leak was detected in the water return line which carries process water from the tailings repository back to the mill for re-use. Repairs were completed on 5 April. The leak occurred at a buried joint in the pipeline (Figures 2 and 3) and was located by an ERA chemist following up conductivity measurements. This return water pipeline lies in a corridor drain which runs the full length from the tailings area to the mill. It is designed to catch any leaks and divert them into a central sump. The sump can be pumped back to the system or overflow into the pit where the water is contained. The corridor drain is constructed from compacted earth.

A runoff drain, which collects surface run-off from a recently rehabilitated part of the waste rock dump, passes beneath the corridor drain, through the tailings road corridor culvert (installed in 1997) and into a wetland filter zone in the Corridor Creek catchment. The wetland is designed to capture any contaminants which may be released with runoff before discharging into Magela Creek (Figure 1). Currently ERA is trialing this drain and associated wetlands filter as a treatment and discharge area for waters from the dewatering bore DW3A. This borewater is usually treated through the Djalkmara wetland system but due to stage 5 development of the mine, that area will no longer be available as a discharge point for this water.

In response to the incident following the notification of the leak by ERA on 28 April, officers from the DME visited the site and interviewed ERA staff and inspected relevant areas. Subsequently they have reviewed monitoring data and generated this report which draws conclusions as to the likely cause and impact of the manganese contamination.

Throughout the course of this incident, there has been no indication that uranium levels have been of concern even when manganese levels were high.

FIGURE 1 – SCHEMATIC LAYOUT PLAN



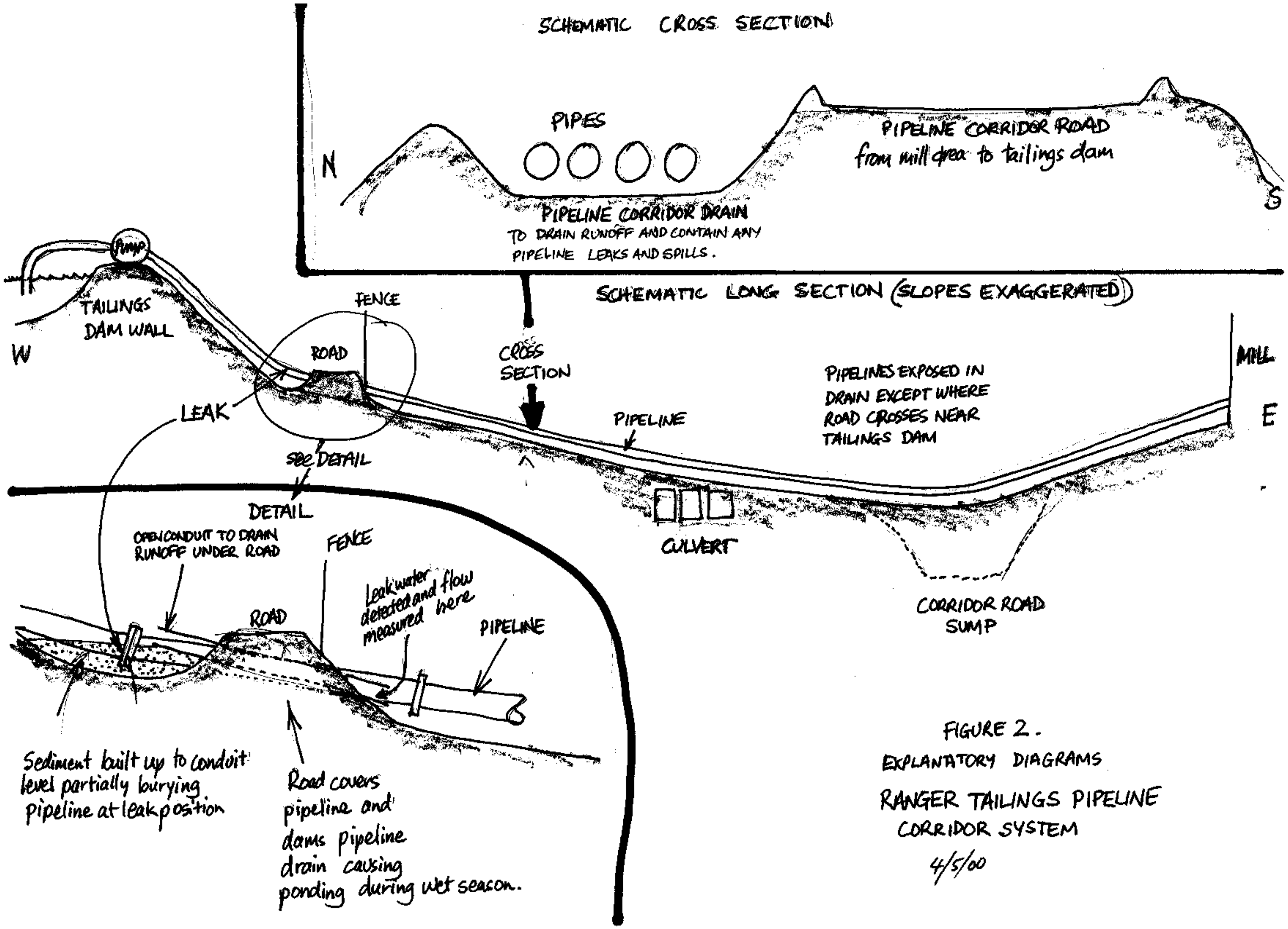


FIGURE 2.
EXPLANATORY DIAGRAMS
RANGER TAILINGS PIPELINE CORRIDOR SYSTEM
4/5/00

2.0 Incident Aspects

The incident which has occurred involves the following areas of the mine operation: the tailings repository (dam), process water return pipeline and its containment drain, corridor road culvert which passes under the drain, the dewatering trial and the Corridor Creek wetlands. These aspects are discussed separately as follows.

2.1 Tailings Repository (TD)

The TD is located at the south-eastern corner of the site and contains tailing material which has been deposited since the mine began operation in 1980. The tailing material comprises the mill wastes and associated liquor which separate on standing. This results in a consolidating sediment overlain by the tailings water, a chemical rich supernatant. This supernatant is drawn off through a decant pipe and re-used as the main process water in the mill.

The supernatant water exhibits high levels of manganese and is transferred to the mill via a pipeline from the eastern wall of the TD. The source of manganese in the tailings water is primarily from the addition of manganese dioxide (pyrolusite) in the production of U_3O_8. A secondary source is the processed ore. Indicative water quality parameters are given in Table 2 below.

Table 2: Tailings supernatant; typical water quality.

Parameter	*TDWW* *Jan 97-Mar 00*
EC (µS/cm)	16,000 - 21,000 (19,000)
pH	4.2 - 6.1 (4.5)
SO_4^{2-} (mg/L)	5,600 - 22,000 (18,000)
Mn^{-f} (µg/L)	350,000 - 1,200,000 (830,000)
U^{-f} (µg/L)	52 - 460 (100)
Mg (mg/L)	2,000 - 4,200 (3,600)
HCO_3^- (mg/L)	<0.1 - 2.1 (<0.1)
NH_3 (mg/L)	~500*

*Indicative value; not enough data for analysis.

Bracketed figures indicate median values.

2.2 Process Water Return Pipeline

The process water return pipeline carries tailings water to the mill for re-use in the refining process. This pipeline runs from the top of the TD, through a pump, to the mill, passing over the corridor road culvert with a global low point above the corridor road sump (see figure 2). The pipeline is one of four situated between two earthen bunds which are designed to retain liquid which may leak from the pipelines. Any such liquid is then delivered to the road sump where it can be pumped back into the system or overflow into the pit. The pipeline is exposed throughout its length except for one point where it is crossed by an access road near the TD. It is at this point where a leak from the pipeline has occurred. This leak has been the result of a separation of a flange joint, most likely due to corrosion. Given that the pipeline is covered by sediment, it is apparent that a small leak could remain undetected for some time, especially during the wet season when the area tends to remain saturated (figure 3). The leak was observed on 3 April and repaired on 5 April. It seems unlikely that the leak has been present for a significant time and certainly unlikely that it was present in the previous dry season.

As the pipeline drain has occasionally been the receptacle for tailings material and tailings supernatant, any water entering the drain is expected to become contaminated to some extent. This is because contaminated water contacting the earthen drain is expected to leave residual contaminants on the sediment surface.

Sampling and analysis of water in this drain area by ERA staff following this incident provided the water quality parameters shown in Table 3.

Table 3: Water Quality data, Corridor Drain, March 2000

Parameter	*Pipe Seepage into Corridor Drain, upstream culvert site.*	*Corridor Drain, downstream culvert site.*
Mn^{-f} (mg/L)	728	825
SO_4^{2-} (mg/L)	11,519	12,551
Mg^{2+} (mg/L)	2,180	2,350

During the course of the investigation, ERA has found ammonia levels of approximately 50 mg/L in the drain. This is indicative of the tailings water which is also high in ammonia.

2.3 Road Culvert

The road culvert consists of several concrete sections which are butted together to form 3 parallel under-road conduits. The sections are covered with earth to permit the use of the culvert as part of the access road. The corridor drain passes directly above the butted sections with an estimated 0.5m of compacted earth between the corridor drain and the culvert. This culvert was installed in 1997.

This culvert (upstream of VLGCRC) facilitates surface run-off from a recently rehabilitated area of the waste rock dump, and from December 1999 to April 2000, a trial discharge using water from the DW3A dewatering bore. It is on both sides of this culvert where ERA first noticed elevated manganese levels on January 25 and February 2. On the downstream side of the culvert they observed manganese levels higher than the upstream side which implied that there was a secondary source of Mn entering the system between the two sampling sites. The ERA investigation also observed a seep of water between these two sampling sites and found it also to contain elevated manganese levels. These analyses are summarised below.

Table 4: Results of culvert area investigation.

Site	Pool above culvert	Pre-culvert	Seep	Post-culvert Pre-VLGCRC	VLGCRC	Downstream ≈200m	Downstream ≈700 m
pH	7.6	7.7	4.5	7.4	7.6	8.0	8.0
EC (µS/cm)	1,100	1,100	16,000	1,100	1,100	970	860
Mn (µg/L)	400	360	890,000	970	840	620	23
Mg (mg/L)	150	150	2,600	140	150	130	110
SO_4 (mg/L)	460	460	13,000	450	470	430	360
NH_4 (mg/L)	<0.05	<0.05	ND	0.46	0.36	<0.05	<0.05
U (µg/L)	260	270	ND	ND	290	240	ND

ND = Not Determined

Of note from these data is the observation of ammonia downstream but not upstream of the road culvert. This ammonia is indicative of tailings water contamination. Importantly the samples taken further downstream (well before the Mt Brockman Bund (GCBR)) show no residual ammonia and the manganese levels have been lowered to levels less than those upstream of the culvert. This provides prime evidence that the contamination has been rapidly attenuated by the wetland and no environmental harm has occurred. Unfortunately no ammonia measurements were taken at the seep upwelling site as this would have provided prime evidence that this was in fact the expression of the seepage into the culvert. A recent visit to the site (11/5/00) observed that this upwelling has become an algae-rich pool. This observation implies that the pool is rich in nutrients (most likely nitrate). As the tailings water contains ammoniacal and nitrate-nitrogen, whereas the upstream flows under the culvert are ammoniacal-nitrogen lacking and nitrate nitrogen depleted, it seems likely this seepage contains an amount of tailings water.

Also on February 2, a DME sampling crew, on site for routine monitoring, noticed a black sediment/precipitate in the same area. This observation prompted sampling of the associated water. Analyses of these samples are yet to be finalised. However, it is possible that the black material is either a manganese mineral phase which has precipitated directly, or it is a bacterially induced deposit of mixed metal species precipitated as metal oxyhydroxides.

Given the corridor drain is permeable, the amount of manganese present in the drain, and the previous manganese and ammonia results, it appears that seepage through the drain above and/or around the culvert is the likely source of Mn rich waters.

In this culvert there was observed to be a drip of liquid from the roof of the culvert conduit. ERA sampled and analysed this material and found that it contained high levels of Mn and associated contaminants which appear to be similar to those found in the tailings water. These levels are shown in the following table.

Table 5: Culvert drip data

Parameter	Culvert Seep
SO_4^{2-} (mg/L)	11,486
Mn (µg/L)	317,419
Mg (mg/L)	1,758

Historical water quality parameters measured by ERA at the VLGCRC are shown in the following table.

Table 6: VLGCRC data

Parameter	VLGCRC		
	1997/98	*1998/99*	*1999/00*
EC (µS/cm)	310-500 (390)	280-1,340 (670)	310-1,100 (590)
pH	6.1-6.8 (6.3)	5.0-6.7 (5.6)	6.9-8.1 (7.5)
SO_4^{2-} (mg/L)	97-180 (140)	66-570 (300)	105-460 (190)
Mn^{-f} (µg/L)	NA	Up to 25,000#	97-5,900 (1,800)
U^{-f} (µg/L)	10-18 (13)	13-170 (64)	55-380 (190)
Mg (mg/L)	29-56 (39)	23-130 (70)	32-140 (79)
HCO_3^- (mg/L)	NA	10-40(15)	15-35*

NA = Not available
Bracketed numbers represent median values. Maximum and minimum displayed where insufficient data for meaningful determination.
Data supplied verbally by EWL Sciences

The historical elevated manganese illustrated in the above table are most likely originating from the waste rock run-off area which is considered to be high in soluble manganese.

2.4 Dewatering Trial

ERA has been trialing the use of the Corridor Creek wetland as a treatment and disposal area for water from the dewatering bore D3WA from December 1999 to April 2000. Typically this water is of good quality and indicative parameters are illustrated in table 7.

Table 7: Bore DW3A Data

Parameter	*DW3A* *Jul 97- Mar 00*
EC (µS/cm)	940-1,200 (1,100)
pH	7.7-8.2 (7.9)
SO_4^{2-} (mg/L)	290-520 (430)
Mn^{-f} (mg/L)	<1 - 5.5 (<1)
U^{-f} (µg/L)	12-31 (17)
Mg (mg/L)	130-200 (160)
HCO_3^- (mg/L)	190-310 (230)

This water is discharged from the dewatering bore onto the partially-rehabilitated waste rock dump. There may be the potential for this area to provide some contamination and EWL Sciences has previously examined the effect of leaching on this waste rock. The results shown in table 8, comparing distilled water and buffered (pH 4.5) leaching show that at near neutral pH levels, little manganese is leached from the waste rocks. However, data presented in Table 6 indicate that some manganese is present in the leachate.

Table 8: 5:1 Liquid/Solid batch leach results for Mn (note change in units to µg/L to simplify reporting of low levels in distilled water) on Pit #1 waste rock.

	Distilled water	*pH 4.5 acetate buffer*
Laterite 1	1.5	6,104
Laterite 2	1.0	14,336
Laterite 3	1.5	11,320
Transitional 1	1.3	7,992
Transitional 2	12.2	4,764
Transitional 3	22.5	8,968
Primary 1	0.3	4,112
Primary 2	0.6	3,644
Primary 3	1.3	5,472

Again the origin of this manganese may be from the presence of soluble manganese salts and minerals. This interaction may be the cause of the elevated Mn levels seen by EWL Sciences at the VLGCRC in the 98/99 wet season (table 6 above).

2.5 Corridor Creek and Statutory Monitoring Points

The Corridor Creek wetland system comprises 3 wetlands and bunds which are designed to remove contaminants from run-off prior to discharge into Georgetown Billabong and thence Magela Creek (see figure 1). The starting point of this system is the VLGCRC and the statutory monitoring point is in Georgetown Billabong. Between these two points there are no statutory monitoring sites. However, ERA has historically monitored two sites in this wetland at the Mt Brockman Bund (GCBR) in the upper wetland and further downstream between the MBL Bund and Sleepy Cod dam (GC2).

The results of this monitoring indicate no significant manganese levels which could be considered indicative of environmental impact in the wetland system. The data for these sites are illustrated in table 9 below.

Table 9: Georgetown Billabong(GB),Mt Brockman Bund [#](GCBR) and Sleepy Cod Dam (GC2) monitoring data (10%ile-90%ile (Median)).

Site		*GCBR*			*GC2*			*GB*	
Year	*97/98*	*98/99*	*99/00*	*97/98*	*98/99*	*99/00*	*97/98*	*98/99*	*99/00*
EC (µS/cm)	26-390 (57)	26-440 (47)	52-185 (92)	49-98 (75)	61-130 (85)	74-120 (82)	17-73 (32)	19-58 (40)	17-38 (26)
pH	6.6-8.3 (7.0)	6.6-8.3 (7.0)	6.5-7.3 (7.0)	6.7-7.1 (7.0)	6.9-7.7 (7.2)	6.9-7.5 (7.3)	6.0-6.7 (6.4)	5.9-7.3 (6.5)	6.0-7.1 (6.6)
Ca (mg/L)		2.1-5.7 (5.5)	2.0-3.4*	<1*	1.5-1.8 (1.7)	1.7-2.0*		0.88*	0.51-0.62 (0.52)
Mg (mg/L)	1.7-51 (4.2)	1.8-56 (5.9)	4.0-21 (8.2)	4.3-8.4 (6.3)	5.8-13 (8.5)	8.1-12 (9.1)*	0-1.9 (0.47)	0.45-2.7 (1.5)	1.0-2.0 (1.2)
NH4 (mg/L)									<0.05*
SO4 (mg/L)	1-14 (2.3)	2.4-18 (5.2)	4.4-38 (9.9)	3.2-14 (6)	3.4-20 (9.8)	7.3-25 (14)	0.1-1.6 (0.41)	0.51-2.0 (0.74)	0.45-3.0 (1.5)
Mn-f (µg/L)		1.3-27 (2.0)	1.9-35 (8.3)		3.6-24 (11)	3.7-16 (7.0)		3.3-6.2 (5.9)	3.2-120 (7.6)
U-f (µg/L)	1.0-150 (2.1)	0.50-210 (4.2)	2.3-33 (4.2)	1.9-19 (3.3)	1.6-7.2 (3.2)	1.6-4.3 (2.6)	0.10-1.7 (0.31)	0.12-0.69 (0.32)	0.20-0.46 (0.34)

* Insufficient data for analysis

[#]DME officers examined this site and found that fish were present in the wetland and that there was no apparent indication that flora had been impacted. These observations support the conclusion that no significant impact to the environment has occurred.

The DME has a statutory monitoring point at (GS8210009) which has been monitored for many years. Historical monitoring from this site is summarised in table 10.

Table 10: Summary of parameters at GS8210009 (10%ile-90%ile (Median)).

Parameter	1997/98 reporting period	1998/99 reporting period	1999/00 reporting period
EC (µS/cm)	8.9-20 (14)	8.5-26 (14)	6.7-26 (11)
SO_4^{2-} (mg/L)	0.29-1.5 (0.46)	0.25-4.2 (1.4)	0.27-2.0 (0.85)
Mg (mg/L)	0.33-0.70 (0.60)	0.35-1.8 (0.8)	0.40-1.05 (0.62)
Filterable U (µg/L)	0.08-0.23 (0.11)	0.1-0.35 (0.12)	<0.1-0.19 (0.10)
Filterable Mn (µg/L)	3.5-13 (5.3)	1.8-12 (3.9)	1.4-14 (7.0)
Filterable ^{226}Ra (mBq/L)*	<2-2.7	2.3-17	Not available

The Office of the Supervising Scientist has, in conjunction with the DME, the Northern Land Council (NLC) and ERA, determined baseline monitoring and investigation action thresholds. They are currently in draft and are shown in the following Table:

Table 11: Proposed trigger values for Magela Creek[1]

Key variable	Trigger Level 1	Trigger Level 2	Minimum and Maximum values
pH	5.85, 6.51	5.52, 6.84	5.19, 7.17
EC (µS/cm)	23	33	47
Turbidity (NTU)	12	28	66
U (µg/L)	0.30	1.9	3.5
Mn (µg/L)	11	21	47
Mg (mg/L)	Use EC triggers		Use EC maximum
SO_4 (mg/L)	Use EC triggers		Use EC maximum
^{226}Ra	18	18	To be advised

From the data in tables 10 and 11 there appears to be evidence that trigger level 1 has been tripped for manganese in each of the three years. However, tripping of trigger level 1 necessitates a “watching brief”, which consists of further sampling at least at a daily frequency to verify whether an upward trend is occurring. But tripping level 2 consists of more than a single measurement above the trigger 1 level and this has not been the case.

[1] Klessa, D.A. (2000) “Assessment of Change in Water Quality Downstream of Ranger”, DRAFT, 6 pages.

The most recent sampling of the wetland system shows that there is little evidence that the contaminated water has impacted on these areas. This is shown in Table 12.

Table 12: Most recent sampling in area of concern.

Site	TDWW	DW3A	VLGCRC	VLGCRC	GCBR	GCBR	MBL BUND	GC2
Date sampled	05-03-99	02-05-00	01-05-00	02-05-00	01-05-00	02-05-00	02-05-00	02-05-00
Time	12:55	16:52	13:04	11:57	13:14	11:43	11:23	11:00
EC (µS/cm)	15450	1157	811	1144	64.6	153.8	86.3	100.2
pH	4.4	8	7.1	7.94	6.87	7.04	7.18	7.17
Ca (mg/L)	390	11	14	12	0.77	1.6	0.76	1.2
Mg (mg/L)	2550	130	74	130	4	12	6.9	8.3
SO_4 (mg/L)	14300							
NO_3 (mg/L)	0.29							
Mn^{-f} (µg/L)	860000	<1		420		2	3	30
Mn^{-t} (µg/L)	820000	<1	5376	400	5.33	2	3	31
U^{-f} (µg/L)	780	13		250		2.1	0.4	1.5
U^{-t} (µg/L)	820	12	75	240	4.058	2.3	0.5	2.2

Site	SLEEPY COD	GB	GB	GB	GB	GS8210009	GS8210009
Date sampled	02-May-00	06-Dec-99	01-Feb-00	18-Apr-00	02-May-00	19-Apr-00	01-May-00
Time	10:37	11:19	11:00	11:08	10:06	12:15	10:57
EC (µS/cm)	98.9	57.5	33.7	35.8	41.1	20.5	18.9
pH	6.94	5.22	6.14	5.82	7.48	7.03	5.98
Ca (mg/L)	1.2		0.53	0.9	0.63	0.61	0.75
Mg (mg/L)	7.7		1.9	1.7	1.6	0.72	0.82
SO_4 (mg/L)		2.9	1.6				
NO_3 (mg/L)			0.005				
Mn^{-f} (µg/L)	10	53	2	16	4	3	4
Mn^{-t} (µg/L)	20	68	53	19	5	4	5
U^{-f} (µg/L)	1.2	0.1	0.2	0.2	2.1	<0.1	<0.1
U^{-t} (µg/L)	1.6	0.6	1.1	0.3	2.1	<0.1	<0.1

TDWW	Tailings Dam West Wall
DW3A	Ranger #3 dewatering
VLGCRC	Culvert under Corridor Road, receiving VLG (Very Low Grade) runoff
GCBR	Brockman Bund on the Corridor wetland
MBL BUND	MBL (Mine Bore L) Bund on the Corridor wetland
GC2	Statutory monitoring point on Georgetown Creek, down gradient of the Corridor wetland
SLEEPY COD	Sleepy Cod Dam, Georgetown Creek, downstream of GC2
GB	Georgetown Billabong
GS8210009	Statutory monitoring site on Magela Creek, downstream of the project area

3.0 Discussion and Conclusions

In reviewing the data from this incident in which a minor amount of contaminants have escaped, it is apparent that chemical data alone would be insufficient for determining the mechanism of contamination in a short time frame. Given the current level of technology available, investigations of this type will be reactive rather than proactive as weeks, and sometimes months, may have passed by the time an anomaly becomes evident.

Since the elevated levels of manganese present at the VLGCRC are not seen further downstream at GCBR, GB or at site GS8210009, and coupled with the positive observations of flora and fauna, it seems extremely unlikely that any significant environmental harm has occurred in either the wetland filter or Magela Creek. It is most likely that manganese entering the wetland system has been rapidly taken up in the sediment, oxidised and precipitated or phyto-remediated by the native flora.

The presence of ammonia in the tailings repository, its absence in the waste rock runoff upstream of the road culvert and its presence in VLGCRC water lends weight to the likelihood of the corridor drain as the source of the contamination.

The leaching data from EWL Sciences and the analyses of the D3WA bore waters indicate that it is unlikely a near neutral (much less a faintly alkaline) solution would be capable of leaching the significant levels of manganese found in the VLGCRC from the rehabilitated waste rock dump but does not preclude the possibility of periodic flushing and manganese mobilisation by lower pH runoff and groundwater. Manganese is acid soluble but at pH levels above 8, is readily removed from solution by complexation, precipitation and co-precipitation.

Coupled with this information is the physical evidence that the earthen drain in the vicinity of the culvert is of moderate permeability. Seepage into the VLGCRC from on top of and around the culvert appears to be the most likely entry path for the TD water which has originated from the up-gradient tailings water return pipe leak.

Considering that there has been no environmental harm as a result of this leak, there appears to be no case for infringement. Environmental Requirement 16 states:

> "The company must directly and immediately notify the Supervising Authority, the Supervising Scientist, the Minister and the Northern Land Council of all breaches of any of these Environmental Requirements and any mine-related event which:
>
> (a) results in significant risk to ecosystem health; or
>
> (b) which has the potential to cause harm to people living or working in the area; or
>
> (c) which is of or could cause concern to Aboriginals or the broader public."

Since the contamination has not caused environmental harm and there is no related ecosystem risk, items a) and b) cannot be considered as breached.

Since there has been no environmental harm and there is no potential for harm to health, there is no basis for this incident to be of concern to the Aboriginals and broader public. Therefore item c) is not considered by the DME as having been breached .